Technische Universität München
TUM School of Social Sciences and Technology

On Combining Network Research and Computational Methods on Historical Research Questions and its Implications for the Digital Humanities

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Vollständiger Abdruck der von der TUM School of Social Sciences and Technology der Technischen Universität München zur Erlangung des akademischen Grades einer

Doktorin der Philosophie (Dr. phil.)

genehmigten Dissertation.

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Die Dissertation wurde am 22.09.2021 bei der Technischen Universität München eingereicht und durch die TUM School of Social Sciences and Technology am 17.01.2022 angenommen.

Acknowledgments

Let me express my joy in the support I have received over the years. I want to thank my doctoral father Jürgen Pfeffer for this adventure and the trust he placed in me, and the academic support I received from my colleagues and mentors. My sincerest gratitude go to my friends and family: Without your unwavering support, I would not be where I am today. Thank you for always being there.

Abstract

Computer-based methods and approaches increasingly find entry in the humanities. The digital humanities are perceived as a research paradigm that introduced computational, quantitative, and digital methods into the humanities, which originate from a vast range of fields such as computer science, math, or the social sciences.

This thesis evaluates the chances and challenges when combining network research and computational methods in historical research based on two main case studies. In the first case study, we assessed the extent of political judiciary in the autocratic Corporate State of Austria based on court records of 1935 from both Viennese provincial courts. We analyzed structural configurations of a conviction dependent on the political orientation of the defendants using quantitative methods, network analysis, and qualitative historical contextualization. In the second case study, we analyzed influence networks of intellectuals based on a Linked Open Dataset in a series of articles, applying a relational approach to the history of intellectuals. We evaluated the network positions of intellectuals and the structural evolution of their influence networks in time.

These mixed methods approach combining network research, computational methods, and historical contextualization allowed us to extend on and to falsify historical knowledge both on the judicial practices during the Corporate State and on the importance of intellectuals in time.

This thesis provides an overview of the historical development and prospects of the digital humanities and network research, focusing on the interdisciplinary work of digital history and historical network research. We address the limitations and implications of the epistemological and ontological changes when working with the digital and critically reflect on the multimodal literacies–such as data and methodological literacy, as well as tool criticism–needed to assess the implications of computationally derived insights.

Zusammenfassung

Computergestützte Methoden und Ansätze finden zunehmend Eingang in den Geisteswissenschaften. Die Digital Humanities werden als ein Forschungsparadigma wahrgenommen, welches zur Einführung von *computational methods*, sowie digitalen, quantitativen und qualitativen Methoden in den Geisteswissenschaften geführt haben, die wiederum aus einer Vielzahl verschiedener Disziplinen wie der Computerwissenschaft, Mathematik oder den Sozialwissenschaften stammen.
Diese Thesis evaluiert Chancen und Herausforderungen der Anwendung von Netzwerkforschung und *computational methods* in der historischen Forschung anhand zweier Fallstudien. In der ersten Fallstudie untersuchten wir das Ausmaß politischer Justiz im autokratischen Ständestaad Österreichs anhand von Gerichtsakten von 1935 der beiden Wiener Landesgerichte. Wir analysierten strukturelle Konfigurationen einer Verurteilung abhängig zur politischen Orientierung der Angeklagten mithilfe quantitiativer Methoden, Netzwerkanalyse, und einer qualitativen historischen Kontextualisierung. In der zweiten Fallstudie untersuchten wir *influence networks* von Intellektuellen basierend auf einem Linked Open Dataset in einer Reihe von Artikeln, in welchen wir einen relationalen Ansatz auf die *history of intellectuals* anwendeten. Dazu analysierten wir die Positionen der Intellektuellen im Netzwerk und deren strukturelle Entwicklung im Verlauf der Zeit.
Dieser *mixed methods* Ansatz verbindet Netzwerkforschung, *computational methods* mit einer historischen Kontextualisieren, welcher es uns erlaubt an bestehender historischer Erkenntnis sowohl zur Justizpraxis im Ständestaat als auch zur Bedeutung von Intellektuellen anzuknüpfen, zu erweitern und zu falsifizieren.
Diese Thesis gibt einen Überblick zur historischen Entwicklung und zu den Möglichkeiten der Digital Humanities und Netzwerkforschung mit einem Schwerpunkt auf die interdisziplinäre Arbeit der Digital History und Historical Network Research. Wir gehen dabei auf die Grenzen und Implikationen der epistemologischen und ontologischen Veränderungen bei der Arbeit mit dem Digitalen ein und reflektieren kritisch ob der *multimodal literacies*–wie Daten- und Methodenkompetences, sowie *tool criticism*–, welche notwendig sind, um die Implikationen computergestützerter Erkenntnis zu bewerten.

Publications

This thesis is based on five peer-reviewed papers, which are listed in the overview in Table 1. These papers are organized around two big topics: the first targeting the extend of political judiciary during the Corporate State, the latter analyzing a big data network of a Linked Open Dataset on the history of intellectuals.

Table 1: Peer-reviewed publication basis of this dissertation

No.	Year	Authors	Paper	Venue
1	*2021*	Petz, Cindarella & Pfeffer, Jürgen	*Configuration to Conviction: Network Structures of Political Judiciary in the Austrian Corporate State*	Social Networks, vol. 66, July 2021, pp. 185–201. DOI: 10.1016/j.socnet.2021.03.001.
5	*2021*	Petz, Cindarella & Ghawi, Raji & Pfeffer, Jürgen	*Tracking the Evolution of Communities in a Social Network of Intellectual Influences*	Journal for Historical Network Research (JHNR) 2021, accepted for publication Sept. 18, 2021.
3	*2020*	Petz, Cindarella & Ghawi, Raji & Pfeffer, Jürgen	*A Longitudinal Analysis of a Social Network of Intellectual Influence*	IEEE/ACM International Conference on Advances in Social Network Analysis and Mining (ASONAM) 2020, pp. 340–347. DOI: 10.1109/ASONAM49781.2020.93-81318
4	*2021*	Ghawi, Raji & Petz, Cindarella & Pfeffer, Jürgen	*Dynamics of Influence in a Social Network of Intellectuals*	Social Network Analysis and Mining (SNAM) 2021, vol. 11, number 63. DOI: 10.1007/s13278-021-00771-x.
2	*2019*	Ghawi, Raji & Petz, Cindarella & Pfeffer, Jürgen	*'On the Shoulders of Giants', Analysis of a Social Network of Intellectual Influence*	Sixth International Conference on Social Networks Analysis, Management and Security (SNAMS) 2019, pp. 248–255. DOI: 10.1109/SNAMS.2019.8931821.

The following list includes invited talks and presentations I gave during this dissertation:

Date	Title and Venue
05/2021	*Historical Network Research in a Nutshell: On courts, intellectuals, and the perks of networks*, Seminar "Digital History" (Dr. U. Hasenöhrl) at Innsbruck University (virtual).
03/2021	*A mixed methods approach to political judiciary*, Conference "Digital Methods and Resources in Legal History" (DHL2021), Max Planck Institute for Legal History and Legal Theory, Frankfurt am Main (virtual). Postponed from 2020 to 2021.
12/2020	*A Longitudinal Analysis of a Social Network of Intellectual History*, IEEE/ACM International Conference on Advances in Social Network Analysis and Mining (ASONAM) 2020, The Hague, Netherlands (virtual).
07/2020	*Analyzing Political Trials during the Austrian Authoritative Rule using a Network Approach*, SUNBELT 2020 Virtual Conference.
10/2019	*Historische Netzwerkforschung und Politische Justiz am Beispiel Wien 1935 (Diss.)*, Oberseminar, Research Institute for the History of Technology and Science at the German Museum Munich.
09/2019	*Political Judiciary in the Corporate State of Austria*, 4th European Conference on Social Networks (EUSN), Zurich.
06/2019	*Networks of Political Judiciary in the Corporate State: The provincial courts of Vienna in 1935*, Poster Presentation, 2$^{\text{nd}}$ Heidelberg Computational Humanities Summer School "Mixed Methods in the Making" (HCH), Heidelberg University.
05/2019	*Disseminating Political Judiciary with ERGM*, Kolloquium Prof. C. Stadtfeld, ETH Zürich.
05/2019	*Networks of Political Judiciary in the Corporate State in Austria*, 13th Workshop Historical Network Research "Networks across Time and Space." Methodological Challenges and Theoretical Concerns of Network Research in the Humanities, Akademie der Wissenschaften und der Literatur Mainz.
03/2019	*Gerichtsakten als Quelle historischer Netzwerkanalyse zur Politischen Verfolgung im Österreichischen Ständestaat*, Workshop "Von Chancen und Herausforderungen." Werkstattgespräche zur Historischen Netzwerkanalyse, FWF-DACH-Projekt "Issues with Europe", Forschungszentrum Digital Humanities at Innsbruck University.
06/2018	*Networks of Political Prosecution*, XXXVIII SUNBELT Conference Utrecht.

Contents

Chapter 1

Introduction

The digital has become a commodity in the humanities. While the digital has found entry into humanities research work in terms of computer-assisted searching, text production, and publication, the implementation of computer-based analysis and its sensible concatenation with qualitative approaches still remain in many open questions.

At the beginning of this thesis, the development of the digital humanities was still about to turn to a professionalization and formalization of computer-assisted digital and computational methodologies and argument-driven analysis. This direction gained traction during the course of this thesis.

The underlying goal of this thesis is to identify hidden patterns in data, that are too big to easily overview and to further historical knowledge on specific historical research questions using a mixed methods approach that combines traditional hermeneutics from the historical studies with computational methodologies from the fields of computer science, (computational) social science, and the digital humanities in general. This is put to practice in two case studies: on political judiciary in an autocratic regime, and on a big data analysis of the history of intellectuals utilizing a Linked Open Dataset (LOD).

This thesis assumption is that the DH offer a broad kaleidoscope of tools and methods which necessarily need to be contextualized by domain-specific knowledge–a traditional historical core–in order to be able to interpret any findings of technical methods. Interdisciplinary computational-based methods provide a magnifying glass or prism for historical research in order to detect connections, structures and patterns even in established research fields–if put under a considerate, pronounced method, tool, and (digital) source criticism.

The underlying epistemic framework of this endeavor is that of modeling.[1] Based on the classical definition by Herbert Stachowiak (1973), models offer an approximation to reality through the–subjective–selection of (supposedly) important or representative factors and parameters and their (subjective) weighting and evaluation. Modeling is a fundamental epistemic tool: "We model to understand," summarized this Le Moigne

1. This idea of the importance of modeling for the digital and computational humanities has been picked up in a workshop organized by GESIS in January 2017, which results have been published in a supplement of the Historical Social Research journal by Ciula et al. (2018), the compendium on modeling in the digital humanities edited by Flanders and Jannidis (2019b) and Piotrowski (2020).

(2004) paraphrasing Stachowiak (1973, p. 56)'s take that all insights are insights in models or through models[2] (compare also to Piotrowski 2020, p. 10) As a consequence of the selection of (or: focus on) certain attributes, any model is ultimately subjectively biased, and constitutes only one instance of an "endless number of potential other models" (Rehbein 2020, p. 265). Principally, it can be refined constantly to represent reality (the research object) more closely, dependent on the available data. As such models to only offer a 'crutch' to understanding and insight, but can not give an absolute 'truth' on the object of research (Drucker 2011).

With this framework of modeling, this thesis re-conceptualizes computational methodologies for historical research questions: in the papers, we conceptualize court records as networks consisting of e.g., co-occurring pairs of paragraphs, uni-, bi- and multimodal networks of judges, prosecutors, their cases, and the defendants; identify modeling as an inherent concept within the historical studies, i.e. the historical narrative as a best-fit model to explain the how and why of history and periodization as models of time-scales as a model or construct of analysis to sharpen focus; and the use of networks as epistemic tools.

This thesis provides a critical discussion of the digital humanities (DH) and reflects on their state, prospects, and the methodological and epistemic implications of digital research with a special focus on the interdisciplinary work of historical network research (HNR), which combines historical studies with computer science- and social science-based methodologies in two case studies. The two main case studies provide (1) new historical insights on their respective topics, and (2) proof-of-concept of a sensible application of a computational methodology in combination with historical contextualization, which are then (3) critically discussed and their implications evaluated.

The first part of this thesis attempts a classification of the DH, their status, and their historiographical development, and locates the DH in a dichotomous tension field between digitization and digitalization. The focus of this thesis lies on network research, which in the second part is defined and discussed alongside its historiographical development and theoretical origins in order to make inferences on network methodology.

This thesis presents two main case studies in five papers. The first case study is based on the analysis of the extend of political judiciary on the example of court records from the autocratic Corporate State of Austria. There, we analyzed the configurations of a conviction dependent on the political orientation of the defendants using quantitative methodologies, network analysis, and qualitative historical contextualization.
The second case study is based on a Linked Open Dataset, which infers on a social network of intellectual influences in the broad strokes of a master narrative. In a series of papers, we employed various big data analyses on this data, which we successively extended, identifying the most important scholars in time based on their structural

2. The original quote reads in German: *"Hiernach ist alle Erkenntnis Erkenntnis in Modellen oder durch Modelle, und jegliche menschliche Weltbegegenung überhaupt bedarf des Mediums 'Modell'."* (Stachowiak 1973, p. 56)

position, their development in time, and changes in their community compositions, and critically discuss its applications and limitations.

In the discussion, this thesis critically discusses digital research, and reflects on the epistemological and ontological transformations when working with the digital, and assesses the implications of computational derived insights, as well as pitfalls, issues, and biases, and the importance of a multimodal literacy, that combines computational, quantitative, digital, and qualitative approaches. Finally, this thesis gives an outlook on future research strands specific for the case studies as well as within the DH that include to establish a computational and methodological literacy, and various digital competences.

Chapter 2

Digital Humanities

2.1 Defining Digital Humanities – a tension field

There is a lot of arguing on what are the digital humanities (DH).[1] While a definite answer has no been set, within the growing scientific community of DH it constitutes a “sport” to come up with ever-new and individual definitions of what are the DH.[2] The digital humanities can be described as a movement within the humanities answering to the technological changes of digitization, digitalization and the demands and possibilities of big data, that have transformed not only the scientific world. As such the term encompasses the many. It can be located in a tension field between its status of an independent discipline[3], a summary of a plethora of sub-fields, a meta-discipline, or an auxiliary science[4]. The term DH is used to describe a wide range of processes incorporating the digital into the humanities’ research by interdisciplinary methods (Düring 2015; Jannidis et al. 2017), tools (Ayers 1999), or workflows. More vaguely, DH describe pure digitization projects as well, which facilitate the widespread accessibility through online availability of sources to humanities’ scholarship.

By its practitioners and supporters, the digital humanities are considered a paradigm change.[5] In the following, we will discuss these tension fields of the DH, its aims, implications, historiography, and methodologies.

2.1.1 DH as independent discipline vs. sub-field

The DH show all signs of being established as an independent discipline[6] in its professionalization in institutions and formalized gatherings specialized on the research of the

1. We will refer to the digital humanities in the following in the plural form, as it describes an encompassing term for a multitude of fields within the humanities.

2. Compare exemplary Sahle (2015, p. 47) or Terras (2011). It is a requisite for the attendance of the “Day of Digital Humanities” Conference to define the DH; the website https://whatisdigitalhumanities.com/ shows a new definition collected with the conference’s participants whenever refreshed.

3. Such as suggested e.g., by Jannidis et al. (2017).

4. As characterized e.g., by Fickers (2017).

5. Compare to the discussion in section 6.2.3.

6. A discipline is characterized according to Krishnan (2009) by a specific object of research, accumulated specialist knowledge, theories, concepts and research methods, a specific terminology, and institutionalization. Piotrowski (2020, p. 9) argued as well that the DH qualify as a discipline.

DH. The DH are discussed in an increasingly unoverseeable number of highly specialized conferences, workshops, and journals[7]. Since the late 1990s[8], a wide range of specialized institutions were founded to push research projects related to the DH: in associations[9], working groups[10], and departmental institutions[11]. While the new DH institutions tend to have non-traditional formats such as focus centers instead of departments, examples can be found for both traditional and non-traditional initiatives. Alongside of new DH degree programs[12], an increasing amount of professorial positions are appointed at almost every university all over the world, alongside other (im)permanent academic positions[13].

The process of institutionalization, professionalization, and thus that of the independence of the field DH, is not yet finite. This is also reflected in the integration of these new positions within the broader universities organizations. Few research facilities have a distinct "digital humanities" department, though they are of growing number.[14] Most are part of the more traditional fields such as e.g., digital history positions or working groups within the history or computer science departments[15]. These are clearly organized as sub-disciplines within their respective originating fields, but aim to connect traditional studies with new technical methodology originating from the humanities, computer science or the social sciences respectively, applying a quantitative and compu-

7. Such as i.a. the *Digital Humanities Quarterly* (DHQ, founded in 2007, http://www.digitalhumanities.org/dhq/), the *Journal for Digital History* (JDH, 2020, https://journalofdigitalhistory.org/en), the *Frontiers in Digital Humanities* (2014, https://www.frontiersin.org/journals/digital-humanities#), the *Journal for Historical Network Research* (2017, https://jhnr.uni.lu/index.php/jhnr).

8. For an overview on the development of the digital humanities and digital history see section 2.2.

9. Such as the *European Association for Digital Humanities* (EADH, http://eadh.org/), the *Digital Humanities im deutschsprachigen Raum (DHd, https://dig-hum.de/)*, or the *Alliance of Digital Humanities Organizations* (ADHO, http://adho.org/).

10. Exemplary, the *Arbeitsgemeinschaft Digitale Geschichtswissenschaften* (founded in 2012, https://www.historikerverband.de/arbeitsgruppen/ag-digitale-gw.html) organized in the *Verband der Historikerinnen und Historiker Deutschlands* (VHD).

11. For an overview of institutions in Germany compare to Hohls (2018, A.1-26–28).

12. An overview provides CLARIN-DARIAH's voluntary course registry for Europe (https://registries.clarin-dariah.eu/courses/).

13. For Germany, Sahle (2016, 2019) keeps tracking the creation of openly denominated DH professorships. Since Germany's first professorship of *"Archäoinformatik"* (computational archeology) 2008 in Berlin, 101 DH professorial positions have been announced. This development is accelerating: as from 2015, 10 and more new professorial positions are created per year in Germany (Sahle 2019).

14. Noteworthy example is the DH Department at University of Stuttgart (https://www.ilw.uni-stuttgart.de/abteilungen/digital-humanities/). Usually instead, DH centers and labs with less formal institutionalization are created, as e.g. the Austrian Center for Digital Humanities at the University of Vienna with a *"Forschungsschwerpunkt"* (established in October 2020, https://fsp-digital-humanities.univie.ac.at/).

15. An example would be the in 2019 newly inaugurated professorships for digital history at the Institute for History at Humboldt University of Berlin (https://www.geschichte.hu-berlin.de/de/bereiche-und-lehrstuehle/digital-history) and for digital transformation and digital humanities at the faculty for computer science at Otto von Guericke University of Magdeburg (https://www.dtdh.ovgu.de/).

tational approach to traditional humanities' research questions.[16] As such the DH can be considered a conglomerate of various sub-disciplines within the broader humanities.[17]

As we will show in section 2.2, what we call the digital humanities has been humanities computing in the 1980s, and–at least for the historical studies–cliometrics in the 1960s. Each of those had introduced machine-based methodologies and an advancement of humanities' theories to the existing method tool-boxes of the humanities with varying success. Hayles ([2011] 2012) and Sahle (2015, p. 47) argued that the successful re-naming and concatenating of these fields signify the "coming of age" of the digital humanities, and the discussions of their status as a sign of self-awareness and professionalization as their own discipline. The ongoing discussion on the definition and scope of DH are interpreted also as a need for legitimization of digital or computational approaches within the humanities (compare to Schnapp and Presner 2009), which is reflected in its professional implementation as that of a (or many) sub-discipline(s).

Several schematic views have been introduced to make sense of this multiplicity of the DH, and its relationship to the various mother disciplines. A sphere model on the status of DH shows it as threefold: as independent discipline, as digitally transformed disciplines, and as that of a sub-discipline's incorporation of digital elements in still traditional disciplines (Sahle 2013, pp. 6–7; Sahle 2015, p. 50).
Recently, another layered sphere model was introduced by Rehbein (2020, p. 254), in which he argued for accepting the dual-nature of the digital humanities as field and sub-field, that oscillates between the humanities and the quantitative sciences. This oscillation results in gradual greater influences by either side, as in e.g., digital history which is more influenced by the humanities, or historical information sciences (now more often referred as computational history) more influenced by the quantitative sciences.

2.1.2 DH as a meta-discipline

Due to these problems of proper categorization of the DH as a field or sub-field, some scholars argue that the DH can be best described as a meta-discipline, transcending the restrictions of usual disciplines, and establishing something of a post-disciplinary field.[18] As such, the DH offer the "productive uncertainty" of a "diplomatic" interpretative

16. An exception to this development provides computer linguistics at the intersection of linguistics, philology, and computer science, which are widely founded in independent institutions and increasingly are accepted as their own field of research, such emancipating themselves from both linguistics and the digital humanities.

17. In this line of though, the question arises whether the new field of computational social science can be considered part of the DH, too. This is closely related to the question, whether the social sciences can be considered part of the humanities. The reasons for this lie in the relatively recent emergence of the social science from the humanities, which in turn developed to use more quantitative methodologies than the humanities.

18. E.g., Sahle (2015) and König (2016); similarly also interpreted as a transformative science by Jannidis et al. (2017, p. XI).

transdisciplinary field, which allows a certain flexibility to choose its focus and methodology in an interpretive "diplomatic" position (Breckmann 2014, p. 287), and stresses on the devotion for openness and "compatibility" to other research areas (König 2021, p. 40).[19] In this vein, Rehbein (2020, p. 254) proposed a two-fold definition of the DH:

- First, the DH encompass all kinds of research in the Humanities that partly gains its findings from applying computer-based procedures, practices, and tools. In this understanding, the DH are purely humanities' scholarship, as its objects and questions are those from the humanities. An example of this would be digital history for the historical studies.

- second, the DH encompass the design, development, and generalization of these computer-based procedures, practices, and tools, as well as the study of their underlying theories and models. In this understanding, the DH are rather an auxiliary science located at the intersection between humanities and computer science. Proposed implementations entail a sort of information science for the humanities, such as humanistic informatics (Aarseth 1997, compare to) or historical information science for history (Boonstra et al. [2004] 2006). If however the epistemological interests were to be grounded in the functional question of this intersection, the DH would posses their own objects and questions for study, and such would constitute a "science of its own, with its own methodological framework" (ibid., p. 10; compare also to Piotrowski 2020, p. 9).

Similarly, Roth (2019) argued for the DH as three different disciplines: the digitized humanities, the numerical humanities, and the humanities of the digital. The digitized humanities, Roth (2019) characterized as the digitizing enterprises within humanities, as well as the application of computational methodologies, while the numerical humanities involve a different epistemic practice in the development of "mathematical abstraction and modeling" (ibid., p. 617) and the discovery and validation of "general mechanisms" of social processes (ibid., p. 618). While the former are prevalent in the humanities, the later, Roth (2019, pp. 622–3) identified as mainly part in the social science's new fields of computational social science.[20]

19. This follows the argument brought forward by Breckmann (2014) for intellectual history, that could be applied analogous for the DH as well. Just as the DH, intellectual history is basically a container term for multiple different fields, such as history of ideas, social history of intellectuals, history of the book, and more. Breckmann (2014, p. 287) argued that intellectual history's "lack of firm location within the present epistemological and institutional organization of the disciplines" would provide a "productive uncertainty" and constitute the field's "biggest strengths" for flexibility as a meta-discipline. The DH shares this status with intellectual history containing a plethora of different subfields; both can as such be considered "meta-disciplines."

20. Which is coincidently a result of that Roth regards the social sciences as part of the humanities, which classical methodological divide grew smaller in the process of turning to quantitative (and computational) methods.

2.1.3 Descriptive definitions of DH

Beyond the argued status of DH, the term DH is used on processes of digitization and digitalization.[21]

DH as a process of digitization

In a more vague manner, the term DH is applied on projects primarily occupied with the digitization of analogue sources to a computer-processable format. The DH were vastly understood as means to establish the digitization of publications and primary sources, archives, and any other physical matter, ranging from texts to photos to artifacts. In digitization, we can differ between two types of digital objects:

- **Retro digitals.** The result of converting (or digitally migrating) analogue sources via e.g., scanning, (digital) photography, or manual or automatic transcription is called retro digital ("*Retrodigitalisat*"), a static digital copy that represents the analogue original. Post-processing of retro digitals often involves a manual text transcription or automated text recognition via OCR[22] or HTR[23] of texts, and pictures annotations, enriching them with further content-based metadata besides

21. When working with the digital, we have to establish a sensitivity towards the differences between digitalization and digitization (following Brennen and Kreiss 2014). When addressing the transformation of the analogue into the digital–a machine-processable conversion–this is digitization. Digitalization is when we infer on the influences of the digital on life, work, social structures, scientific research. These terms are frequently mixed-up and used interchangeably; the Oxford Learner's Dictionaries for example lists both as "the process of changing data into a digital form that can be easily read and processed by a computer," missing out on a differentiated view (compare to https://www.oxfordlearnersdictionaries.com/definition/english/digitalization and https://www.oxfordlearnersdictionaries.com/definition/english/digitization; accessed 2018-05-08).

22. Optical Character Recognition is a process of pattern recognition , which works best on standard fonts printed on bright backgrounds (Holley 2009) as most commonly used models have been trained for commercial purposes of contemporary documents. Examples are the proprietary ABBYY *FineReader* (https://pdf.abbyy.com/de/) or Kofax *OmniPage* (https://www.kofax.de/products/omnipage), as well as *Tesseract* developed by Ray Smith (HP Lab, https://github.com/tesseract-ocr/tesseract) or OCRopus/OCRopy by Tom Breuel (DFKI Kaiserslautern, https://github.com/ocropus/ocropy) both published by Google in open source format. Prints of the 20$^{\text{th}}$ are considered a problem solved with a recognition accuracy of close to 99% (Springmann and Lüdeling 2017). OCR for historical prints however remains an ongoing challenge due to typographical heterogeneity, special characters (such as incunabula), and structuring problems through layout diversity that make the blocking and tokenization of the page more difficult (compare e.g., to Cordell 2017; Springmann and Lüdeling 2017). An example for current research project would be the OCR-D project of the DFG (since 2015, currently in project phase III putting the prototype software on use-cases, https://ocr-d.de/de/).

23. Handwritten Text Recognition. Since 2018, the tool "Transcribus" developed by READ-COOP at the University of Innsbruck makes this more accessible (https://readcoop.eu/de/transkribus/). Statistical deep learning is combined with a model set of human transcribed text to train the HTR tool Transkribus for corpora of handwritten texts, which 'learns' by connecting correctly transcribed handwritten text parts with text images. The amount of error decreases significantly with more model training data sets (compare to e.g., Muehlberger et al. 2019).

their resolution. This digital migration or re-mediasation of analogue objects is applied in order to protect the original from potentially harmful usage when accessing, as in the case of rare manuscripts, and increases their (remote) accessibility[24], and in general serve to secure and publicize the inventory of memory institutions (*"Bestandssicherung"*, Baum and Stäcker 2015, p. 9).[25] As such, digitization democratizes access and, consequently, knowledge.

- **Born digital objects.** Objects of digital origin are called born digital. In the context of constantly changing operating systems and data formats, born digital objects might have to be (re-)viewed by emulating (i.e., imitating) the original software environment, and as such have to be considered dynamic digital objects. Increasingly these born-digital objects become relevant for historical research as well, as historians turn to study the beginnings of the internet, or start to use social media data for analysis (Terras 2012; Rehbein 2020, p. 260).

- **Metadata.** Meta data are structural tags with machine-processable information on digital objects (both on born digital and retro digital objects). Metadata include (but are not limited to) timestamps, geo-information, image resolution, copyright and license information, or description of the content, dates, materials. The process of inserting explicit tags about implicit features of digital objects is called markup language.[26]

In the course of the last three decades, a wide-range of projects have been funded to digitize archives, journals, and books.[27] The digitization is usually applied on text and documents, whereas in object-based sciences e.g. archeology or art history, this also entails the 3D-digitization of objects and artifacts (compare to Bock et al. 2013; Kohle 2017).

This vast-scaled digitization led to a democratization of access to knowledge, and in the words of the "World Digital Library" (founded by the Library of Congress and UNESCO in 2009) is suited to "promote international and intercultural understanding" by "tell[ing] the story of the world's culture."[28] The digitization of analogue sources is an on-going project, but the general state of digitization is not far of.

Edelstein et al. (2017, p. 416) argued that the next step of digitization would be the harmonization of data through standardization and interlinkage, as in e.g., through Linked Open Data (LOD). Developments pointing into this direction are an increasing

24. Consequently, the original underlies greater protection, and thus reduced physical accessibility. Researchers need a heightened justification to access such rare originals *in vito*, which physical access is thus decreased, ironically, while improving their digital accessibility.
25. On the methodological implications of transforming sources to data, which apply especially to retro digitals, compare to section 6.3.1 on data biases.
26. Compare to TEI P5 guidelines (TEI Consortium 2020).
27. Compare to section 2.2.
28. https://www.wdl.org/en/

number of initiatives to find a common data structure for within the humanities, as in e.g., the long term national data infrastructure project (*Nationale Forschungsdaten Infrastruktur e.V.*, NFDI)[29], a joint project of the DFG and German Ministry for Education and Research (BMBF) to find a common data structure for both the humanities and the natural sciences. Projects like these are designed to provide the grounds for future interoperable analysis of data, in which various research projects can contribute to a reusable supra-database. As such, the discussions on the definitions of DH are also intended to raise awareness about the DH to go beyond of a purely digitizing enterprise in a process of emancipating the DH.

Challenges for digitization. Even before anything becomes digitized, digitization projects experience significant problems due to reservations regarding the legal protection of privacy, copyright restrictions, and prevention of misuse. Legal restrictions surrounding the protection of personal (and copy) rights are progressively eased through the so-called "moving wall" (Guthrie 1999, p. 297) of permitted publication–in Germany 70 years after the death of the author, regulated in §64 of the *Urheberrecht*[30] (Metzger 2010).[31] In Germany, the copyright law was updated to the current requirements of the "knowledge society" that specifically regulated digital resources only in 2018.[32] Before, the copyright law had last been significantly extended in 2007 (effect in January 1, 2008) to specify restrictive usage of electronic reading places of archival media to cater to the necessities of the "information society."[33] Ethical considerations play a role in the context of publications that entail discrimination, violence, genocide, and appropriation (Royakkers et al. 2018).

This conversion process to a machine-readable format is full of technical challenges. The (automated) recognition of characters is not without faults: wrongly recognized letters result in wrongly spelled words that in turn become un-retrievable (compare e.g., Cordell 2017).[34] A famous problem is the one of the long-S in pre-19th century texts, distorting the meaning of certain words and constitute unwanted "artifact[s] of

29. www.dfg.de/nfdi

30. https://www.buzer.de/s1.htm?a=64-66&ag=4838

31. The Open Access movement however regulates different forms of access through license standards. Demanding to make information "widely and readily available to society" "Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities" (2003), an Open Access movement formed in the early 200s to make scientific publications and research accessible and re-usable by researchers and society, defining different forms of licenses to use data freely (Müller 2006; Heise 2017). This was extended too for Open Source, Open Data, and to shape a shift in scientific culture to Open Science.

32. The *"Gesetz zur Angleichung des Urheberrechts an die aktuellen Erfordernisse der Wissensgesellschaft"* came into effect in March 1, 2018 (https://dip.bundestag.de/vorgang/gesetz-zur-angleichung-des-urheberrechts-an-die-aktuellen-erfordernisse-der/81080), and its limited period of validity has been repealed in July 2021 (https://www.bmjv.de/SharedDocs/Gesetzgebungsverfahren/DE/UrhWissG.html).

33. Compare to the *"Zweites Gesetz zur Regelung des Urheberrechts in der Informationsgesellschaft (2. InfoGesellUrhRG)"* (https://www.buzer.de/gesetz/7937/a152235.htm.

34. Further problems and biases that arise from digitizing will be discussed in section 6.3.1.

the digitization process" (Crymble 2021, pp. 33–4). Usually, re-keying through an human annotator is applied in order to catch those issues, but accuracy still would not reach more than 99% correctly identified words, the current gold standard for OCR (Springmann and Lüdeling 2017).[35].

After conversion, the standardization of digitized objects remains another challenge. Any humanities data is notoriously heterogenous, which constitutes a problem for highly standardized methodologies and processing via computers.[36] There are attempts to standardize the kind of necessary meta-data for digital objects as in the regularly updated TEI Consortium Guidelines (e.g., the "*TEI P5: Guidelines for Electronic Text Encoding and Interchange*" by TEI Consortium 2020). In 2016, the DFG for the first time published in *DFG-Praxisregeln "Digitalisierung"* a set of recommendations concerning the digitization of sources as a requisite to receive funding, regulating technical processes, parameter (such as color intensity or image resolution), necessary metadata informations, or rules for citations. These recommendations apply of course only to DFG-funded projects since 2016. In the US, the Federal Agencies Digital Guidelines Initiative (FADGI) (2016) updates their "*Technical Guidelines for Digitizing Cultural Heritage Materials. Creation of Raster Image Files*" regularly as well, but which vary slightly from the recommendations of the DFG. As a result various levels of standardization exist for metadata or digitization requisites over all projects.

In 2019, the NFDI[37] was founded in Germany to standardize data and metadata over all disciplines. In an extensive process, each (sub-)disciplines are forming consortia to discuss their own data challenges, and to develop suitable standardized formats, which then are supposed to be merged to one national research data standard over all disciplines, the natural sciences and the humanities alike. However, as Rehbein (2020, p. 263) puts it, the fear pertains that "consistent formalization among potentially heterogeneous sources is difficult if not impossible to attain." To undertake this maybe impossible endeavor offers the reward of a huge range of research possibilities[38]: making previous research data sets available for current research; allowing to ask new questions on old data; enabling cross-disciplinary research using discipline-foreign data sets; easy recycling of former research outputs in replication studies, as well as with an updated analysis or further research goals; permitting meta-studies over various data sets; and in general promoting the accessibility and machineprocessability of data sets in a coherently managed data format over various projects, that ideally do not need to be processed time-intensively anymore (in a sort of 'ready-made' data format).

The digital transformation is not the last step in the process of digitization: the sustainability of digitized objects entail a range of problems for any provider in regards

35. As e.g., shown by Crymble (2021, p. 35) for the Old Bailley Proceedings Online with still one error in every 4000 words after rekeying

36. For a discussion of humanities data and biases in digitized sources compare to section 6.3.1.

37. *Nationale Forschungsdaten Infrstruktur e.V.*, https://www.nfdi.de/

38. And if only at least for the standardization of humanities' data.

to the upkeep[39], contextualization[40], and security risks management[41] of both the digital objects and the infrastructure they are embedded in (exemplary Cunningham 2008; Conway 2010; Terras 2012). Ensuring sustainably is last but not least also a cost factor. Institutions such as the DFG hard-coded the need to ensure sustainability in data management as a requisite to receive funding through the format of the project's data output[42]–without providing a clear (financial) path on how the applicants should ensure their long-term maintenance.

Finally, beyond reservations due to security issues on the protection of legal rights, many memory institutions such as archives and museums are hesitant to give up the interpretation *ex cathedra* of their sources ("*Deutungshoheit*"), despite their mandate for the public utilization of archival resources out of fear of misrepresentation and potential abuse. "Politically, many heritage institutions are reluctant to relinquish control over the catalogues of the cultural patrimony entrusted to them," summarized this Hotson (2019, p. 250). This also has a financial aspect in potential "loss of revenue from rights and reproduction activities" as pointed out by Kapsalis (2016, p. 10). But there are also potentials of this "digital remediation" for heritage and memory institutions (Ward and Wisnicki 2019, p. 200): increased accessibility of their collections, potentially increased traffic and as such importance of the collection, and the potential for new discussions on the collections as in the context of e.g., colonial pasts and provenance[43]. As a side-effect of the digitization, differences in the collection behavior between archives and libraries are vanishing in the digital realm, when collections are merged in digital supra-libraries: borders between unique and duplicate source collections are blurred as both are provided digitally online–which is heavily criticized by Cunningham (2008, pp. 532–3). Increasingly, collections are only made available digitally.

39. Preservation of accessibility and continuous maintenance, including the potential emulation of digital objects when data standards change to ensure interoperability, as well as the accessibility and usability of the interfaces the objects are embedded into in terms of performance effectiveness.

40. Providing a framework of e.g. metadata of these digital objects, and their origins in i.e. a collection in order to ensure their archival provenance.

41. In order to ensure authenticity and security from manipulation. Possible future enterprises are to secure digital objects from manipulation using the block chain technology.

42. The "*DFG-Praxisregeln "Digitalisierung"*" (2016, p. 9) read in German: "Die Langfristverf´ugbarkeit der Ergebnisse von Digitalisierungsprojekten ergibt sich einerseits aus der Wahl der Daten- und Metadatenformate. Andererseits ist sicherzustellen, dass die digitalen Daten auch physikalisch verfügbar bleiben. Dabei gilt: Kosten für die projektbezogene Sicherung der Daten werden [...] als Eigenleistung für die Laufzeit des Projects anerkannt. Eine Förderung diesel Kosten aus DFG-Mitteln kann nicht erfolgen."

43. Such as e.g., in the joint pilot project "*3-Road Strategy for the Documentation and Digital Publication of Collections from Colonial Contexts held in Germany*" by various collection-holding stakeholders and the Federal Foreign Office and the Ministers of Culture und Cultural Affairs of the Länder (Museum für Naturkunde Berlin 2021).

DH as a process of digitalization

The digitization of digital sources constitutes one premise of the digitalization of research: the potential to do new research with new kind of sources, as e.g. with historical network research (Rehbein 2020, p. 259).

In another strand, the efforts within the DH to combine technical advancements to humanities' work can be described as a process of digitalization. As such the DH entail a broad variety of approaches that combine humanities' thought with heterogeneous quantitative and computational methodologies as well as novel formats of representation of the natural sciences, mainly computer science, mathematics, and quantitative methods developed in the social sciences.

These interdisciplinary approaches are still in the process of sounding to the requirements of the specific applications within the humanities, and as such use not thoroughly formalized methods except for the established means of application from the originating fields. These methods entail statistics and computational methods, network research, text mining, and more, such as data base management and the creation of specialized websites. As such, the DH are part of a digitalization process within the humanities and general science. As the DH do not favor any specific methods, Thaller (2017a, p. 15) characterized the DH "method neutral despite their methodological implications". In many instances, the DH are equated with a variety of computational tools and methods: the "sum of all attempts to apply information technology to the objects of Humanities scholarship" (Thaller). This is also represented in the idea of the reformation–or update–of the traditional humanities through these methodologies, as in the concept of a "contemporary humanities" (Piotrowski 2020, p. 4), working digitally with pre-formatted tools (but rarely with computational methodologies, as in the "computational humanities").

Several suggestions have been made to classify the DH according to their usage of technology. Systematic interpretations of the DH propose a scale-oriented model of either low-end DH (where researchers use generic tools) and high-end DH (where they develop new and highly specialized tools and methods (compare to Burghardt and Wolff 2014, p. 40)), or a minimalist understanding of DH (as an auxiliary science adding tools and methods) vs a maximalist one (as a paradigm change in how to do research in the humanities (see Kirsch 2014). In a similar vein, Fridlund (2020, pp. 74–6) differentiated between a regular history ("1.0") that has naturalized certain digital elements which go mostly "invisible" (such as online searching or databases), and a revolutionized completely digital and computational history ("2.0").[44]

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44. Compare to section 6.2.3 evaluating the extend of DH and the paradigmatic changes it represents.

2.2 Historiographical perspectives on the DH and Digital History

Whereas the incentives of the DH are new, the usage of quantitative or computer-based methodology in the humanities is certainly not.[45]

Earliest beginnings and narratives of foundation. "Unlike many other interdisciplinary experiments, humanities computing has a very well-known beginning," claimed Hockey (2004, p. 4). Canonically, the history of the DH began with the indexing of the writings of Thomas Aquinas by the Jesuit monk Father Roberto Busa (1913–2011) in the 1940s using reading machines and room-filling computers in cooperation with IBM. Often described as "seminal work" on word concordance, Busa (in cooperation with a range of female computer operators Terras and Nyhan (2016) devised a punch-card-based concordance of the writings of Thomas Aquinas in what would become a 56 book-edition of the "Index Thomasticus" (published in 1992 as hypertext-featuring CD-ROM and online in 2005 as "Corpus Thomisticum"[46]), laying the foundation for the development of corpus linguistics, and ultimately the creation of humanities computing (e.g., Hockey 2004; Svensson 2009; Graham et al. 2016, pp. 19–26; Gaffield 2018, p. 123; Hohls 2018, A.1-14; Winters 2019; König 2021, p. 38).

This narrative traces a genealogy of the DH from computer linguistics (Reiche et al. 2014; Knopp 2018, p. 20; Sula and Hill 2019, p. 191) that in a "first wave [...] focus[ed], perhaps somewhat narrowly, on text analysis (such as classification systems, mark-up, text encoding, and scholarly editing) within established disciplines" (Presner 2010a, p. 6; see also Hockey 2004).

This founding narrative has since been criticized (such as by Piotrowski 2020, p. 12; Sula and Hill 2019, p. 191; Crymble 2021, p. 17), and unmasked as a "founding myth" (Interview with Tito Orlandi in Nyhan and Flinn 2016, p. 80) and a "useful fiction" (Juliane Nyhan in the same interview with Tito Orlandi in ibid., p. 80). "[C]omputation in research is [...] about a way of thinking algorithmically about a problem and applying certain principles of problem solving to evidence, in search of a solution. The groundwork for this algorithmic thinking had been set decades if not centuries before 1949," stressed Crymble (2021, p. 18).

Other pioneers of computational thought are increasingly (re)discovered: such as William Weaver or Norbert Wiener (Interview with Tito Orlandi in Nyhan and Flinn 2016, p. 79), or pioneers of non-numerical computing and the social functions of textual computings by Andrew Donald Booth and Warren Weaver (compare to Rockwell 2007; Sula and Hill 2019, pp. 192–3).

Especially history has a long tradition to employ quantitative and computer-based

45. The following focuses on the history of the DH with a special focus on the integration of quantitative and computer-based methodologies in the historical studies.

46. http://www.corpusthomisticum.org/

thinking: In quantitative history (also called cliometrics, or econometrics) a quantitative perspective opened previously non-utilized types of sources up for analysis since the early 20th century (Crymble 2021; Thaller 2017b; compare to the following section on quantitative history). Similar remarks have been made for quantitative methods in linguistics that traces stylometry going back to the 19th century (Hockey 2004, p. 5; compare also to Knopp 2018, pp. 20–1).

Humanities Computing, 1960-80s. Machine-based approaches and computational approaches were first popularized in the humanities under the terms 'humanities computing' and 'computing in the humanities'. Founded in an interest in structuralism, the new technological advances and availability of computing machines[47] led to an opening of quantitative approaches and statistical software to the humanities that allowed to search for patterns and insights using machines, focusing mainly on texts in linguistics and literary studies (Hockey 2004, p. 5; Crymble 2021, p. 24). The ability to count "in much greater numbers and much more accurately than any human being" led to a series of studies in regards to large-scale concordances, authorship attribution, and literary styles (Graham et al. 2016, p. 21). The 1962 conference "The Use of Computers in Anthropology" in Burg Wartenstein, Austria, is often referred as the "first 'digital humanities' meeting" (Zaagsma 2013, p. 7) and "presumably the first attempt to clarify a methodological position for the interdisciplinary world between the humanities and computer science" (Thaller 2012, p. 8).

Noteworthy are the e.g., the influential study by Mosteller and Wallace (1964) to identify the disputed authors of the "Federalist Papers," or the first electronic version of the "Modern Language Association International Bibliography" in the late 1960s, that was searchable using telephone couplers (Knopp 2018, p. 21), or the "Thesasaurus Linguae Graecae" (TLG) at the University of California, Irvine, a databank of Ancient Greek texts (Hockey 2004, p. 9).[48]

During the 1970s and 1980s, text analysis methodologies consolidated (ibid., p. 9; Svensson 2009) as a result of both methodological and technical advances, such as an increase in "storage and processing capabilities" (Sula and Hill 2019, p. 191). During this time, humanities computing experienced increasingly a professionalization: besides the inauguration of the journal *Computation and the Humanities* in 1966 (Boonstra et al. [2004] 2006, p. 15) that would represent the humanities computing until 2004[49], new computer-based text-focused methodologies were discussed and presented in multiple recurrent conferences in the UK and in the USS[50], and an increasing number of

47. At first punch card reading machines, then in the late 1950 in size ever shrinking computing machines, this development culminated in the 1980s in the personal computer.

48. For an overview on projects compare to Hockey 2004; Knopp 2018, pp. 21-22.

49. By which point the journal had lost its dominant status in the field (Svensson 2009; Sula and Hill 2019, p. 191.

50. Such as the *International Conference on Computing in the Humanities* (ICCH)

specialized study centers and organizations[51] and their publishing venues[52] (compare to Hockey 2004, pp. 7–8).

From humanities computing specialized sub-disciplines evolved such as computer philology and computer linguistics[53], or history and computing, and historical information science (Boonstra et al. [2004] 2006). Hockey (2004, p. 13) noted that humanities computing lost “some aspects of linguistic computing, particularly corpus linguistics, to conferences and meetings of its own” and “continued to be a separate discipline.”

From the 1980s on, computers had finally “pervaded every conceivable field of the humanities,” summarized Boonstra et al. ([2004] 2006, p. 13) the integration of the personal computer and electronic mail, alongside new advances in how files could be processed by computers (Hockey 2004, p. 9). Instead of having to do batch processing or sequential processing, results were instantaneously obtainable from searches with early DOS-based text analysis programs (ibid., p. 10).

As one of the greatest accomplishments of the humanities computing, Hockey (2004, pp. 12, 16) identified as the *Text Encoding Initiative*[54], which in 1994 had published their first *Guidelines for Electronic Text Encoding and Interchange*, a joint project of the ACH, ALLC, and the *Association for Computational Linguistics* (which renamed to *Text Encoding Initiative* in 2001).

Quantitative History, 1960s-80s. Independent from–and in parallel to–the introduction of machine-based approaches to textual processing in humanities computing, machine-based approaches of quantification also found entry to the historical studies. Computational thinking can be identified since the Early Modern period in demographical and socio-historical studies utilizing the products of earliest forms bureaucracy of taxation and census, and in the late 19th century in the quest for ‘objectively’ study the past during the professionalization of the historical studies[55] (compare to S. Gordon (1991) 2003; chapter 1 in Novick 1988; Crymble 2021, pp. 20–7). As Anderson (2007) noted, “true ‘data analysis’ in the current sense had to await the growth of the social and statistical sciences in the first half of the twentieth century, and the diffusion to universities in the 1950s of the capacity for machine tabulation of numerical records, and then of mainframe computing in the 1960s.” Since the late 1920s, the French *Annales d’historic economique et sociale* school had subsequently focused on serial census lists, registers, tax records, and more, as historical sources to write a new quantitative social history

51. The *Association for Literary and Linguistic Computing* (ALLC) was founded in 1973, the *Association for Computers and the Humanities* (ACH) in 1978. Both jointly organized recurrent conferences on humanities computing.

52. Publishing before in *Bulletins*, the ALLC founded their own journal *Literary and Linguistic Computing* in 1986, which would become the “key publication for humanities computing” (Svensson 2009).

53. E.g., in 1963 the *Centre for Literary and Linguistic Computing* was founded at Cambridge University (Hockey 2004, p. 7).

54. Founded in 1987, https://tei-c.org/.

55. Part of which branched out to focus on the rules on how groups and societies form, growing to become the social sciences and sociology.

of the lives of the ordinary people , giving a point of contrast to the dominant historiography of the elites (the 'great men') (Anderson 2007; Crymble 2021, p. 22). These early studies involved computational thinking, and/or working with the newest methodological and technological advances in statistical analysis: starting with human computers (often female statisticians), proto-computers (punch card reading machines), and then with electrical mainframe computers, that each offered new possibilities in working with quantitative-based data (ibid., p. 21), and enabled the easy access to "machine-tabulation of numerical records" in the 1960s and the aggregation of "historical patterns of multiple events or phenomena" (Anderson 2007).

From the 1950s to the late 1970s, quantitative-based historical studies gained traction; an increasing number of historians started to incorporate quantitative methods from the social sciences into historical research projects. This finally lead to the formation of two new historical sub-fields: social history and economic history (Reynolds 1998, pp. 141-2; Aydelotte 1966, Boonstra et al. (2004) 2006, p. 25; Anderson 2007). This new quantitative history–also known as cliometrics or econometrics (focusing on economic history)–was carried by the younger generation within historical studies (Whales 1991, p. 296; Crymble 2021, p. 25) that gained broader popularity in the 1960s, as access to adequate technical support had increased (Aydelotte 1966; Reynolds 1998, pp. 141–2; Boonstra et al. (2004) 2006; Anderson 2007).

Computational and quantitative exemplary studies included pioneering distant approaches of macro analysis to history, as e.g., the *longue durée* studies by Fernand Braudel on the Mediterranean (1949, extended and republished in 1966) tracking long-term changes resulting from the "constant ebb and flow of poverty and other endemic structural features" that lie "beyond the narrow focus of individual events" that the *Annales* School, too, had refuted (Graham et al. 2016, p. 22). Similarly, Katz (1975) "traced economic mobility over decades using manuscript censuses" (Graham et al. 2016, p. 22).

Other new economic historians used micro analytical studies (Williamson 1965, p. 109), which, e.g., utilized computers to "statistically support arguments" to identify a middle social hierarchy of small scale farmers as a third part to the previous "dichotomy of rich slave owners and poor white people" in the antebellum US-South (Owsley 1949; compare also to Crymble 2021, pp. 17–22); assessed the "Making of an American Community" in an American Frontier County using newspapers, private papers, county histories, and censuses of the mid- to late 19^{th} century (Curti et al. 1959; compare also to Anderson 2007); or that challenged the assertion that railroads were central for the industrial development in the US, and quantitatively argued that the "combination of wagon and water transportation [via canals, added by CP] could have provided a relatively good substitute for the fabled iron horse" (Fogel 1964, p. 219; compare to Williamson 1965; Anderson 2007). More controversially received were studies on the prosperity of slavery and the effects of the US civil war in the South (*"The Economics of Slavery in the Ante Bellum South"* by Conrad and Meyer (1958); or "*Time on the Cross. The economics of*

American negro slavery" by Fogel and Engerman (1974)). Fogel and Engerman (1974)'s study was criticized as being apologetic to slavery, and "has since become a caricature for statistical approaches to history gone wrong" (Crymble 2021, p. 23; compare also to the contemporary review by Haskell 1975).

New Journals were created to host these new approaches, such as the *Historical Methods Newsletter* in 1967 (Reynolds 1998, p. 141). Quantitative historical research found their way into established historical journals such as the *American Historical Review*[56], and were featured in conferences–e.g., a special feature on quantification in history at the AHA conference in 1967–, or in the humanities computing journal *Computers and the Humanities* (Graham et al. 2016, p. 23). Graham et al. (2016, p. 23) noted how computational history in the 1960s was primarily associated with studies of demographic, population, and economic histories," despite them also being published in humanities computing contexts.

"For a time in the 1970s, it looked like history might move wholesale into quantitative histories, with the widespread application of math and statistics to the understanding of the past," noted (ibid., p. 24; compare to Fridlund 2020, p. 76). While quantitative research projects have been featured in traditional journals, conferences, and integrated into and into institutional structures and university curricula[57], their approaches also met resistance due to actual and perceived claims of quantitative methodologies making "more substantial 'truth' claims" or supposedly offering "a 'scientific method' of history" (Graham et al. 2016, p. 23). Common were also accusations of positivism and reductionism– of unjustified reduction of complex historical phenomena to numbers, and focusing only on what is enumerable[58]–, in which quantitative history would have been "pushed too far" (as refuted e.g., by Aydelotte 1966, p. 821) and "too much trust [placed] in counting" a fragmented historical past (Boonstra et al. [2004] 2006, p. 25),[59] or in danger to replace the "subjective craft" of the qualitative methodology with statistical approaches (as addressed by Bullough 1967, p. 61). As such, quantitative history was often perceived as a "betrayal of the historical project" (Anderson 2007).[60] These claims, accusations, and criticism of the more "orthodox" historical studies were (ultimately unsuccessfully) refuted by e.g., Aydelotte (1966) or Bullough (1967), who argued for the "positive possibilities of the computer in historical research" (ibid., p. 61; compare also to Reynolds 1998, p. 141).

As a result, "cliometrics became estranged from the mainstream of the profession" (Graham et al. 2016, p. 23), having failed to sufficiently answer to accusations that quantitative methodology would deviate too far from traditional historical research questions

56. https://academic.oup.com/ahr

57. Statistical methods had been introduced in around 40% of US curricula by the early 1980s (Anderson 2007).

58. As have been brought forward against e.g., Fogel and Engerman (1974).

59. Instead, quantitative historians had work on to establish a reflection on the limitations of the sources used, as well as the reliability of their content, as Crymble (2021, p. 25) stressed.

60. On the actuality of this criticism and opposition, compare to section 6.1.3.

and methodology (Aydelotte 1966; Reynolds 1998). Its popularity "collapsed suddenly" in the 1980s as Ayers (1999) described this due to its "own inflated claims, limited method and machinery" facing an 'orthodox' historical scholarship. This lead to a recline in the usage of statistical methods since 1985 and stagnation in the usage of what Reynolds (1998, pp. 141–2) described as more elementary statistics;[61] established institutions or curricula were "folded back in with history departments" (Crymble 2021, p. 26).

Quantitative history had but secured a niche in historical studies–most successful in economic history, to a lesser extend in political and social history as perceived by Aydelotte (1966, p. 809), but in general quantitative methodology was instead regarded as a specialization of "some historians" instead of a "methodological necessity" (Anderson 2007), having failed to be incorporated in the historical toolkit (Reynolds 1998, pp. 146–7).

The decline of cliometrics in the broader historical studies followed on foot with the methodological implications of the post-structuralist cultural turn (influenced by anthropology) in the mid-1980s, and the new focus on the social nature of text and text analysis of the linguistic turn (influenced by literary studies), which questioned the objectivity of data (ibid., p. 146; Anderson 2007). "Texts replaced tables," summarized this Ayers (1999).

Usually, the history of cliometrics is not regarded as part of the history of the DH. The focus on textual analysis in the historiography of the DH led to an omission of the developments of computer-based methodologies in quantitative history[62], which utilized statistical methodologies to historical research questions. While there is a continuity in the usage of computer-enabled research, overviews like Anderson (2007) does not use the term of DH nor 'digital history', but instead "'technologically enabled' history." Similarly remarked this Hohls (2018).

Advent of the Personal Computer, the Internet and Beginning of Mass Digitization, mid-1980s to early 2000s. The niche of quantitative history found new impetus in the *Association for History and Computing* (AHC, established in 1987)[63], and its respective

61. Aydelotte (1966, p. 808) had advertised that statistical methods for history would be generally "not complex," and therefore very feasible: A "few totals, a few percentages, and a few correlations in which the relationship between certain variables is examined while other variables are controlled." In contrast, Reynolds (1998, pp. 145–6) observed that the migration to "newer and more arcane statistical techniques" had not happened in the majority of the field of quantitative history.

62. Sula and Hill (2019, p. 192) criticized that cliometrics fell "outside the narrow focus on the text that is found in the standard narrative [on the history of the Digital Humanities] and received no mention." Hohls (2018, A.1-16) mentioned quantitative history as a "second strand" to the digital humanities.

63. Zaagsma (2013) gives the date of 1985 for its foundation, whereas the website of the AHC gives the date of proposition in 1986 at the Westfield conference, and its foundation in 1987 (compare to https://web.archive.org/web/20010702205234if_/http://odur.let.rug.nl:80/ahc/; retrieved URL from the Internet Archive – version 2001; accessed 2021-08-02).

Journal of the Association for History and Computing (JAHC, 1998–2010)[64] In the Westfield conference in 1986, the "microcomputer revolution" was described as the future of history (Boonstra et al. [2004] 2006, p. 29) with the onset possibility of personal computers.[65]

In the 1990s, the World Wide Web revolutionized the usage of computers. Focused turned to the possibilities of the then-new internet: novel means of publication and access, hypertexts, digital libraries, and new forms of collaborative editing were developed (Sula and Hill 2019, p. 191), and achievements in database search and retrieval, automation, hyper card stacking, development of easier-to-use tools, and large-scale digitization projects (compare to Graham et al. 2016; Schnapp and Presner 2009; Presner 2010b). Hockey (2004, p. 14) stressed while many new projects were envisioned, it was highly problematic to receive funding; as a result "few of these [planned] publications saw the light of day except as prototypes or small samples."

These developments in the 1990s to early 2000s, Schnapp and Presner (2009) and Presner (2010b) described as the first wave of the DH. This, too, Graham et al. (2016, p. 24) regarded as the second wave of computational history[66], in which quantitative history "re-emerged" within humanities computing as 'history and computing' with the "advent of personal computing," and their shift in focus on texts. Historians turned to linguistically inspired humanities computing and cultural analytics in the wake of greater access to digitized resources, which finally lead to the overlap of the traditions of quantitative history and computing in the humanities (Crymble 2021, p. 27). Crymble (2021, pp. 42, 18) however argued against a linear genealogy between quantitative history, and the linguistically focused work (cultural analytics) of the early digital humanities/history computing of "simple" similarity using computers, as they weren't rooted in the same intellectual premises and purposes.[67] Instead, *digital history* was born out of their combination in the mass-digitization in the 90s.

One of the first digital libraries was Project Gutenberg[68], established in 1971. Thaller (1987) developed an influential first CLIO historical database management system in the 1980s (Boonstra et al. [2004] 2006, pp. 26–7). The first historical online-only pub-

64. Which on its website (https://quod.lib.umich.edu/j/jahc/; Accessed 2020-08-02) claims to have been sponsored by the *American Association for History and Computing*(AAHC, founded in 1996), that appears to be the successor to the AHC Graham et al. (2016, p. 24).

65. Working with computers however was still tedious: Anderson (2007) described how one had to "order tapes and paper codebooks, which were delivered by mail" and then "mounted on a mainframe computer, to be accessed in a statistical package" in order to access archived data sets in the 1980s as e.g., at the Inter-university Consortium for Political and Social Research (ICPSR), while oftentimes universities charged for the privilege of computer access. This progressed to have mainframe replaced with personal computers, and to be able to directly download data files on the desktop by the early 2000s.

66. After the first wave being quantitative history.

67. Crymble (2021) argued, that Busa's humanities computing work was "fundamentally different from the various econometric analyses." While Busa mostly did linguistic or literary analysis of the choice of work, this was based on a methodological focus instead of on historical insights (ibid., pp. 27–8).

68. https://www.gutenberg.org

lication was *The Valley of the Shadow* by Edward L. Ayers (launched in 1993), which detailed the life "two communities in the American Civil War," offering access to "letters and diaries, newspaper and speeches, census and church records [...]. Giving voice to hundreds of individual people, the Valley project tells forgotten stories of life during the era of the Civil War."[69] In 1994, the *Roy Rosenzweig Center for History and New Media* (RRCHNM) was founded. One of its earliest projects was "History Matters: The U.S. Survey Course on the Web"[70] (launched in 1998), that entailed an annotated digital archive with multiple options to historical "web resources and [...] unique teaching materials, first-person primary documents, and goes to analyzing historical evidence"[71] accompanied by an online forum, syllabi, and interviews for "using the historical sources in the classroom" (Robertson 2016, p. 292). Similar projects to digitize historical resources emerged, which had a clear focus on public history (ibid., pp. 292–3; this also became clear in the focus on web presentation as in Cohen and Rosenzweig 2005; or in the definition of digital history as "examining and representing the past [...] with new communication technologies" by Seefeldt and Thomas 2009). Examples for this are the Virginia Center for Digital History[72] (founded in 1998, and one of the first uses of 'digital history', which was "charged with creating new forms of historical scholarship and with performing public service and outreach"[73]; or the "Digital History Project"[74] (founded in 2002) for educational purposes; or the "September 11 Digital Archive"[75] (launched in 2002 by the RRCHNM), which "use[d]" electronic media to collect, preserve, and present the history of September 11, 2001 and its aftermath," containing "more than 150,000 digital items" that have been collected and crowdsourced (Robertson 2016, p. 293); or cartographing projects that combined historical resources with GIS, such as the "Texas Slavery Project"[76] founded in 2007 by Andrew J. Torget, or "The Geography of Slavery in Virginia"[77] founded in 2005 by Tom Costa. In 1996, the "Internet Archive"[78] and its front-end, the "Wayback Machine," were introduced to archive the web as a born digital archive (compare to Romein et al. 2020, pp. 5–6; (for an extensive overview on web history see Brügger and Milligan 2019)); it was extended to an Open Library in 2005 (ibid.)). In Germany, the information and communication forum "H-Soz-Kult"[79] was founded early in 1996, which conjoined in 2002 with "Clio-online - Gateway for

69. Compare to https://valley.lib.virginia.edu/ (Accessed 2021-06-18).
70. http://historymatters.gmu.edu/
71. Compare to http://historymatters.gmu.edu/expansion.html (Accessed 2021-06-18).
72. http://www.vcdh.virginia.edu/index.php?page=VCDH
73. Compare to the Virginia Center for Digital History (http://www.vcdh.virginia.edu/index.php?page=About; accessed 2021-08-02).
74. http://digitalhistory.unl.edu/
75. https://911digitalarchive.org/
76. http://www.texasslaveryproject.org/
77. http://www2.vcdh.virginia.edu/gos/
78. https://archive.org/
79. https://www.hsozkult.de

Historical Scholarship e.V."[80] funded by the German Research Foundation as an open access and community network.

Renaming to "Digital Humanities." Around the same time of the emergence of digital history[81], the term 'digital humanities' was introduced as befitting of the new possibilities of the personal computer and the internet. Blackwell's "*A Companion to Digital Humanities*" edited by Schreibman et al. (2004) is usually credited with the first use of the term DH, which caused a process of renaming the humanities computing to 'digital humanities' (König 2021, p. 44), whereas a seminar at the University of Virginia's English Department had already mentioned the term in 2001, where the "Digital Humanities Curriculum Seminar" ran from 2001 to 2002 (Drucker and Unsworth 2002; compare to Allington et al. 2016; Crymble 2021, p. 29). Slowly, the humanities computing became 'digital humanities' by a shift in focus from 'computing' to 'digital' (ibid., p. 27).

"A pertinent question is whether the discursive transition from humanities computing to digital humanities is mainly a matter of repackaging (humanities computing), or whether the new level also indicated an expanded scope, a new focus or a different relation to traditional humanities computing work," Svensson (2009) analyzed this change and noted that "it is obvious that the term 'digital humanities', as used by the humanities computing community, often serves as an overarching denotation in book and journal titles," but that still "humanities computing is often used in the actual narrative."[82] "The shift towards the digital humanities was not simply a shift in nomenclature, although there are elements of that as well," instead it constituted a "new method of thinking," claimed Graham et al. (2016, p. 25).

The term of 'digital humanities' provided a vision for (a new field) to encompass all the humanities, introducing projects from archaeology, art history, history, lexicographic, music, multimedia studies, performing arts, philosophy, and religion (Sula and Hill 2019, p. 192), that was suited to extend the function of humanities computing as "technical support to the 'real' humanities" (Berry 2011, p. 3) and to broaden their focus.[83]

The change in terms is often understood as signifying the independence as a professional field (compare to Hayles [2011] 2012), and the occupation with its genesis as an act of "canonization and self-ascertainment" (Sahle 2015, p. 47). Its use however remains criticized as often meaning "little more than 'new"' (Crymble 2021, p. 165).

80. https://www.clio-online.de/

81. The Virginia Center for Digital History used the term as one of the first, in 1998.

82. Similarly, Boonstra et al. ([2004] 2006, p. 18) still perceived 'history and computing' as the "most neutral and encompassing term" for the computerization of the humanities/digital history. Tellingly, Boonstra et al. ([2004] 2006) do not mention the term 'digital humanities' at all in their discussion of the past and future of digital history.

83. In order to re-adjoin humanities computing to the DH, McPherson (2009) declared a trias of fields: the computing humanities, the blogging humanities, and the multimodal humanities all covered by the DH umbrella (Sula and Hill 2019, p. 192).

This change was also reflected institutionally: In 2005, the ALLC fused to the *Alliance of Digital Humanities Organizations*, which was then joined by the *Society for Digital Humanities/Socieété pour l'étide des méDias interactions* (SDH/SEMI) in 2008, and "predominantly address[ed] textual analysis, markup, retrieval systems and related areas" (Svensson 2009; compare also to Sula and Hill 2019, p. 192). The journal of *Humanities and Computing* discontinued in 2004; it was renamed in 2005 as *Language Resources and Evaluation* and "had by this time lost its status as one of the 'official' journals for humanities computing" (Svensson 2009).

Since the mid-2000s, humanities computing evolved to what Schnapp and Presner (2009) and Presner (2010b) described as the second wave of DH, characterized by a focus on the "qualitative, interpretive, experiential, emotive, generative [...]. It harnesses digital tool kits in the service of the Humanities' core methodological strengths: attention to complexity, medium specificity, historical context, analytical depth, critique and interpretation" and in "creating the environments and tools for producing, curating, and interacting with knowledge that is 'born digital' and lives in various digital contexts." Manfred Thaller described this developments as "break-through" in applicable methods since the 2000s.

While the first digital editions were mere replications of printed scholarly editions in a virtual format in the 1990s, soon digital scholarly editions became extended on: to provide additional analytical features, visualizations, and tools (Romein et al. 2020, pp. 9–10); examples for this are the "Samuel Beckett Digital Manuscript Project"[84] (founded in 2011) offering a digital library and "genetic edition" of his works genesis (Neyt and Van Hulle 2020), or the "Wittgenstein Source"[85] (founded in 2009) that hold the digitized collections of the written legacy of Ludwig Wittgenstein, which the "WITTfind" project[86] semantically processed to enable search queries, image and transcription reviews. One of the pioneering projects in data management was the charter encoding initiative "Monasterium.net"[87] founded in the early 2000s, which Rehbein (2020, p. 260) lauded as exemplary in regards to their systematic approach, the completeness of sources (hosting over 400,000 charters), and transparency on the shortcomings and approaches to the collection; since 2014 it is developed in open source.

The interlinkage of humanities computing and computer linguistics remained to continue in the close connection between DH and the digital literary studies (Robertson 2016, p. 291; Crymble 2021, p. 30)[88], whereas digital history ventured more often within

84. https://www.beckettarchive.org/
85. http://www.wittgensteinsource.org/
86. Founded in 2018 by the Wittgenstein Archives of University of Bergen and LMU Munich, http://wittfind.cis.uni-muenchen.de/
87. https://www.icar-us.eu/cooperation/online-portals/monasterium-net/
88. Which hegemony in also reflected in the distribution of newly created professorial positions in Germany, of which roughly one third were created in the field of language studies and literature studies (compare to Sahle 2019).

public history projects (Robertson 2016, pp. 292–3; Hohls 2018, A.1-8; König 2021, p. 38).

The developments within DH–introduction of methodologies, progress of digitization, data standardization, automatic annotation, data linkage, visualization and publication media–served as an accelerator for their subfields, such as digital history (Boonstra et al. (2004) 2006, pp. 20–1; Rehbein 2020, p. 259). As such, digital history is rooted deeply within the digital humanities; the term is used as an interdisciplinary collecting basin for any ‘digital’ research employed on historical fields, data, or research questions, or using computational or computer-based methods (Romein et al. 2020, pp. 3, 293; König 2021, p. 38). Their research conversations however remained for a large part “distinct”: Crymble (2021, p. 30) observed a “preference for presenting in history-focused venues” such as at conferences of the *American Historical Association*, which casted “doubt on the depth of connection between history and digital humanities research.”

Within history, the status of digital history is not that of a formal sub-discipline, but more of a set of new methodologies, tools, and reflections on the nature of the newly digitized sources (retro digitals), as well as the (specialized) use of softwares and tools. As such, digital history can be considered a new frontier in methodological patchwork “mosaic” of historical studies (compare to Guldi 2020, p. 327; Fridlund 2020, p. 73). Following the argument that quantitative history is a sub-field of history characterized by its specific methodology (Anderson 2007), it can be argued, too, that digital history constitutes a sub-field characterized by a certain methodological use. Hohls (2018, A.1-24) stressed that digital history is a field still in the process of creation.

Computational Turn. Large-scale digitization projects and building of technology infrastructure since the 1990s resulted in an ‘explosion of image, video, and audio”’ (Crymble 2021, p. 27).

Europeana[89] (founded in 2008) represents an international European project to connect localized national digital libraries and digital archives. In the early 2000s, corporate initiatives–on the forefront: Google *Books* which started scanning books in 2002 first as *Project Ocean*–spearheaded the digitization of books (Shillingsburg 2009; Conway 2010; Somers 2017). State-based libraries followed soon, and famously founded public-private partnerships, such as the Austrian National Library cooperated with Google Books in the Project “Austrian Books Online”[90], who jointly digitized over 600,000 works in the public domain using the technological infrastructure of Google (Kaiser and Majewski 2013).

This mass digitization raised new questions: “What do you do with a million books?” (Cane 2006). Accompanied by decreasing storage costs, the emergence of cloud computing, new methodologies (and tools, increasingly open source) had to be developed that could deal with this *big data* (Graham et al. 2016, pp. 26–7; Rosenzweig 2003), and to

89. https://www.europeana.eu/de
90. https://www.onb.ac.at/digitaler-lesesaal/austrian-books-online-abo

assess the practical limitations of this new frontier, i.e. developing a new digital source criticism, or more efficient online repositories (Crymble 2021, p. 33), that have been criticized as relatively lacking a debate and reflection (e.g., Zaagsma 2013, p. 5). The Google *Ngram Viewer*[91] was announced in 2011 as an automatic tool to mine the Google Books corpora for word frequencies, and "was presented as a revolutionary new way of looking at culture" (Romein et al. 2020, p. 14).[92]. Using a macro perspective on dealing with the abundance of data was summoned oftentimes: such as in the computational guidebook for historians (the "*Exploring Big Historical Data. The Historian's Macroscope*" by Graham et al. 2016); in the macroanalysis of stylistics by Jockers (2013); or in the development of the concept of "distant reading" to grasp big data collections by Moretti (2005). Put in contrast to the "close reading" of examining each source material individually, originally "distant reading" was intended to make clear what was missing in bibliographic data. The technique was reinterpreted to provide an overview on big data, which was successively expanded by the compound of distant and close reading, "scalable reading" (first coined as "not-reading" in Mueller 2013, then re-named to "scalable reading," compare to the conference program of Weitin 2015).

This wave saw the launch of new journals such as the *Digital Humanities Quarterly*[93], the *Journal for Digital History*[94] (JDH, in 2020), the *Frontiers in Digital Humanities*[95] (in 2014), or the *Journal for Historical Network Research*[96] (in 2017), as well as a series of *Debates in the Digital Humanities* that "highlight current issues in the field [...] and track[] the field as it continues to grow" since 2012.[97]

These developments have been described as the third wave of the DH, and as an "computational turn" (Berry 2011, p. 11).[98] Berry (2011, pp. 4–6) argued an epistemic paradigm in knowledge production through the computer: "computational technology became the condition of possibility required in order to think about many of the questions raised in the humanities today." In this the medium of computers changed the way of thought, and the underlying and implicit assumptions of research, such as "close reading, canon information, periodization, liberal humanism," have to be questioned that have been taken for granted before. The "computational turn" thus would signify the "understanding [of] culture through the digital," and the "cultural dimensions to

91. https://books.google.com/ngrams

92. The study by Michel et al. (2011a) to use digitized book to explain culture was put under pronounced criticism; the mere existence of a book would not suffice, but would need "careful contextualization through structured metadata: knowing who wrote what, when and in which context [...] to explain changes in frequency" (Romein et al. 2020, p. 14), and make interferences about culture.

93. http://www.digitalhumanities.org/dhq/ (DHQ, founded in 2007)

94. https://journalofdigitalhistory.org/en

95. , https://www.frontiersin.org/journals/digital-humanities#

96. https://jhnr.uni.lu/index.php/jhnr

97. urlhttps://dhdebates.gc.cuny.edu/

98. Berry does not seem to have invented the term. Other sources are quoting the website http://www.thecomputationalturn.com/ as one of the first of using this term. This website however as of 2021 is defunct.

computation" and the "medial affordances of software."

Berrys understanding of the importance of reflection on how codes are used in research and in life, are following the impetus of the critical code studies[99]. Fuller (2006) even claimed, that "[i]n a sense, all intellectual work is now 'software study', in that software provides its media and its contexts," pointing towards a new critical encounter needed. Similarly was this also coined as "cultural software" by Manovich (2011), based on the idea that "all disciplines which deal with contemporary society and culture [...] need to account for the role of software and its effects in whatever subjects they investigate."

In this context, it is an act of autonomy and emancipation of the field, when arguing for that coding and programming should become a requisite in the future (Matthew Kirschenbaum 2009). Initiatives to support programming in the historical studies such as the "*Programming Historian*"[100] founded in 2008 by William J. Turkel and Alan MacEachern, which at first focused primarily on Python, and then was restructured as an "open access peer reviewed scholarly journal of methodology for digital historians" in 2012[101]. The online guidebook "*Computational Historical Thinking*" by L. A. Mullen (2019) also offers a similar introduction to programming for historians, just as the overview on available tool in the "*Historians Macroscope*"[102] by Graham et al. (2016). New, specialized tools (increasingly in open source format) were development for analysis, and their usage encouraged for further research projects: such as *Palladio*[103] was developed by Stanford University by the Humanities Design Lab in the course of analyzing the correspondence-(metadata-)networks of the *Mapping the Republic of Letters* project as a prototype in 2009 and subsequently further developed. *Voyant*[104] was originally published under the name *Voyeur* in 2011, but soon renamed. *Voyant* and *Mallet*[105], are a linguistic processing tools: *Mallet* allows for "statistical natural language processing, document classification, clustering, topic modeling, information extraction, and other machine learning applications to text" (compare to the introduction in ibid., pp. 126–9). The *Gephi*[106] (launched in 2010) remains a popular tool for network visualizations (e.g., Grandjean 2015; Graham et al. 2016, pp. 253–263).

This epistemic paradigm furthermore would be signified in the change from individualistic research to "truly collaborative" endeavors (Berry 2011, p. 9), and fundamentally challenged what reading and writing should mean in the computational age (ibid., p. 7).

Changes resulted in a variety of fields. Increasingly journals were replaces with social media platforms of blogging from publishing behavior replacing many journals with social media and informal blogging that became important publishing venues for the discussions

99. Compare to section 6.3.1.
100. https://programminghistorian.org/
101. Compare to https://programminghistorian.org/en/about (Accessed 2021-08-17).
102. http://www.themacroscope.org/2.0/
103. https://hdlab.stanford.edu/palladio/
104. https://voyant-tools.org/
105. http://mallet.cs.umass.edu/
106. https://gephi.org/

of the DH, while the human computing journals alongside newer DH journals, such as the *Journal Digital Humanities*, which ceased to publish in 2014 (Crymble 2021, p. 4). To this date, the amount of research projects, organizations, publications, and venues have reached an unoverseeable amount–an assessment that Sahle (2015, p. 45) already shared for 2015–as such the projects presented here and in overviews (compare e.g., to Arguing with Digital History working group 2017; Romein et al. 2020; König 2021) only represent a small recollection.

In the 2010s, the "hack vs. yack" debate dominated discussions in the DH and the relationship / importance of building software vs. discussing theory. This debate "centered on the idea that DH was what I do, not what you do," summarized this Crymble (2021, p. 163), which "failed to capture the broad scope of activity."

Since the late decade of 2010s, stake holders started to push for more "digital argumentation," and to increase computational modeling, led to the wake of the computational humanities/computational history within the DH/digital history.[107] This has been described as the third wave of digital/computational history that has "potential to transform the practice of historians research" (Fridlund 2020, p. 69), if methodological reflections are integrated beyond mere buzz word dropping. This development is accompanied by an increasing professionalization of the research infrastructure, programs, and professorial positions as described in section 2.1.1.

2.3 Methodologies in the DH

The digital humanities combine methodologies from the humanities as well as computer science and a range of other disciplines such as (computer) linguistics and social science. These involve both the traditionally qualitative hermeneutical approaches of the humanities, as well as quantitative/computational[108] and digital[109] approaches.

An overview of methods in the DH provides this list (without claiming completeness):

– statistical analysis, using inferential methods such as frequency, means, distributions, significance testing, regressions, and more. For an introduction to quantitative methods in the digital humanities compare to Lemercier and Zalc (2019) or

107. Compare to section 6.1.2 "On the need to define DH."

108. The difference between quantitative and computational methods are fluid: quantitative methods for the most part are computational, as they are performed using computers. The term 'computational methods' tends to be used for more complex computational methods, such as e.g., machine learning or network analysis (Jäger and Winckler 2013, p. v).

109. This thesis wants to differentiate digital methods from computational ones. While the terms are often used interchangeably–as e.g., in the overview article on digital methods by Reichert in Jannidis et al. (2017, pp. 29–34), computational methods such as text analysis, sentiment analysis, network analysis are discussed–this thesis wants to differentiate between the applied data-driven analysis of computational methods and digital methods, that are more concerned with the presentation, transformation, and structural modeling of data.

Jannidis et al. (2017, pp. 279–97); for general statistical methods e.g., to Everitt and Skrondal (2010).

- automated textual analysis of the so-called "Distant Reading" (Moretti 2005) that makes the "accurate reading of a historical source" as "not necessarily central for understanding the past anymore" (Rehbein 2020, p. 261) by allowing a distanced overview over a selection of sources/corpora. (Semi) automated text analysis entails NLP techniques that identify linguistic patterns, such as word frequencies, automatic indexing, contextualization with (key) words in context, unique word ratios in texts, collocation and co-occurrences, automated entity resolution/disambiguation (Named Entity Recognition, Place Name Ambiguation), complex relation extraction, sentiment analysis, which allows automated processing and/or coding of structured (historical) data, and topic modeling using LDA, or to identifying authors through statistical attributes in texts (stylometry, compare e.g., to Rebora 2019. For an overview on text analysis, exemplary: Blei et al. 2003; Grimmer and Stewart 2013; Schürer et al. 2015; Reinert et al. 2015; Lemke and Wiedemann 2016; Lemercier and Zalc 2019, pp. 142–54; J. Kuhn 2019; Romein et al. 2020, pp. 14–6).

- As well as more advanced computational methods such as supervised and supervised machine learning (see Bloothooft et al. 2015): as applied in topic modeling (Blei et al. 2003); or in neuronal networks, e.g., used to detect and classify features of images and identify trends in historical archives (Wevers and Smits 2019); or used in automatic optical character recognition[110].

- spatial approaches using geographical information systems and analysis, employing GIS and other tools that "compute on location data in order to understand how geography or region shaped a [...] process" (Arguing with Digital History working group 2017, p. 18; compare also to Jannidis et al. 2017, pp. 299–312; Gregory et al. 2015). Spatial approaches overlap to textual analysis (e.g., Place Name Disambiguation) or network research (e.g., spatial networks).

- relational approaches as in formalized network analysis, describing relations between entities structurally, e.g., network density, centrality of entities, tie formation behavior, and more.[111]

110. For an overview on Optical Character Recognition (OCR) compare to Holley (2009), Cordell (2017), and Springmann and Lüdeling (2017); also to section 2.1.3 on retro digitals. The tool *Transkribus* (https://readcoop.eu/de/transkribus/) is a project to advance Handwritten Text Recognition (HTR). Statistical deep learning is combined with a model set of human transcribed text to train *Transkribus* for corpora of handwritten texts, which 'learns' by connecting correctly transcribed handwritten text parts with text images. The amount of error decreases significantly with more model training data sets (compare to Muehlberger et al. 2019)

111. Compare to the following chapter 3; for an introduction to network research see Lemercier 2012; Stark 2016; Düring et al. 2016; Jannidis et al. 2017, pp. 147–160.

– source critical and hermeneutical approaches of analogue sources updated to be applicable to digital data and digital sources and the changes in their epistemological implications (prominently advocated, e.g., by Fickers 2016, 2017, 2020). Hermeneutics as coined by Droysen ([1882] 1977) entail the interpretative "close reading" of sources[112] and their interpretation: the data source is studied by the researcher, interpreted, contextualized[113], and its purported perspectives critically examined[114]. The goal of an hermeneutical approach is to derive to source-driven inferences similar to the "grounded theory" approach of the social sciences. This is applicable both to the analogue sources, as well as to the digital source in a "new standard" of adapting traditional hermeneutics to the needs and challenges of the digital (Guldi 2020, p. 330), i.a. the epistemological changes through the digital mediatisation.[115] Hermeneutical qualitative approaches are bound by the quality criteria of good scientific practice such as verifiability, elaborateness–"a commitment to showing as much as possible" (Seale 1999)–, reproducibility, limitation of applicability, validity (e.g., through triangulation), reliability (e.g., through documentation and transparency), and intersubjectivity. Source critical approaches include data literacy.[116] A digital hermeneutics constitutes an epistemological and ontological research paradigm: a transfer from analogue sources to digital data, and a new critical reflection that is needed to work with them.

- digital methodologies related to the management, processing and online presentation of data or information (as in databases, digital scholarly editions, repositories), which "freed from the constraints of the printing press, [...] can create searchable and linkable connections between textual features," including visualizations, in a "virtually unlimited critical apparatus and commentary" (Romein et al. 2020, p. 9). These digital methodologies mainly originated from the computer sciences/information technology and rely heavily on structuring and tagging (meta)data with e.g., TEI guided XML (Extensible Markup Language), web presentation with HTML (HyperText Markup Language), and format standardizations to optimize data reuse such as RDF for Linked Open Data[117] (Compare to D. Schmidt 2012; Jannidis et al. 2017; and various best practice recommendations such as by the National Information Standards Organization (NISO) 2007).

112. In contrast to the "distant reading" of computational methodology.
113. For which extensive surrounding knowledge of the direct source is needed.
114. E.g., texts are adaptable and can change their meaning with each reading (Baum and Stäcker 2015, p. 9).
115. Compare to section 6.3.1 on "Establishing Literacy."
116. See section 6.3.1 on "Establishing Literacy."
117. Compare to section 5.2.2 on Linked Open Data.

Chapter 3

Network Research and Historical Network Analysis

3.1 Networks and models

Network research is famously characterized by Freeman (2004, p. 3) according to the following four criteria: (1) an (intuitive) analysis of social relations of actors, (2) a systematic analysis of empirical data, (3) the graphical representation of such data, and (4) mathematical, computer-assisted formal models to analyze such data.

A network is a semantically annotated "specific set of linkages among a defined set of persons, with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behavior of the persons involved," following the commonly used definition by Mitchell (1969b, p. 2). Basis of this concept is the focus on the interdependences of entities rather than on their independence (Wasserman and Faust 1994, p. 4); these interdependencies thus form the scope of action of the entities involved, and that their patterns of relations define "economic, political and social structures" (Wetherell 1998, p. 126). The underlying idea of such a relational approach is that the position of an entity in a social network is of importance: for power, performance, or the 'capital' of potential social exchange in terms of social, economic, or political connections. A network stands in for (and is the result of) the social connections between entities, which allow inferences on "political, social and cultural phenomena" (Romein et al. 2020, p. 17).

The mathematical definition of a network is that of a semantically annotated graph that consists of nodes (also referred to as actors or vertices) and edges, i.e. the relations between entities in a network:

A graph G = (V, E) with V = a set of nodes, and E = a set of edges.

The semantic annotation of a network is dependent on the research objective, and can comprise of different types of relations in order to grasp complex information (compare to Emirbayer 1997). The types of nodes present in a network can belong to the same group (an unimodal network) or to different ones (bi- or multimodal). Dependent on the view on the network, we can differentiate between ego-networks (focusing on the relations of a specific node), or complex (whole) networks (see e.g., Wetherell 1998, pp. 127–8). These relation can be formally and structurally described: from centralities of entities to the density of the network to complex agent-based simulations and modeling.[1]

Network models. In their core, networks are models that are operationalized based on specific relations or interconnections between entities. Networks–as any model–are only a representation of reality following the classic definition on models by Stachowiak (1973). A model offers an approximation to reality through the (ultimately always subjective) selection of supposedly important or representative factors and parameters and their subjective weighting and evaluation. The goal of modeling is to facilitate understanding on the object of research. Modeling is a fundamental epistemic tool: "We model to understand," summarized this Le Moigne (2004) paraphrasing Stachowiak's (1973, p. 56) take that all insights are insights in models or through models.[2] As a consequence of the selection of (or: focus on) certain attributes, any model is ultimately subjectively biased, and constitutes only one instance of an "endless number of potential other models" (Rehbein 2020, p. 265). Principally, it can be refined constantly to represent reality (the research object) more closely, dependent on the available data. As such models to only offer a 'crutch' to understanding and insight, but can not give an absolute 'truth' on the object of research (Drucker 2011).

Networks as a reduction of complexity. As epistemic tools, networks provide a relational perspective on the object of research by having the modeler selecting representatives types of interconnections–the choices of which influence the perspective on the research object and which aspects of reality are going to be tackled (or approximated). Consequently, it can be argued that networks are a model to analyze social structures at a reduced complexity: they offer an abstract, focused, and thus undercomplex perspective on and description of the vast heterogenous changing and (sometimes fuzzy) relations between entities that the model is focused on (or reduced to).[3] Networks be-

1. For a general introduction to network research compare to e.g., Wasserman and Faust (1994), Jansen (2006), Stegbauer and Häußling (2010b), Hennig et al. (2012), and Düring et al. (2016).

2. The original quote by Stachowiak (1973, p. 56) reads in German: *"Hiernach ist alle Erkenntnis Erkenntnis in Modellen oder durch Modelle, und jegliche menschliche Weltbegegenung überhaupt bedarf des Mediums 'Modell'."*

3. Similarly this has been argued as a reason for the formations of networks. Niklas Luhmann (1984) had argued that social organization in systems constitute a reduction of complexity. In this he diverted from his teacher Talcott Parsons et al. (1961): not survival structured these social systems, but the reduction of complexity, i.e. by limiting the infinity of possible options trough their composition and institutions to provide security and relief. Luhmann illustrated this with various examples: cultural practice which provide guidance; language which structures the interpretation of communication; law which provides a framework of acceptable and punishable behavior. This idea has been also already present in the writings of Gehlen, who developed a theory of humans as "acting beings" that are able to decide, and therefore able to break the stimulus-reaction chain (which characterize animals) with cognition. This theory resolved around the assumption that humans are "Mängelwesen" that need to transform their environment in order to survive; they establish institutions in order to satisfy the human need for safety and stability. This transformed environment Gehlen ([1940] 1986) considered

come overcomplex, when (too) many attributes are included; this results in what is called meaningless "giant multivariate networks" that include all possible information of a dataset (Graham et al. 2016, pp. 250–1). Another danger is that of misinterpretation, when the quality, complexity, and importance of connections cannot be properly assessed or is inconsistent (Hennig et al. 2012, p. 96; Graham et al. 2016, pp. 250–1; Rehbein 2020, p. 264). As any other tool, networks need to be reflected on critically–what can it show, where does it fall short?–and be subjected to a critical computational literacy.[4]

3.2 Origins of network research

The history of network research is closely connected to the development of the field of sociology beginning in the late 19th century, which was dedicated to study how people form social relations, groups, and societies. Common historiography of the modern network research is associated to be inaugurated with the sociometry by Jakob L. Moreno and Helen H. Jennings in the 1940s.

Intellectual ancestors. One of the intellectual ancestors to network research was Georg Simmel, who is credited with founding sociology as a field of research when trying to find explanations for the formation of society, and organizations of humans (compare to Raab 2010, p. 30). Simmel himself did not use the term 'network', but theorized a similar group concept – that of "social circles" – in order to explain the creation of society in his main body of work on *"Vergesellschaftung"*. Simmel theorized that group have a great influence on individuals, while at the same time memberships in a group reflected a specific choice of individuals. Simmel (1908, 1911) theorized the concepts of *social circles*, and differentiated between organic circles (whom individuals were born into such as family or neighborhood) and rational circles (to whom individuals opted in, such as organizations) (Schnegg 2010, pp. 21–2). The decisions of individuals are the basis for group formations and various social circles, which could overlap. Simmel (1908, pp. 326–7) stressed the reciprocal influences of the actor on the network, and vice versa.[5]. Simmel also noticed that people categorize and recognize other people in typified social roles (Fuhse 2010, p. 168) The idea of overlapping and mixing social circles were later further developed in the conceptualization of the *social role* as by Nadel (1957), and different dimensions of relationships, such as kinship or neighborhood (Gluckman 1955, p. 18), and later on as single-/multistrained or uni-/multiplex relationships (Schnegg 2010, p. 22).

Simmel's student Leopold von Wiese renewed the interest on social relations in the

to be culture, which self-disciplines humans by offering orientation for certain behavior and through institutions. This can be too considered a form of reduction of complexity.

4. Compare to section 6.3.1.

5. The original quote reads as follows: *"[A]us Individuen entsteht die Gesellschaft, aus Gesellschaften entsteht das Individuum."*

concept of *"Beziehungslehre"* (study of relationships), and identified the main goal of sociology as the study of patterns and mechanisms of social behavior in forming groups (Wiese [1924] 1933, p. 109). Wiese worked with four categories of analysis: the *social processes* directing the closeness/distance of two individuals (*social distance*) in a non-physical *social room*, the relationships forming *social constructs* (ibid., p. 113; Schnegg 2010, p. 22). Wiese theorized that individuals would orientate their actions/relations accordingly to these social constructs (organizations, state, etc.), which Fuhse (2010, p. 168) characterized as supra-personal structures of expectations (*"überpersönlichen Erwartungsstrukturen"*). These in turn lead to the manifestation of these constructs and empowerment over these individuals (Wiese [1924] 1933, pp. 24–5). These deliberations of formal sociology interpreted humans as acting agents, who oriented their actions on supra-personal structures (Fuhse 2010, p. 168).

In another strand, in the 1940s, structural functionalist Radcliffe-Brown (1940, p. 2) defined the field of ethnology as the science to study social structures, situated in a "network of actually existing relations." Radcliffe-Brown interpreted culture accordingly as a product of social structure, and therefore as an imprecise category of study (as opposed to the US research on ethnology; compare to Schnegg 2010, p. 23). He proposed to study network structures instead as the research goal of ethnology (Radcliffe-Brown 1940, p. 3).

These three intellectual ancestors formulated different theories on why humans form social relations/groups/societies, but agreed in that groups and therefore society are an emergent product of social relations of individuals. This placed the (sociological) foundation for social network research (Schnegg 2010, pp. 23, 26). This early assessment on the inner mechanisms of society follows closely Freeman's (2004) first category of defining network research; however Schnegg (2010, p. 27) noted that neither the relation of the micro and macro, nor the creation and dynamics of societies in social network theory are solved until today.

Founder of network research. In general, the foundation of network research is placed with the creation of sociometry in the 1940s by Jakob Moreno and Hellen Hall Jennings[6]. J. L. Moreno (1948, p. 122) regarded his work on the *"Stegreiftheater"*[7] developed in 1923 as the "decisive inspiration" for the succulent development of the sociogram and "sociomatrix" of sociometry, which was one of the early schematic graphical representations of groups. After his emigration to the US, Moreno and Jennings started studying the Sing Sing prison and girl's classes at the Hudson School for Girls, where they surveyed participants on their most important relations (J. Moreno 1936). The *sociograms* used simplified graph models to show the various networked relations between the subjects

6. Who increasingly is acknowledged for her significance contributions to Moreno's research (see e.g., Freeman 2004, pp. 35–6).

7. A method still used by psychologists in playing different social roles in the "Psychodrama" (Schnegg 2010, p. 23).

studied (Jansen 2006, p. 40; Nitschke 2016, p. 12). Moreno theorized that social configurations had an effect on the wellbeing of individuals, which configurations would be produced by (psychological) powers of attraction and rejection (compare to ibid., p. 12). Jennings is credited with the idea that in-coming relations do not follow a normal distribution (Barabási 2002; Schnegg 2010, p. 24), but are skewed left (ibid., p. 24), which led to discovery of the concept of *surplus choices* that an actor could draw on themselves (Moreno and Jennings 1938). This concept was later reiterated by Barabási and Albert (1999) for all sorts of complex networks as *preferential attachment* (also commonly referred to as the *Matthew effect*). The work of Moreno and Jennings resulted in the foundation of the journal *Sociometric Review* (1936), which was renamed *Sociometry* in 1937. Wiese (1949, pp. 202–3) had read Moreno's sociometric studies and agreed that the "concept of sociology is basically a system of relations between men."[8]

This foundation of modern network research is since continuously traced back further (Nitschke 2016, p. 11). Heidler et al. (2014) (re-)discovered the works of Johannes Delitsch, who already in 1880 portrayed friendships of pupils in sociomatrices; his research however had been ignored until recently.

Early network research centers: New York, Harvard, Manchester, and London. In parallel, two early network research centers developed in New York, and in Harvard around Radcliffe-Brown (Schnegg 2010, p. 25).

In New York, one early path finding study was Lundberg and Lawsing's analysis of Lady Bountiful in an American community, which studied the social status of an old lady who lived from donations. Lundberg and Lawsing (1937, p. 333) theorized a connection between social status and prosperity, and questioned whether individuals form relations within/outside their own social economical class, and tested these based on empirical network data, as one of the first studies on what would be later known as *homophily* (Schnegg 2010, p. 25). Another well-known study from New York is the one on social structures in worker's colonies such as by Wiese (1937).

Radcliffe-Brown educated a generation of students on the empirical analysis of networks at Harvard University. One of which was the anthropologist W. Lloyd Warner, who first studied social structures among native groups of the Murngin in Australia 1937. W. L. Warner transferred ethnological/anthropological research methods on organization theories, where he studied patterns of interaction in an urban context, and the influence of social context on these interaction processes (compare to Freeman 2004, pp. 43–5; Jansen 2006, pp. 45–7; Schnegg 2010, p. 26; Nitschke 2016, p. 13). W. L. Warner is most famously known for his work with psychologist Elton Mayo on the Hawthorne works (1924-1932), where they reviewed the influence of outside factors on the productivity of workers. This study resulted in the discovery of the influence of infor-

8. Unlike von Wiese, Moreno actually did not try to explain the formation of society, but thought in social relations the cause for societal problems; understanding these social relationships with network research would offer a cure for these problems with psychoanalysis (ibid., p. 26).

mal social relations on the productivity of formal work relations. The results published by Roethlisberger and Dickson (1939) visualized these social structures graphically in network graphs resembling conduits, in order to illustrate the groups but without further structural analysis; they also did not cite to Moreno's sociograms (Nitschke 2016, p. 14). In the "Old City"-Study, Warner research on a racially biased class society at Natchez, Mississipi, and in the "Yankee City"-Study the emergence of cliques (Warner and Lunt 1941), where he first described and structurally analysed resulting networks and positions in matrices (compare Nitschke 2016, pp. 13–5). This research was furthered in the "Deep South"-Study by Davis et al. (1941) on the communication in cliques, and identification for patterns in class' membership, which is still perceived as an exemplary data set of two-mode matrices (Borgatti and Everett 1997; Nitschke 2016, p. 15).

In the post-war era of the 1950s, in Manchester and in London, a ethnologist influenced network research developed at the University of Manchester (famously headed by Max Gluckmann) and at London School of Economics, influenced by the ideas of Radcliffe-Brown (Freeman 2004, pp. 103–5; Nitschke 2016, p. 16) A series of studies focused however more on personal ego-networks instead of a broad analysis of society, leading to the development of the ego-centered network analysis (ibid., p. 16). Noteworthy here are the studies by Barnes (1954) on class in a Norwegian community, innovations in data collections and perspective on networks in the survey of both marriage partners in the studies by Bott (1957) on family structures (Jansen 2006, p. 43), and the theoretical and methodological reflection of multiplex network relationship by Mitchell (1969a), as well as the studies by Boissevain (1974) and Kapferer (1969) (compare to Nitschke 2016, pp. 16–8).

Early network studies include as well as the fundamental sociological studies by Claude Lévi-Strauß on kinship, or unemployment and community by Paul Lazarsfeld and Maria Jahoda, on role models and reference groups by Robert Merton, on communication in groups social psychological studies by Kurt Lewin or by Alexander Bavelas, or the rational choice theory developed by George C. Homans. Freeman (2004, pp. 129-30) argued that these however focused on the individual person's research and did not lead to a general establishment of a relational perspective in sociology.

Methodological breakthroughs. In 1936, Dénes König published a coherent graph theory based on the ideas of Leonhard Euler on the topological and graph theoretical mathematics used to solve the *"Königsberger Brückenproblem"* in 1736, which would be the beginning of a mathematical graph theory (Nitschke 2016, pp. 18–9).

In the 1950s another breakthrough was achieved: the description of the mathematical properties of substructures of social structures building upon Heider (1946)'s theory of interpersonal balance in positively and negatively charged relationships (Cartwright and Harary 1956; compare to Jansen 2006, p. 41; Nitschke 2016, p. 19).

In the late 1950s, the research by Erdös and Rényi (1959) on random graphs and the emergence of networks at a threshold number of nodes and edges revolutionized the field of graph theory (Barabási 2002, p. 245; Nitschke 2016, pp. 20–1). Erdös and Rényi (1959) thought this as evidence that all existing networks must be guided by randomness; however social networks did not consequently follow the theorized behavior of random graphs (Nitschke 2016, p. 21).

Milgram (1967) and Travers and Milgram (1969) proved that it is possible to reach in only 5.5 steps any other human solely relying on personal contacts, later named after the Broadway-Show "Six Degrees of Separation" by John Guare (1990; compare to Barabási 2002, pp. 18–9, 29; Nitschke 2016, pp. 21–2), closely representing the results on random networks threshold by Erdös and Rényi (1959).

In the 1950s, sociology had focused mainly on surveys, attributes, and variables (the so-called *"Variablensoziologie"*), and mostly ignored social relations until the 1970s (Ziegler 2010, p. 39). In sociology, two approaches stood against each other: a positivist view of attributes and empirical statistical analysis, and the structural functionalism coined by Parson. The breakthrough of a relational perspective and a graph theory based network research in sociology and mathematics coincided with further advancement in the computerization of the universities, which enabled computational research and facilitated a fastened analysis of quantitative data. Raab (2010, p. 32) claimed this situation had made time "ripe" for a relational turn in sociology, offering sort of a third methodological strand in the field.

In the 1960s, Harrison White formed a new center at Harvard University, which focused on the relational sociological perspective. White's group's research ultimately lead to a renewed interest in network research in general sociology and related disciplines, and other major innovations until the 1980s, combining innovative conceptualizations and the employment of mathematical and computational prowess (ibid., pp. 29, 31; Nitschke 2016, pp. 23–4). White was influenced by Lévi-Strauss[9] and had a strong structural perspective on sociology, from which he conceptualized role structures, which would then evolve into the concept of *structural equivalency* (Lorrain and White 1971), as well as basic matrix computation (Raab 2010, p. 31). This made possible to mathematically compute (and compare) social roles–and paved the way for an "allegedly exact" formal network science (Nitschke 2016, p. 23). White made clear in his courses that the attribute analysis of survey-based sociology was to fail (Raab 2010, p. 32). White's focus was on networks as the object of research from a global perspective, therefore on their structural composition and patterns (such as role structures) in networks. They developed methods to compare networks and their structures (White and Breiger 1975) in order to derive to a formal generalizations, position and role structure network analysis with cognizant mathematical models (Raab 2010, p. 33). Their concept of *structural equivalence* in block model analysis (White et al. 1976; Boorman and White 1976) offered an operationalization of a central sociological concept, that of the social role, for network research: structural equivalency described two actors that have the same rela-

9. Such as in White (1963) work on kinship, which built upon Lévi-Strauss ([1949] 1969)'s concepts and kinship diagrams.

tions to the same other actors based on the algorithm CONCOR (convergence of iterated correlations) (Jansen 2006, p. 47; Raab 2010, pp. 33–4). White thus placed the foundations for a "widefounded legitimacy" of a mathematically based network methodology and helped its spread with his teaching (Freeman 2004, p. 125; Nitschke 2016, p. 24).

Two other network research groups formed outside Harvard: one around Linton Freeman at UC Irvine California focused on the development of centrality measures (compare e.g., Freeman 1978), another group of Edward Lauman and James Coleman at University Chicago focused on stratification, power structures, *social capital* (e.g., Coleman 1998) and the composition of political and social networks (Freeman 2004, pp. 148–9; Nitschke 2016, p. 25).

Professionalization in 1980s. Since the late 1970s, network research experienced a successive formalization and upturn in reception (compare e.g., to Stegbauer and Häußling 2010a).

The systematic integration of these groups were made possible by the foundation of the *International Network for Social Network Analysis* in 1978 (Raab 2010, p. 32; Nitschke 2016, p. 25). In Germany, too, a research association *Analyse sozialer Netzwerke* (1977–1981) was founded by the DFG (Ziegler 2010, p. 39). The relational turn brought a change in the dissemination of sociology, focusing on the functions and changes in social structures (ibid., p. 40).

Methodological innovations of the 1980s included the concept of *embeddedness* (M. S. Granovetter 1985, p. 490)–bridging economic and sociological theory stressing the "role of concrete personal relations (or "networks") of such relations in generating trust and discouraging malfeasance" as a structuring mechanism of behavior–, the concept of *weak ties*, and the modeling of different types (strengths) of edge relations, and the effects of network structures e.g., on the successful job hunt (M. Granovetter 1973), or on how to find information on sensible topics such as abortion through chains of friends (Lee 1969). Schnegg (2010, pp. 26–7) and Nitschke (2016, p. 26) both noted the sound effect of these studies to further a relational perspective in sociology and the acceptance of network analysis into sociology.

Further achievements have been made in the field of structural equivalence and blockmodelling: a *regular equivalence* which makes structural positions comparable through different networks (Borgatti and Everett 1989), or a generalized blockmodeling by Doreian et al. (2005). Bonacich (1987) furthered Granovetter's concepts in differentiating between positive and negative exchange systems, which Burt (1992) combined in the concept of structural holes, and positional roles profiting from *weak ties*. Watts and Strogatz (1998) mathematically described *small word* networks as a class of random graphs, characterized by the clustering coefficient and the average shortest path length–these characteristics are shared by a wide range of real-world networks, which allows them to be analyzed applying the same mathematical models. The studies on power law distributions and preferential attachment in networks by Barabási and Albert (1999, pp. 66–9) mathematically sustaining Moreno's observation on *surplus choices* (Nitschke 2016, pp. 28-9).

Since then, research in network approaches resulted in an unoverseeable list of publications and insights since the late 1990s–from exponential random graph modeling (Lusher et al. 2012) to stochastic graph modeling of complex networks (compare e.g., to Block et al. 2019; Ragozini and Vitale 2020) to brokerage in networks (Burt 2005) to dynamic and temporal network analysis (Freeman 2003; Batagelj et al. 2014) or context-aware social networks (e.g., Schönfeld and Pfeffer 2020), among many more–, and experienced a spread of methodologies into other disciplines, such as in history.

3.3 Development of Historical Network Research

The spread of network research methodology into historical studies is considered a transdisciplinary research paradigm by its practitioners.[10] Historical network research (HNR) consists of methodological approaches adopted from the interdisciplinary field of network research (which itself combines input from sociology, anthropology, political studies, mathematics, and computer science) to study network models of the past embedded into a larger context of historical research to generate greater understanding and new insights on historical objects of research.

"The roots of HNR go back to the year 2009 when Ulrich Eumann, Martin Stark, Linda von Keyserlingk-Rehbein and Martin Düring decided to organize a workshop for historians interested in social network analysis", recounts the website of the "Historical Network Research Community"[11] the origins of historical network research. Despite this assertion, we can identify multiple strands influencing the creation of the field of HNR, resulting in its popularity since the late-2000s.

Early historical network studies. Network studies based on historical research topics emerged in the 1990s after SNA's "maturing" in the late 1980s and 1990s (Wetherell 1998, p. 125), but lacked the involvement of trained historians–a result of the change in focus in historical studies from social history to postmodernist thought during the 1980s, the reception of network analysis in the general field of history itself was very limited (ibid., p. 125; Reynolds 1998; Gamper et al. 2015a, p. 24).

In 1993, the political scientists John F. Padgett and Christopher K. Ansell published the now-famous study on the rise of the Medici in Florentine (1499–1434), linking the Medici economical influence to a specific marriage strategy using a network approach and blockmodel analysis. The sociologist Roger V. Gould in 1995 published on social

10. A research paradigm is considered a consensus-based set of procedures that define what object to be studied, what kind of questions be asked, and what kind of hypotheses be tested, according to T. S. Kuhn ([1962] 2012).

11. https://historicalnetworkresearch.org/about/)

movement and identity in the Paris communes of revolutionary France in the 19th century.

In the general historical studies, a network perspective did not found greater doorway; instead, a niche in the quantitatively-based economic, business and social history began to form. Early network studies by historians were made in business history, drawing from sociological organizational theory: such as a study by Cookson (1997) on the inter-firm relations of textile engineering industry in mid-19th century Yorkshire[12] or e.g., on bank network relations and credit distribution (Godley and Ross 1996), or on how networking activities of fire insurance offices in England influenced economic development during British industrialization (Pearson and Richardsson 2001). These network studies in general entailed a relational perspective based on the "concept of 'networking"' (ibid., p. 657) without describing the emergent network structures formally. In social history, Wetherell (1998) tried to popularize a network methodology in historical studies by showing how HNR (then termed *Historical Social Network Analysis*) "can advance our understanding of historical kinship" and community, lauding the potential of a network methodology to the study of history, while lamenting how historians have been "slow to adopt the approach" (ibid., p. 125).

An exception to this tendency of a lacking historian involvement was the work by Wolfgang Reinhard: based on his concept of *"Verflechtung"* (embeddedness) Reinhard focused on different types of relationships as result of social contexts and social roles, but deliberately avoided the usage of the term 'network' (Reinhardt 2002, p. 236).[13] This specific network approach was not receipted within general historical studies, and is now considered an island development; Reinhardt (2002, pp. 239–41) argued that Wolfgang Reinhard's embedded study of elites did neither relate to then prominent focus on *"Alltagsgeschichte"* (ordinary history) nor to the shift from quantitative-based approaches to text.

In contrast to the highly formalized and structural analysis of social network research, the use of 'networks' in historical studies have been criticized as metaphorical (e.g., Gamper et al. 2015a, p. 8) or as undifferentiated use of "buzz"-words for social interactions (Düring 2015, p. 42), and in general used inflationary for a relational perspective but lacking a formalized (mathematical) approach (Rehbein 2020). The value of these less formalized approaches however has been identified as e.g., by Reitmayer and Marx (2010, p. 876) in the shift in perception from isolated historical actors to a relational perspective on the web of dependencies historical entities operate in.

12. Cookson (1997, p. 5) preferred the metaphor of the "wheel" over that of a network ("for that concept implies the equal status of each member") to describe business hierarchies in the textile engineering industry.

13. Reinhardt (2002) argued that this concept of *"Verflechtung"* would be better placed under the term of patron-clientele-relationships.

A growing HNR community. Since the turn of the millennia, Gamper et al. (2015a) registered an explosive growth' in publications concerning historical network research, of which a regularly updated online bibliography tries to keep track of.[14] This development happened on the backdrop of the growing popularity of computer-assisted work through the mass digitization of the 1990s, the introduction of the personal computer and the internet, and the popularization of the digital humanities.[15]

In 2009, a workshop was organized on *"Historische Netzwerkforschung"* (Kücking 2010) heralding an on-going initiative to advance historical network research in Europe with a series of yearly German-based workshop meetings since 2009, and a series of Europe-wide "HNR conferences" since 2013[16]. This was accompanied by the establishment of *historical network research* as the common denominator for network approaches in historical research contexts, dropping the previously used moniker 'social' from historical social network analysis (compare to Wetherell 1998).

HNR unifies very heterogenous research endeavors from diverse fields from the humanities (from archeology to history of art, literature and language studies), social studies (sociology, political studies), and the MINT fields (computer science, physics) by using the common methodology of network approaches[17] on historical data sets. In 2010, Reitmayer and Marx (pp. 870–1) differentiated between two basic research strands within HNR, which are frequently mixed: for one, to research networks as a regulating mechanism that permits and constrains action of entities within the networks–such as the concept of social capital and rational-choice theory, identified mostly within business and economic history. For two, the existence and the function of the network as is and diverse interpretative frameworks and the possible scope of action of entities as in mainly social history. Since Reitmayer and Marx's (2010) assessment the scope of research with historical research questions and/or historical data has extended dramatically: network approaches and methodologies are explored in studies over all periods on:[18]

- correspondence and citation networks, such as the reconstruction of the (multi-modal) intellectual network of two astronomers at the Rēš́ temple in Uruk during the Seleucid period based on colophons of astronomical tablets (Ossendrijver 2011), which however focused on a visual reconstruction and abstained from a structural analysis. The study on astronomer's networks in the Early Modern period by Knopp (2018) used correspondences to identify the most important individuals,

14. Starting from 2013, there are over 1060 publications recorded at https://historicalnetworkresearch.org/bibliography/ (vol. 8, accessed 2021-08-27; compare this also to its adjacent Zotero group at https://www.zotero.org/groups/209983/historical_network_research/items/98BTGBUE/library).

15. Compare to section 2.2.

16. Compare to the overview on https://historicalnetworkresearch.org/hnr-events/.

17. Reitmayer and Marx (2010, p. 867) stressed that the incorporation of network methodologies in the historical studies happened "pragmatic and eclectic" as addition to the historian's tool box, and therefore have to be labeled as "approaches" only.

18. The following list is exemplary and does not aim for completeness, but is intended to show the scope of research areas and methodologies.

and studied the ego-networks of selected key players, such as Johannes Kepler and Johannes Hevelius. Noteworthy, too, are the on-going projects to reconstruct and map the "Republic of Letters" (Grafton 2009a; Winterer 2012; Edelstein et al. 2017; Vugt 2017; Hotson and Wallnig 2019), which range from manual drawings of networks on maps, e.g., in the reconstruction of flows of information to Issac Newton from his contacts and their sources (e.g., Schaffer 2008, Fig. 4 on p. 39) to the computer-facilitated quantiative analysis and mapping of multi-layered dynamic networks of letters (Vugt 2017).[19]

- organizational, business, and economic networks. Noteworthy here are studies on the personal and capital embeddings, such as the social influence on economic success in a historical credit market (Stark 2014; Reupke and Stark 2015) or on interlocking of positions in intercorporate networks (for an overview compare to Carroll and Sapinski 2011).

- clientele networks. A prosopographical patronage-clientele study of the professional relationships between individuals mentioned in stamped bricks of Rome (0–300 CE[20]) identified important players in the brick industry, and computed the density in occupational communities (Graham and Ruffini 2007).

- elite networks, such as on movement and migration in social networks of intellectuals (Verbruggen et al. 2020), or the reconstruction of the personal networks of the aristocratic abbot of Cluny in the early Middle Ages building a relational database in Microsoft Excel (Rosé 2011, pp. 214–5). Noteworthy is the formal network analysis of the Dominican investigation of Cathar heresy in the "Great Inquisition" of 1245–46 based on a digital edition of the source text "BM Toulouse MS 609"[21] that was created in the course of their project (Rehr 2019).

- political network analysis. Prominent here are the works by Preiser-Kapeller geographically mapping conflict among power elites in Medieval Europe and the Near East based on nonlinear time series analysis and agent-based modeling (Preiser-Kapeller 2015), or the study reframing empires as "networks of princes" in the early 13th century by Gramsch (2013), which was succecently extended to detect communities in the emperors aristocratic circles (Dahmen et al. 2017; Gramsch-Stehfest 2020).

- criminal networks, such as the network reconstruction of the conspirators of the July 20th assassination attempt on Hitler, representing the state of knowledge of the Gestapo investigation (Keyserlingk-Rehbein 2018). Social network analysis in criminology (for an overview, compare to Masys 2014; Diviák 2018; Burcher

19. Compare to section 5.2.1 on network approaches in intellectual history.
20. Common Era
21. https://eadh.org/projects/de-heresi-documents-early-medieval-inquisition

2020; Bright et al. 2021) often, too, uses historical datasets, such as the network reconstruction of the South African arms deal in the late 1990s drawn from two secondary literatures (Kriegler 2014), or the regression analysis of dyadic relational data testing the influence of kinship and violence on cooperation in criminal organizations in Italy, whose networks were reconstructed based on phone transcripts (Campana and Varese 2013).[22]

- judicial networks. Oftentimes these are essentially cooccurrence networks, such as the on-going project by Schwandt (2021) to reconstruct spatial networks of traveling judges of the Kings Bench mentioned in the courts protocols of English counties in the 13th century in order to reconstruct the judicial practices of the Kings Bench justice in competition to the county courts. From legal studies, judicial network analysis is used to study judicial decisions and the genealogies of law (e.g., Shomade and Hartley 2010; Kastellec 2010; Clark and Lauderdale 2012; for an overview compare to Box-Steffensmeier et al. 2016) or the internal and external organizational effects of courts such as the influence of amicus curae networks on court decisions (Box-Steffensmeier and Christenson 2014). These kinds of analyses are based on court documents, and interview data, briding from the social sciences to legal studies.

Since the mid-2010s, a variety of introductory and overview works has been published on network analysis (Jansen 2006; Scott and Carrington 2011; Hennig et al. 2012; Kranakis 2013; Ragozini and Vitale 2020) and its applications in the humanities (compare to Gamper et al. 2015b; Düring et al. 2016; Düring et al. 2020). In 2013, the yearly SUNBELT conference (of the *International Network for Social Network Analysis*, INSNA) incorporated for the first time a track on historical network research[23], that has since become a recurring part of the program under varying names, suggesting the firm location of HNR as part of the general network research community.

22. Oftentimes, criminal network analysis finds application to support and to facilitate policing and law enforcement during active investigations especially against organized crime (compare to Diviák 2018; Burcher 2020).

23. Compare to the program of the XXXIII SUNBELT at University of Hamburg (https://www.dropbox.com/s/lzz7magmaajh44o/33_Program.pdf?dl=0), that has since become a recurring part of the program under varying names.

Chapter 4

Case Study Political Judiciary in the Corporate State

In our first study "Configuration to Conviction. Network Structures of Political Judiciary in the Austrian Corporate State," we computationally analyzed the extend of political judiciary during the authoritarian Corporate State in Austria, and discussed the obtained results in the light of their historical context and the preexisting, mainly qualitative scholarship in order to carefully draw historical implications. Our main research question in this project was if there is evidence for political judiciary in the judicial practice of the Corporate State on the example of Viennese courts in 1935, and investigated differences in the legal prosecution of the political opposition.

In the following, we will extend on the topicality of targeting a political opposition and on the definitions of political judiciary, before introducing the paper itself. Finally, the methodologies used in the paper will be reflected on, and its innovation discussed.

4.1 Topicality

Targeting a political opposition is a typical character trait of an autocratic regime. Until today, we see examples of this in Europe, where the division of politics and judiciary is slowly undermined.

In Poland, the government introduced laws to retire non-compliant judges early between 2017 and 2019, which were taken back after pressure from the EU (BBC.com 2019). In Hungary, a transformed judiciary is used to prosecute the political opposition (Kingsley 2018; Novak and Kingsley 2018), and in 2020, prime minister Viktor Orbán assumed unlimited power to supposedly better battle the coronavirus crisis in Hungary (SZ.de/kit/mati 2020). The extend of these transformed systems became painfully clear in the maneuvers of both country's governments to decouple constitutional legality as a requisite of EU funding schemes (which the EU accused both Poland and Hungary to have critically damaged) threatening to hinder the negotiations of a joint EU effort to support the European economy during the coronavirus crisis (compare e.g. to, tagesschau.com 2020b; se/fab (dpa, afp, ap) 2020). While a consensus was found in the distribution of EU budget and corona stimuli by end of 2020 (tagesschau.com 2020a), the conflict between the EU and Poland and Hungary is still on-going in regards to their judicial transformation and constitutional legality (Strupczewski 2020; Riegert 2021).

The Austrian "Corporate State" used to be such an transformed system, too, put into place by elected Chancellor Engelbert Dollfuß (1933–1934) and his Secretary of Justice and later successor Kurt Schuschnigg (1934–1938) in Austria. Ruling the former republic of Austria with emergency decrees since March 1933–based on a wartime accreditation law of 1917–, the regime gradually tightened control over the justice system, abolishing the constitutional court and introducing an oath of loyalty, overriding the lay judiciary, and continuously restricting civil rights and political freedom. This resulted in open political repression and the creation of an autocratic regime.

4.2 On political judiciary

The legal situation in Austria has been retroactively assessed as fitting the characteristics of political judiciary, often under the more generic term of repression (compare to e.g., Holtmann 1975a, 1975b, 1978; Neugebauer 1995a, 1995b, 1995c; Jesionek 1995; Reiter-Zatloukal 2012, 2013; Rothländer 2012; Neugebauer 2012; Wächter 2013; Wenninger et al. 2017).

Governments operate at an intersection of governing their state's population, and letting themselves be governed by this population's political engagement. Beyond perspectives of legalism–the assumption that the rule of law is an end of itself–, the purpose of law in general is considered to organize humans interactions, and to punish violent or deviant behavior (Posner 2005, p. 89). What constitutes political judiciary is a controversially discussed and sensitive topic–as it is often decided retroactively from the perspective of a succeeding or victorious system in transitional settings (ibid., p. 77).[1]

Political justice stands at as the embodiment of an unfair justice, which punishes political expression while ignoring legal safeguards, as due process or equality in front of the law. While there is no consensus on the true nature of political judiciary, per common definition the very political expression (or: opposition) of a dissenter is prosecuted in a (thus political) trial, following the seminal work by Otto Kirchheimer (1964, 1965): *"Wenn gerichtsförmige Verfahren politischen Zwecken dienstbar gemacht werden, sprechen wir von politischer Justiz"* (Kirchheimer [1955] 1964, p. 96). Political judiciary is such characterized to use the judiciary to serve political purposes. One form of this is the control of political dissent: political trials where political partisanship is prosecuted; or when such partisanship is a coveted factor for the prosecution of not-necessarily political crimes; or in trumped up charges for non-political crimes that get politicized to target political partisans (instead of being applied unambigiously). The law thus gets

1. The question therefore arises, wether there can be a non-political justice at all, as the legal system is based on the ideals of a political elite, and subjected to major changes in time.

weaponized against a political opposition, which Kirchheimer (1965, pp. 80–1) coined a *political lawsuit*.[2]

Ernst Fraenkel ([1927] 1968, pp. 36–7) specified the same concept as *tendency justice*, stressing that also pre-existing laws could be construed disadvantageously against a political opposition. Fraenkel ([1927] 1968) conceptualized *political judiciary* instead as the personal political beliefs of the judge which could influence the dispensation of justice in the verdict.

More broad definitions of political judiciary are concerned with the political executive influencing justice, i.a. that include any connections between the judiciary and politics (see Hannover and Hannover-Drück 1987, p. 13). Holtmann (1978, p. 57) reinterpreted the concept of *tendency justice* in the sense of Kirchheimer's *political lawsuit* and stressed its momentum of deterrence. Belknap (1994, p. xvi) stressed that political trials should enclose those which "immediately affects or is intended to affect the structure, personnel, or policies of government, that is the product of or has its outcome determined by political controversy, or that results from the efforts of a group within society having control of the machinery of government to use the courts to disadvantage its rivals in a power struggle which is not itself immediately political or to preserve its own economic or social position." Whereas Posner (2005, p. 75) defined political trials as those when "the defendant's opposition to the existing government or the constitutional order is the main issue." Broader definitions are usually applied in the literature on Austrian legal history, or not defined at all while implicitly assuming a connection between political influences and juridical decisions as political judiciary (compare e.g., Neugebauer 1995a).

As Kirchheimer has noted, political justice is not only present in authoritarian or totalitarian regimes[3], but also in democracies as "legitimate" political judiciary forms as e.g., in defense of the system, against a threat to society, in the quest of security and stability, or due educational purposes (not only in a transitional context) as a kind of a "dark side" of justice (Ooyen 2012, p. 243; for an analysis of (ill)legitimate form of political judiciaries in democracies compare to Posner 2005). From a legalistic point of view, political trials are always objectionable as they violate legal norms and the due process (ibid., p. 89), and represent a "corruption of the judicial process and a betrayal of liberal principles" (ibid., p. 78).

The Austrian Corporate State proves ample examples for these kinds of political trials, as will be shown later[4] in the legal foundations for prosecution of oppositional partisanship, as well as in the direct influence on the independence of judges, who were subjected to an oath of loyalty, and had their permeability removed, forced to change court or into retirement. While the Austrian Corporate State can be considered an authoritarian

2. Whereas in show trials, the result–the guilt of the defendant–is determined *a priori*, and the trial itself serves as a platform of propaganda.

3. In one interpretation, Kirchheimer argued that the common association of political judiciary with autocratic or totalitarian regimes could be false; because these regimes controlled justice completely, justice would not be possible, but only "friend-enemy" politics (Ooyen 2012, p. 243).

4. Compare to Petz and Pfeffer (2021).

regime, it's judiciary still had a little scope of control as will be shown in the conclusions of our case study; it's control of the judiciary was not absolute, even though the permeability and independence of judges has been revoked, the constitutional court has been abolished, and a series of highly specialized laws has been introduced that eased the prosecution of political opposition and repressed civil rights and freedom of expressions.

For analysis, we operationalized political judiciary two-fold according to the definition given by Kirchheimer's *political judiciary* and *political lawsuit*, supplemented by Fraenkel's concept of *tendency justice*. In the following case study, we examined whether the law was strategically utilized against specific groups (Kirchheimer's *political lawsuit*) and as in the more lenient version of Fraenkel's *tendency justice*, we analyzed whether the law was disadvantageously interpreted for specific partisanship up to a blatant breach of judicial conduct.

4.3 Innovation and discussion

4.3.1 Extending on previous qualitative scholarship

The "*Vergangenheitsbewältigung*"[5] of the Austrian authoritarian pre-NS past is a more recent phenomena in Austria, which was delayed by the long held narrative of Austria as the first victim of NS-Germany, and Dollfuß' and Schuschniggs' Corporate State as 'savior' or 'rampant' from Nazism held in postwar-Austria (compare e.g., to Wenninger 2021, p. 70).[6] In the 1970s, encouraged by the Scientific Commission of the Theodor-Körner-Stiftungsfonds and the allocation of the "Leopold Kunschak Price to Research Austrian History between 1927 to 1938", a younger generation of Austrian historians looked into the question of responsibility for the dictatorship in Austria after the First Republic (compare to Jedlicka 1975). Later, the nature of the regime was controversially discussed, and still is heterogeneously assessed in scholarship. This ranges from claims of an Austrian specific type of fascism–"austrofashism"–(e.g., Tálos 2013) picking up on the contemporary usage as a "*Kampfbegriff*" of the Social Democratic opposition against the regime, such as by deputy chairman of the SDAPÖ Otto Bauer (Botz 1985). The fascist nature of the Corporate State is abnegated by other researchers, who stress that the regime lacked a thorough penetration of society except for the organization of the *"Heimwehr"* party (compare to Holtmann 1978; Botz 1980). Holtmann (1978, p. 15) considered the Corporate State authoritarian, not totalitarian. The term "Corporate

5. This term does not find an english exact match, but entails the public (scientific) dissemination, reflection, judicial processing, and work of remembrance in order to coming to terms with the past.

6. Schuschnigg cultivated this image as well. After having been detained in a series of concentration camps as a prominent "*Sonderhäftling*" in the course of the "Anschluss," and kept with certain privileges for a show trial for after a successful NS-war, Schuschnigg moved from Italy to the US in 1947 (after being refused to remigrate to Austria), and attained citizenship and a professorship for state law at the University of St. Louis through his contacts (Saint Louis University, n.d.). In 1968, he returned to Austria, and published his final book *Im Kampf gegen Hitler. Die Überwinderung der Anschlußidee* in 1969.

State" was the self-referral nomen of the regime; both terms have however become a term of analysis in the history of Austria (Schwarz 2013).

A more recent scholarship focuses since the early 2010s on the still open questions of social and administration aspects of the Corporate State, as well as on the scope and development of the repression (compare to e.g., the anthologies edited by Reiter-Zatloukal et al. (2012), or by Dreidemy and Wenninger (2013), among others). There are still many open questions about these five years of pre-NS-dictatorship in Austria, especially in the field of the judicial history of the Corporate State. Research on the judicial history of the Corporate State has focused on a qualitative evaluation in overview studies (focusing on the introduction of new laws) and specific isolated cases of the political repressive system of the drumhead courts and great show trials against political agitators in the early years of the regime (1933/34) and in the later period just before the integration of Austria into NS-Germany (1937/38) (Neugebauer 1995a; Reiter-Zatloukal 2007, 2012, among others). Additionally, scholarship has focused on the more turbulent early and late period of the Corporate State, while the intermediate period of the more consolidated regime of 1935/36 was not considered much.[7] Methodologically, previous scholarship built on qualitative analysis; only few quantitative studies on the Corporate State have been conducted.[8] A research project conducted at University of Vienna addressed this lack of quantitative analysis and collected empirical data on politically motivated court cases with a focus on Viennese courts in 1935, and expanded this project for the following years (Wenninger et al. 2017). The analysis of political judiciary in the Austrian Corporate State with means of modern technological advances and qualitative knowledge is a missing void that this case study aimed to fill.

4.3.2 Methodological approaches

In this work, we were interested in the extend of political judiciary in the Corporate State.[9] Was the law strategically utilized against specific groups (following Kirchheimer's *political lawsuit*), or was the law disadvantegously interpreted–up to blatant breach of judicial conduct–for specific partisanship (fitting Fraenkel's concept of *tendency justice*)? We innovatively modeled court trials as multimodal networks, which structures we analyzed quantitatively; the results of which we contextualized drawing from the mainly qualitative scholarship. While judicial network analysis (influenced from a perspective of law studies) considered the genealogies of laws and court decisions as citation networks, or developed sociological interview-studies to evaluate the extend of e.g., amicus curae influence on court decisions, these do in general not analyze the networks structurally

7. Such as in the qualitative study on political judiciary in the Corporate State by Neugebauer (1995a), the sentence practice of 1935 is not mentioned, except for the *"Schutzbundprozess"* in April 1935.

8. Such as by Botz (1995), who analyzed the relationship of politics and judiciary in the First Republic in regards to violent crimes, but used a tiny sample; or the quantitative-based dissertation by Bauer (2001) on the social structure of the July Putsch 1934.

9. For the following compare to Petz and Pfeffer (2021).

as criticized by Whalen (2016, p. 540). In historical studies, there have been few studies on judicial matters: Schwandt (2021) traced travel patterns of traveling judges in 13^{th} England in spatial networks, while Keyserlingk-Rehbein (2018) reconstructed the state of knowledge of the Gestapo investigation against the conspirators of the July 20^{th} assassination attempt. Noteworthy are also the Old Bailey Proceedings[10] which offer a rich available database on historical court trials, but has been mainly analyzed using text mining approaches in regards to a social history of criminality and insights into 'ordinary history' (Hitchcock 2013; Graham et al. 2016, pp. 4–8; Emsley et al. 2018).
In this study, we combined statistical and network methodologies in order to study a historical phenomena: the penal practice exerted in the provincial courts of Vienna in 1935. As we can show with this approach a network analysis beyond its metaphorical use offers new perspectives and insights upon the Corporate State and allowed us to identified patterns of prosecution and structures relevant of convictions or acquittal. We implemented the following analyses using the *Python::NetworkX*[11] library for network analysis, and *Python::Numpy*[12] and *Python::Pandas*[13] for statistical analysis.

Operationalizing the aforementioned concepts of political judiciary, we investigated the usage of certain charges for particular groups, and the penal practices applied on them in order to detect biases against the political opposition.

- We analyzed statistically distributions of prosecution, conviction, acquittal, and imprisonment rates for each group. We computed the standardized residuals for each (compare to e.g., Everitt and Skrondal 2010, p. 367), which show the difference between the observed and expected counts and the standard deviation of the expected count, such measuring the strength of difference between observed and expected values. We did the same for the percentages' distribution of offenses leading to trial or conviction or imprisonment. None of the standard residuals showed significant results in outliers.

- Then, we looked for significant differences in the treatment of both left- and right-wing groups in dependence to their sentence lengths in convictions via a t.test, which evaluates the differences in two groups and tests whether both are from the same distribution (ibid., p. 420); it revealed significant differences. With a χ^2-test (ibid., p. 81), we tested the significance of influence of specific political partisanship in cases where the defendant was brought to trial or not, or was convicted or acquitted, or was sentenced to prison or not in the verdict.

- We introduced a technique to match the actual sentence in the possible sentence range as regulated in penal law, in order to infer whether the sentences can be

10. https://www.oldbaileyonline.org/
11. https://networkx.org/
12. https://numpy.org/
13. https://pandas.pydata.org/

considered severe. As two different principles led the range of possible sentence– the principle of absorption (the most harsh individual offense) and the principle of aggravation (cumulative sentence)–, we computed for each the upper, lower, and aggravated limits of penalty for each case with a prison sentence and delicts of convictions. This allowed us to identified key players and tandems in a social network of judges and prosecutors, who stood out in the sentencing of particular political groups.

- We harnessed the advantages of a network approach in the visual representation of the characteristics of an average case of each political group using a clustered graph approach as suggested by Brandes et al. (2008), showing a fingerprint of each aggregated co-occurrence networks of the ego-networks of political defendants.

- We tested for systematic predispositions, such as specialized charges for political groups employing cooccurrences networks. A co-occurrence network shows elements that occur next to each other. Originally, this is used in text analysis in order to mark words that appear in close proximity to each other, usually in the same text, or as *keywords in context* in a distance of a number n other words around the target word (Wasserman and Faust 1994, p. 295) We employed the concept of co-occurrence from text to court cases: if a judge, prosecutor, defendant, or offense appear in the same case, we perceive them as co-occurring, and therefore draw an edge between those entities. We constructed various such co-occurence networks: multimodal ones of judges, prosecutors, and court processes (group trials of various defendants), or of judges and prosecutors only, as well as of the different offenses of inquiries, charges, or delicts of conviction. In these cooccurrence networks of offenses, we analyzed significant combinations of inquiries, charges, and delicts of convictions, and their specialized usages for certain political groups. We constructed an average occurrence of an edge between two offenses, such constructing a threshold over all political partisan groups. In differentiating between co-occurrence networks of each political group, e.g., an inquiry co-occurrence networks of Social Democrats, we are able to highlight above average combinations, visually representing such in an easily readable format. This helps to disseminate specialized strategies for political groups in the evolution of charges.

- We tested for specialization of judges on political groups, which we found inconclusive.

- In a co-occurrence network of judges and prosecutors cooperating in cases, we identified clusters using a spectral cluster analysis. The spectral cluster analysis is based on a normalized graph Laplacian closely related to a random walk in order to identify clusters in the component, as described by Luxburg (2007) for sparse networks. We chose the amount of suitable clusters based on the spectrum of the normalized graph Laplacian, which showed a gap after the third eigenvalue indicating three clusters. The actual clusters were then extracted from the corresponding first three eigenfunctions of the graph Laplacian using a k-means algorithm (Wasserman and Faust 1994, p. 708). The clustering algorithm identified three clusters–one of which in the separate component of the remnant Steyr court–, and securely identified both Viennese courts in the data.

- We identified one judge as the best connected node in the network–the vice president of LGSt Vienna II–with a Pagerank score. This Pagerank score shows the node with the highest degree, i.e., the most edges to other nodes.[14] Despite this, we refrained from centrality analysis in the networks, as this would show the mere quantity of choice, but not real 'importance' as in a social network, and does not make sense in the context of trials.

Discussing the results of our quantitative and computational-based analysis, we were able to falsify and extend on the historical knowledge of qualitative-based scholarship on judicial practice during the consolidated period of the Corporate State in 1935.

14. Compare to the documentation of *Python::networkx.pagerank* (https://networkx.org/documentation/networkx-1.7/reference/generated/networkx.algorithms.link_analysis.pagerank_alg.pagerank.html).

Configuration to Conviction. Network Structures of Political Judiciary in the Austrian Corporate State

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In

Social Networks, vol. 66, July 2021, pp. 185–201. DOI: 10.1016/j.socnet.2021.03.001.

Abstract

In this paper, we analyze the extent of political judiciary in the transformed system of the Corporate State of Austria using the computational methods of a network approach. We investigate the differences in the legal prosecution of the political opposition, namely of members of the Communist, Social Democratic and National Socialist parties based on Vienna as a case study. Based on over 1,800 court records from 1935 processed at the Viennese provincial courts, we evaluate the courts' practice in contrast to the official legislature during the consolidated phase of the regime. In this study, we examine whether the law was strategically utilized against specific groups (following the concept of Kirchheimer's *political lawsuit*), and as in the more lenient version of Fraenkel's *tendency justice*, we analyze whether the law was disadvantageously interpreted for political partisanship up to a blatant breach of conduct. Combining quantitative and qualitative methods with network science approaches, we identify patterns of political prosecution and structural predispositions for the sentencing of left- and right-wing groups of the political opposition. We can prove different practices of political judiciary and differentiate between the different treatment of Social Democrats, Communists and National Socialists in 1935 in Vienna. We identify specialized strategies to prosecute the political opposition, resulting in a clear bias against left-wing groups and a relative leniency in the conviction of National Socialists based on the evolution of charges in the courts' actions. Using a multimodal network approach, we reveal key players and cooperation of judges and prosecutors which accounted for harsher sentences. We provide evidence that the system of control over the judiciary and over the political opposition was already crumbling in the Austrian capital in 1935, even before the *"Anschluss"* to NS-Germany in 1938.

Contribution of thesis author

Theoretical operationalization, computational implementation and analysis, qualitative evaluation and contextualization, as well as manuscript writing, revision, and editing.

Contents lists available at ScienceDirect

Social Networks

journal homepage: www.elsevier.com/locate/socnet

Configuration to conviction: Network structures of political judiciary in the Austrian Corporate State

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ARTICLE INFO

Keywords:
Historical network research
Judicial networks
Network analysis
Big historical data
Mixed methods
Computational history
Digital humanities

ABSTRACT

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1. Introduction

The division of politics and the judiciary is one of the founding principles of a democracy (Jesionek, 1995, p. 141). Today, we observe attempts to obstruct this principle all over the world: political agents intervene in the independence of judges in order to effectively target a political opposition, or to control the direction of the judiciary. In early 2018 the Polish government introduced a law that could force non-compliant judges to retire early.[1] Hungary used such a transformed judiciary to prosecute the political opposition (Kingsley, 2018; Novak and Kingsley, 2018) as well. During the recent coronavirus crisis, Hungary's prime minister assumed power for an unlimited time based on emergency decrees — without future checks and balances by Parliament or the judiciary (SZ.de/kit/mati, 2020). The Austrian Corporate State (1933–1938) used to be such an example, too.

Historical background. Founded by the specifications of the Treaty of Saint-Germain (1919), the Austrian democracy lasted until March 1933, when Chancellor Engelbert Dollfuß took power over the parliament with the use of police force in a "cold coup" (Holtmann, 1978, p. 166). Gradually, Dollfuß established a dictatorship in Austria by ruling with emergency decrees, such utilizing a remnant wartime economy accreditation law of 1917. Dollfuß changed the former republic in the May Constitution of 1934 as Federal State of Austria, as "Corporate State" (in German *Ständestaat*) with a distinct Catholic notion. Its

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[1] As of November 2018, the EU pressured the Polish government to reinstate those forcefully retired judges (Day, 2018). This fight re-ignited in early 2020, when the European Court ruled every judge appointed by the Polish government since 2018 as dependent, annulled their judicial decisions (Hassel, 2020), and recently nullified governmental disciplinary measures imposed on Polish judges (SZ.de/dpa/jsa/bix, 2020) after having first refrained from intervening (Gökkaya et al., 2019).

https://doi.org/10.1016/j.socnet.2021.03.001

"austrofascist" nature – an Austrian-specific way of fascism, as coined by Social Democratic contemporaries such as by Otto Bauer, deputy chairman of the SDAPÖ (Botz, 1985) – is contested in the literature (Holtmann, 1978; Botz, 1980), and it is considered authoritarian, not totalitarian (Holtmann, 1978, p. 15). This transformation into an autocracy targeted the civil legislature as well as the justice system itself.

Control over the judiciary. Stressing the need to establish the state's authority in the political takeover, then Secretary of Justice Kurt Schuschnigg administered the regime's subsequent gradual restructuring of the justice system, the courts, the professional and lay judiciary, and the scope of competence of the police forces. The first victim of this control was the constitutional court in Vienna, which was dissolved by Dollfuß on May 23, 1933, thus removing the only instance with the legal capacity to object to the regime's emergency decree rule (Neugebauer, 1995a, p. 115; Reiter-Zatloukal, 2012b, pp. 286, 317).

"Judges who confuse politics and jurisprudence need to be removed from the judicature", proclaimed Kurt Schuschnigg in July 1933 (translated from German by the author, quoted in Holtmann, 1978, p. 61). Judges were suspected of not behaving in line to the new directives. These suspicions were based on their German-national sympathies, and subsequent anti-communist and partisan National Socialist sentiments, and more profoundly, anti-state resentments as part of the former empire's elite that had supported the foundation of "German-Austria" in 1918 (Holtmann, 1978, p. 57; Neugebauer, 1995c, p. 319; Stimmer, 1997, pp. 881–3; Mattel, 2007, p. 69; Botz, 1995, pp. 110–1; Neugebauer, 1995b, p. 58; Kann, 1975, p. 155).

In a "masked claim to power" (Holtmann, 1978, p. 56) designed not to oppose the conservative judges and to keep up the appearance of a seemingly independent judiciary, the regime required every judge to give an oath of loyalty from May 10, 1933. This slow approach on judicial control was taken in order to keep good relations with the former Triple Entente, and not to be put on a par with the German Reich's policies (Neugebauer, 1995b, pp. 52–3). While in the May Constitution, articles 100 to 102 regulated the non-transferability[2] and independence of judges as a cornerstone of an independent judiciary, these passages were overthrown in the Corporate State's *Verfassungsübergangsgesetz* of June 19, 1934 (Neugebauer, 1995b, 56). After having at first suspended the judge's permanency and non-transferability for only one year in early February, the professional judiciary's independence was finally dissolved permanently in order to "preserve the authority of the State and the well regard of the jurisdiction" (translated from German by the author, quoted in Neugebauer, 1995b, p. 53; Tálos, 2013, p. 277; Holtmann, 1978, pp. 62–3, 110-11; Neugebauer, 1995a, p. 118). The civil unrest of February and July 1934 had made the need for exerting control over the ordinary courts to prevail over any reservations about the international regard.(Neugebauer, 1995a, p. 118). Henceforward, the Department of Justice would regulate the allocation of duties and personal of the judiciary. This allowed the regime to replace judges easily in order to react to "changing needs in the allocation of individual senates or divisions within the same courts" (translated from German by the author, quoted in Neugebauer, 1995b, p. 54).

The lay judiciary was mistrusted, too. The regime suspected lay judiciary of being supported by and supportive of Social Democrats, as the regulation of laymen nomination used to be proportional to party representation. The lay judiciary was relegated to an outside role by mid-1934 (Holtmann, 1978, pp. 56–58; Reiter-Zatloukal, 2012b, pp. 311–12 ; Neugebauer, 1995a, p. 115).

In parallel, the regime established a system of police justice by 1934 assigned with virtual judicial functions, which would ensure faster prosecution, by-passing the traditional judiciary in furtherance of "immediate atonement and deterrence" (translated from German by the author, quoted in Holtmann, 1978, p. 59, see also p. 50; Reiter-Zatloukal, 2012b, p. 307). This intended effect was not always successful. Reiter-Zatloukal (2012b, p. 317) stressed the more experimental than consistently planned nature of police policy; other scholars pointed out the ambivalent position of the police towards the regime, too, favoring National Socialist groups (Rivo, 2011, pp. 13, 34; Kann, 1975, p. 155; Jedlicka, 1975, p. 158).

Political repression. The regime restricted various forms of political expression, among them the civil right to gather and to strike, the freedom of political expression (Reiter-Zatloukal, 2012b, pp. 272–4), and introduced preventive censorship (Duchkowitsch, 1995, p. 568). In parallel the regime encouraged state prosecutors to tighten inquiries for prosecution (Holtmann, 1975b, p. 45). Simultaneously, the treatment of the political opposition grew more repressive and resulted in the legal abolishment of the opposition's political groups (Reiter-Zatloukal, 2012c, p. 61): the Communist Party KPÖ as early as in May 1933, the Social Democratic Party SDAPÖ in February 1934 after the civil fights, rendering Social Democratic political engagement illegal retroactively (Reiter-Zatloukal, 2012b, p. 338). In February 1934, Schuschnigg proclaimed a state of emergency facing civil unrest (*"Staatsnotstand"*, Holtmann, 1978, p. 96). New repressive laws were introduced, such as the aggravation of criminal law, the far-reaching confiscations of property, the introduction of martial law and the death penalty for the insurgents (Holtmann, 1978, p. 132; Neugebauer, 1995b, pp. 116–7); also new crimes were created in penal law.[3] These served to criminalize, prosecute and harshly punish any perceived enemies of the regime under the guise of retaining public security (Reiter-Zatloukal, 2012c; Neugebauer, 1995a; Reiter-Zatloukal, 2012b; Schölnberger, 2012; Tálos, 2013; Rothländer, 2012b). The increasingly violent National Socialist groups were only prohibited in July 1934 after their failed putsch attempt but successful assassination of Chancellor Dollfuß.

Uncovered areas. Holtmann's doctoral thesis (1978) on the prosecution of the workers' movement, and the more recent research conducted by Reiter-Zatloukal (2012c) and Neugebauer (1995a) on repressive politics, among others, brought to notice political judiciary practices during the authoritative rule of Chancellor Engelbert Dollfuß (1933–1934) and his successor Kurt Schuschnigg (1934–1938). Previous studies refrain, with rare exceptions,[4] from a quantitative analysis. Instead, they have focused on a qualitative evaluation of the approaches of the regime to take control over the judiciary and the police, as well as legal frameworks of judicial prosecution against the political opposition and the early year's show trials (Reiter-Zatloukal, 2012a,b, 2013; Neugebauer, 1995c,a), on class justice against left-wing groups (Holtmann, 1978), the system of detention camps (Schölnberger, 2012), proprietary confiscations (Rothländer, 2012b), and more generally on the origins of National Socialist engagement in Austria (Rothländer, 2012a; Botz, 1980; Rivo, 2011) leading to the *"Anschluss"* in 1938. They showed qualitatively the legal prerequisites and political agenda of the Corporate State in order to control and prosecute citizens based on their political activities.

Missing are studies on the quantitative aspects of political repression, as well as on the actual legal practices outside the early and late period of the Corporate State.[5] A research project conducted at University of Vienna by Wenninger et al. (2017) addressed this lack,

[2] Judges are not to be removed from office nor transferred.

[3] Among them: disturbance of public tranquility, death sentences, double jeopardy, and permanent preventive internment.

[4] Such as Botz (1995), who analyzed the relationship of politics with the judiciary in the First Republic with regard to violent crimes, but used a tiny sample. Also, the dissertation by Bauer (2001) focused in a quantitative way on the social structure of the July Putsch.

[5] Neugebauer (1995a) broad qualitative study of the whole period does not mention the sentence practice in 1935, except for the "Schutzbundprozess" in April 1935.

and collected empirical data on politically motivated court cases with a focus on Viennese courts in 1935, which is the data foundation for this paper's analysis. The analysis of political judiciary in the Austrian Corporate State with means of modern technological advances and qualitative knowledge is a void that this paper aims to fill.

This paper situates itself in regards to the computational methodology employed by the Digital Humanities using historical network analysis. More formalized quantitative network methods are applied in this field recently in order to study complex historical dependencies, and to identify patterns of interaction, such as on networks in Modern history such as by Düring (2015) or von Keyserlingk-Rehbein (2018). In another strand, legal studies use network approaches to study judicial decisions (such as Clark and Lauderdale, 2012) or internal and external organizational effects of courts (such as Shomade and Hartley, 2010; Box-Steffensmeier and Christenson, 2014). A project bridging legal studies and social history are the Old Bailey Record project (Emsley et al., 2012), in which close to 200,000 court trials in London from the 17th to the 19th century were analyzed applying text mining approaches (Hitchcock, 2013; Graham et al., 2016).

In this paper, we analyze the extent of political judiciary in the transformed system of the Corporate State in Vienna during the calmer and more consolidated period of the regime in 1935. The civil unrest of the prior year had passed, as well as the major legislature changes had taken effect. We investigate the legal prosecution of the political opposition, namely of members of the Communist, Social Democratic and National Socialist parties in Austria. Based on over 1,800 court cases from 1935 tried at the Viennese provincial courts, we evaluate how the courts' applied the legislation originating from times of distress and the need for preservation of power in the much calmer period of 1935. Our main research question is: *Were there differences evident in how the political opposition was prosecuted?* Based on over 1,800 court cases, the contributions of this paper are the following:

- We analyze penal practice applied to Social Democrats, National Socialists and Communists, identifying patterns of prosecution and structures of conviction.
- We identify structural predispositions in trials relevant to the prosecution, conviction, or acquittal, analyzing co-occurrence networks of inquiries, charges, and delicts of conviction.
- We identify key players and cooperation of actors, who stood out in the sentencing of particular political groups, based on a social network of judges and prosecutors.

This paper is organized as follows: in Section 2, we operationalize different forms of political judiciary, and describe the data. There, we introduce clustered graphs as fingerprint of each political groups' cases. Section 3 is devoted to the analysis of prosecution and penalties of political groups, and of co-occurrence networks of charges and key players, the results of which we juxtapose to the assumptions in the literature. Finally, we address limitations of working with historical data and discuss in Section 5 this study's conclusions on the system of political judiciary in the consolidated phase of the Corporate State.

2. Data and method

2.1. Data description

The data for this study was collected by a research project on political repression during the Corporate State coordinated by Wenninger et al. (2017). Between 2015 and 2017, this project created an unpublished database on over 1,800 suspects' case files tried before the Viennese provincial courts I and II. They collected and transcribed archival case records featuring political charges of the year 1935 from the municipal and provincial archives of Vienna, as well as the archive of the Viennese provincial courts for criminal cases.[6] The database consists of court records tried before the provincial courts I (LGSt I) and II (LGSt II) of Vienna, with the exception of 8 records that were transferred from other courts to LGSt I or II, to be either re-tried there,[7] or to open prosecution in Vienna instead before a sentence was derived in the other court.[8] The only differences between LGStI and LGStII were in their jurisdiction over different quarters within Vienna: LGSt I, located in the infamous "gray house", attended to the Viennese districts 1 to 12, 16, 17, and 20, while LGSt II dealt with the remaining districts and the surrounding commuter belt of Vienna (compare to Waldstätten, 2012; Bundesministerium für Justiz, 2009).

The archival case files include information on:

- The cognizant jurisdiction authority, the respective province, where the offense had occurred, and the initial subject-matters of investigation by the police against the suspect (henceforward referenced as inquiries);
- In prosecution cases, the charges brought forward by the prosecutor against the suspect, the names of the prosecutor and judges leading the prosecution, and if existent, the defender and witnesses approved by the court;
- In criminal conviction cases, the verdict given by the judges with the delicts the defendant was convicted of (henceforward: delicts of conviction), the date of conviction, the kind of punishment (detention for a certain period, possible mode fees), and the date of incarceration, and possibly of the release,
- And miscellaneous information, such as added letters.

The database of Wenninger et al. (2017) added, among other things, unique case IDs, source origins, and the duration of the imprisonment, as well as personal information on the involved persons.

As we use court proceedings as base, we have to be aware of context bias. Schwerhoff (2011) rightly noted that court-documents are involuntary ego-documents, and as such the courts, the judiciaries, and the police have a specific and non-objective worldview imposed on their defendants and cases. Therefore, we can make inferences only on the view on the suspects' punishable oppositional behavior as presented by the records of the courts. As such any findings necessarily reflect the view of the courts.

Based on the strict Austrian privacy laws for archival data, we used unique and anonymous identifiers for every person in the database, which can be translated back if needed. For analysis, we focused on the following categories of political orientation: Communists, Social Democrats, National Socialists, and a container category for miscellaneous memberships such as in religious or loyalist groups, and one

[6] As such, there is of course a selection bias in the transmission of records. The case files were pre-selected in 1980 by the Institute for Contemporary History at the University of Vienna, which assessed 10,057 case files and discarded them until 3,000 remained today (Wenninger et al., 2017). Unfortunately, neither lists about these discarded records nor information on the removal criteria exist anymore. It is very likely that disproportionately high amounts of political actions survived. The research project at the University of Vienna on political repression (2015–2017) identified 1,836 cases, which apply to the above-mentioned definitions of political actions (Wenninger et al., 2017). The focus on mentions of political orientation and politically-charged accusations falls short, on the one hand, on political agitators, who could have been charged with something non-political and whose consecutive trial did not mention their affiliation. On the other hand, there is little reason to believe that the regime would mask their intent to prosecute a political orientation so that it could have the intended deterrence effect.

[7] As in the case of the investigation against nine members of the NSDAP at Kreisgericht Steyr, of whom six were sentenced in January 1935 in Steyr. Of the remaining three, who were not prosecuted then, one was accused and convicted of illegal membership in a secret organization, and imprisoned for 14 days with mitigated punishment.

[8] As in the case of two National Socialists transferred from BH Tulln to LG Vienna II, and sentenced for "*Aufwiegelung*" and "*Agitation*".

for unknown political orientation. We derived to these categories by mapping the actual group membership recorded in the database to one of these categories, e.g. members of the *Wachtturmgesellschaft* of Jehovah's Witnesses as "religious", the SDAPÖ and Schutzbund as "Social Democrats", or the Revolutionary Socialists as "Communists".[9]

To translate all charges in the documents, we used the then most recent version of the criminal law edition (Tlapek, 1933), and supplemented it with the then relevant legal updates published in the *Bundesgesetzblatt* preserved by the *Österreichische Nationalbibliothek*. Austrian penal law of 1935 recognized different forms of anti-state disruptions, such as riots, insurrections, public disruption, gatherings, incitement, and *"Agitation"*, which differentiated between violent and non-violent assemblies and gatherings which resisted against State power. Many of these had only been recently introduced by the Dollfuß-Schuschnigg regime. We left them untranslated in order to preserve their unique connotations, but gave an interpretation each. Then, we grouped offenses based on content, i.e. the group of high treason (§58–61) consisting of §58 defining high treason, §59 its punishment, §60 punishing the misprision to prevent high treason, and §61 the respective punishment. Additionally, we grouped scam, embezzlement and theft as monetary offenses, as well as murder and homicide as homicidal offenses.

The database is focusing on Vienna. During the Corporate State, Vienna was the only mega city in Austria, and in 1934 was home to 1.9 Mio of 6.7 Mio of the total population in Austria (Statistik Austria, 2015). With the new constitution of 1934, Vienna lost its status of *Bundeshauptstaat* and its independence as *Bundesland*; instead it was reorganized as *bundesunmittelbare Stadt* in the course of centralization (compare to the May constitution of 1934 as in Kimmel, 1936, p. 95), but remained the political center of Austria (Suttner, 2017, pp. 23, 47). Therefore, it is reasonable to assume the pivotal role of Vienna during the Corporate State, and the focus of analysis of the de facto capitol of the Dollfuß-Schuschnigg regime.

The dataset encompasses 1,836 individual cases in 549 group trials investigated by the police on 1,521 suspects at LGSt I and LGSt II of Vienna,[10] and their inquiries, charges, and delicts of conviction, and punishments. Within a subsample of 490 cases, the database records additional information on the court personnel in 204 cases with verdicts: the judges, prosecutors, defenders, and witnesses involved in each case.

315 individuals were the subject of more than one inquiry, 259 of them were investigated twice, and 21 three times. Three individuals were investigated four,[11] five,[12] and eight times[13] 21 defendants were sentenced twice; the highest rate of four sentences was imposed on an ambassador of the Yehovah's Witnesses.

Communism, Social Democracy and National Socialism cover 91% of all suspects' political orientations. There are no prominent cases or show trials; instead, these processes represent the day-to-day business in court.

We interpret these court trials as multimodal networks. The main information of an exemplary single case are shown on the right in Fig. 1. This case's suspect was a twenty year old metalworker and member of the Socialist Youth, who was accused of forbidden gathering, of discrimination against the administration and general societal values, and of spreading rumors. This defendant was sentenced in June 1935 for the discrimination charges, and imprisoned until June 1936. This case was part of a group trial alongside fifteen other accused Social Democrats, who were charged with individually tailored offenses.

Viewing court trials as networks allows us to draw relations between different types of nodes, and to analyze their structures quantitatively using a network research methodology. As the court trials offer diverse pieces of information, for analysis we have to focus on certain attributes of these cases. Fig. 1 shows a sample network of 206 cases with verdicts in 88 group trials, featuring judges, prosecutors, and suspects of various political orientation only. This allows us to make inferences on their relations based on different interpretations of connections, e.g. as here edges represent convictions. For analysis, we assume that all cases in the relatively short time-frame of 1935 were tried close together, and were heard in parallel. Therefore we treat court personnel that co-occurred in other cases as ''knowing'' each other based on them working together.

In order to explore the dataset, we used the clustered graph approach (Brandes et al., 2008; Lubbers et al., 2010) to give an overview on the characteristics of cases against defendants of the main groups of the political opposition, namely Social Democrats, Communists, and National Socialists. We interpreted each defendant's case as ego, and the information of the case as alteri within the following six case attributes (henceforward referred to as "classes"): the judges bench, the prosecutor bench, the witnesses' bench, the inquiries of the police, the charges by the prosecutor, and the delicts of conviction by the judiciary. We aggregated the average amount of elements in each alter class, which is reflected in the node size. The shade of each alter class reflects their aggregated ratio of co-occurrence. Here, we differentiated between inter-class co-occurrences and within-class co-occurrence. The within-class co-occurrence shows how many elements of the attribute appeared together in other cases as well. In the visualization, the shade of the node shows the average of this relative co-occurrence within each class. The inter-class co-occurrence shows whether e.g. one judge of the judges bench appeared together with a witness in another case, attributing to the case a 0 (no co-occurrence) or a 1 (at least one co-occurrence to another class of alteri).[14] For the visualization, we averaged the aggregated inter-class co-occurrence represented as the shade of edges.

We thus constructed an average case for each main group of the political opposition. In Fig. 2, Social Democrats and Communists share a very similar profile. There are gradual differences in the Communists' graph in the much higher average and higher inter-class co-occurrence rate of witnesses, and a slightly less inter-class co-occurrence for judges and delicts of convictions. The high inter-class co-occurrence for the levels of inquiries display a very homogeneous accusation structure of the same charges. In contrast to the left-wing groups, the National Socialists' graph shows an average of two judges, who only occasionally worked together on cases. The lower inter-class co-occurrence of inquiries suggests that National Socialists were not charged for more diverse crimes, but surprisingly got inquired by the police and were convicted by the judiciary for very similar offenses throughout the dataset. All political groups only had one prosecutor.

The clustered graphs show visual differences in the co-occurrence networks of the political defendants: each group has their own distinct "fingerprint" structural characteristics.

[9] There are some instances, when individuals were recorded with multiple memberships, which we mapped into one political orientation only, e.g. if the database records for a defendant a membership in the Social Democratic Republican *Schutzbund* and in the Communist party, we picked the more 'pronounced' partisanship, and coded this person accordingly as "Communist".

[10] Of these 21 defendants in 8 group trials had been either investigated or tried in other courts, and their records were transferred for re-trial in Vienna.

[11] A tenured professor at the Anthropological Institute in Vienna and editor of the Austrian Journal for Racial Studies.

[12] A vice-mayor of Vienna.

[13] An ambassador of the Yehovah's Witnesses, who later emigrated to Switzerland.

[14] Computation of density punishes the amount of people involved: If there are three judges and three witnesses and each judge knew one other witness from other cases, it would be three co-occurrences out of nine possible ones, therefore a co-occurrence ratio of 33%. While in reality, it is of more importance if there is a connection at all, which could be the defining moment whether the defendant would be convicted or not. As we were more interested in whether there was an overlap within these classes, we used a binary definition of co-occurrence: 1 if there was any co-occurrence, 0 if there was none.

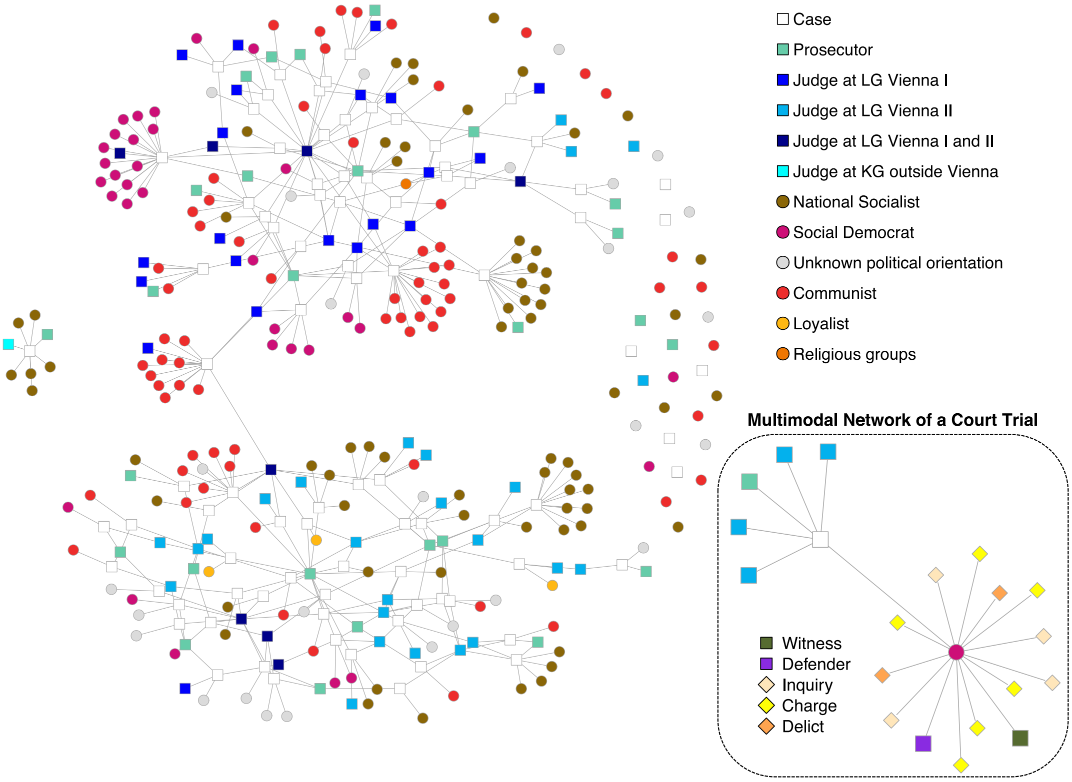
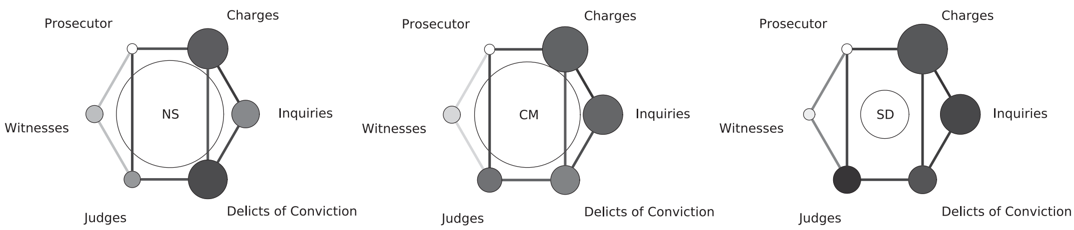


Fig. 1. Figure of a multimodal sample network of 88 court proceedings, featuring 201 defendants in 204 cases with verdicts, 55 judges and 27 prosecutors. An edge equals a conviction. On the right: Figure focusing on one defendant in a random single case's court trial interpreted as a network. The suspect shown here was a twenty year old metal worker and member of the Socialist Youth, who was – individually charged alongside fifteen others – accused of forbidden gathering, discrimination against the administration and general societal values, and of spreading rumors. The suspect was sentenced in June 1935 due to the discrimination charges, and was imprisoned until June 1936. Layout algorithm used: Fruchterman-Rheingold in R::igraph..



(a) National Socialists (n=71) (b) Communists (n=70) (c) Social Democrats (n=32)

Fig. 2. Clustered graphs of convicted members of political groups. Node size shows the average amount of elements within each graph's attributes' class.

2.2. Operationalization of political judiciary

We operationalized political judiciary for analysis two-fold according to the definition given by Kirchheimer's *political judiciary* and *political lawsuit* (1955/1964, 1965), supplemented by Fraenkel's concept of *tendency justice* (1927/1968).

In his fundamental work on politically influenced judiciaries, Kirchheimer (1955/1964, 1965) defined *political judiciary* as justice and the judicial system serving political purposes. We saw evidence for this already in the legal foundations for prosecution of oppositional partisanship as described above. Kirchheimer (1965, pp. 80–1) specified a politically influenced legal practice as *political lawsuit*, which he characterized as the weaponization of the law against an opposition. Fraenkel (1927/1968, pp. 36–7) coined the same concept as *tendency justice*, while stressing that even pre-existing laws could be disadvantageously applied against specific groups in order to serve a political purpose.[15]

In the literature, there is some disagreement on the definition of political judiciary. Holtmann reinterpreted the concept of *tendency justice* in the sense of Kirchheimer's *political lawsuit* and stressed its momentum of deterrence (compare Holtmann, 1978, p. 57). Broader definitions of political judiciary are very common, which include any connections between the judiciary and politics (Hannover and Hannover-Drück, 1987, p. 13). These broad definitions are usually applied in the

[15] Fraenkel thought of political judiciary as the influence on the dispensation of justice by the judges' own political beliefs and the "interests and ideologies of a ruling class", which we could not include in this study.

Table 1
Table of cases on the frequency of prosecution, and the respective group percentages and standard residuals. Roughly 42% of police inquiries against political groups were brought to trial, but there is not significant bias evident against a singular group.

	n	No Trial	Trial
All suspects	1836	1076	760
–Group Percentage	1.00	0.59	0.41
Political Groups	1,673	971	702
–Group Percentage	0.91	0.58	0.42 (−0.96)
National Socialists	836	504	332
–Group Percentage (St.Res.)	0.46	0.60 (0.86)	0.40 (−0.96)
Left-wing Groups	837	467	370
–Group Percentage (St.Res.)	0.46	0.56 (−0.81)	0.44 (1.01)
Communists	456	242	214
–Group Percentage (St.Res.)	0.25	0.53 (−1.35)	0.47 (1.66)
Social Democrats	381	225	156
–Group Percentage (St.Res.)	0.21	0.59 (0.26)	0.41 (−0.23)

literature on Austrian legal history, or not defined at all while implicitly assuming a connection between political influences and juridical decisions as political judiciary (compare e.g. Neugebauer, 1995a).

In this study, we examined whether the law was strategically utilized against specific groups (Kirchheimer's *political lawsuit*) and as in the more lenient version of Fraenkel's *tendency justice*, we analyzed whether the law was disadvantageously interpreted for specific partisanship up to a blatant breach of judicial conduct.

Hence, in biases against the political opposition, we investigated the usage of certain charges for particular groups. We tested for systematic predispositions, such as tandems of judges and prosecutors, and their possible individual predispositions leading to more or harsher convictions. Thus we use a mixed methods approach in supplementing quantitative and qualitative methods to analyze practices of political judiciary in the provincial courts of Vienna in 1935.

3. Analysis

In order to make inferences with regard to differences in the prosecution of the political opposition, we first investigated possible biases against oppositional partisanship. *Was a political group unfavorably tried in the dataset?*

3.1. Prosecution and conviction rates

In the frequencies of their prosecution, we found no significant evidence of a bias against a singular group in the sense of Fraenkel (1927/1968)'s *tendency justice* (compare Table 1). Instead, the left-wing groups of Communists and Social Democrats and the right-wing group were relatively evenly prosecuted, and even similarly in size.[16] There was a slightly higher tendency of Communists to be tried at 47%, constituting an above average prosecution in comparison to the total of 41% of prosecuted suspects. However, we did not see significant standard residuals.

The conviction rates in cases with prosecution revealed a clear tendency to sentencing (see Table 2). Consistently over the three big groups, 87% were found guilty if a trial commenced, even though the proportion for a Social Democrat's conviction was higher than for any other group. Over the whole dataset, if a defendant was tried in court, this meant an 83% chance of being sentenced to imprisonment (or, if convicted, 96% were imprisoned). There is some difference from an almost 100% incarceration rate for convicted National Socialists and

Table 2
Table of the frequency of acquittals and convictions in verdicts, and the respective group percentages and standard residuals. Roughly 87% of cases would result in a conviction.

	Trial	Acquittal	Conviction
All suspects	760	99	661
–Group Percentage	1.0	0.13	0.87
Political Groups	702	90	612
–Group Percentage	0.92	0.13	0.87
National Socialists	332	41	291
–Group Percentage (St.Res.)	0.44	0.12 (−0.15)	0.88 (0.11)
Left-wing	370	49	321
–Group Percentage (St.Res.)	0.48	0.13 (0.29)	0.87 (−0.05)
Communists	214	37	177
–Group Percentage (St.Res.)	0.28	0.17 (1.92)	0.83 (−0.65)
Social Democrats	156	12	144
–Group Percentage (St.Res.)	0.20	0.08 (−1.78)	0.92 (0.68)

Table 3
Table of the frequency of incarcerations in convictions, and the respective group percentages and standard residuals. A conviction meant a prison sentence in 97% of cases of political groups. Some variation between a 100% incarceration rate of National Socialists vs. a 88% incarceration rate in Social Democrats.

	Conviction	No Prison[a]	Prison[a]
All suspects	661	38	636
–Group Percentage	1.0	0.06	0.96
Political Groups	612	31	594
–Group Percentage	0.93	0.05	0.97
National Socialists	291	0	291
–Group Percentage (St.Res.)	0.44	0.0 (−3.7)	1.0 (0.90)
Left-wing	321	31	303
–Group Percentage (St.Res.)	0.49	0.01 (3.75)	0.94 (−0.78)
Communists	177	10	176
–Group Percentage (St.Res.)	0.27	0.06 (0.33)	0.99 (0.0)
Social Democrats	144	21	127
–Group Percentage (St.Res.)	0.22	0.15 (5.29)	0.88 (−1.09)

[a]Note that an incarceration verdict could be combined with a monetary penalty; Therefore, these columns do not necessarily add up to 100.

Table 4
Table of average prison sentence lengths (in days) in convictions. While right- and left-wing groups were convicted in a similar number of trials, National Socialist defendants were, on average, sentenced to 160 days less than left-wing defendants.

	Mean	St.Error
All suspects	306.9	(15.1)
Political Groups	320.8	(15.9)
National Socialists	239.6	(10.9)
Left-wing	399.6	(28.7)
Communists	376.6	(31.53)
Social Democrats	430.1	(52.5)

Communists, and a 12-point lower one for convicted Social Democrats (see Table 3). This observation might be connected to the type of offenses specified against the right- and left-wing groups, as will be shown later.

3.2. Prison sentence lengths

In order to evaluate the differences within these prosecution frequencies, which seemed to imprison National Socialists slightly more frequently than left-wing groups, we examined their lengths of imprisonment (see Table 4). Comparing the left-wing and right-wing groups of similar sizes, a clear bias against left-wing groups becomes evident in the differences of absolute sentencing. Social Democrats and Communists were sentenced to over a year of incarceration on average. The particularly high standard errors for Social Democrats

[16] However, the courts tended to treat leftist print works of Social Democratic members as being of Communists, leading to an fluent attribution of Social Democratic and Communist membership. This is another factor to combine both partisanships in the left-wing group in the subsequent analyses.

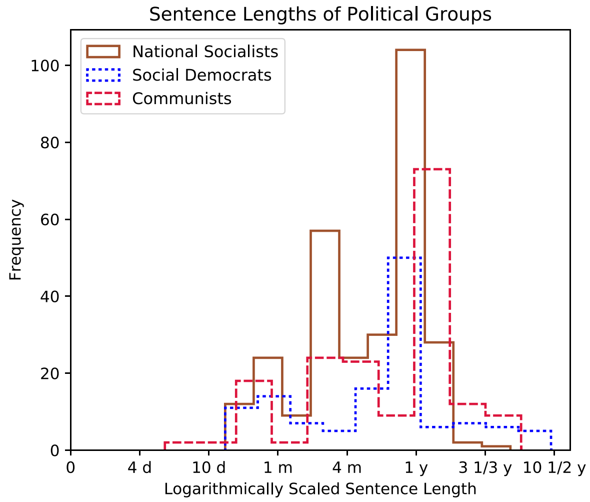


Fig. 3. Histogram of prison sentence lengths of political groups in $\log_{365}$ on the x-Axis (In order to increase readability, we marked Social Democrats in blue). National Socialists were mostly sentenced up to one-year of incarceration, while left-wing groups received much more extreme sentences, resulting in a much higher average. A t-test revealed significant differences between the sentence lengths of left- and right-wing groups. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

suggest a very widespread distribution of sentences. By contrast, National Socialists were convicted in the almost same amount of cases, but received on average a prison sentence of 160 days less than the left-wing groups. A t-test revealed these differences in sentence lengths between left- and right-wing groups to be significant (t=5.1, p<0.001). These differences are the result of the circumstance that Communists and Social Democrats received much more extreme sentences with up to 10-year prison sentences, thus increasing their average, which National Socialists' convictions were missing. Fig. 3 shows a relatively homogeneous sentence distribution for National Socialists, who received most frequently sentences of up to one-year of incarceration. Up until this range, the sentences of Communists and Social Democrats were more lenient, but beyond that showed the most extreme sentence lengths. The lower average of sentence lengths over the whole dataset (306.9 days) suggests a more lenient imprisonment of the other suspects groups, too, in comparison to the left-wing groups (399.6 days).

We tested whether these differences were statistically significant for National Socialists', Communists' and Social Democrats' cases at court using a χ^2-test, employing a significance level of 0.05. For the dataset of 1935, we found significant differences between political partisans based on the tests of whether the defendant was brought to trial or not ($\chi^2 = 6.5$, DoF = 2, p = 0.03), and whether the defendant was convicted or acquitted ($\chi^2 = 7.5$, DoF = 2, p = 0.02). Very significant results showed the test on prison or no prison sentences in the convictions dependent on political partisanship ($\chi^2 = 41.9$, DoF = 2, p<0.001).

The parity of Social Democrat's and Communist's sentence lengths is more remarkable when attribution is implicated: The courts considered left-wing printed works as Communist, which were some of the most frequent offenses for Communists (around 15%). Therefore, Social Democrats, who published those printed works, were more likely treated as Communists, too. Thus, the courts (and as such the database) had a bias for an over-attribution to Communism. The political attribution represented the view of the courts, and not necessarily the individually perceived political orientation of the defendant. Still, the average length of sentences are very similar between Communists and Social Democrats, which indicates that there was no real difference between those two groups in the eyes of the courts.

In general, Communists were almost always imprisoned if convicted, but in absolute numbers Social Democrats received the most extreme sentences. This does not mean that National Socialists got lenient sentences in general. In fact, up to the one-year sentence mark, they had very similar absolute sentence lengths compared to the left-wing groups, and even more one-year sentences than they did.

3.3. Proportionality of sentences

While the absolute lengths and frequencies of sentences can be considered rather high, we investigated next whether these sentences can be viewed as severe in the eyes of the contemporary penal law. Therefore, we established the proportionality of sentences to the official degree of penalty for offenses as regulated in penal law. This allows us to analyze the question, if there was an *a priori* harsher conviction of defendants based on their political orientation, following Kirchheimer (1965)'s concept of political judiciary as operationalized above.

The proportionality of convictions is difficult to measure, as in penal law the degree of penalty varied greatly from, e.g. a minimum degree of penalty (henceforward: lower limit) of 6 months, to an upper degree of penalty (upper limit) of 1 year of incarceration with an optional aggravated degree of penalty (aggravated limit) of up to 5 years, as for the offense of deceiving, facilitating, or hiding a crime (§214, see Tlapek, 1933). The final sentence was a composite of the individual degree of penalties for each charge, which by code of conduct could be based on either the principle of absorption (in German *Absorptionsprinzip*), or the principle of aggravation (in German *Asperationsprinzip*). The principle of absorption sought to apply the individually most harsh penalty from all the accused offenses, but the penalty would not add up to the sum of each individual offense. The principle of aggravation regulated a cumulative sentence in cases of many delicts, but again would not reach the summed degree of penalty for each individual offense either.[17] The principle of absorption is named oftentimes in the convictions. But as in case no. 1888 or 1859, a one-year incarceration was sentenced, whereas the individual degrees would not have exceeded 6 months. Therefore, the degrees were added, and both absorption and aggravation principle ignored, and instead an extra-legal accumulated punishment used. This constitutes one of the breach of law concepts that Fraenkel (1927/1968) theorized as *tendency justice*. Did the courts decide to sentence more harshly than usual in these two exemplary cases, or can this be considered common practice in the courts? As penal law did not regulate for every offense an aggravated, upper and lower limit for degree of penalty, we replaced missing limits with one level down, e.g. the missing aggravated limit with the existent upper limit, so that aggravated limit ≥ upper limit ≥ lower limit.

Sentencing based on principle of aggravation. To test the proportionality of sentences in terms of the principle of aggravation, for each case, we summed all its offenses all lower limits of punishment, all upper limits, and all aggravated limits, and compared the sentence length of the case's verdict to these penalty limits' boundaries. In Table 5, we evaluated whether the prison sentence in a trial reached the summed punishment of the individual offense's penalty limits of a case's delicts. According to the principle of aggravation, the sentence would have to be lower than the summed penalty of each offense.

Around 92% of defendants were sentenced below the upper limit of the summed penalties for each case's charges, in which Social Democrats peaked with 98% of cases. The Social Democrats were convicted most coherently within this legal prerequisite: 51% were convicted within (and including the lower) and the upper penalty limits, and 2% within the upper and aggravated penalties. Social Democrats reached neither the summed penalty of the upper nor the aggravated

[17] This paragraph did not change until today, except its number from §28 to §22 (JUSLINE Österreich, 2020).

Table 5
Table showing the principle of aggravation in cases with prison sentences and delicts with penalty limits. Did the sentences reach the summed penalty of each offense's penalty limits in a case? Abbreviations: L = Lower Limit, U = Upper Limit, A = Aggravated Limit of Applicable Penalty.

	n	<L	=L	L<U	=U	>U (noA)	U<A	=A	>A
All suspects	504	0.47	0.09	0.35	0.03	0.03	0.02	0.01	0.01
Political Groups	467	0.46	0.1	0.36	0.02	0.03	0.02	0.01	0.004
National Socialists	212	0.42	0.14	0.33	0.04	0.05	0.01	0.005	0.0
Left-wing	255	0.50	0.06	0.37	0.01	0.01	0.03	0.02	0.01
Communists	144	0.53	0.06	0.31	0.01	0.01	0.03	0.03	0.01
Social Democrats	111	0.46	0.05	0.46	0.0	0.01	0.02	0.0	0.0

limit. National Socialists had the highest value (4%) for sentences of the accumulated upper limit, and Communists with 3% for sentences of the accumulated aggravated limit, which according to the principle of aggravation would not be legal. The 1% of Communists with sentences above the accumulated aggravated limits, and 5% of National Socialists above the accumulated upper limits (as well as for Communists and Social Democrats of 1% each) constituted breach of law as well. The extremely high percentage of sentences below the accumulated lower limit of penalty suggests that the principle of absorption was not applied commonly by the Viennese courts. These results contradict the scholarship's assessment of a common cumulative sentencing in the Austrian courts during the Corporate State (Neugebauer 1995a, p. 119; Reiter-Zatloukal 2012c, p. 75). In the consolidated phase of the regime, we cannot assume that accumulated sentences were common practice. Instead, we see some evidence for an excessive punishment beyond the limits of the law when applying the principle of aggravation, which focused on the Communist political group, as well as on National Socialists.

Sentencing according to principle of absorption. In Table 6, we analyzed the application of the principle of absorption, in which the delict with the harshest penalty limits would constitute the sentence.

Here, National Socialists received with 83% most of the sentences below the upper limit of a single delict's penalty, whereas Social Democrats and Communists the least in this category (68% and 74%, respectively). An interesting observation is also that Communists received by far the most sentences outside the aggravated limit (6%), as well as a notable 5% of National Socialist member cases outside the upper limit of penalty, which both constitute a breach of conduct based on the principle of absorption. For Social Democrats, a drastic high number of 19% of cases received the exact aggravated penalty limit (6% National Socialists, and 9% Communists). Again, the large number of sentences of below the highest single lower limit of penalty are noteworthy (around 29%), and highest for Communists (34%). This would mean that in general, sentences would not exceed the possible harshest penalty for an offense, but in fact would go much below that.

3.4. Interim conclusions I

We can already summarize that the Viennese courts (and as such the regime) prosecuted left- and right-wing groups in equal numbers, which marked a new line of policy since the regimes' focus in the previous year on the left after the February Fights and then on the right after the July putsch (Holtmann 1978, p. 144; Neugebauer 1995a, p. 118). We were able to show that there were only slight differences in their prosecution: Communists had a higher likelihood for a trial opening and a higher acquittal probability, but also a close to a 100% imprisonment rate, as did National Socialists. Over all political groups, when a trial commenced (in more than 40% of police inquiries), political defendants were most of the time found guilty (87%), and imprisoned (97%).

We saw clear signs for bias against left-wing groups in the verdicts, who received the most extreme prison sentence lengths.

When evaluating the proportionality of prison sentences, we could show that the verdicts were usually not extreme according to the specifications of law. The courts did not seem to insist on deterrence effects and refrained from extreme sentences, as the legal range of penalty, with few exceptions, was not exploited to the fullest (and in roughly a third of cases was even below the lower individual penalty limits). Death penalties, which had remained a legal option for high treason, for example, were not issued anymore either. Scholarship indicated that with the end of the prominent *"Schutzbundprozess"* of April 1935 (which was investigated by late 1934, and does not appear in our dataset) marked also the end of the policy of compurgation justice (German *Rechtfertigungsjustiz*) and preventive discipline of the regime (Holtmann 1978, pp. 144–6, 150; Neugebauer 1995a, p. 117; Neugebauer 1995b, p. 56). This comports with our observation here.

Aside from the court's refrainment from extreme exploitation of penalty ranges, the sentence range limits were severe nonetheless. New, excessive offenses were still introduced in February 1935 so that divergent press and printing works could be prosecuted as "anti-state" with up to one year of incarceration, and if they were of "high-treacherous character", with up to 5 years, which were designed to destroy the newly formed left underground movement Holtmann (1978, pp. 148–9). We should also stress the fact that a judicial conviction (as well as a mere political inquiry) could and would ruin an individual's existence in the interwar society (Holtmann, 1978, p. 156) by causing their removal from employment, pension benefits, housing, and subjected them to confiscations and other additional monetary penalties, or daily lump sum charges for their detainment in *"Anhaltelager"* (Schölnberger, 2012). As such, political trials must be considered a weapon to ostracize targeted individuals.

Our observations also show that cumulative sentencing was not as common as scholarship assessed for the earlier periods of the regime (Neugebauer 1995a, p. 119; Reiter-Zatloukal 2012c, p. 75), as 46% of political group's cases had sentences below the accumulated lower penalty limits of their offenses.

We were also able to contradict scholarship's assertion that legal practice would be tied to the written law in the Corporate State (Neugebauer, 1995b, p. 58). We could show that judicial decisions oftentimes would go beyond the written law, or breach the regular legal conduct, which fit Fraenkel (1927/1968)'s concept of *tendency justice*. We found examples for double jeopardy, too, when trials were repeated until the seemingly appropriate punishment was received.[18]

This observed relative leniency on trials against National Socialists becomes clear when the specialized strategies on the evolution of charges are taken into account (see Section 3.5 on structural predispositions).

We investigated this matter further when we looked at the judges' co-operations and whether some judges influenced these punishments outside the legal prescriptions (see Section 3.6 on cooperation structures).

3.5. Structural predispositions based on the kind of offenses

Next, we investigated whether the differences in sentencing can be explained with different oppositional behavior of right- and left-wing groups, and/or with structural differences in how the courts handled their cases. Hence, the subject-matters of investigation by the police,

[18] As in the case when a defendant was not found guilty by the court for the charge of planning an explosives attack in the first trial, but was retried by a different set of judges, and found guilty for the mere possession of explosive materials. However, we have to mention double jeopardy might not be suitably represented in our dataset, as police sentences are not part of the court records. Scholarship refers to judicial sentences and police sentences as orchestrated to supplement each other, e.g. when the release from judicial prison was followed by police imprisonment (Holtmann, 1978, p. 152).

Table 6
Table showing the principle of absorption in cases with prison sentences and delicts with penalties. Did the sentence exceed the maximum penalty limit of a case's single offense? Abbreviations: mL = maximum Lower Limit, mU = maximum Upper Limit, mA = maximum Aggravated Limit.

	n	<mL	=mL	mL<mU	=mU	>mU (noA)	mU<mA	=mA	>mA
All suspects	504	0.30	0.24	0.23	0.05	0.03	0.02	0.1	0.03
Political Groups	467	0.29	0.25	0.23	0.05	0.03	0.02	0.1	0.03
National Socialists	212	0.25	0.30	0.28	0.05	0.05	0.005	0.06	0.01
left-wing	255	0.32	0.22	0.18	0.06	0.01	0.04	0.13	0.04
Communists	144	0.34	0.22	0.19	0.04	0.01	0.04	0.09	0.06
Social Democrats	111	0.29	0.22	0.17	0.08	0.01	0.04	0.19	0.01

the charges by the state prosecution, and the delicts by the judiciary will be analyzed in the following. This means that the kind of offenses brought forward in each phase represents the focus of the respective court's action.

Structural Predisposition of Offenses leading to Conviction. Following the line of thought of Kirchheimer's *political lawsuit* (1965), we analyzed whether specific offenses led to convictions. We looked at inquiries that did (or did not) result in a trial, as well as charges that resulted in a conviction (or not).

Over the whole dataset, the most common inquiry was of high treason (38.8% of cases), followed by *"Aufwiegelung"* (non-violent sedition against the State, 38.5%), membership in an illegal organization (33.3%) and *"Agitation"* (non-violent enmity against morality, property or legality, 31.4%). Of those with a trial, 44.6% were due to *"Aufwiegelung"*, *"Agitation"* (39.9%), high treason (35.3%), and illegal organization (17.9%), gossip (17.1%) and *"Beschwerdesammlung"* (collection of appeals, 16.3%). This stayed similar in cases with a verdict: *"Aufwiegelung"* (43.6%), *"Agitation"* (38.4%), secret organization (31.8%), and anti-state printed works (22.7%).

The mere frequencies of punishable offenses being prosecuted or dropped show that there were no specific initial inquiries leading to trial. The most common inquiry in the dataset, high treason (38.8%), was not prosecuted in 23% of cases (60% of police inquiries due to high treason), but in only 15% led to a trial. The most common charge was participation in an illegal or secret organization in 22% of cases, but 1/3 of those charges did not lead to a trial. Also *"Agitation"* (enmity against morality, property or legality) more often did not lead to a trial.

We could argue that high treason would often result in a trial, and that twice of the inquiries for participation in a secret organization were prosecuted, but overall the type of inquiry brought forward against a suspect does not seem to have determined a trial.

We can assume thus that other decisions must have determined whether a case was brought to trial. Among these decisions was the obvious need for evidence. Whether or not a piece of evidence in court was genuine cannot be accessed anymore. Beside references to printing matters, we know of witnesses in court. The members of the executive branch constituted the biggest proportion of a particular profession for the witnesses in cases involving all three major political groups. In 206 cases recorded with witnesses, 33.7% of them were policemen or country constables. The percentage was higher for cases with Social Democratic defendants (43.1% of 51 witnesses), and National Socialist defendants (42.3% of 182 witnesses), and lowest in cases with Communists (27.1% of 199 witnesses). It is therefore not far-fetched to infer that the evidence needed for a trial could be presented with the means of the police force alone, and erased the need for other evidence.

Structural Differences in Allegations against Political Partisans. We found clear differences in the kind of allegations brought forward against left- and right-wing groups in the process of the court's action.

High treason was a particularly National Socialist inquiry (in 22% of cases) and charge (18%), which shrank in the judges' convictions to appear in only 7.5% of cases. Instead, the rates for participation in illegal organization started out with 14% of cases in the inquiries, dropped to 8% in the charges, and rose to 21% in the convictions.

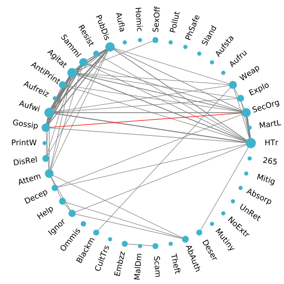
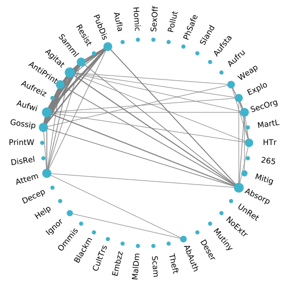
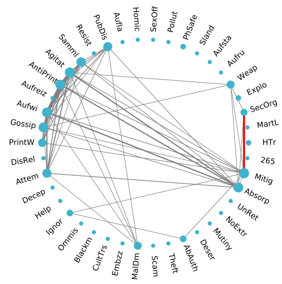
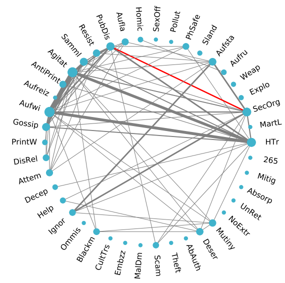
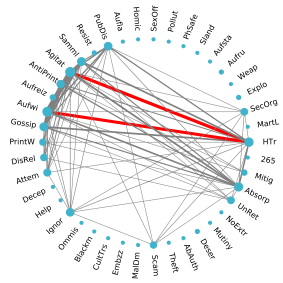
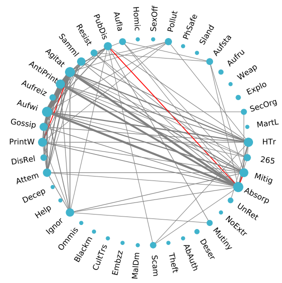
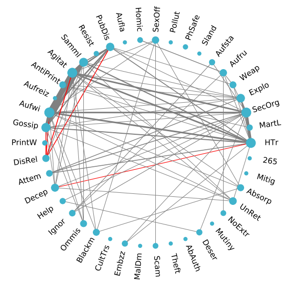
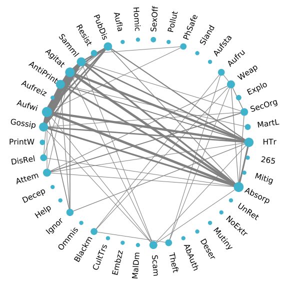
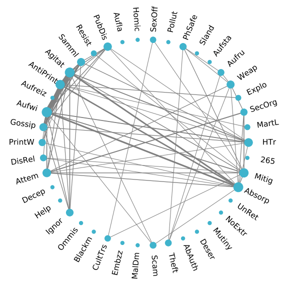
While high treason was almost equally represented in cases involving Social Democrats and Communists (around 8%), this rose in the prosecutions' charges to 12% for Social Democrats, and dropped again to 4% in the convictions. For Communists however, the high treason offense led to a conviction in less than 4% of cases. Communists were accused and sentenced based on the so-called rubber paragraphs (in German *"Kautschukparagraphen"*) *"Aufwiegelung"* and *"Agitation"*, that could be flexibly adapted to cover a wide variety of conduct; Social Democrats to a lesser extend. It must be especially noted, that a mitigation of punishment was ordered by the court for every 7th National Socialist, but only for 3 and 2 out of 100 Communists and Social Democrats, respectively.

It is striking that violent crimes have a negligibly small share on all these charges and delicts. Offenses concerning weapons and explosives, violent resistance and homicide all fall under a 1% barrier for both left- and right-wing groups, except the singular observation of 2% of cases with police inquiries on violent resistance for Communists. The police investigated in less than 1% of cases on weapon delicts, 3% on violent resistance, and 1% on homicide, which in the verdicts amounted to less than 1% of cases in each of these three categories of violent acts. We can conclude that the differences in sentences cannot be explained by a more violent behavior of a political group. This observation of a non-violent opposition is in direct contradiction to the generalized assumption of qualitative scholarship, that the right-wing groups were openly violent against infrastructure, institutions, individuals — in contrast to the "verbal radicalism" and defensive use of force of the left-wing groups (Reiter-Zatloukal, 2012b, p. 273) –, as well as to the regime's assumption about a violent left-wing opposition. Instead, we did not find differences in violent acts of the political opposition in 1935 regarding weapons, violent resistance and homicide: There was no higher use of openly violent acts by neither group, of which almost all fall under a 1% barrier of cases. Across the whole dataset, offenses connected to violence were rare.

These findings could also revise several other scholarly assertions on common judicial behavior. Among them is the assertion that high treason would tend not be applied as it is poorly verifiable, as well as §287 participation in secret or forbidden societies (Neugebauer, 1995a, p. 118). We found high treason in 1935 to be one of the most common police inquiry (39%), and in prosecution's charge (35%), but this offense was used in only 11% of verdicts in the dataset. Allegations of §287 membership in secret societies were among the most common charges used for right-wing groups, too, and also in the whole dataset in 33% of cases when investigated by the police, 18% when charged by the prosecution, and in 28% of cases with verdicts. We could verify the claim that the most common offenses were those of so-called press delicts, which Neugebauer (1995a, p. 118) defined as §300 *"Aufwiegelung"*, §305 *"Agitation"*, §308 "Gossip", and §310/2 *"Beschwerdesammlung"*. These appeared in 40% of inquiries, 47% of charges, and 41% of verdicts.

Structural Predispositions in Co-occurrences of Allegations against Oppositional Partisans. Another indication of a structural predisposition could be the combination of allegations brought forward to prosecution against the political opposition. We identified offenses co-occurring in

Table 7
Networks of co-occurring offenses of members of left- and right-wing political groups. Members of the National Socialist group (NS) show an above average combination of gossip and illegal organization membership. Noteworthy are their high frequency of mitigation of punishment in combination with membership in illegal organizations in the verdicts. Members of the Communist group (CM) were most often investigated for public disruption and secret organization memberships, and ac cussed of high treasonous offenses in an above average combination of *"Aufwiegelung"* and *"Agitation"*, but convicted for public disruption and anti-state printed works. Social Democratic members (SD) were investigated most prominently for high treason and deception, disrespecting religion, public disruption, gossip, *"Aufwiegelung"* and *"Agitation"*, whereas have no peculiarities in their charges and delicts of conviction. Circular Layout Algorithm used in python::networkx.

	Inquiries	Charges	Delicts
NS			
CM			
SD			

the inquiries, charges, and delicts of convictions, and marked those who appeared more frequently together than others.

In general, the most frequent combination of inquiries was *"Aufwiegelung"*–*"Agitation"* in 30.0% of all cases, and different forms of high treason (28%). The most common inquiry for Communists was in almost 11% of cases *"Aufwiegelung"*–*"Agitation"* and in 7% high treason offense combinations. For Social Democrats these were in 8.7% of cases *"Aufwiegelung"*–*"Agitation"* and in 6.4% high treason offenses, and for National Socialists in 14.2% high treason delicts and 9% *"Aufwiegelung"*–*"Agitation"*. In the charges, high treason offenses increased for Communists' cases by 4 points to 11.4%, but decreased for Social Democrats to 5.4%, and rose slightly for National Socialists to 15.8%. There, also *"Aufwiegelung"*–*"Agitation"* increased for Communists by 4 points to 15.7%, for Social Democrats to 10.5%, and to 10.1% for National Socialists. In the delicts, Communists were sentenced in 12.6% of cases with *"Aufwiegelung"*–*"Agitation"*, and over 7% for either *"Aufwiegelung"* or *"Agitation"* in combination with anti-state printed works. This holds true for Social Democrats as well, but with a more broadly differentiated range of charge combinations, *"Aufwiegelung"*–*"Agitation"* reaching 8.7%, followed by 3.7% for *"Agitation"*-a-nti-state printed works. Whereas for National Socialists, in the delicts the accusation of high treason disappeared by half (5.9%), instead 17.5% of cases were convicted for illegal organization offenses, and 8.3% for *"Aufwiegelung"*–*"Agitation"*, and *"Aufwiegelung"*–anti-state printed works (7.2%).

The visualizations in Table 7 of these co-occurrence networks for National Socialists', Communists', and Social Democrats' cases show the specific combinations of inquiries, charges, and delicts of each political group, which are inherently different for each. There, we additionally highlighted the outlier combinations of co-occurring paragraphs in each group. For this, we constructed threshold values that signify whether a combination of paragraphs occurred more often than the average occurrence of this combination over all political groups; we colored the edge red, if the combination occurred more than 1.95 times of the average occurrence of this combination. The co-occurrence highlighted above of illegal organization and gossip in police inquiries for National Socialists is also noteworthy. For Communists, the combination of illegal organization and public disruption was above average in the police inquiries, whereas Social Democrats were charged above average with disrespecting religion, public disruption, *"Agitation"* and gossip, as well as deception and high treason. Communist had a clear high combination of high treason with *"Aufwiegelung"* or *"Agitation"* in the prosecutors' charges. In the verdicts, National Socialists had an above average co-occurrence of illegal organization and mitigation of punishment, but Communist in illegal organization and absorption principle, and public disruption and printed works regulations. Social Democrats did not show any above average co-occurrences in their charges or delicts of conviction.

3.6. Interim conclusions II

These findings on offenses applied characteristically to specific political partisanship reveal a structural predisposition for conviction based on political partisanship, explaining the differences in prison lengths for right- and left-wing groups. These observations show a structural evolution in the kind of offenses brought forward by the police, the prosecution, and the judiciary for each political group, which influenced the severity of their subsequent sentences. Namely for National Socialists, the most common inquires of high treason by the police declined rapidly in the prosecution's charges, and were reversed to the much 'lighter' crime of illegal participation in secret groups by the judiciary. This, in turn, influenced the relative leniency on National Socialist cases' sentences imposed by judiciary. Holtmann (1978, pp. 260–1) mentioned a new law to take effect in 1936 that was designed to put an end to judges favorably changing charges from high treason to illegal secret organization participation, and thus the preferential treatment of National Socialists by the judiciary.

These specialized prosecution strategies for political groups fit clearly Kirchheimer (1965)'s concept of the *political lawsuit*.

This observed lenience for right-wing groups fits the orientation of legal practice within the First Republic and the show trials of 1934 only to some extent. For a small sample of trials during the First Republic, scholarship had identified a tendency for conspicuously lenient sentences for right-wing perpetrators and more serious sentences for left-wing ones (Reiter-Zatloukal 2007, p. 90; Holtmann 1978, pp. 1, 52), which in general was characterized as class justice (Neugebauer 1995b, p. 115; Holtmann 1975a, p. 158; Botz 1975, p. 159).[19] This judicial bias was attributed to the judiciary favoring the "anti-Marxist street fight" of the right-wing groups (Botz, 1995, pp. 109–11).

Other "conspicuously lenient sentences" (Holtmann, 1978, p. 1) were recorded by scholarship for the July putschists compared to the February fighters (Holtmann 1975b; Neugebauer 1995b, pp. 57–8). This leniency was again attributed to the German sympathies of the judiciary, but answered also to political pressure from NS-Germany. This might be the case in 1935 again, which resulted in the selection of charges on how right-wingers were prosecuted, but with the difference that generally the convictions did not exceed the possible limits of penalty.

3.7. Cooperation structures

In the preceding sections, we focused on the case properties and the kind of charges that were brought forward. Next, we looked at the court personnel themselves. The dataset features 204 cases in 88 court proceedings, where at least one judge was recorded by the digitization project (see Fig. 1). This sample features 55 judges and 27 prosecutors working on 204 cases with verdicts on 201 different defendants from 88 processes. Did certain judges specialize on prosecuting political partisanship? Did the cooperation of certain judges and prosecutors result in harsher sentences? Did court personnel stand out in crucial positions, whom we can consider as key players?

[19] And criticized, as such, for misattribution, as neither left- nor right-wing groups consisted of a homogeneous class (compare Wandruszka, 1975, p. 110).

Specialization in political groups. When we looked for specialization in political groups, we found certain judges who focused on specific groups. This is visibly striking as in Fig. 1, where several judges are surrounded by groups of one political orientation only, as the 12 National Socialists surrounding Judge Oskar Strasser of LGSt II. However, this would ignore the historical fact that multiple defendants could be accused in one (big) proceeding. In order to elicit this sort of over-attribution of judges, we grouped cases according to their trial numbers. There are 549 cases with a unique trial number out of a 1,836 individual cases against 1,521 different defendants. Of these 549, 278 group trials (processes) were opened, with convictions in 256. In 278 trials, 39% had 3 or more different defendants (in a total of 111 group trials). Within these grouped cases, each defendant received an individually tailored sentence.

An analysis taking the group processes into account shows no clear specialization on any group by judges and prosecutors in our sample (compare Fig. 4). This might be used, however, to complete missing information on political orientation of individuals.

Cluster Analysis. The courts LGSt I and LGSt II of Vienna were responsible for separate districts of the city: LGSt I was responsible for the Viennese districts 1 to 12, 16, 17, and 20, while LGSt II dealt with the remaining districts and the surrounding commuter belt of Vienna (Waldstätten, 2012; Bundesministerium für Justiz, 2009). We were able to show, however, that judges did not work solely within their respective courts.

A spectral cluster analysis using a normalized Laplacian closely related to a random walk on the graph (for a comprehensive description of spectral clustering see von Luxburg, 2007) reveals three clusters on two connected components in Fig. 5. The two clusters on the biggest component coincide with the two provincial courts of Vienna, while the third cluster constitutes a case processed at the court of Steyr.[20] We see cooperations spanning from the provincial court of Vienna I to II and vice versa, and certain individuals working in both courts.

Harshness of Verdicts dependent on Judges, Prosecutors and their Cooperations. We analyzed the average sentence practice for each judge, prosecutor, and their cooperations, and computed the percentage of the applicable range between the lowest and highest penalty limit, having 0 as the penalty minimum, and 1 as the penalty maximum. We differentiated again between the principle of aggravation, constructing the penalty minimum/maximum cumulatively, and the principle of absorption, which took the highest penalty of each upper, lower and aggravated limit. In order to allow for reasonable inferences, we restricted this analysis to all court personnel who brought forward a conviction in a minimum of 8 cases (compare Fig. 6).

For court personnel, who made convictions in at least 8 cases, the highest average for an accumulated sentence (= principle of aggravation) was 35% of the possible maximum penalty by Judge Dr. Gasser of LGSt II in 15 cases against Social Democrats (ranging within the lower and the upper penalty limit) in combination with Prosecutor Dr. Schmidt of LGSt I, as well as Schmidt with Judge Dr. Eder of LGSt I and II (35%) The lower individual average of Eder (32%) suggests a slightly less stern sentence behavior, as in another case against a National Socialist he gave a sentence below the lower limit.

This trio (compare to upper right corner in Fig. 6) also stood out with the highest average for sentences based on the principle of absorption with 61% of the highest penalty limits. In their cases, eight of 15 Social Democrats received the highest single upper penalty limit, and four the aggravated one.

[20] Steyr appears in this data set, because a court record about nine National Socialists defendants (of which six were convicted in January 1935 in Steyr, and three were not prosecuted) was transferred to LGSt II for the trial of one of those remaining three defendants who were not prosecuted yet. This defendant was finally found guilty of secret membership in an illegal organization in June 1935, and was imprisoned for 14 days. As this corresponding court record now is to be found in the provincial court archive, it was recorded in the database.

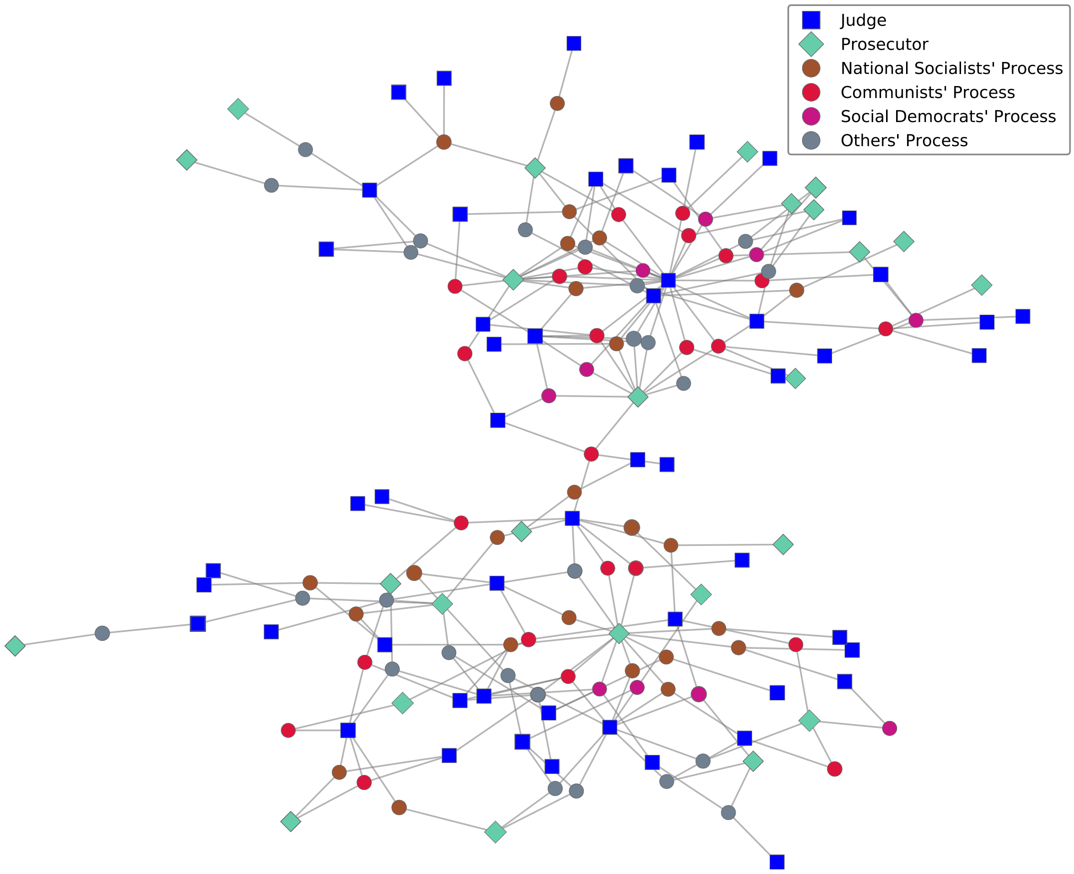


Fig. 4. Network of 53 judges, 25 prosecutors, and 84 processes (of cases with convictions) colored according to its majority's political orientation. Edges represent convictions. Layout algorithm used: Kamada–Kawaii in python::networkx. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

A fourth judge affiliated with this group, the Vice President of the Viennese provincial court Judge Dr. Alois Osio (active at both LGSt I and II), also had an average 60% sentence rate (absorptive sentencing) respective 35% (accumulated sentencing) in combination with Prosecutor Schmidt. Individually, however, Osio had an average of 33% of the possible maximum penalty (according to the principle of absorption) in 58 cases, which were evenly distributed among the political groups. Of these, only one was above the upper limit of the sentence, and 8 below the lower limits. Did Osio push the aggravation in this one case? His own lower average does not seem to suggest this. In terms of cumulative sentencing, he individually administered on average -5% of the applicable penalty range, suggesting an average sentencing below the lower penalty limit provided by penal law for the convicted offenses. Interestingly though, Osio was described by contemporaries as conservative, outspokenly anti-communist (Meisel, 1985, p. 56) and famous for harsh sentences (Kreisky, 2014), having sentenced the Young Socialist Joseph Gerl to death in martial court in 1934 (Pal, 2006, p. 9).[21] In our dataset notwithstanding Osio did not appear to be an extremely harsh judge. A PageRank clustering score revealed Osio as the most central node in the sample, as reflected by his many cases in the sample.

Another group consisted of judges mainly from LGSt I (see Fig. 6 in the upper middle) that were conspicuous in their sentence practice in regard to the principle of absorption. Individually, Judge Dr. Naumann of LGSt I gave 57% of the highest penalties on average in 9 cases against Communists, of which 3 received sentences below the lower limit, and 2 above the aggravated limit. OLGR Judge Dr. Standhartinger of LGSt I had an average of 41% in 10 Communist and 4 Social Democrat cases as an individual. Both formed with Prosecutor Ludwig Tlapek of LGSt I (individual average of 16%) and Judge Dr. Anton Werner of LGSt I and II (15%) another quartet that had an average sentence of 57% of the maximum penalty (absorptive sentencing) in 9 cases, suggesting that in fact Naumann and Standhartinger were the hardliners in that group. This is also supported by the observation that Tlapek with Judge Dr. Brick of LGSt I had an average of −5% in 21 cases against left-wing groups, suggesting an average sentence rate slightly below the lower limits of penalty.

The lowest average based on a cumulative and an absorptive sentence had Judge Dr. Felix Cazafura of LGSt II in 9 cases with -40% and -14% below the lower accumulated and individual sentence limits against all political groups. Noteworthy here is also prosecutor Dr. Ferdinand Nagl of LGSt II with a penal practice of −2% (accumulated sentencing) and -3% (absorptive sentencing) of the applicable range: he had 18 cases with National Socialists only.

[21] Osio targeted Communists, Social Democrats and National Socialists alike (DöW, 0000b). His processes against National Socialists made him one of the first prominent deportees from Vienna to the Dachau concentration camp after the Austrian *"Anschluss"* (DöW, 0000a). Osio died in January 1939 in Buchenwald. Socialist Otto Binder remembered meeting his former judge shortly before Osio's death as an "invalid", drawn by the camp illness phlegmone (Binder, 2010, p. 80).

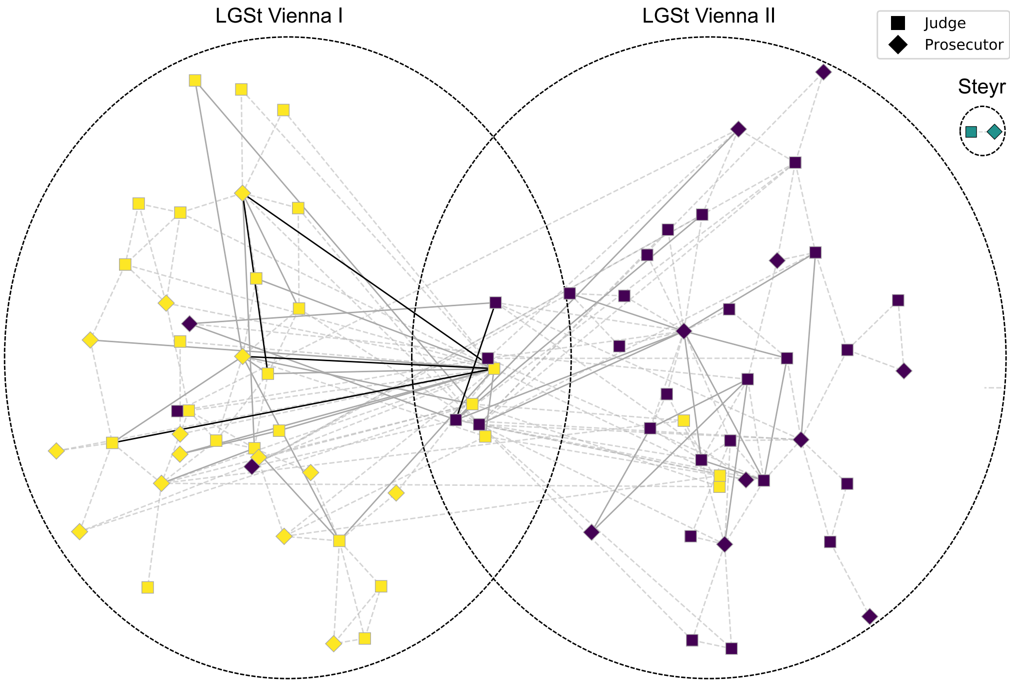


Fig. 5. Network of judges and prosecutors grouped based on their trials' court house. An edge symbolizes collaboration in the same processes; the dashed line signifies overlaps in 1 process, gray more than 1, and black in at least 5 processes. A spectral cluster analysis revealed three clusters, as represented in node colors. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

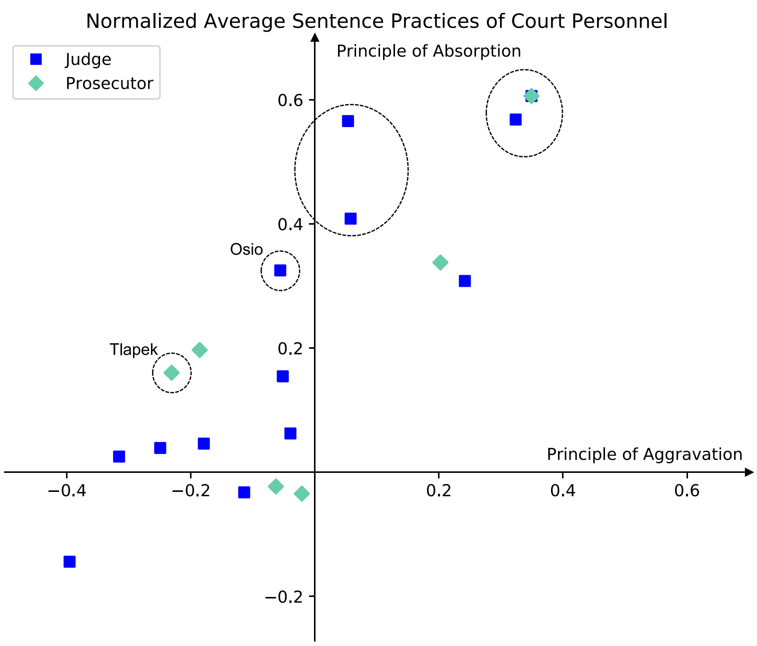


Fig. 6. Average sentence practices of judges and prosecutors with convictions in at least 8 processes based on the principle of aggravation (x-axis) and of absorption (y-axis). The sentence practices constitute the average penalty these court personnel brought forward in convictions. The penalty was normalized based on the percentage of the applicable range between the lowest and highest penalty limits of each individual case, having 0 as the penalty minimum and 1 as the penalty maximum. If values are negative, the average sentencing was below the lower penalty limit provided by penal law.

4. Limitations

Court proceedings as a social historical source can shed light on the social strata of criminality as well as on the evolution of penal law practice (Hoffmann, 1995). A few challenges appear when working with this kind of data. We have to take different forms of biases into account.

We have to consider a selection bias in the transmission of records. The case files were pre-selected in 1980 by the Institute for Contemporary History at the University of Vienna, which assessed 10,057 case files and discarded them until 3,000 remained today (Wenninger et al., 2017). Unfortunately, neither lists about these discarded records nor information on the removal criteria exist anymore. It is very likely that disproportionately high amounts of political actions survived. The research project at the University of Vienna on political repression (2015–2017) identified 1,836 cases, which apply to the above-mentioned definitions of political actions (Wenninger et al., 2017). The focus on mentions of political orientation and politically-charged accusations falls short, on the one hand, on political agitators, who could have been charged with something non-political and in the consecutive trial did not mention their affiliation. On the other hand, there is little reason to believe that the regime would mask their intent to prosecute the political orientation so that it could have the intended deterrence effect.

The case records as historical sources need to be considered fragmentary. There is an unknown number of incomplete records, as parts of the documentation were removed or deliberately destroyed by administration officials during the Corporate State, or simply have been lost. Others were not properly documented at the time, which is especially true for the fragmentary transmission of the period of imprisonment. Often times, the entrance or release date is not known, and there were duration differences in official rulings and served sentences. The fees for imprisonment and/or prosecution in most cases were not enumerated in the case records, but we know of contemporary witness' accounts that those were in fact imposed. Other issues arise owing to illegible hand-written entries or other missing information.

The database is noisy, too. The transcription process executed by many different people is not without fault: Transposed digits, missed information or simply illegible names contribute to another kind of fragmentary data, which was not coded into the database. The examining magistrate (who is different from the judges in the trial), associated lay assessors as well as other witnesses not appearing in court, are missing as well. We do not know how long those cases were tried at court based on the database, their duration is only indirectly coded based on the first imprisonment by the police and later imprisonment by the court. The data was initially not gathered with a quantitative analysis in mind. It must be noted that sentence length could be incomplete, too, owing to sloppy police documentation or lost documents, but holds true to the data available in archives. During pre-processing, we corrected as many of these noises as much as possible.

Using fragmented and fuzzy data on historical network research fundamentally differs from other social sciences: Historians work with archival source material instead of being able to interview, and in general try to rebuke the problem of sources with their diversification, disclosure of their lacks, and clarification of their authenticity and origin.

Also networks are always a representation of real-world systems, and as such a reduced (not complete) version of it (Lemercier 2012, pp. 24–5; Hennig et al. 2012). While missing data can be problematic when studying social networks, there is also evidence that centrality metrics are indeed suited to accurately describe the dataset (Costenbader and Valente, 2003; Borgatti et al., 2006).

The size of the dataset counterweights such fragment issues. Lemercier and Zalc (2019, p. 39) recently stressed that there is "almost no reason in historical research to gather more than 1,000 cases" following the line of the law of big numbers. A dataset of over 1,800 cases should suffice for this rule. We can therefore infer tendencies of the politically influenced prosecution in 1935 Vienna.

Finally, we have to consider context bias. The data does consist of court records, and does not account for every police record or confiscation record, which could be used for an encompassing picture if they exist. Schwerhoff (2011, p. 40) has argued that court-document are involuntary ego-documents of the accused within the administrative-legal area such as questioning or witness protocols. The courts, judiciaries and police have a specific and non-objective worldview imposed on their defendants and cases. Therefore, the findings on the dataset represent the view of the world as seen by the courts: for example, leftist print works of Social Democratic members were treated as being of Communists. This does not change the validity of the results.

5. Conclusion

The Corporate State of Austria (1933–38) gives a vivid case example on the transformation of justice in order to serve political purposes of the ruling elite. Research so far has focused on a qualitative evaluation of the system of political repressive in the early years, and on the reorganization of the former democracy to become an authoritarian state by its chancellors Engelbert Dollfuß (1933–34) and Kurt Schuschnigg (1934–38) using emergency decrees. This had revealed the mechanics of the purification of and control over the judiciary, and the ongoing aggravation of criminal law, and criminalizing of a political opposition. These practices fit the definitions of political judiciary by Otto Kirchheimer and Ernst Fraenkel very closely, which emphasize the weaponization of the law and the executive against any perceived enemies of the State. Whereas previous research disseminated the early years of the great show trials against political agitators (1933/34) and the later period leading to the integration of Austria into NS-Germany, this paper focused on the structural forms of political judiciary in the brief consolidated phase of the regime in 1935. In this paper, we were able to identify the following patterns of prosecution:

We found a clear tendency to sentencing of the political opposition in the Viennese courts, which tended to give more extreme sentences to left-wing groups. This relative leniency towards the National Socialist group in Austria can be explained with a specialized strategy of prosecution: For National Socialists indictments of serious crimes such as high treason were transformed by the prosecution and the cognizant judges to less serious offenses as forbidden membership in illegal organizations, and listed more often mitigating reasons in verdicts. Communists and Social Democrats were convicted with the so-called *"Kautschukparagraphen"* of *"Agitation"* and *"Aufwiegelung"*. This shows clear parallels to aspects of political judiciary as in the utilization of law against specific political groups, conceptualized by Kirchheimer's *political lawsuit*, as well as the breach of conduct for certain groups as theorized in Fraenkel's *tendency justice*. We could furthermore refine various assumption of qualitative scholarship on the legal practice and mechanism in the consolidated phase of the Corporate State based on the example of its capital, such as the use of accumulated penalties, usage of high treason allegations, and more. Finally, we revealed key players and cooperation of judges and prosecutors which accounted for harsher sentences at court.

A crumbling system. Overall, we found evidence that the system apparatus did not work entirely uniformly. The prosecution and the judiciary still had their own agenda on what kind of charges were allowed for a political defendant, and their subsequent convictions.

The extent of judicial guilt, according to Neugebauer (1995b), should be closely related to its agency. Courts were the "preferred weapon" against Social Democracy in the civil war (Neugebauer, 1995b, p. 55), whose composition was dependent on the regime and who implemented laws designed to suppress the political opponents. The regime however distrusted its courts. The abolishment of the formal independence of judges, the inauguration of special courts to sentence the July putschists, and other regulations in order to put the judiciary in line were a testimony to that "fundamental distrust" of the judiciary (Neugebauer, 1995b, p. 57). As a result, the judicial branch was under constant calibration by the regime. The judiciary could not satisfy the "changing regulations of a centrally initiated tendency justice" (Holtmann, 1978, p. 118) fast enough, quite literally.[22]

Consequently, Neugebauer (1995b, pp. 51–2) argues, the courts could not be held responsible for their judicial decisions. We disagree with this notion of a not-guilty judiciary during the Corporate State. In our study of 1935 Viennese courts, we could see clear signs of agency within the police, the prosecution and the judiciary, resulting in a drastically different interpretation of the suspects' supposed offenses. On the one hand, this shows that the judiciary was not controlled sustainably enough by the regime. On the other hand, this suggests that the judiciary can be held guilty owing to its own still-independent agency.

On January 10, 1935, Schuschnigg proclaimed that the July putschists and February fighters had both been enemies to the State alike, which suggested no difference in the legal treatment of the left-wing movement or the National Socialist groups (Holtmann, 1978, p. 169).[23] In legal practice, this stance did not hold true, because of the differences in prosecution and conviction as described above.

These cracks in the system foreshadowed its own failure by disagreement. The Austrian regime was not a totalitarian system Holtmann (1978, p. 15), but its authoritative stance crumbled under its internal contradictions in the apparatus itself.

In May 1935, on the day of the first anniversary of the Corporate State's constitution, most of the regime's convictions were amnestied (Holtmann, 1978, p. 171), which was followed by the "Christmas amnesty" in December 1935 (Reiter-Zatloukal, 2012a, p. 346; Marschalek, 1990, pp. 179–181). These amnesties were already a nod to the stressed relations with the German Reich, and to the criticism experienced by the former Triple Entente, and intended to calm down the workers movement as well (Holtmann, 1978, p. 278; Reiter-Zatloukal, 2012a). On July 11, 1936, the deal with the German Reich was finalized, followed up by a new wave of amnesties of mainly National Socialists convicts (Reiter-Zatloukal, 2012a). The so-called *"Deutscher Kurs"* became prevalent: the tendency for lenient sentences for National Socialist offenders became stronger, while for Socialist defendants the penalty range would be exhausted as described by Neugebauer (1995b, p. 58). A subsequent analysis of the period leading to the German *"Anschluss"* in 1938 would elaborate on these judicial developments.

Outlook. By connecting historical network methods and statistical analysis in a historical study of the provincial courts of Vienna in 1935, we revealed key players cooperating in harsher sentences, and identified specialized strategies and structural predispositions to sentence the political opposition. Thus, we were able to widen the historical knowledge obtained before by qualitative research on the legal practice and mechanism during this time.

The dataset used in this study was not intended for a quantitative analysis. In future research, we could tackle some of its limitations by building a database of court records that were digitized employing Optical Character Recognition and Handwritten Text Recognition. Then, we could use text mining approaches in identifying different usages of wording in the inquiries and verdicts of the political opposition. This would also allow a comparative perspective on the evolution of differences in the judicial treatment of Social Democratic, Communist and National Socialist perpetrators in Austria. Another in-depth analysis on the internal and external influences on the judiciary will become possible when the personal files of judges of the Corporate State are opened for general research. The latest research suggests that external agents such as the right-wing *"Deutscher Klub"* exerted their influences on the judiciary during the First Republic (Huber et al., 2020). Future examination of these personal files will shed light on the inner structures of judges.

[22] The courts could not keep up with the amount of trials. By the end of July 1934, the majority of cases concerning the civil unrest of February were not tried yet. After the putsch in July, the so-called *"Februarprozesse"* declined rapidly (Holtmann, 1978, p. 118). In this dataset of 1935, still 60 cases related to the previous year's February fights are recorded, of which 6 were brought to trial.

[23] The regime did however tailor laws to illegalize activities of certain political groups, such as the retroactive ban of the Social Democratic party after the civil unrest in February 1934, or to set harsher sentences on printing works interpreted as "anti-state".

Acknowledgments

We would like to express our sincere gratitude for the cooperation with Dr. Florian Wenninger and Philipp Tzaferis (University of Vienna), who shared their database with us for this research project. Additionally, we are grateful for the valuable feedback we received from the historical network research community on our conference presentations.

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Chapter 5

Case Study Social Networks in the History of Intellectuals

In the following series of studies, we approached the history of intellectuals with a network perspective, computationally examining the relational importance of individuals in intellectual history based on a Linked Open Dataset extracted from YAGO3, an ontology linking knowledge mainly from Wikipedia. Our main research question was whether we can make historical inferences on the patterns of relations of intellectuals.

In the first paper of this series, "'On the Shoulders of Giants' – Analysis of a Social Network of Intellectual Influence" (paper no. 2), we considered the complete history of intellectuals, and identified those intellectuals over all time with the greatest influences (network centralities) and the longest reaching influences (influence cascade trees). In the second paper "A Longitudinal Analysis of a Social Network of Intellectual History" (paper no. 3), we introduced a longitudinal perspective on the dataset, which we enriched with a periodization. Within the resulting network snapshots, we looked for the most important scholars within periods, in interperiod combinations, and in accumulated periods, and identified the brokerage roles of intellectuals. In "Diffusion Dynamics of Influence in a Social Network of Intellectuals" (paper no. 4), we extended this paper by influence cascade trees and analyzed their diffusion dynamics.

In the final paper, "Tracking the Evolution of Communities in a Social Network of Intellectual Influences" (paper no. 5; forthcoming), we enriched the dataset furthermore with geographic locations of the scholars, and their disciplines, enabling a deeper dissemination of the inner workings of these periods, and identified structures of communities of scholars.

5.1 On intellectuals and intellectual history

There is no common definition of intellectuals that can be applied universally (Ringer 1990, p. 281). There are distinctions of the 'intellectual' as a "social class charged with the business of thinking"[1] and a "class of phenomena [...] that is not tied to any specific

1. Such as suggested by Lasch (1965) to consider intellectuals as a social type since the late 19th century. However, Wickberg (2001, p. 387) noted, that a generalization of intellectuals as a social type would not be historically correct.

class of persons" (Wickberg 2001, p. 385). In general, the term is used for anybody concerned with thinking, i.a. researchers, philosophers, writers, scholars.

Intellectual history entails both the study of discarnate, "ageless" concepts and ideas, as much as the lives and achievements of the intellectuals bringing forward those. Intellectual history itself is an umbrella concept entailing as argued by Wickberg (2001, p. 383) on one hand the history of ideas/thought, history of science, technology, and academic disciplines (as well as their methodologies), history of the book and reading, conceptual history, and on the other hand the history of intellectuals ('intellectual life' and intellectual biography), and their meeting grounds of cultural history, cultural sociology, sociology of science, and the social history of ideas and of intellectuals (compare also to P. E. Gordon 2013).

Dependent on the focus within intellectual history, influence studied can be the influence of concepts on each other, but also personal influences of intellectuals (and their work) on each other.

5.2 Innovation and discussion

In this series of case studies, we proposed to study the history of intellectuals from a formalized network approach by taking the embeddedness of scholarship into account. This allows us to understand the interconnections of thinkers throughout time, and the dynamics of influence and the spread of ideas through history.

5.2.1 Relational intellectual history

The concept that the history of intellectuals and of ideas are situated in a complex net of interdependencies is focus of the social history of ideas (also known as: historical sociology of knowledge; or: social history of intellectuals), which places intellectuals and ideas (or concepts) in an "anterior social reality" of their historical context and social environment (Wickberg 2001, p. 384), and disseminates as well the "conditions and modalities of 'knowledge production"' (Goldman 1994, p. 266).

This concept of a relational positioning of ideas goes back to the 1970s and the works of Pierre Bourdieu and Karl Mannheim. Ideas have positional or relational attributes and exist in an "intellectual field" of negotiation processes[2] within a "cultural unconscious" (Bourdieu 1969, p. 89) or a "cultural pre-consciousness" as coined by Ringer,

2. Ringer (1990, p. 270) explains this concept as follows: "The intellectual field at a given time and place is made up of agents taking up various intellectual positions. [...] it is a configuration or a network of relationships. The elements in the field are not only related to each other in determinate ways; each also has a specific 'weight' or authority, so that the field is a distribution of power as well. The agents in the field are in conflict with each other. They compete for the right to define or to co-define what shall count as intellectually established and culturally legitimate." These elements can entail ideas, concepts, theoretical positions, or persons.

(p. 270) following Mannheim ([1952] 1993) concept of the "pre-theoretical" grounding of worldviews. [3]

Wickberg (2001, p. 385) described this development of a relational intellectual history as the result of a monolithic culture called into question and turn to an ordinary history of the "little people" (in contrast to a history of the elites) in which intellectual history is updated "into a form of social history."[4]

Drawing from Quentin Skinner, Ringer (1990, p. 272) argued for the "need to understand a great text positionally, by understanding its relationship to an intellectual field," which can be extended to the body of works and the authors themselves, and is based on the assumption, that texts stand in a discourse to each other. "One cannot chart the influence of Darwin or of Nietzsche," Ringer (1990, p. 277) wrote, "without knowing and explaining a great deal about those who subsequently used or misused their works." Wickberg (2001, p. 391) however warned about to determine the "relevance of a text" based on the "social identity of the thinker." This kind of prejudice can be avoided by sampling texts in an relational perspective, such as an "intellectual field" as theorized by Bourdieu (Ringer 1990, p. 276).

A relational perspective on the history on ideas puts the focus on context. This includes also local, national, trans- and international perspectives–in order to track the "transtemporal and transnational voyage" of ideas (Armitage 2014). This follows both the remark by Bonaventure D'Argonne of 1699 that ideas "embrace [...] the whole world" (quoted in Grafton 2009b, p. 1) and picks up on the contention by Lovejoy (1940) that ideas are the "most migratory things in the world." Baring (2016, p. 568), too, suggested to place "Machiavelli to post-Savonarola Florence, Freud to fin-de-siecle Vienna" to enable new perspectives on ideas in context. These recent suggestions for a transnational relational intellectual history answers to criticism (such as by Ringer 1990, p. 278) of the constricted focus on "more specialized and usually biographical studies," limited to specific regions or time spans as a trade-off for thorough comparative and textual analysis (compare also to Subrahmanyam 2017). Attempts to rectify these closed perspectives and to write a global intellectual history as by Moyn and Sartori (2013) have been criticized to focus again on already well-research intellectuals despite their

3. One effect of these negotiation processes and the situateness of ideas and intellectuals is the *habitus* of groups: the habitus understood as an "tacit social knowledge internalized in the individual" (Wagner 2012, p. 450) and as a "structuring structure" it is "shaped and transmitted by the social and institutional environment, as well as by the practices and traditions of a culture" (Ringer 1990, p. 275), as e.g., evident in the structural homologies between Gothic architecture and scholasticism (Panofsky 1951; compare to Ringer 1990, p. 274).

4. Wickberg (2001, pp. 388–90) warned that if intellectual history would become truly part of social history, ideas as entities would become causally instrumentalized: ideas would "come to be seen as tools," or "instruments to achieve goals," ignoring that ideas could come from nothing and are not necessarily shaped by agency (which is the driving force of social actors as perceived in social history) nor experience. Similarly remarked this also Ringer (1990, p. 281): he warned about the tendency of historical sociology of knowledge to portray ideas as "mere effects" of social situations and preferences, which "deemphasize[s] the *originality of creative individuals* [emph. in original]."

transnational approach (Subrahmanyam 2015).

Network approaches in intellectual history

"The digital age has been a boon for intellectual historians," emphasized Edelstein (2016, p. 237), as it made sources more accessible, "research more efficient than ever," and provided increasingly more sophisticated options for their dissemination–but "[t]he same cannot be said, however, about our methods." Edelstein (2016, p. 240) criticized the underutilization of the methodologies developed in the Digital Humanities for intellectual history, faced with the challenge of finding meaning in the quantitative abundance.

In related works, network methodologies have been implemented in the study of communication and correspondence networks. The concept of a relational history of intellectuals has been applied in various studies, which most often use a non-formalized and metaphorical network perspective to analyze historical structures, such as study of the ego network of philologist Gottfried Groddeck (Bednarczuk 2017) or the correspondence networks of naturalist Conrad Gessner (Delisle 2008). A noteworthy exception to this is the early study on Jesuit travels, in which Harris (1999, pp. 228–9) hypothesized "thread maps" as schematic models, which he differentiated using a network terminology, e.g., by identifying outgoing links. Lacking the tools to depict those networks systematically, Harris (1999, p. 227) voiced the regret that these "thread maps" remain "an exercise in imagination" as "the actual mapping of provenance for all the constituents of a scientific text would be an exceedingly tedious task." In a further step of progression, the early study by Schaffer (2008) to reconstruct the influences and contacts on Isaac Newton's "*Principia Mathematica*" already used maps, on which these information have been manually identified and linked. Advances in the computational depiction of space–such as in historical GIS–and tools have been developed since.

The web-based visualization tool *Palladio*[5] was one such tool, which was developed in 2009 in the course of a project at Stanford University to map and link historical intellectual networks of the *respublica litterare*. The project "Mapping the Republic of Letters"[6] was one of the first studies on intellectual history employing digitization of sources, text processing, and formalized network methodologies. In 2008, the project started at Stanford University with the objective to research the network of letters of intellectuals of the 17^{th} and 18^{th} as a whole as well as focusing on individual ego networks in a series of case studies[7], mapping the epistolary exchanges and migratory patterns as spatial networks of a "cultural space" (Edelstein et al. 2017, pp. 421–2). More recent

5. https://hdlab.stanford.edu/palladio/
6. http://republicofletters.stanford.edu/
7. In these, the ego network of Jesuit polymath Athanasius Kircher (Edelstein et al. 2017, pp. 404–9), the international relationships of John Locke (compare to http://republicofletters.stanford.edu/publications/locke/), the ties of Voltaire to England (Edelstein and Kassabova 2020), and Benjamin Franklin's correspondences during the "London Decades" (Winterer 2012) were researched, as well as the ties of British architects on the Grand Tour in Italy (Cesarani et al. 2017).

projects on the "Republic of Letters" have incorporated a temporal perspective on multilayered dynamic networks (Vugt 2017), or reflected on the challenges to model discrete and continuous time when dealing with fuzzy dating (Kudella 2019, p. 50). In 2019, a compendium was published reflecting on the challenges encountered when "*Reassembling the Republic of Letters in the Digital Age. Standards, Systems, Scholarships*" (edited by Hotson and Wallnig 2019), addressing issues with assembling and standardizing data, the transcription of text, and modeling of geographies, chronologies, prosopographies, and mining the available database of letters. The volume intended to pave way for a greater linkage of data to fulfill their vision to "reconcile the records of all the learned letters scattered across and beyond Europe" (Hotson 2019, p. 450).

Recently, also Verbruggen et al. (2020) studied in an actor oriented approach organizational mobility patterns of social activists and reformers in the long 19^{th} century based on the biographical database TIC Collaborative[8], which records for the 19^{th} and early 20^{th} century international organizations and congresses memberships (ibid., p. 133). Influenced by the analysis of social movements and collective actions, this study tracked temporal changes in the "evolution of networks and organizational exchanges" using the tools *Nodegoat* and *Gephi* (ibid., p. 127).

5.2.2 Methodological approaches

The following series of case studies combine both a global transnational perspective on the history of intellectuals and a formalized network analysis of the emerging networks of influences, and builds on the concept that the history intellectuals is a sequence of intellectual genealogies and their competing influences on each others.

A formal network analysis of a social network of intellectual influence

We considered the complete history of intellectuals as recorded in the knowledge database YAGO.

On LOD and YAGO. YAGO[9] is a knowledge base developed at the Max Plan Institute for Informatics, that links open data from Wikipedia[10], WordNet[11], and GeoNames[12]. YAGO's extraction of information from these sources employ text mining and web scraping techniques, as well as natural language processing of e.g., entity disambiguation and result filtering (compare to Suchanek et al. 2007, n.d.; Mahdisoltani et al. 2015). Linked Open Data (LOD) are license-free data formatted in the standardized *Resource*

8. https://www.ghentcdh.ugent.be/projects/tic-collaborative
9. Yet Another Great Ontology. See https://www.mpi-inf.mpg.de/de/departments/databases-and-information-systems/research/yago-naga/yago; compare also to Suchanek et al. (2007).
10. https://www.wikipedia.org/. Information are extraced from e.g., Wikipedia's categories, redirects, and infoboxes.
11. In order to extract senses, hyponymy, etc.; compare also to Miller (1995).
12. http://www.geonames.org/

Description Framework (RDF) (for an overview compare to Bizer et al. 2009). These data are tagged with information using unique and machine-processable identifiers (*Uniform Resource Identifiers*, URI), which allow to establish relations between entities from previously unrelated datasources. The idea of the LOD goes back to the idea of the interconnected *Semantic Web* and to establish a *Web of Linked Data*–with the intend to fruitfully utilize the available (open) data. This creates many areas of application; one well-known example is that of Google's Knowledge Graph, which evaluates the context of a search term in order to provide relevant information (Singhai 2012; Romein et al. 2020, p. 11). YAGO is one of the pioneers to contribute to the *Web of Data*: it hosts more than 120 million information on more than 10 million entities and it is integrated into the linked data cloud through the DBpedia ontology[13] and the SUMO ontology[14]. We worked with YAGO 3 (published 2015, which we extracted in 2018), which records in an *yago:influence* predicate the relations of scholars who are influenced by the ideas, thoughts or works of other scholars, as specified in datasources of YAGO such as Wikipedia and WikiData; it's accuracy has been evaluated as of 95% (Mahdisoltani et al. 2015). We extracted a (raw) dataset from YAGO3 that encompasses all influence relationships available with an SPARQL query[15] as suggested by Ghawi and Pfeffer (2019). Using the triple structure of the RDF data model (subject, predicate, object), we reinterpreted this as a (node, edge, node) relationship within a social network of influence, in which the influence relation between two scholars make up the edges and nodes in our social network of influence.

Methodological approaches. In "'On the Shoulders of Giants' – Analysis of a Social Network of Intellectual Influence"[16] (paper no. 2), we identified the most important intellectuals according to their positions in a social network of intellectual influence, and studied the underlying influence structures in the network. The directed network graphs as described in the following were created in Python with the *Python::NetworkX* library[17] (Hagberg et al. 2008). We described the network's properties of

- connectivity (identifying the amount and size of strongly and weakly connected components)[18] in order to identify the largest weakly connected component, which entails 81% of nodes and 93% of edges of the complete network, which we used for the remaining analysis.

13. https://linkeddata1.calcul.u-psud.fr/sparql (Accessed 2019-07-15).
14. http://www.mpi-inf.mpg.de/gdemelo/yagosumo/
15. For an introduction to SPARQL compare to Prud'hommeaux and Seaborne (2008) and Harris and Seaborne (2013).
16. The following descriptions draw from Ghawi et al. (2019).
17. https://networkx.org/
18. Strongly connected components are sub-graphs that consist of a maximum number of nodes, which have a direct path to another node within the sub-graph. Weakly connected components have at least one undirected path between nodes (compare to Hennig et al. 2012, pp. 114, 120).

- centrality and degree distribution (identifying the most central scholars, with the greatest betweenness[19] and closeness[20] centralities, as well as those being the most influential to others–with the highest out-degree–and most influenced by others, i.a. with the greatest in-degree. The analysis of their distribution allowed us to identify the network as a scale-free network with a power-law degree distribution (Clauset et al. 2004; Hennig et al. 2012, pp. 119–20).

- flows of influence (identifying what we conceptualized as *source* nodes[21], *inner* nodes with positive in- and out-degrees, and *sink* nodes[22], as well as evaluating the reciprocity of influences[23].

- triadic census (frequencies of the 16 possible triadic configurations as described by Holland and Leinhardt (1976) and Batagelj et al. (2014), e.g., to identify three nodes that influence each other in a 'teacher-student' cycle when u influences v, who influences w, and u also influences w).

- Furthermore, we identified the diffusion dynamics of influence by tracking the longest reaching influences in the network[24] in influence cascade trees, which size[25], (average) depth[26], and (average) breadth[27], and their correlations we studied. A cluster analysis using a k-mean clustering algorithm with k=2 (MacQueen 1967; Lloyd 1982) identified clusters of small and large cascades. The emergence of large cascades we interpreted as the result of far-reaching influences from Greek-Roman antiquity and the Medieval Ages.

Longitudinal analysis. In "A Longitudinal Analysis of a Social Network of Intellectual History"[28] (paper no. 3), we extended our previous analysis with a temporal perspective, adding a longitudinal perspective on how these intellectual influence networks were formed. We therefore extracted birth and death dates for each scholar in the dataset, and controlled for missing information, which we either deduced by subtracting 60 years from their death date and vice versa (up to the symbolic year of 2020), or manually verified them when both were missing. This also involved some cleaning of data that did

19. Measuring how often an entity lies on the shortest path between two other entities, i.a. which intellectuals serve as a bridge from one intellectual to others.
20. Measuring how close an entity is to all other entities in the network, i.a. identifying the intellectual with the shortest directed path of influence to other scholars.
21. Who are not influenced by another scholar, i.a. their in-degree is zero.
22. Who have no succeeding influence on another, i.a. whose out-degree is zero.
23. Which we found to be evident in contemporaries only.
24. For which analysis, reciprocal ties had to be resolved by arbitrarily choosing one of the reciprocal edges in order to transform the graph into a directed acyclical graph (DAG) for each *root* node with an in-degree of zero, which we referred to as *cascade*.
25. The amount of nodes present in a cascade starting from a root node.
26. The length of the largest path starting from the root node in the cascade.
27. The maximum number of (influenced) entities at any depth of a cascade.
28. The following descriptions draw from Petz et al. (2020).

not correspond to individual intellectuals, such as e.g., concepts, legendary characters, or groups.

In related work, longitudinal networks (also refereed to as: temporal, dynamic or time-varying networks) have been used to model the changes of networks in time by collecting edge-relations at various time-points, which are then analyzed using time-slices of the complete network at various time points, i.e. resulting in static networks that can be described with the established network methodology (Wasserman and Faust 1994, pp. 730–1; Hennig et al. 2012, pp. 55–6; Batagelj et al. 2014, pp. 23–5).[29] As data at varying time-points is hard to acquire, this is used most often in panel data based on interviews in social studies (as for example in the study on changes in personal networks of immigrants by Lubbers et al. 2010) in order to understand how social structures develop or change over time (Batagelj et al. 2014, p. 2; for an overview compare to Holme and Saramäki 2019).

In order to transform the static complete network, we structured the dataset into periods using a global periodization, which satisfies the demands for an inclusive, transnational and global view on the history of intellectuals in order to move beyond the "master narratives" (Gänger and Lewis 2013, p. 347) of a Western European centrist view (Subrahmanyam 2017).[30] The global periodization as proposed by Osterhammel (2006) compartmentalized the continuous time-span of history into sections, i.a. consecutive periods or eras, into which we embedded the network entities. We mapped each scholar into a singular and unambiguous era by calculating the midpoint of the scholar's lifespan (minus the first 20 years of their lives) and manually outliers resulting from different dating schemes (e.g., missing signs for BCE, or the Hijri calendar instead of the Gregorian) correcting reverse links of eras (this usually happened, when the influencing scholar lived much longer than the influenced one). The final cleaned data set consists of 22,485 influence links among 12,506 intellectuals.

The periodization allowed us to slice the whole network into six network snapshots, in which we interpreted micro-level influences among scholars as macro-level influences among periods of history. Using these network snapshots, we proceeded in a fine-grained analysis of influence networks within each period (which we dubbed *within-era*), between chronologically ordered but not necessarily consecutive pairs of periods (*inter-era*), and in consecutively accumulated periods (*accumulated-era*, which include all intellectuals up to and including a target period). This allowed us to make more fine-tuned inferences

29. Recent conceptualizations of longitudinal networks include stochastic actor-oriented models for dynamic networks, in which "composition changes are modeled as exogenous events that occur at given time points" (Huisman and Snijders 2003, p. 253; compare also to Snijders et al. 2010), Relational Event Models (REM) (Butts 2008), or Time Varying Graphs (TVG) (Casteigts et al. 2012), or new approaches such as stream graphs with temporal nodes and temporal links (Latapy et al. 2018).

30. On the conceptualizations of periodizations compare to the following part on periodization as a model.

on

- the importance of scholars (greatest influence within a period, on contemporaries, and on intellectual descendants in succeeding periods),
- the characteristics of these longitudinal sub-networks (in regard to their structural metrics, degree, number of weakly and strongly connected components, reciprocity, and transitivity as has been outlined above for the complete network–which in the context of the network snapshots represents the final accumulated-era network–, as well as e.g., on the self-containment of a period's influence or its influence on other periods),
- patterns of influence of intellectuals over periods (We described *influence patterns* of periods to establish the frequency of directed influence from a period to another. We conceptualized an individual *longitudinal influence power* of scholars as an indicator for the influence of an intellectual throughout history, which considers both the number of influence links (= influence intensity) and the consistency of influence over many periods, i.a. the temporal influence diversity), and
- the structural knowledge broker roles scholars took in these influence networks (following the concept by Gould and Fernandez 1989), in which we re-framed the concept of group membership as that of in periods, differentiating between Liaison[31], Gatekeeper[32], Representative[33], and Coordinator[34] brokerage.

This study was extended in "Diffusion Dynamics of Influence in a Social Network of Intellectuals"[35] (paper no. 4) to consider influence cascade trees and the diffusion dynamics in the networks.

Periodizations as models. We split the time-span using a periodization that takes a global perspective into account, befitting the internationality of the scholars in our dataset.

A periodization is a construct of analysis: it is used to divide time into sections that share meaningful characteristics based on important caesura points–which are usually not based on the calendarial flow of time (Osterhammel 2006, pp. 52–3). Osterhammel (2006, p. 49) called periodization part of the basic vocabulary of history; as such they

31. When a node A influences B, which in turn influences C, B has the structural position of a Liaison, if all nodes belong to different groups/periods.
32. The node B has the structural position of a Gatekeeper, if the node A does not belong to the same group/period as B and C.
33. The node B has the structural position of a Representative, if the node C does not belong to the same group/period as A and B.
34. The node B has the structural position of a Coordinator, if all nodes belong to the same group/period.
35. The following descriptions draw from Ghawi et al. (2021).

are both "inevitable" but only "ostensibly exact" ("*scheinexakt*", Osterhammel 2006, p. 48). Periodization are highly variable: each field of research argues for their own timeline-characterizing periods, which are dependent on different weighting of points of caesura and on the respective object of research (Pot 1999, p. 63; Osterhammel 2006, pp. 50–51, that are a compromise of "either highly local definitions or definitions that are so broad and vague as to be all encompassing" (Rabinowitz 2014).

We can reframe the constructive nature of periods as that of a model that structures the perception of and group processes in time based on attribution and significant points of caesura. Recently also Flanders and Jannidis (2019a, p. 3) expressed the idea that periodizations are models shaped by "choices we made in representing and analyzing the materials we study." These models of periodization are necessarily a reduction.

These events used as anchoring caesura might be the result of previous developments and not their starting point, but used out of custom, such as the end of the German *Kaiserreich* with the loss of World War I in 1918, instead of already politically in mid-1916 (Osterhammel 2006, pp. 49–50); the beginning and end of processes might also be difficult to directly pointed to a specific data (ibid., p. 48). As such, periodization are put under high scrutiny and discussion–used as a tool of focus to analyze certain phenomena.[36]

"Periodizations are always a play with many solutions, not a puzzle which can be put together 'correctly'," summarized Osterhammel (2006, p. 57) the problematic argumentative nature of periodizations.[37] In oder to establish a longitudinal perspective on a global scale that matches the internationality of intellectuals in our dataset, we operationalized the global periodization as proposed by Osterhammel (2006). He structured the process of time from a global perspective into six consecutive periods: from Antiquity (up to 600 AD), Middle Ages (600—1350), Early Modern Period (1350—1760), Transitioning Period (1760—1870), Modern Age (1870—1945), and Contemporary Period (1945—2020).

As a consequence, differences in the evolution of network structures are not necessarily related to those historical events; but might be the result of previous developments, and not their starting point.

Detecting communities. In the final paper, "Tracking the Evolution of Communities in a Social Network of Intellectual Influences"[38] (paper no. 5; forthcoming), we enriched the dataset furthermore with geographic locations of the scholars, and their disciplines, enabling a deeper dissemination of the inner workings of these periods, and identified

36. The project "Periods, Organized" (PeriodO, 2014–2018) by Adam Rabinowitz and Ryan Shaw reflects on the multiplicity and heterogeneity of periods utilized in scholarship by giving an overview on periods established by scholarship dependent on their spatial and temporal coverage (Rabinowitz 2014), compare to https://perio.do/en/.

37. Translated from German by the author. The quote reads in German: *"Periodisierung ist immer ein Spiel mit mehreren Lösungen, kein Puzzle, das 'richtig' zusammengesetzt werden kann [...]."*

38. The following descriptions draw from Petz et al. (2021).

structures of communities of scholars. We tracked the formation and evolution of intellectual communities (up to and not including the Contemporary period) to facilitate a better understanding of the emergence and evolution of schools of thoughts, and to test whether we can computationally identify trends in the history of intellectuals. The perspective on the history of intellectuals as organized in network communities can thus serve as a starting point for an analysis of the transformation and evolution of intellectual thought.

The underlying idea of community structures in networks is that the nodes within a group (community, or cluster) have a higher likelihood of being connected to (and to interact with) each other than to members of other groups (Girvan and Newman 2002; Leskovec et al. 2008; Fortunato 2010). This closeness of members within communities is based on similarity; is assumes implicitly an underlying structuring principle of homophily[39] (Dakiche et al. 2019; compare also to McPherson et al. 2001). Community detection is used to infer on the organization of networks, and to classify nodes based on the roles they take within their community. Several methods have been developed to find communities in networks (for an overview compare to Fortunato 2010).

In addition to the previously describe pre-processing (data cleaning, adding a global periodization, mapping intellectuals into periods), we further manually enriched the dataset with the geographic domain of agency for each intellectual (geo-location) and their main area of work (main discipline) in a human annotation process with preselected categories; the result in turn was then manually verified. In the process of this, we found further entities that had to be removed as they were either non-intellectual inspirations[40], or groups which members already were included in the dataset. The final cleaned dataset (of up to the Contemporary period) consists of 5,287 intellectuals with 7,803 influence relations. We described the general characteristics of the network based on the frequencies of the disciplines, regions, and periods, and the distribution of scholars of their combinations in 2-dimensional matrices (era-discipline, region-era, region-discipline), which allowed to inferences on e.g, differences in centralization of research in the Medieval Arab world and in Medieval Europe.

Then, we constructed the five accumulated influence networks over the five periods, and

- applied a community detection algorithm. As the influence network is a directed network, we used the *InfoMap community detection algorithm* as implemented in the map equation framework (Bohlin et al. 2014): neighboring nodes are joined into modules (clusters), which then are joined into super modules. We applied this InfoMap algorithm on each of the five accumulated-era networks. As the InfoMap algorithm is based on random walks, it would produce different results each time when executed–therefore, we had to chose one seed (the algorithm's

39. Conceptualized by McPherson et al. (2001) as a selection strategy within social processes based on common features.

40. Such as the sailor Owen Chase, whose biography had inspired Hermann Melville's "Moby Dick."

entry configuration) in order to provide for a consistent clustering run over all five networks. We developed the following evaluation method in order to derive to the most coherent result: We based this evaluation on the homogeneity of these communities on the attributes surveyed in preprocessing, and defined a *diversity measure*, which ranges from 1 if the group is completely heterogenous, and 0 if completely homogenous:

$$\text{diversity}(A) = \begin{cases} 0 & \text{if } L = 1 \\ \frac{N-1}{L-1} & \text{otherwise} \end{cases} \tag{5.1}$$

For each era, we evaluated the diversity of the community detection algorithm 10 times with a different randomization seed, in order to derive to homogenous communities. We combined these results with a weighted average[41]; the diversity of each clustering run was then calculated as the average diversity of the communities detected. Out of this sample of 10 randomized clustering run, we chose the initial seed of the clustering that had the lowest diversity, i.e. the most homogenous set of communities.[42]

- we described the composition and size of the resulting communities in each (accumulated) period network. An interesting phenomena in this regard, is that communities in each period were characterized by a major era and major region, and an intermediate level of diversity in disciplines, despite the weighting as described above.

- tracked the evolution of these communities over time in the consecutive eras following the approach by Greene et al. (2010). This identifies as set of *dynamic communities*, i.e. a type of "evolving complex networks" present in a network across various time steps[43], which composition change due to the behavior of its members (Dakiche et al. 2019, p. 1085; compare also to Qiu et al. 2010). The evolution of a dynamic community can be described with life-cycle events of each of their step communities at time step *t*, such as its *birth*[44], *death*[45], *merge* events[46],

41. We weighted the disciplines the highest with 45%–following the observations that scholars of specific disciplines influenced others of the same discipline the most–, regions 30% following the contention that spatial distances are not unbridgeable and that connection should weight more in a transnational perspective (Baring 2016), and eras 25%.

42. The influence of the recorded discipline in the evaluation of the homogenity/diversity of communities is obvious. A robustness analysis of the influence of the specificity of the main discipline could shed light on the changes in the diversity measure, when different or multiple disciplines were to be recorded for each intellectual (instead of focusing on only one main discipline as in this analysis).

43. A community at a certain time step is therefore referred to as *step communities*.

44. The ermergence of a step community at time step *t*, when there is no preceding corresponding dynamic community.

45. The dissolution of a dynamic community, that has no succeeding corresponding step community.

46. Two dynamic step communities match to a single step community, and share a common timeline from this time step.

as well as *split* or *continuation* events. In order to identify these life-cycles of dynamic communities, their evolution needs to be tracked in time: a heuristic threshold-based method allows to to this with many-to-many mapping approach between communities across different time steps.[47] The matching and classification process[48] continues until all communities have been processed. The matching process is dependent on a matching threshold of similarity. While usually the Jaccard index[49] is used for this matching (as e.g., proposed by Greene et al. 2010), it focuses on the overlap in two communities, instead of on how many members of a front community is present in the next step community. We opted to use instead the Quantity Insertion measure (QI) (Boujlaleb et al. 2017, p. 6132), which focuses on the amount of members of a front community present in the subsequent step community. If the similarity of front and step communities exceeded a matching threshold of $\theta \in [0, 1]$, the community pair is matched, and can be classified according to the life-cycle events as outlined above. For our analysis, we used a similarity threshold of $\theta \geq 0.5$, i.a. a match occurred if 50% or more scholars of a step community belonged to the respective front community.[50] This allowed us to structurally describe the number of step communities (that start a dynamic community), the number of distinct intellectuals across the whole dynamic community and their average number of scholars (which subtracted allows us to measure the change behavior of a dynamic community and differentiate between self-containing stable and highly changing unstable communities), and to describe the pattern of evolution of communities per era. Furthermore, we could establish the step-wise similarity of communities for scholars using the Jaccard and QI measured and based on the three dimensions of geo-categories, periods and disciplines using a cosine similarity[51]. This allowed us to structurally describe the step-wise similarity of communities analyzing the loss and gain numbers of lost and new members in the step communities, the forward and backward stability of ratio of scholars present in the succeeding and preceding step community, and their correlation, and specific sub-type of a *self-contained community* with a stable set of members

47. Many-to-many mappings refer to the mapping of relationships of the instances of entities, that can be present in source/parent instances and in target/children instances in another entity. In this context, this means that a community can consist of scholars that are present in a subsequent or preceding community of a later or earlier period; this relation is tracked by the method. A matching of communities occurs, if the similarity of both exceeds a certain threshold of $\theta \in [0, 1]$. The step community at a time-step t is considered a front, the succeeding community at time-step $t + 1$ its respective step community.

48. The identification of the relationship between step communities within a dynamic's community, as fronts and steps (iteratively progressing with each time step).

49. The Jaccard index/coefficient establishes the similarity of a sample set (i.e. communities), based on the overlap of the sample set (e.g., the overlap of two communities) divided by the size of the united sample set (e.g., the sum of those two communities combined).

50. This entails that intellectuals can 'change' their step communities in different periods.

51. This allowed us to describe each dimension in vector form: e.g., a community with 6 scholars from Europe and 4 scholars from the Americas can be represented as (0,6,0,0,4,0).

through its dynamic evolution. This helps to study the genealogy of scholars as operationalized in the evolution of dynamic communities, and to understand the variety of relation influence, as well as provides a means to computationally identify schools of thought (operationalized as homogeneity in community members), which we then can exemplify in the changes of core groups and floating members.

A master narrative. The aforementioned studies are based on a dataset extracted from YAGO. Intellectuals as recorded in YAGO entail a broad group of thinkers: from philosophers, natural scientists, artists, writers, anthropologists, to physicians, mathematicians, polymaths, and many more.[52] An intellectual (and their influence relations) appears in the dataset extracted from YAGO if there was an influence recorded from or to other scholars in the datasources that are linked within YAGO: Wikipedia, WikiData, DBpedia, WordNets, or GeoNames[53] As a result, the information on the influence relations of intellectuals in YAGO are not exhaustive.[54] The information of the included intellectuals and their main influences draw mainly from Wikipedia–the "primary source of knowledge for a huge number of people around the world" (Anderka 2013, p. 12)–, and consequently represent a crowd-sourced and semi-popular knowledge on intellectuals and their influence relations in history.

The reliability of the information on the online encyclopedia Wikipedia is ensured with a consistent "major peer review activity" (Viseur 2014, p. 3). This review process has been majorly professionalized in the last decade, including regular proof-reading and peer-reviewing, traceability of changes and version control, and the facilitated reversing of vandalized articles using the MediaWiki software[55] (Anderka 2013, p. 9). As such we consider the collection of and information on scholars to closely represent the current state of research. They encompass what can be considered the 'main' intellectuals in history. These are neither exhaustive nor unbiased: they are focused on major 'canonized' and male scholars from mainly Europe (despite featuring scholars from all over the world). This "gender gap" entails a lack of entries on female scientists and the higher probability of those to be deleted (K. Krämer 2019). Projects such as the 'WikiProject Women in Red" by Roger Bamkin[56] and the "Project Vox" at Duke University Libraries[57] addressed this by systematically including the under-represented female entries. In 2016, only 16.72% of entries in the English Wikipedia were on women (Stephenson-Goodknight 2016); this was raised to 18% in 2018 (K. Krämer 2019). These changes however are not reflected in the dataset, as YAGO3 was created already in 2015.

52. The following parts are based on Petz et al. (2021).
53. Compare to section 5.2.2 on LOD and YAGO.
54. We might note e.g., the Medieval writer Bernardus Silvestris (1085–c. 1160), who influenced "the father of English poetry" Geoffrey Chaucer (c. 1340–1400). While the former is not included in the dataset, the latter is; his main influence however is recorded as Ovid.
55. https://www.mediawiki.org/wiki/MediaWiki
56. https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Women_in_Red (Accessed 2020-09-12)
57. https://projectvox.library.duke.edu/ (Accessed 2020-09-12)

When reviewing for female philosophers of the Early Modern period as highlighted by "Project Vox," 3 out of 7 appear in this dataset.[58] Scholars from Asia, Africa, and the Americas, too, are vastly underrepresented in the English Wikipedia.

The dataset extracted from YAGO constitutes an abstract view on intellectual history recording the 'most important' influences on the 'most important' (canonized) intellectuals, which reflects closely the current state of research as added by a crowed-sourced and crowd-curated Linked Open Data community–a contemporary view on the history of intellectuals and their main influences on another similar to the broad strokes of a *"Meistererzählung"* (master narrative),[59] Any findings necessarily iterate their representation–as such the results derived represent the main figures and their main influences and entail representation biases favoring male European intellectuals (despite a general global stance of the dataset).[60]

58. These are philosopher-rethorician Mary Astell (1666–1731), philosopher-mathematician Émilie du Châtelet (1706–1749), and philosopher Anne Conway (1631–1679).

59. Jarausch and Sabrow (2002, p. 10) reflected on master narratives to encompass both diverging interpretations of historical events, and an universalist macro-perspective on a recollection of history. The term oscillates between the respect for the *opus magna* of a "*poet laureatus*," and the ironization of the love poems of the Late Medieval *Meistersinger* (master singers)–both lines of traditions point to the "constructive character of any historiography" (translated from German by CP, ibid., p. 12).

60. For a discussion of future directions to counter-act these biases please refer to section 6.3.4.

'On the Shoulders of Giants', Analysis of a Social Network of Intellectual Influence.

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In

Sixth International Conference on Social Networks Analysis, Management and Security (SNAMS) 2019, pp. 248–255. DOI: 10.1109/SNAMS.2019.8931821

Abstract

Intellectuals, scholars, philosophers, writers, and scientists, and their work are embedded in a long history of ideas. These traditions disseminated and diffused over a long history spanning from Greek-Roman antiquity to recent times. But how did those lines of traditions and influence of thoughts develop over the ages? How did intellectuals influence each other? What is the most farreaching impact of influence, as well as who are the most immediate influencing, and the most influenced by other intellectuals in history?
To answer these types of questions, we mined a network of influence among over 12 thousand intellectuals, from YAGO, a pioneering data source of Linked Open Data. We conducted several essential types of social network analysis, concerning connectivity, degree distribution, prestige (influence), and importance (centrality). We studied the diffusion dynamics of influence by analyzing the influence cascades in terms of size, depth and breadth. One interesting finding is the identification of two major, disjoint categories of small and large cascades of influence.

Contribution of thesis author

Theoretical operationalization, iterative evaluation of computational implementation and analysis, contextualization, as well as manuscript writing, revision, and editing.

'On the Shoulders of Giants', Analysis of a Social Network of Intellectual Influence

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***Abstract*—Intellectuals, scholars, philosophers, writers, and scientists, and their work are embedded in a long history of ideas. These traditions disseminated and diffused over a long history spanning from Greek-Roman antiquity to recent times. But how did those lines of traditions and influence of thoughts develop over the ages? How did intellectuals influence each other? What is the most far-reaching impact of influence, as well as who are the most immediate influencing, and the most influenced by other intellectuals in history?**

To answer these types of questions, we mined a network of influence among over 12 thousand intellectuals, from YAGO, a pioneering data source of Linked Open Data. We conducted several essential types of social network analysis, concerning connectivity, degree distribution, prestige (influence), and importance (centrality). We studied the diffusion dynamics of influence by analyzing the influence cascades in terms of size, depth and breadth. One interesting finding is the identification of two major, disjoint categories of small and large cascades of influence.

I. Introduction

"If I have seen further, it is by standing on the shoulders of Giants", wrote natural scientist Isaac Newton in 1675 to his contemporary, the polygraph Robert Hooke [19]. By these words, Newton expressed the meaning of learning through imitation and building-upon established knowledge. This concept goes back to 12th century, attributed to scholar Bernard of Chartres [25]. The history of ideas (and as such the history of intellectuals) is such a sequence of ideas based upon ideas that came before, intertwined lines of thoughts, and competing traditions of influential intellectuals.

There are changing assessments on who the most influential intellectual supposedly was, and recent discussions point to the need of a more global and representative perspective of who to actually include in a history of intellectuals [22]. Understanding the interconnections of thinkers throughout time, and the dynamics of influence and spread of ideas through history, we argue this should be answered by taking the embeddedness of scholarship into account. We tackled this using a network approach, re-framing the question of the most important intellectuals to their position in a network of a history of ideas. This allows to study their social relations and interactions [27], [11], [20], and to provide deep insights into the underlying social structure of the network. We such place over 12 thousand intellectuals from Greek-Roman antiquity to recent times in their web of influence by extracting these connections from linked open data from YAGO, as proposed first in [7]. At YAGO, influence relations appear in terms of the `yago:influences` predicate that relates a person (intellectual) to another when the latter is influenced by the ideas, thoughts, or works of the former. Studying this type of influence social network provides us deep insights in the evolution of the history of intellectuals. Which scholar influenced the most other intellectuals? Who was most inspired (or influenced) by others? And what tradition has proven to be of longest lasting influence? To understand their social structure of influence, we conduct different basic analysis including the connectivity and triadic census of the network, the degree distribution and centrality of the actors, and the reciprocity and transitivity of the influence relations. Our particular interest lies in the dissemination of diffusion dynamics of influence, as the spread of influence takes the form of *cascades* in the network. These influence cascades can be characterized using several properties, such as size, depth, and breadth. For all actors in the network, we measure and analyze these properties, and categorize the actors based on the properties of their influence cascades.

The contributions of this paper are:

- we address the intellectual influence among scholars, philosophers, writers, and scientists through history using a network approach.
- we extract a social network of influence among intellectuals from YAGO, a major linked open data source.
- we conduct essential social network analysis, to answer several research questions about the the social structure of intellectual influence.
- we study the diffusion dynamics of influence through the analysis of influence cascades in terms of size, depth, and breadth. Among our findings is the identification of two distinct categories of cascades.

The paper is organized as follows. Section II gives an overview about the used data and the analysis method. Section III presents the essential analysis of the network, such as connectivity, degree distribution, and centrality. Section IV is devoted to the analysis of the diffusion dynamics of influence. Section V concludes the paper.

II. Data and Method

A. Data

The Web is evolving from a "Web of linked documents" into a "Web of linked data". Underpinning this evolution is a set of best practices known as Linked Open Data (LOD)

[3], which provide mechanisms for publishing and connecting structured data on the Web in a machine-readable form with explicit semantics. Recently, the so called LOD cloud contains over 1200 datasets, with billions of facts from many different domains like geography, media, biology, chemistry, economy, energy, etc, and millions of links between entities from different datasets. The richness and openness of LOD make it an invaluable resource of information, and create new opportunities for many areas of application. One of the interesting data sources of LOD is YAGO (Yet Another Great Ontology) [23], [15], which is a huge semantic knowledge base, developed at the Max Planck Institute for Computer Science in Saarbrücken. YAGO was among the first projects to extract semantic knowledge at large scale from Wikipedia. Together with DBpedia [4], it is one of the pioneering contributors of the web of data. Currently, YAGO contains more than 10 million entities and more than 120 million facts about these entities. The information in YAGO is extracted from Wikipedia[1] (e.g., categories, redirects, infoboxes), WordNet [18] (e.g., synsets, hyponymy), and GeoNames[2]. The accuracy of YAGO was manually evaluated to be above 95% on a sample of facts. To integrate it to the linked data cloud, YAGO has been linked to the DBpedia ontology[3] and to the SUMO ontology[4]. YAGO has been used in the Watson artificial intelligence system [6].

We used YAGO as our data source, where we are particularly interested in `yago:influences` predicate that relates intellectuals based on their influence relationship. The confidence score of this relation is 0.9625, as calculated by YAGO. However, the way YAGO recovered this type of knowledge from Wikipedia and WordNet is a sophisticated process, that exploits Wikipedia infoboxes and categories, and involves entity disambiguation and result filtering among others. [23], [24], [15]

To extract our target influence social network, we used a SPARQL [21], [10] query as shown in Figure 1. The query has been executed over YAGO's SPARQL endpoint.[5] The result of the query is a list of 22,818 records, where each record has two elements labeled u and v, that represent two actors (intellectuals) where u influences v. These records represent the edges of our target social network of influence.

Fig. 1. SPARQL query used to extract the influence social network

```
SELECT ?u ?v
WHERE {
  ?u yago:influences ?v.
}
```

This technique to extract social networks from LOD is called *direct extraction* pattern, as described in [7]. A case study has been presented in [8], where this extraction pattern is used with `yago:influences` predicate to extract *ego-centric* networks of several intellectuals. Other extraction patterns, such as *derivation*, are also described in [7], [8].

B. Method

The list of edges obtained as results of the SPARQL query (Fig. 1) is used to create a directed graph using python NetworkX library [9]. The obtained graph consists of 12,705 nodes and 22,818 edges.

We tackle the analysis of the influence network in two major parts. The first part (Section III) concerns essential types of analysis, such as:

- **Connectivity**: is the network (weakly/strongly) connected? how many components are there? and what is the size of the largest connected component?
- **Distribution of node degrees**: how the node degrees (in-/out-) are distributed? does the distribution satisfy a power law? if yes, what are its parameters? who are the most influencing, and most influenced actors?
- **Flow of influence**: do all nodes have predecessors and/or successors?
- **Reciprocity**: are there any mutual influences (such as actors who influence each other)?
- **Centrality**: who are the most important (central) actors?
- **Triadic census**: what are the frequencies of interesting triadic configurations, such as 3-cliques and full cycles?

The second part of analysis concerns the *diffusion dynamics of influence* (Section IV). For each actor, we construct a cascade of influence as a DAG (directed acyclic graph). We study these cascades using a set of features, including: size, depth, average depth, and breadth. We then analyze the distribution of cascade features, and find the top actors based on those features. Finally, we apply a clustering algorithm to identify main categories of influence cascades.

III. Analysis

In this section we tackle essential types of analysis.

A. Connectivity

Our network consists of 12705 nodes and 22818 edges, but are all nodes connected? In directed networks, there are two semantics of connectivity: weak and strong connectivity. Two nodes are strongly connected if they are reachable from each other (there exists a directed path from each one to the other). They are weakly connected, if at least one undirected path exists between them. The maximal sub-graphs in which all pairs of nodes are strongly or weakly connected are called the strongly or weakly connected *components*. [11], [27]

Our influence network consists of 830 weakly connected components (WCC, Table I). The largest WCC has 10353 nodes and 21261 edges, which comprises about 81% of nodes, and of 93% of edges of the original network. The remaining components are small isolated groups: For instance, the second largest component is a group of contemporary South Korean

[1] https://www.wikipedia.org/
[2] http://www.geonames.org/
[3] http://www.mpi-inf.mpg.de/departments/databases-and-information-systems/research/yago-naga/yago/linking/
[4] http://www.mpi-inf.mpg.de/ gdemelo/yagosumo/
[5] https://linkeddata1.calcul.u-psud.fr/sparql, as of July 2019.

comedians; and the third largest component is a group of artists and painters from medieval China. For the rest of the analysis, we will consider only the largest connected component (LCC).

TABLE I
ESSENTIAL CHARACTERISTICS OF THE INFLUENCE NETWORK

Complete network	
Nodes	12,705
Edges	22,818
Weakly connected components	830
Nodes in largest WCC	10,353 (81.5 %)
Edges in largest WCC	21,261 (93.2 %)
Nodes in largest SCC	211 (1.7 %)
Edges in largest SCC	640 (2.8 %)
Density	0.00014
Reciprocity	0.01236
Transitivity	0.02116
Average clustering coefficient	0.03262
Diameter (longest shortest path)	26
Largest WCC	
Density	0.00020
Reciprocity	0.01251
Average shortest path length	0.32541
Average clustering coefficient	0.03858

B. Degree Distribution

Now let us look at the node degrees. Table II shows the statistics of in- and out-degree of nodes: average, minimum, maximum and standard deviation. While the in-degree and out-degree have (obviously) the same average and the same minimum value (0), they have significantly different maximum value, which is 48 for in-degree, and 158 for out-degree.

TABLE II
DEGREE

	avg.	min	max	std.
in-degree	2.05	0	48	3.17
out-degree	2.05	0	158	6.07

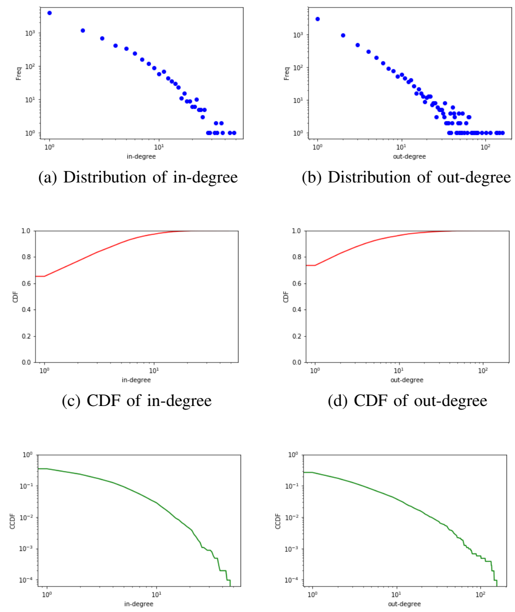
Figure 2 demonstrates the distribution (on log-log scale), CDF (Cumulative Distribution Function), CCDF (Complementary CDF) of the in-degree and out-degree of nodes. This visualization suggests that the degree distributions satisfy a power-law [5]. That is, the fraction $P(x)$ of nodes in the network with x connections to other nodes goes for large values of x (for $x \geq x_{min}$) as:

$$P(x) = Cx^{-\alpha}$$

where α is a parameter, x_{min} is the minimal value from which the scaling relationship of the power law begins, and C is a constant which is related to α and x_{min}:

$$C = (\alpha - 1)x_{min}^{\alpha-1}$$

To estimate the power law parameters of in- and out-degrees, we used the *powerlaw* python package [1]. Table III shows the estimation results, where α and x_{min} are the power law parameters, σ is the estimate error, and R and p are the results of comparing the fit to exponential distribution.[6] Hence, the influence network in hand is called *scale-free* network as it has a power-law degree distribution. [11]



(a) Distribution of in-degree
(b) Distribution of out-degree
(c) CDF of in-degree
(d) CDF of out-degree
(e) CCDF of in-degree
(f) CCDF of out-degree

Fig. 2. Distribution, CDF and CCDF of in-degree and out-degree.

TABLE III
ESTIMATED POWER LAW PARAMETERS OF DEGREE DISTRIBUTION

	α	x_{min}	σ	R	p-value
in-degree	4.457	11.0	0.200	12.95	0.0085
out-degree	2.665	10.0	0.078	50.44	0.0002

Who are most influencing, and most influenced actors?

The most influencing actors are those with the highest out-degree; they represent the prestigious intellectuals with the highest impact over others. Conversely, the most influenced actors are those with the highest in-degree; and they represent intellectuals with diverse backgrounds and inspirations from many predecessors.

Table IV shows two lists of top 10 influencing actors (with their out-degree), and top 10 influenced actors (with their in-degree). Marx, Nietzsche, Hegel, Kant, Aristotle and Plato are the most influencing actors, each has > 100 influenced actors (followers).

[6] R is the log-likelihood ratio between the two candidate distributions. This number will be positive if the data is more likely in the first distribution (power-law), and negative if the data is more likely in the second distribution (exponential). The significance value for that direction is p. [1]

TABLE IV
TOP 10 INFLUENCING ACTORS, AND TOP 10 INFLUENCED ACTORS

Top Influencing		Top Influenced	
Actor	D_{out}	Actor	D_{in}
Karl Marx	158	Friedrich Nietzsche	48
Friedrich Nietzsche	146	Christopher Hitchens	44
G.W.F. Hegel	137	Karl Marx	38
Immanuel Kant	135	Gilles Deleuze	37
Aristotle	115	Alexandru Macedonski	37
Plato	102	Michel Foucault	34
Martin Heidegger	90	Jacques Derrida	33
Ludwig Wittgenstein	80	Paul Auster	33
James Joyce	79	Martin Heidegger	32
Søren Kierkegaard	77	Benjamin Fondane	29

C. Influence Flow

We observe that there are many actors in the network who do not have predecessors, i.e., they are not influenced by others (or at least we have no information about it!); and there are many other actors who do not have successors, i.e. they do not influence others. We will call the former group as *source nodes*, and the later group as *sink nodes*. This way, we can regard this influence network as a multiple-source multiple-sink flow network (Figure 3).

Source nodes can be identified by having a zero in-degree ($D_{in} = 0$), while sink nodes are identified by having a zero out-degree ($D_{out} = 0$). The rest of nodes, called *inner nodes*, have positive in-degree and out-degree. Table V shows the number and percentage of these three group of nodes: source, inner, and sink nodes.

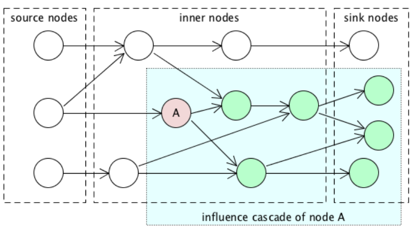


Fig. 3. Influence Network as a multi-source multi-sink flow network

TABLE V
DISTRIBUTION OF SOURCE-, INNER-, AND SINK-NODES

	source nodes	inner nodes	sink nodes
count	2,828	2,959	4,566
%	27 %	29 %	44 %
avg. in-degree	0.0	3.99	2.07
avg. out-degree	1.66	5.60	0.0

D. Reciprocity

Are there any mutual influences, such as actors who influence each other? We measure the reciprocity of the network, which is the likelihood of nodes in a directed network to be mutually linked. It is the ratio of the number of links pointing in both directions mutual to the total number of links. In our network, the reciprocity is: 0.0125, that is about 1% of influence relations are mutual.

We also extracted a list of pairs of actors having the mutual influence, it comprises of 133 pairs. Table VI shows the top 10 (ranked based on the product of actors degree).

These forms of reciprocity and mutual influence occur among contemporaries only.

TABLE VI
TOP MUTUAL INFLUENCE RELATIONS

Charles E. Lindblom	Robert A. Dahl
Eadweard Muybridge	Étienne-Jules Marey
Carles Riba	Màrius Torres
Ilona Lénárd	Kas Oosterhuis
Henry Briggs	John Napier
Jon Folkman	Lloyd Shapley
Abhijit Banerjee	Esther Duflo
Gabriël Metsu	Jan Steen
Göran Tunström	Leonard Cohen
Lloyd Shapley	Martin Shubik

E. Centrality

One of primary tasks in network analysis is the identification of structurally important actors and, more generally, the relative importance of all actors [11]. The most elementary actor-level indices of importance are *degrees* that can be considered as measures of actor activity or involvement. However, there are more elaborate ways of defining the actor importance, such as closeness centrality and betweenness centrality. Closeness centrality of a node is the inverse of the sum of distances to all other nodes. It measures how close an actor is to all other actors in the network. Actors in the center can quickly interact with all others, have short communication path to others, and reach others in a minimal number of steps.

$$c_C(u) = \frac{1}{\sum_{v \in V} d(u,v)}$$

Betweenness centrality assesses the degree to which a node lies on the shortest path between two other nodes. It is a way of detecting the amount of influence a node has over the flow of information in a network, and is often used to find nodes that serve as a bridge from one part of a network to another. Betweenness centrality of a node u is the fraction of shortest paths between any two nodes s and t via u to all shortest paths between s and t:

$$c_B(u) = \sum_{s \neq u \neq t \in V} \frac{\sigma(s,t \mid u)}{\sigma(s,t)}$$

where $\sigma(s,t)$ is the total number of shortest paths from node s to node t and $\sigma(s,t \mid u)$ is the number of those paths that pass through u.

For our influence social network, we calculated closeness and betweenness centralities of all nodes, and ranked the nodes based on centrality value in descending order. Table VII shows two lists of the top 10 central actors, based on betweenness in the first list, and on closeness in the second. Apparently, intellectuals with highest centrality such as Nietzsche, Dostoyevsky, and Sartre are those who bridge different cultures and periods of time as they lay on large amount of pathways of influence.

TABLE VII
TOP 10 CENTRAL ACTORS

Betweenness	Closeness
Jack Kerouac	Christopher Hitchens
William S. Burroughs	Gary Forrester
Friedrich Nietzsche	David Mitchell
Fyodor Dostoyevsky	Chuck Palahniuk
Jean-Paul Sartre	Homi K. Bhabha
Walt Whitman	Richard Rorty
William Carlos Williams	Noah Cicero
Alexander Pushkin	Paul Auster
John Keats	Giannina Braschi
Tristan Tzara	Salman Rushdie

F. Triadic Census

Another way to analyze network characteristics is to count configurations. An example is the *triadic census* of a directed graph, in which the frequency of all 16 possible configurations of the three dyads formed by three nodes as shown in Figure 4 are determined. [12], [2].

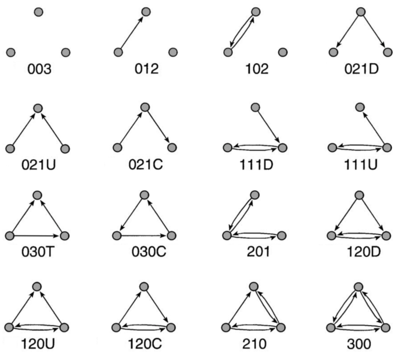


Fig. 4. Triad types in directed networks. The conventional numbering scheme is based on the number of **m**utual, **a**symmetric, and **n**ull dyads (MAN), with trailing characters: U: up, D: down, T: transitive, and C: cyclic.

Table VIII shows the triad census of our influence network. In particular, we are interested in some of the 16 motifs:

- **`300`**: which is a 3-clique; i.e., three nodes are fully connected to each other. There are 4 cases of this motif in the network.
- **`030C`**: which is a cycle of three connections in one direction; i.e. an actor u influences v, who in turn influences w, and w influences u back. There are 6 occurrences of this motif in our network.
- **`030T`**: which is a pure transitivity relation where an actor u influences v, who in turn influences w, and u influences w. There are 7,651 occurrences of this motif.
- **`201`**: two nodes u and v are fully connected to a third node w while they are not connected themselves to each other; i.e. both u and v influence and influenced by w, but they do not influence each other. This motif occurs 75 times in our network.
- **`120D`**: two nodes u and v influence each other, and they are both influenced by a third node w (occurs 203 times).
- **`120U`**: two nodes u and v influence each other, and they both influence a third node w (occurs 198 times).

TABLE VIII
TRIAD CENSUS OF THE INFLUENCE NETWORK

Triad	Count
003	184,675,147,475
012	216,554,712
102	1,370,448
021D	189,609
021U	53,029
021C	124,905
111D	1,774
111U	3,863
030T	**7,651**
030C	**6**
201	**75**
120D	**203**
120U	**198**
120C	13
210	11
300	**4**

IV. DIFFUSION DYNAMICS OF INFLUENCE

In this section, we observe the diffusion of influence throughout the network.

We refer to the influence path formed as actors influenced by an original actor, influence other actors, as a cascade and the original actor as the root actor.

For each actor, we construct his influence cascade, by considering out-going edges starting from that actor, as shown in Figure 5. We seek to avoid exhaustive search by converting the network into a directed acyclic graph (DAG), thereby, reducing the time complexity. Hence, we need to avoid cyclicity, therefore, in case of reciprocal edges between a pair of nodes, we arbitrarily choose one of the reciprocal edges. Thus, the result we obtain is a directed acyclic graph (DAG), which we call henceforth a *cascade*.

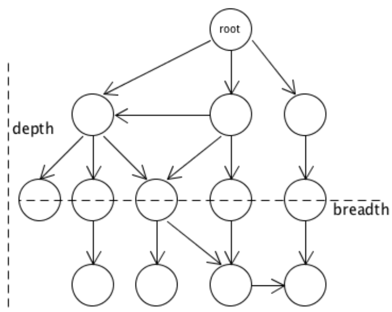


Fig. 5. Cascade properties

A. Characteristic cascade parameters

In order to characterize the influence cascades, we employ the following features as used in [26], [16].

- **Size** represents the number of nodes in the DAG which are reachable from the root actor. It corresponds to the total number of unique actors involved in the cascade.
- **Depth** is the length of the largest path from the root node of the cascade. The depth of a cascade, D, with n nodes is defined as

$$D = \max(d_i), 0 \leq i \leq n$$

- **Average depth** is the average path length of all nodes reachable from the root actor. For a cascade with n nodes, we define its average depth (AD) as

$$AD = \frac{1}{n-1}\sum_{i=1}^{n} d_i$$

  where d_i is the depth of the node i.
- **Breadth** is the maximum number of nodes present at any particular depth in the DAG.

$$B = \max(b_i), 0 \leq i \leq d$$

  where b_i denotes the breadth of the cascade at depth i and d denotes the maximum depth of the cascade.

B. Analysis of influence cascades

For all nodes in the influence network in hand, we extracted their cascade DAGs, and computed the properties of cascades: size, depth, average depth and breadth. First, we observed that some nodes do not have cascades. That is because they do no have successors; hence those nodes are exactly the group of sink nodes as discussed before, which comprises about 44% of all nodes. Therefore, the cascades we obtained are 5,787 nodes and correspond to source- and inner- nodes.

Figure 7 shows a histogram of cascade properties. We observe that there exist two disjoint categories of cascades based on the size and breadth, the first category is characterized by small size ($\leq$ 1000) and small breadth ($\leq$ 300), while the second category by a large size ($\geq$ 4000) and large breadth ($\geq$ 400).

In Table IX we show the top 10 actors based on the characteristics of their influence cascades. We observe that top cascades by size and by breadth correspond to intellectuals from Greek-Roman antiquity, such as Socrates, Pythagoras, and Euclid. Whereas, top cascades by depth mostly correspond to intellectuals from the medieval Islamic golden age, such as Abū Ḥanīfa and Malik ibn Anas. Both are 8th-century Sunni Muslim theologians, who are the eponymous founders of two of the four schools of Sunni jurisprudence [17].

Figure 7 shows CDF (Cumulative Distribution Function) and CCDF (Complementary CDF) of the cascade characteristics: size, depth and breadth.

Table X shows the correlation among pairs of cascade properties. The values demonstrate that those properties are in general highly correlated. The most correlated features are: (depth, avg. depth) followed by (size, breadth).

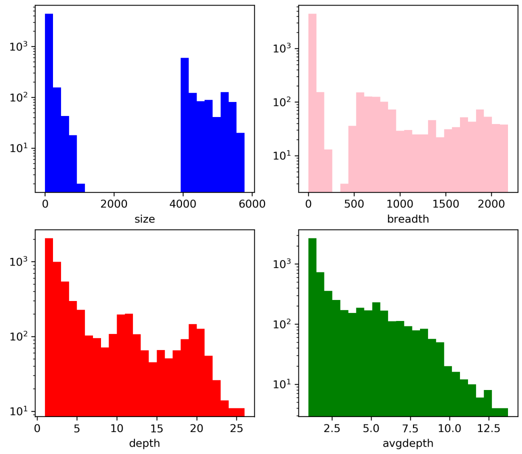


Fig. 6. Distribution of cascade characteristics

TABLE IX
TOP 10 ACTORS BY CASCADE PROPERTIES

top cascades by Size	
Thales	5783
Anaximander	5779
Hesiod	5778
Pherecydes of Syros	5777
Pythagoras	5776
Heraclitus	5766
Xenophanes	5764
Parmenides	5763
Aesop	5759
Socrates	5746

top cascades by Breadth	
Aesop	2179
Crates of Thebes	2171
Hipparchia of Maroneia	2171
Zeno of Citium	2171
Diodorus Cronus	2171
Stilpo	2171
Euclid of Megara	2171
Thrasymachus of Corinth	2171
Pasicles of Thebes	2171
Philo the Dialectician	2171

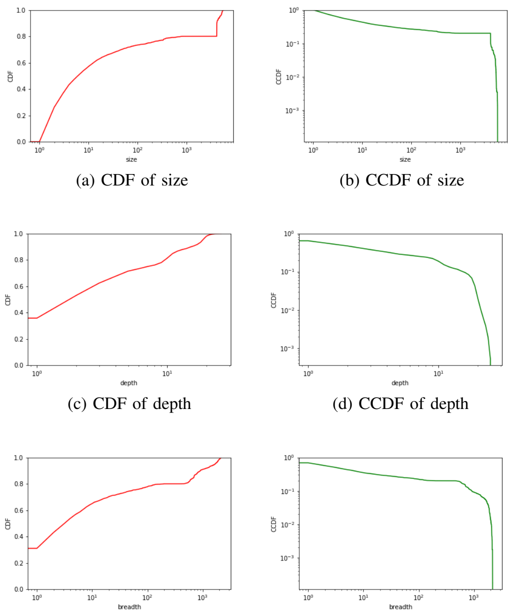
top cascades by Depth	
Abū Ḥanīfa	26
Abu Suhail an-Nafi	26
Hisham ibn Urwah	26
Malik ibn Anas	25
Muhammad al-Shaybani	25
Ibrahim Y. al-Juzajani	25
Ishaq Ibn Rahwayh	25
Ali ibn al-Madini	25
Friedrich Karl Forberg	25
Ibn Jurayj	25

top cascades by Avg. Depth	
Friedrich Karl Forberg	13.72
Abu Suhail an-Nafi	13.29
Hisham ibn Urwah	13.29
Abū Ḥanīfa	13.24
Alfred Binet	12.8
James Mark Baldwin	12.8
Hans Vaihinger	12.72
Jacob L. Moreno	12.71
Conrad Hal Waddington	12.55
Ibrahim Y. al-Juzajani	12.35

TABLE X
CORRELATION OF CASCADE PROPERTIES

Size	Depth	0.856
Size	Avg. Depth	0.81
Size	Breadth	0.929
Depth	Avg. Depth	0.975
Depth	Breadth	0.661
Avg. Depth	Breadth	0.627

Figure 8 plots the correlation among cascade properties. We can clearly identify the existence of the two categories of cascades mentioned before: small cascades (blue) and large



(a) CDF of size (b) CCDF of size

(c) CDF of depth (d) CCDF of depth

(e) CDF of breadth (f) CCDF of breadth

Fig. 7. CDF and CCDF of cascade properties: size, depth and breadth

cascades (green). The distinction between the two categories is obvious in terms of size and breadth, but it is less clear in terms of depth and avg. depth.

C. Clustering the influence cascades

In order to distinguish more precisely these two categories, we apply a K-mean clustering algorithm [14], [13]. As features, we used the four characteristics of cascades, size, breadth, depth, and avg. depth. As a number of clusters, we used $k = 2$. [7] As a result, we obtained two clusters of cascades, as depicted in Table XI.

The cluster of so-called small cascades (SC) contains 4629 cascades; the size of cascades in this cluster ranges from 2 to 952 with an average of 35. Whereas the cluster of so-called large cascades (LC) contains 1158 cascades; the size of cascades in this cluster ranges from 4134 to 5783 with an average of 4481. The depth in the SC cluster ranges from 1 to 14 with average 2.6, while the depth in the LC cluster ranges from 8 to 26 with average 15.6. Similarly, the avg. depth in the SC cluster is between 1 and 8.6 with average 1.8, while in the LC cluster it is between 3.4 and 13.7 with an average of 6.7. Finally, the breadth in the SC cluster ranges between 1 and 203 with an average of 11.4, while in LC cluster it ranges from 419 and 2179 with an average of 1138.6. Figure 9 depicts the average values of cascade features for both SC and LC clusters.

[7] We used `sklearn.cluster.KMeans` python module.

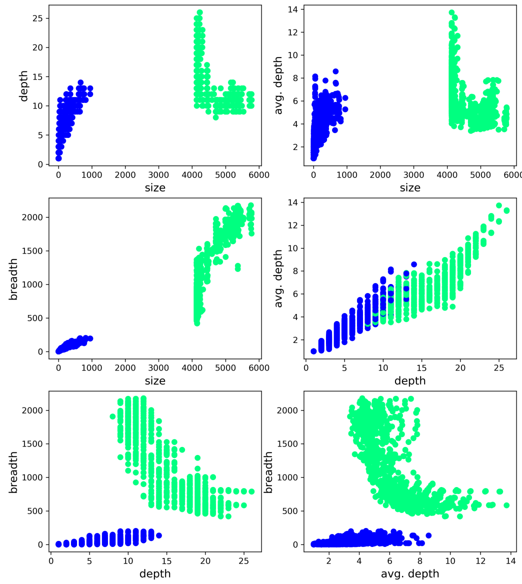


Fig. 8. Correlation among cascade properties

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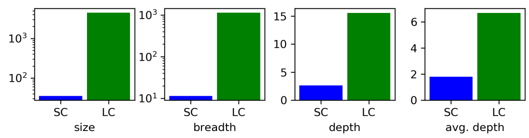

Fig. 9. Cascade features (average) for SC and LC clusters

TABLE XI
FEATURES OF THE TWO CLUSTERS OF CASCADES

	size	depth	avg. depth	breadth
	Small Cascades (4629 nodes)			
avg	35.044	2.636	1.798	11.415
std	99.284	2.382	1.159	25.881
min	2	1	1	1
max	952	14	8.579	203
	Large Cascades (1158 nodes)			
avg	4481.335	15.585	6.706	1138.614
std	477.712	4.177	1.909	532.533
min	4134	8	3.392	419
max	5783	26	13.719	2179

We interpret the emergence of clusters of large cascades to the temporal dimension. Most of the intellectuals in this cluster belong to Greek-Roman antiquity and medieval ages. This far-reaching time span has a major impact on developing such large influence cascades.

V. CONCLUSIONS

In this paper, we extracted a social network of influences among intellectuals from YAGO, which is one of the pioneering contributors of the web of data containing millions of facts extracted from Wikipedia, WordNet and GeoNames. The network extraction was performed using a SPARQL query, which results make up the edges of the network. First, we conducted several essential types of analysis. Concerning the connectivity, we could show that 81 per cent of nodes were connected in the biggest component, with an average shortest path length of 0.325 and almost no reciprocity except for contemporaries. Different definitions of centrality provided a detailed insight into the most influential and influenced actors in the network. We found that Karl Marx and Friedrich Nietzsche were the two most influential and among the Top 3 influenced intellectuals in the biggest component, suggesting that the revolutionary of their ideas would appeal to many contemporaries and thinkers after them. Whereas in terms of the amount of pathways, writer Jack Kerouac, and again Nietzsche came up in the Top 3. In terms of being located closely to all other nodes, author Christopher Hitchens was first. Then, we focused on analyzing the diffusion of influence throughout the network, noticing source nodes with an in-degree of zero making up 27 per cent of the network, and sink nodes with an out-degree of zero 44 per cent of the network. A clustering algorithm identified small (SC) and large (LG) cascades. The construction of these influence cascades revealed that Greek and Roman scholars of antiquity influenced the highest numbers of intellectuals, whereas intellectuals from medieval Islamic golden age, such as Abū Ḥanīfa and Malik ibn Anas, have established the longest influence cascades lasting until recent times.

This study of the social network of influence has revealed deeper insights to interconnections of thinkers throughout time, and the dynamics of influence and spread of ideas through history. Therefore, a more elaborate analysis that takes the temporal aspect of the influence social network is crucial. In future work, we plan to extract a longitudinal version of the influence network, that can be used to analyze the evolution of influence over time more precisely. In addition, we plan to exploit advanced tools such as community detection to identify groups of actors that are highly connected and influence each other more than others. This type of analysis could lead us to a better understanding of the emergence and evolution of schools of thoughts in philosophy, such as idealism, materialism, and existentialism, or in politics, as communism, socialism, and liberalism.

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A Longitudinal Analysis of a Social Network of Intellectual Influence

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In

IEEE/ACM International Conference on Advances in Social Network Analysis and Mining (ASONAM) 2020, pp. 340–347. DOI: 10.1109/ASONAM49781.2020.9381318.

Abstract

The history of intellectuals consists of a complex web of influences and interconnections of philosophers, scientists, writers, their work, and ideas. How did these influences evolve over time? Who were the most influential scholars in a period? To answer these questions, we mined a network of influence of over 12,500 intellectuals, extracted from the Linked Open Data provider YAGO. We enriched this network with a longitudinal perspective and analyzed time-sliced projections of the complete network differentiating between within-era, inter- era, and accumulated-era networks. We thus identified various patterns of intellectuals and eras and studied their development in time. We show which scholars were most influential in different eras, and who took prominent knowledge broker roles. One essential finding is that the highest impact of an era's scholar was on their contemporaries, and that the inter-era influence of each period was strongest on the consecutive era. Furthermore, we see quantitative evidence that there was no rediscovery of Antiquity during the Renaissance; rather, there has been a continuous reception of it since the Middle Ages.

Contribution of thesis author

Theoretical operationalization, iterative evaluation of computational implementation and analysis, qualitative evaluation and contextualization, as well as manuscript writing, revision, and editing.

A Longitudinal Analysis of a Social Network of Intellectual History

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***Abstract*—The history of intellectuals consists of a complex web of influences and interconnections of philosophers, scientists, writers, their work, and ideas. How did these influences evolve over time? Who were the most influential scholars in a period? To answer these questions, we mined a network of influence of over 12,500 intellectuals, extracted from the Linked Open Data provider YAGO. We enriched this network with a longitudinal perspective and analyzed time-sliced projections of the complete network differentiating between within-era, inter-era, and accumulated-era networks. We thus identified various patterns of intellectuals and eras and studied their development in time. We show which scholars were most influential in different eras, and who took prominent knowledge broker roles. One essential finding is that the highest impact of an era's scholar was on their contemporaries, and that the inter-era influence of each period was strongest on the consecutive era. Furthermore, we see quantitative evidence that there was no rediscovery of Antiquity during the Renaissance; rather, there has been a continuous reception of it since the Middle Ages.**

I. INTRODUCTION

“No self is of itself alone,” wrote Erwin Schrödinger in 1918 [15] and noted, “It has a long chain of intellectual ancestors.” The history of intellectuals is comprised of a myriad of such long chains, embedded in a tapestry of competing influences of “ageless” ideas, which —in the words of the French scholar Bonaventura D’Argonne in 1699—“embrace [...] the whole world” [9].

To understand the dynamics of influence and spread of ideas through history, the embeddness and interconnections of scholarship should be taken into account. A network approach offers to identify the most influential scholars via their positions in a network of intellectual influence through the history. This allows the study of their social relations [25], [11], [19], and to provide deep insights into the underlying social structure.

A recent study by Ghawi et al. [5] addressed the analysis of such a social network of intellectual influence, incorporating over 12,500 scholars from international origins since the beginning of historiography. In this paper, we build upon [5], and extend the analysis of that network by incorporating a temporal dimension. We analyze the network of scholars dependent to their time, adding a longitudinal perspective on how scholars formed networks. By doing so, we opt for an inclusive, global perspective on the history of intellectuals. This perspective of a vast longitudinal global network of intellectuals is a response to recent discussions on not-global-enough research within intellectual history [10]. We thus attempt to go beyond the traditional “master narratives” [4] of a Western European centrist view on intellectual history [23]. The goal of this paper is not only to understand how the influence relations among scholars evolved over time, but also to get deep insights on their influence on historical periods.

- How did these influence networks evolve over time?
- Who were the most influential scholars in a period?
- And which patterns of influence did emerge?

To answer these, we analyze the evolution of influences in time in order to identify periods and scholars, who stand out.

Our contributions are as follows:

- We incorporate a longitudinal perspective on the social network analysis of intellectuals based on a global periodization of history.
- We identify patterns of influence and their distribution in within-, inter-, and accumulated-era influence networks.
- We identify influence signatures of scholars and eras.
- We identify scholars with various knowledge broker roles.

This paper is organized as follows. Section II reviews related works. In Section III, we briefly outline the dataset's characteristics and pre-processing. Section IV presents the network analysis of the entire network, and its time-sliced projections into partial influence networks (within-era, inter-era, and accumulated-era), featuring their basic network metrics, degree distribution, and connectivity. In Section V, we identify different influence patterns of scholars and eras. Section VI is devoted to the longitudinal analysis of brokerage roles in scholars.

II. RELATED WORK

The term of intellectual history combines a plethora of approaches on discourse analysis, evolution of ideas, intellectual genealogies, and the history of books, various scientific disciplines, political thought, and intellectual social context [26], [7]. These studies are usually limited to specific regions or time spans as a trade-off for thorough comparative and textual analysis. Endeavors to write a “Global Intellectual History” [16] were criticized for focusing on the more well-known intellectual thinkers despite including a transnational comparative perspective [22].

Network methodologies allow analyzing intellectual history and as such the history of intellectuals as big data, encompassing time and space with a focus on their inter-connections. So far, computational methods have been used in the study of communication networks of the *respublica litteraria*, in which various studies modeled the Early Modern scholarly book and letter exchanges as networks. Among the first was “Mapping the Republic of Letters” at Stanford University in 2008 [1]. More recent studies have incorporated a temporal perspective on these epistolary networks [24].

A recent study [5] proposed to research the entire history of intellectuals with the means of a network approach. This paper defined the most influential as those with the longest reaching influence (influence cascades), and identified as such Antique and Medieval Islam scholars, and Karl Marx as the one with the most out-going influences. In this paper, we extend this analysis by incorporating a temporal dimension in order to establish a deeper insight on how these influences evolved in time.

Much research has been devoted to the area of longitudinal social networks [17], [13], [21], [12]. Longitudinal network studies aim at understanding how social structures develop or change over time, usually by employing panel data [11]. Snapshots of the social network at different points in time are analyzed in order to explain the changes in the social structure between two (or more) points in time in terms of the characteristics of the scholars, their positions in the network, or their former interactions.

III. DATA

A. Data Acquisition and Preprocessing

The source of information used in this paper originated from YAGO (Yet Another Great Ontology) [14], a pioneering semantic knowledge base that links open data on people, cities, countries, and organizations from Wikipedia, WordNet, and GeoNames. At YAGO, an influence relation appears in terms of the `influences` predicate that relates a scholar to another when the latter is influenced by the ideas, thoughts, or works of the former. The accuracy of this relation was evaluated by YAGO at 95%. We extracted a dataset that encompasses all influence relationships available in YAGO, using appropriate SPARQL queries that implement mining techniques of social networks from Linked Open Data [6]. The result consisted of 22,818 directed links among 12,705 intellectuals that made up the nodes and edges of our target social network of influence. In order to incorporate a time dimension to our analysis, we extracted birth and death dates of each scholar. Some scholars had missing birth and/or death dates, which we deduced by subtracting 60 years from the death date, and vice versa, up to the symbolic year of 2020. When both dates were missing, we manually verified them. During this process we had to remove some entities, as they did not correspond to intellectuals. These were either 1) concepts, e.g., 'German_philosophy' and 'Megarian_school', 2) legendary characters, e.g., 'Gilgamesh' and 'Scheherazade', or 3) bands e.g., 'Rancid' and 'Tube.' To this end, we obtained a new dataset of 12,577 scholars with complete birth and death dates.

B. Periodization

In this paper, we do not use the classical concept of network snapshot, which is a static network depicted at a given point in time. Rather, we split the time span (i.e., the history) manually into consecutive periods (eras), and embed the network nodes (actors) into the eras in which they lived. This way, the micro-level influence among scholars can be viewed as a macro-level influence among periods of history. This enables the analysis of the influence network within each era (= within-era), between different eras (= inter-era), and in an accumulative manner (= accumulated-era). By introducing a longitudinal perspective, we split the time-span using a periodization that takes global events into account. Any periodization is a construct of analysis, as each field of research has its own timeline characterizing periods [20] which are dependent on different caesura for the respective object of research [18]. This complicates an overarching longitudinal perspective on a global scale. In order to match the internationality of scholars, we used Osterhammel's global periodization [18] and worked with six consecutive periods (eras): Antiquity (up to 600 AD), Middle Ages (600—1350), Early Modern Period (1350—1760), Transitioning Period (1760—1870), Modern Age (1870—1945), and Contemporary Period (1945—2020).

One conceptual challenge was to map scholars into eras. Many scholars fit to more than one period's timeline. We opted for a single era membership approach since it is more intuitive and easier to conceptualize. A single era membership of each scholar reduces the complexity of analysis and computations, while encompassing the essential membership of each scholar to a single era. It also offers adequate results when we compare eras, since it avoids redundancy. This approach does not change the influences of the scholar to scholars of other periods.

In order to assign a single era to a scholar, we used the following method: We calculated the midpoint of the scholar's lifespan ignoring the first 20 years of their age, as we assumed that scholars in general would not be active then. Then we assigned the era in which this midpoint occurs as the scholar's membership to an era. After this initial assignment process, we verified the global validity of assignments by counting the number of influence links from one era to another. We observed that there were some reverse links of eras, i.e., an influence relation from an actor in a recent era towards an actor assigned to an older era. Those anomaly cases (about 200) were basically due to:

- Errors in dates:
  - some dates were stated in the Hijri calendar, instead of the Gregorian calendar, and
  - some dates were BC and missing the negative sign.
- Errors in direction of the relationship: source and target actors were wrongly switched.
- Inappropriate era-actor assignments.

The anomalies due to errors have been manually corrected. The cases of inappropriate assignment were technically not erroneous. This usually happened when the influencer lived much longer than the influenced, elevating the influencer's period into a more recent one. We solved this by iteratively reassigning either the influencer backward to the era of the influenced, or the influenced forward to the era of the influencer. As a result, each scholar is assigned to exactly one era, such that no reverse links of eras exist. The final cleaned dataset consists of 22,485 influence links among 12,506 intellectuals.

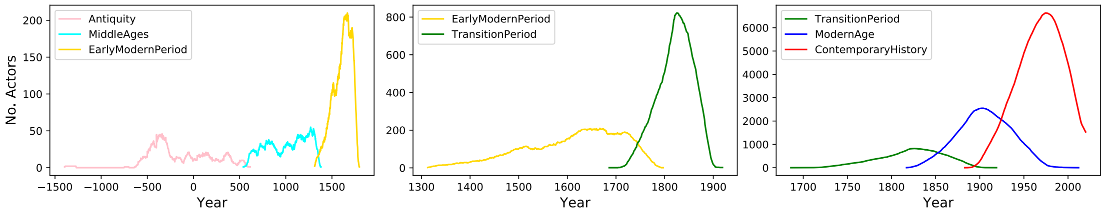

Fig. 1. Number of scholars alive in each year based on their assigned eras.

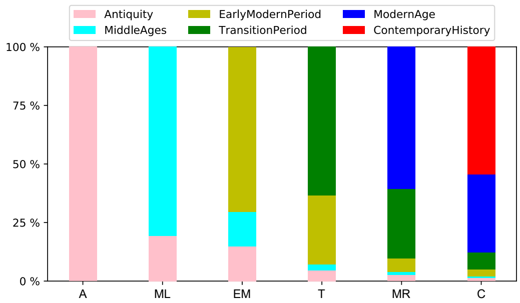

Fig. 2. Percentage of received influences in each era.

IV. ANALYSIS

Fig. 1 shows each era's continuous density of scholars based on their lifespan.

With scholars embedded in their respective eras, the entire influence network can be time-sliced: we projected it into several partial networks based on the source era (of the influencer) and target era (of the influenced scholar). When the source and target eras are the same, we call the partial network a *within-era* influence network. When the source and target eras are different, we call the partial network an *inter-era* influence network. There are no reverse links from a later era to a previous one due to pre-processing.

After time-slicing the whole network, we received six within-era networks corresponding to all the six eras, and 15 inter-era networks, corresponding to all chronologically ordered (but not necessarily consecutive) pairs of different eras. Moreover, we constructed six *accumulated-era* influence networks of scholars living up to and including a target era.

Fig. 2 shows the proportion of influence links among all pairs of eras. There, we can already make two major observations for inter- and within-era influence relations: For one, the highest fraction of influence received by scholars of each era comes from its own era. This means that the internal impact of any era is in general higher than its external impact. In absolute numbers, the vast majority of links occur within the Contemporary era, followed by links from the Modern Age to the Contemporary period, and within the Modern Age, which is clearly owed to the increased amount of scholars in these periods.

The inter-era influences of each period is strongest on its consecutive period. As our earliest period, Antiquity receives only influence links from itself, whereas the influence received in the Middle Ages are 82% internal, and 18% from Antiquity. Subsequently, the amount of the within-era influence shrinks throughout the consecutive periods, but still remains the biggest influence. Noteworthy here is the high proportion of influences of Antiquity on the Early Modern period, which represents their increased reception during the Renaissance. However, the proportionately many links of Antiquity to the Middle Ages reassert the shift in historical research that the Renaissance did not “rediscover” Antiquity, but was received before in the Middle Ages as well [3, p. 3—4].

A. Within-Eras Influence Networks

In the following, we analyzed the six *within-era* influence networks, which represent the internal impact of an era. We extracted the following metrics, as shown in Table I:

- Number of nodes N, and edges E, and density D.
- Average out-degree (= avg. in-degree due to the properties of a directed graph).
- Max. in-degree, max. out-degree, and max. degree.
- WCC: number of weakly connected components.
- LWCC: size of the largest weakly connected component.
- SCC: number of strongly connected components, when the number of nodes is > 1).
- Reciprocity and transitivity.

TABLE I
METRICS OF WITHIN-ERA NETWORKS

Era	A	ML	EM	T	MR	C
N	219	303	610	761	2102	6081
N/A	82%	86%	81%	70%	73%	85%
E	327	387	694	927	2806	7960
Density	.0068	.0042	.0019	.0016	.0006	.0002
avg. out-degree	1.49	1.28	1.14	1.22	1.33	1.31
max in-degree	12	9	17	27	21	26
max out-degree	20	16	23	32	68	58
max degree	32	20	32	41	73	58
WCC	11	21	94	108	208	582
Largest WCC	179	233	245	436	1495	4379
	82%	77%	40%	57%	71%	72%
SCC	0	2	6	8	31	38
Reciprocity	0	0.005	0.023	0.028	0.036	0.014
Transitivity	0.064	0.066	0.071	0.042	0.029	0.017

We included $\frac{N}{A}$ in Table I in order to contain that the number of nodes N in a within-era network could be less than the number of actors of that of era A. This is owing to the fact that not all scholars of an era necessarily participated in its within-era influence network. Some scholars influenced or were influenced by actors of different eras only. However, around 80% of scholars in each era were active in these within-era networks. The highest value of 86% of the Middle Ages refers to their relative self-containment as an era, as well as the lowest value in the Transitioning period of 70% refers to its high out-going influences.

Over all eras, the amount of nodes and edges steadily increased, while the density of networks decreased. On average, the out-degree revolves around 1.25, where the highest value of 1.5 occurs in Antiquity, and the lowest of 1.14 in the Early Modern period. When we compare the evolution of the max. out-degree in time, we find that the expected continuous increase did not always hold due to two exceptionally high observations at Antiquity and the Modern Age. Mutual ties among contemporaries were in general very low. We can report none in Antiquity, and only one in the Middle Ages between Avicenna and Al-Bīrūnī. In the Early Modern period, eight mutual relations were observed, including, e.g., Gottfried Leibniz (1646—1716) and David Bernoulli (1700—1782), whereas 13 mutual relations in the Transitioning period, such as Friedrich Engels (1820—1895) and Karl Marx (1818—1883), or Johann Goethe (1749—1832) and Friedrich Schelling (1775—1854). In the Modern Age, the number of mutual ties increased to 51 (e.g., Jean—Paul Sartre (1905—1980) and Simone de Beauvoir (1908—1986)); and to 54 in the Contemporary period.

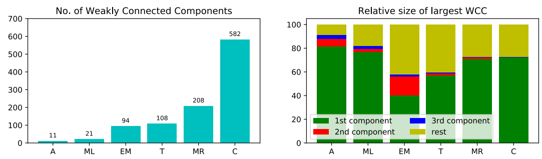

Fig. 3. Weakly connected components in within-era influence networks

Fig. 3 shows the number of weakly connected components (WCCs) in the within-era networks of each era, and the relative size of the largest ones w.r.t the whole corresponding network. The number of WCCs increased gradually over the consecutive eras. In general, the networks consisted of one giant component, which encompassed the majority of nodes, while the rest of components were relatively smaller. This was particularly developed in Antiquity and the Middle Ages, where the giant components constitute of 82% and 77% of the nodes, while the second largest were at 6% and 3%, respectively. The Early Modern period constitutes an exception to this giant component rule: the largest one was only at 40%, and the second largest at 16%. Looking at their composition, the first consisted of natural scientists, mathematicians, and philosophers, such as Descartes, Newton, and Leibniz, while

TABLE II
TOP 5 ACTORS, PER ERA, BASED ON OUT-DEGREE IN WITHIN-ERA INFLUENCE NETWORKS.

Antiquity		MiddleAges		EarlyModern	
Plato	20	Avicenna	16	John Locke	23
Aesop	13	Muhammad	11	René Descartes	22
Pythagoras	10	Al-Ghazali	11	Isaac Newton	15
Plotinus	10	Banū Mūsā	8	Hugo Grotius	13
Euhemerus	10	J. S. Eriugena	8	Leibniz	11
Transition		**Modern**		**Contemporary**	
Goethe	32	Nietzsche	68	Vladimir Nabokov	58
Hegel	29	Jules Verne	35	Friedrich Hayek	50
Lord Byron	24	Henri Bergson	35	Richard Pryor	50
Immanuel Kant	22	Leo Tolstoy	24	Jacques Derrida	48
von Schelling	17	Edmund Husserl	22	Michel Foucault	47

the smaller one was compromise of artists and painters, such as Rembrandt and Raphael. The single giant component phenomenon appeared again in subsequent eras. For instance, in the Transitioning period, there were 108 WCCs, where the largest two incorporated 57% and 1.3% of the nodes. In the Modern and Contemporary Age, the largest components comprised about 70% of nodes.

Who was most influential on their contemporaries? Table II lists the top five scholars per era based on their out-degree in the within-era influence networks. The highest within-era out-degree over all times was achieved by Friedrich Nietzsche (1844—1900) of the Modern Age with 68 outgoing influence links to other scholars of his era.

B. *Inter-Era Influence Networks*

Inter-era influence networks are partial networks where the source era precedes the target era. We interpreted these networks as bipartite, as the actors belong to different groups; the source era and the target era. Therefore, only edges between nodes sets are possible.

TABLE III
METRICS OF INTER-ERAS INFLUENCE NETWORKS

source → target	N	E	N_s	N_t	D	in-degree		out degree	
						avg	max	avg	max
A → MA	82	87	38	44	.052	1.98	7	2.29	12
A → EM	117	145	46	71	.044	2.04	7	3.15	19
A → T	66	66	29	37	.062	1.78	5	2.28	11
A → MA	101	114	42	59	.046	1.93	11	2.71	23
A → C	169	177	49	120	.030	1.47	6	3.61	46
ML → EM	149	144	66	83	.026	1.73	9	2.18	21
ML → T	52	36	22	30	.055	1.20	5	1.64	6
ML → MR	77	62	27	50	.046	1.24	4	2.30	12
ML → C	146	121	50	96	.025	1.26	6	2.42	34
EM → T	392	432	159	233	.012	1.85	16	2.72	24
EM → MR	262	269	101	161	.016	1.67	13	2.66	15
EM → C	437	432	125	312	.011	1.38	7	3.46	35
T → MR	1,111	1,373	436	675	.005	2.03	19	3.15	53
T → C	888	1,041	212	676	.007	1.54	9	4.91	112
MR → C	3,817	4,885	1,271	2,546	.002	1.92	17	3.84	78

Table III shows the metrics for those inter-era influence networks. In general, each era had the most links with its consecutive era, and additionally with the Contemporary period's scholars. Exception to this was Antiquity, which saw its first peak with the Early Modern period relating to Renaissance interests. Their densities were again decreasing through the combinations, except for those periods that had less links to other periods, such as the Middle Ages to the Transitioning period.

Which scholar influenced a successive era the most? Table IV shows the scholars with the highest degrees in the inter-era networks. Noteworthy here is Karl Marx, who had the highest out-degree over all times from the Transitioning period to the Contemporary age, followed by modern philosopher Friedrich Nietzsche and Martin Heidegger on Contemporary scholars.

C. Accumulative Influence Networks

For each era, we constructed an accumulative influence network of all influence links among scholars who lived up to and including that era. We performed essential social network analysis on these six *accumulated-eras* networks, which combine the internal and external impact of eras. The final network of the Contemporary Age is the same as the complete network over all periods [5].

Fig. 4 shows the best connected scholars for each era —those that influenced at least 10 others —in the final accumulated network. We clearly see two joined networks of hubs. The right section is very diverse in terms of including different eras and different fields such as philosophy, theology, and science scholars. The left section consists mainly of writers since the Long 19th Century (1789—1914); Alexander Pushkin (1799—1837) is one of the eldest nodes there. This writers' network shows little diversity in comparison to other historical periods and consists mostly of Modern and Contemporary age writers. That writers are less connected to the philosophy, theology, and science scholars shows that these groups referenced themselves more consistently.

Table V shows the metrics of accumulated-era networks. Regarding node degrees change over consecutively accumulated eras, we observe that at all eras the maximum out-degree is greater than the maximum in-degree. Moreover, those maximum degrees continuously increase over eras, in contrast to within-era networks. The average out-degree changes slightly over time, taking its lowest value of 1.45 at Middle Ages, and highest value of 1.8 at Contemporary age. Noteworthy is the

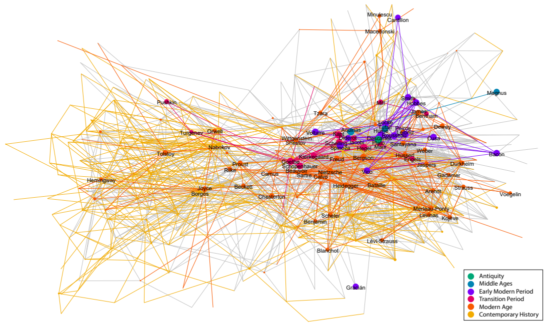

Fig. 4. Network of the most influential actors with at least 10 out-going influences. Node size = proximity prestige, node color = era, links within an era are colored with the color of the era, the other links are gray.

drastic collapse of the largest Weak Component in the Early Modern period, which has steadily risen since.

Who was the most influential intellectual in an era? Fig. 5 shows the evolution of the 10 most influential scholars in the complete network based on their out-degree progression in the accumulative networks.

The top two ranks of the most prolific scholars were consistently taken over by Antique philosophers Plato, and Aristotle (who among contemporaries was only in rank 6) Contemporary scholars came on third rank in the Middle Ages (Avicenna), in the Early Modern period (Ibn Tufail, John Locke, René Descartes), and in the Transitioning period (John Locke, Johann Goethe). This changed in the Modern Age, when Transitioning period scholars Immanuel Kant and Hegel took the first ranks. Aristotle still remained in the top five. The highest out-degree over all times is observed at the Contemporary Age, where Karl Marx had 158 out-going influence links to other scholars of all eras, followed by Nietzsche, Hegel, and Kant.

V. Patterns of Influence over Eras

In this section, we study the influence patterns of scholars over eras. We construct influence signatures based on how

TABLE IV
Top scholars with highest out-degree in the inter-era networks

s → t	First Rank		Second Rank	
A → ML	Aristotle	12	Augustine of Hippo	6
A → EM	Aristotle	19	Plato	14
A → T	Aristotle	11	Plato	9
A → MR	Plato	23	Aristotle	16
A → C	Aristotle	46	Plato	32
ML → EM	Ibn Tufail	21	Thomas Aquinas	9
ML → T	Petrarch	6	Dante Alighieri	5
ML → MR	Dante Alighieri	12	Thomas Aquinas	11
ML → C	Thomas Aquinas	34	Dante Alighieri	10
EM → T	J. J. Rousseau	24	Shakespeare	21
EM → MR	Baruch Spinoza	15	Shakespeare	15
EM → C	Shakespeare	35	David Hume	25
T → MR	Immanuel Kant	53	Karl Marx	43
T → C	Karl Marx	112	Hegel	67
MR → C	Nietzsche	78	Martin Heidegger	73

TABLE V
Metrics of Accumulative-Era Networks

Era	A	ML	EM	T	MR	C
N	219	552	1,227	2,141	4,697	12,506
E	327	801	1,784	3,245	7,869	22,485
N_{src}	54	155	388	677	1,501	3,890
N_{inner}	71	178	353	597	1,331	3,080
N_{sink}	94	219	486	867	1,865	5,536
Density	.0068	.0026	.0012	.0007	.0004	.0001
avg. out-degree	1.49	1.45	1.45	1.5	1.68	1.80
max in-degree	12	16	26	38	48	48
max out-degree	20	24	41	52	75	158
max degree	32	36	50	60	116	196
WCC	11	30	110	211	390	817
Largest WCC	179	441	797	1513	3550	10192
	82%	80%	65%	71%	76%	81%
SCC	0	2	8	16	47	85
Reciprocity	0	0.002	0.010	0.014	0.019	0.011
Transitivity	0.064	0.067	0.064	0.056	0.039	0.021

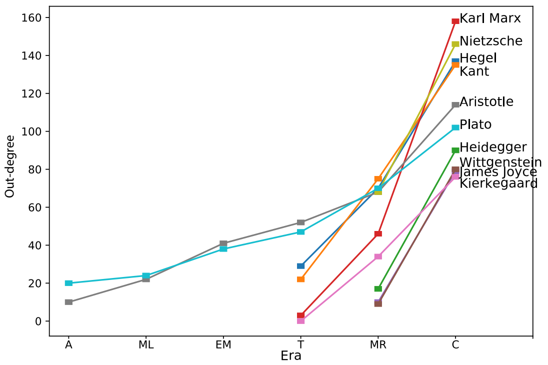

Fig. 5. Top 10 of the most influential intellectuals of the complete network based on their out-degree, and their progression in the accumulated-era networks.

much on average a scholar influenced an era, and which patterns of directed influences characterize an era.

1) Influence Power of Scholars: For each scholar, we construct their influence signature as a sequence of their influence links towards each era, starting from their own. For example, the influence signature of Aristotle was $[10, 12, 19, 11, 16, 46]$, which meant he had 10 influence links within Antiquity, 12 links towards the Middle Ages, etc. Using those signatures, we define the *longitudinal influence power* of a scholar as the average of their influence signature. A scholar would have a high influence power when he has (1) a high number of influence links, (2) over all or many eras. In contrast, having few influence links over several eras, or many links over few eras would give a low value of this influence power measure. For example, with an average around 19 both Aristotle and Shakespeare had similar influence powers. In absolute numbers, Aristotle had almost twice the number of Shakespeare's influence links (114 to 73, respectively). While Aristotle influenced all 6 eras, and Shakespeare only 4, the ratio of the links per era decreased for Aristotle, resulting in their similar influence powers. This measure provides an indicator of the influence power of an intellectual throughout history, and combines both the intensity and the diversity of influence.

Influence power also allows us to compare scholars from different eras. Table VI shows the top 5 scholars based on the longitudinal influence power. Here, Aristotle, Thomas Aquinas, William Shakespeare, Karl Marx, Friedrich Nietzsche, and the writer Vladimir Nabokov (1899—1977) are identified by their influence power as the most influential intellectuals of their respective periods. The highest longitudinal influence powers over all times had Nietzsche (73), followed by Nabokov (58) and Marx (52).

2) Influence Patterns: Which directed influences were most common in an era? We derive these influence patterns of eras by replacing any non-zero entries by X of the scholar's influence signatures, and aggregate all occurrences of each

TABLE VI
TOP 5 ACTORS BASED ON THE LONGITUDINAL INFLUENCE POWER.

Antiquity		MiddleAges		EarlyModern	
Aristotle	19.0	Thomas Aquinas	12.6	William Shakespeare	18.2
Plato	17.0	Dante Alighieri	6.0	Baruch Spinoza	14.8
Augustine of Hippo	6.0	Ibn Tufail	5.8	René Descartes	14.0
Plotinus	4.7	Avicenna	4.6	John Locke	13.0
Heraclitus	4.2	Al-Ghazali	3.6	David Hume	12.5
Transition		**ModernAge**		**Contemporary**	
Karl Marx	52.6	Friedrich Nietzsche	73.0	Vladimir Nabokov	58.0
Hegel	45.7	Martin Heidegger	45.0	Friedrich Hayek	50.0
Immanuel Kant	45.0	Ludwig Wittgenstein	40.0	Richard Pryor	50.0
Søren Kierkegaard	25.3	James Joyce	39.5	Jacques Derrida	48.0
Fyodor Dostoyevsky	23.0	Sigmund Freud	32.0	Michel Foucault	47.0

pattern for each era. We thus ignore the actual values of influence (intensity), but keep the temporal effect (diversity). For example, the influence pattern $[X, 0, \cdots, 0]$ means that the scholarly influences goes to the first (own) era only, with no influence on other eras. The pattern $[X, X, \cdots, X]$ signifies that the influence is distributed over all applicable eras, regardless of the actual values. Table VII gives the top patterns of each era with the pattern's frequency of occurrence with regard to the respective era.

TABLE VII
TOP FREQUENT INFLUENCE PATTERNS OF ERAS (FROM LEFT TO RIGHT)

	A	ML	EM	T	MR	C	
Antiquity	×	0	0	0	0	0	43%
	0	0	0	0	0	×	8%
	0	×	0	0	0	0	7%
	0	0	×	0	0	0	7%
MiddleAges		×	0	0	0	0	56%
		0	×	0	0	0	9%
		×	×	0	0	0	7%
		0	0	0	0	×	6%
EarlyModern			×	0	0	0	51%
			0	×	0	0	13%
			0	0	0	×	7%
			×	×	×	×	7%
Transition				×	0	0	35%
				0	×	0	29%
				×	×	×	11%
				×	×	0	9%
				0	0	×	8%
				0	×	×	7%
ModernAge					0	×	38.8%
					×	0	36.7%
					×	×	24.5%
Contemporary						×	100%

For example, for the Middle Ages the most frequent pattern is $[-, X, 0, 0, 0, 0]$, which represents that 56% of scholars only influenced contemporaries with no influences on other eras. Over all eras, the most common pattern was within-era influence, followed by the influence on the consecutive period. Exception to this rule is the Modern period, which experienced the reverse, and had a higher influence on the Contemporary period than on its own. Since the Early Modern period, the pattern of influencing all successive eras including its own becomes more frequent (from 7% on), and rises with each successive period.

VI. BROKERAGE ROLE

Which roles had scholars in regard to their influence on others? By following the brokerage approach by Gould and

Fernandez [8], we infer on the roles of scholars by analyzing the non-transitive triads, in which node A has a tie to node B, and B has a tie to node C, but there is no tie between A and C. In these triads, B is thought to play a structural role called a *broker*.

The possible roles are shown in Fig. 6, which are adapted from the work of Gould and Fernandez in [8], and Everett and Borgatti [2].[1] This allows us to consider to what extent a node's importance is based on joining two nodes that are members of the node's own era, or on joining others outside their group. We interpret nodal membership in groups as eras.

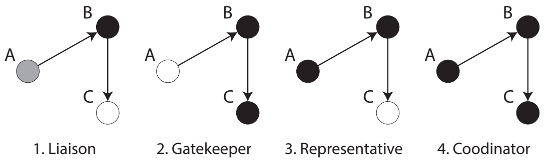

Fig. 6. Brokerage Roles of the top right node of each triad, adapted from Gould and Fernandez (1989) [8].

In Table VIII, we analyze the above-described brokerage roles for each period. Over all eras, 23% of all scholars have on average at least one of the above described brokerage roles. Since the Early Modern period, the amount of scholars with exactly one brokerage role remains very stable at about 12—13%, slightly higher in the Antiquity and Middle Ages. Both the first and the last of the periods could have a maximum of 2 different brokerage roles, because pre-processing didn't allow reverse links. Therefore, Representative and Liaison brokerage was impossible for Contemporary, as well as Liaison and Gatekeeper brokerage for Antiquity. Coordinator and Gatekeeper roles represent the scholars importance within their own period. Gatekeeper had inter-period influences and in turn influenced their contemporaries. The scholars with the highest scores for Gatekeeper in their respective periods are medieval polymath Avicenna (980—1037), Early Modern philosopher René Descartes (1596—1650), and Immanuel Kant (1724—1804), Friedrich Nietzsche (1844—1900), and Michel Foucault (1926—1984). The Coordinators with the highest scores are Plato, Avicenna again, John Locke (1632—1704), Johann Goethe (1749—1832), Friedrich Nietzsche, and contemporary horror writer Stephen King (born 1947). As Coordinators, these scholars represent a within-period influence. Liaison brokers have the longest time frame of influence, which includes three successive periods. Thomas Aquinas, the Dominican friar (1225—1274), and Early Modern philosopher Baruch Spinoza (1632—1677) had the highest scores, and again Immanuel Kant and Friedrich Nietzsche as Liaisons. Representatives took the reverse role of an Gatekeeper: they have a within-era influence that spread to a successive era. Plato, Thomas Aquinas, David Hume (1711—1776), Karl Marx (1818—1883) and Martin Heidegger (1889—1976) stand out.

From Middle to Modern Age, the amount of scholars with all four brokerage roles steadily increased. Noteworthy here were Thomas Aquinas (Middle Ages), Gottfried Leibniz (Early Modern Period), Georg Hegel (Transitioning Period), and Martin Heidegger (Modern Age), who appeared most often in super brokerage roles: They combined Liaison, Gatekeeper, Representative, and Coordinator roles alike in their respective periods. Surprisingly though, scholars with 3 brokerage roles were roughly ten times less common than those with all brokerages (compare Table VIII).

TABLE VIII
NUMBER AND FRACTION OF ACTORS TAKING 1, 2, 3, OR 4 ROLES

No. of Roles	1	2	3	4
Antiquity	55 (21%)	30 (11%)		
MiddleAges	62 (18%)	32 (9%)		12 (3%)
EarlyModern	101 (13%)	51 (7%)	2 (0.3%)	38 (5%)
Transition	136 (12%)	87 (8%)	6 (0.8%)	70 (6%)
ModernAge	363 (13%)	269 (9%)	5 (0.7%)	200 (7%)
Contemporary	879 (12%)	536 (7%)		
overall	1,596	1,005	13	320
	12.8%	8.0%	0.1%	2.6%

VII. CONCLUSIONS

In this paper, we incorporated a longitudinal aspect in the study of the influence networks of scholars. First, we extracted their social network of influence from YAGO, a pioneering data source of Linked Open Data, which records the main influences of and by intellectuals available from Wikipedia, WordNet, and GeoNames. Rigorous pre-processing resulted in a network of 12,705 intellectuals with 22,818 edges, including information on each scholar's era. We opted for a global approach for the periodization of history to match the internationality of scholars, resulting in six consecutive eras to study.

Our main question was whether we could identify patterns of influence, and their change over time. Therefore, we performed essential network analysis on every time-sliced projection of the entire network in within-era, inter-era, and accumulated-era influence networks. We investigated their social network metrics, degree distribution, and connectivity. An influence pattern throughout all eras was that the internal impact of any era was higher than its external impact. The vast majority of scholars influenced scholars of their own period (= within-era influence) with a relatively stable average out-degree. There were only a few instances of reciprocity. When accumulating eras, the max. degrees drastically increased. However, over all eras the maximum out-degree stayed greater than the maximum in-degree. In inter-era influence networks, each era hat the most influence on the consecutive one, and the Contemporary period. The exception to this rule was a spike in the absolute links of antique influences on the Early Modern period, representing the increased reception of antique scholars during the Renaissance. However, proportionally Antiquity's influence on Early Modernity was as high as on the Middle

[1]The fifth brokerage role, the *Consultant*, where A and C belong to one period, and B belongs to another, is not possible in our network, as we didn't allow reverse influences of a more recent period onto a previous one by pre-processing.

Ages, which reasserts the shift in historical research that the Renaissance thinkers did not "rediscover" Antiquity, but that medieval scholars also received it [3, p. 3—4].

With a longitudinal perspective, we can add a more pronounced view on who the most influential intellectuals are. The scholar with the highest out-degree over all periods on contemporaries (= within-era) was Modern age scholar Friedrich Nietzsche. Plato in Antiquity, Avicenna in the Middle Ages, John Locke in the Early Modern period, Johann Goethe in the Transition period and Vladimir Nabokov in the Contemporary period were the most influential on the contemporaries of their respective periods.

When accumulating eras, the most influential intellectuals of an era change: here, Plato was the most influential for Antiquity and the Middle Ages, Aristotle for the Early Modern and Transitioning period, Immanuel Kant for the Modern Age. In the Contemporary period, and therefore for the complete network of intellectuals, Karl Marx.

In the inter-era network analysis, Transitioning period scholar Karl Marx had the highest out-degree over all times to the Contemporary age. Modern intellectuals Friedrich Nietzsche and Martin Heidegger took second place over all time for the Contemporary period.

We constructed the longitudinal influence power of intellectuals based on the average of their influences on eras, which favors consistency of influence. Here, again, Aristotle, Thomas Aquinas, William Shakespeare, Karl Marx, Friedrich Nietzsche, and Vladimir Nabokov were the most consistently influential intellectuals of their respective periods. Nietzsche, Nabokov, and Marx had the highest influence.

In terms of knowledge brokering, we could identify Coordinator, Gatekeeper, Representative and Liaison knowledge brokers, whom we interpreted as passing influence between and within eras. We found that the scholars with all four different brokerage roles were medieval scholar Thomas Aquinas, Early Modern polygraph Gottfried Leibniz, Georg Hegel of the Transitioning period, and the Modern philosopher Martin Heidegger.

This study of the longitudinal patterns of influence is such suited to further the insights on the interconnections of influence of thinkers and the dynamics of eras alike.

Therefore, we plan to study the evolution of communities in these accumulated networks in future work. Another direction of research would be to study the effects of different periodizations on the importance of scholars, as well as deriving an automated periodization based on the dataset. In addition, we would like to compare this YAGO network of intellectual influence with a more detailed network of scholars based on the main books on intellectual history, in order to establish their differences and insights in this field of study.

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Diffusion Dynamics of Influence in a Social Network of Intellectuals

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In

Social Network Analysis and Mining 2021, volume 11, number 63. DOI: 10.1007/s13278-021-00771-x.

Abstract

The history of intellectuals consists of a complex web of influences and interconnections of philosophers, scientists, writers, their work, and ideas. To understand how did these influences evolve over time, we mined a network of influence of over 12,500 intellectuals, enriched it with a temporal dimension dividing the history into six eras. We analyze time-sliced projections of the network into within-era, inter-era, and accumulated-era networks, and identify various patterns of intellectuals and eras and studied their development in time. We also construct influence cascades, analyze their properties: size, depth and breadth, and analyze how the cascades of influence evolve over the consecutive eras. We find out that the cascades are clustered into two categories, namely small- and large cascades. An interesting finding here is that the fraction of small cascades increases, while the fraction of larges cascades decreases over time. We also briefly analyze the community structure within the influence network of scholars.

Contribution of thesis author

Theoretical operationalization, iterative evaluation of computational implementation and analysis, contextualization, as well as manuscript writing, revision, and editing.

Social Network Analysis and Mining (2021) 11:63
https://doi.org/10.1007/s13278-021-00771-x

ORIGINAL ARTICLE

Diffusion dynamics of influence in a social network of intellectuals

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Received: 14 February 2021 / Revised: 12 May 2021 / Accepted: 23 June 2021

Abstract
The history of intellectuals consists of a complex web of influences and interconnections of philosophers, scientists, writers, their work, and ideas. To understand how did these influences evolve over time, we mined a network of influence of over 12,500 intellectuals, enriched it with a temporal dimension dividing the history into six eras. We analyze time-sliced projections of the network into within-era, inter-era, and accumulated-era networks, and identify various patterns of intellectuals and eras and studied their development in time. We also construct influence cascades, analyze their properties: size, depth and breadth, and analyze how the cascades of influence evolve over the consecutive eras. We find out that the cascades are clustered into two categories, namely small- and large cascades. An interesting finding here is that the fraction of small cascades increases, while the fraction of larges cascades decreases over time. We also briefly analyze the community structure within the influence network of scholars.

Keywords Social networks · Intellectual influence · Diffusion dynamics

1 Introduction

"No self is of itself alone," wrote Erwin Schrödinger in 1918 (Moore 1994) and noted, "It has a long chain of intellectual ancestors." The history of intellectuals is comprised of a myriad of such long chains, embedded in a tapestry of competing influences of "ageless" ideas, which—in the words of the French scholar Bonaventura D'Argonne in 1699—"embrace [...] the whole world" (Grafton 2009).

To understand the dynamics of influence and spread of ideas through history, the embeddness and interconnections of scholarship should be taken into account. A network approach offers to identify the most influential scholars via their positions in a network of intellectual influence through the history. This allows the study of their social relations (Wasserman and Faust 1994; Hennig et al. 2012; Otte and Rousseau 2002), and to provide deep insights into the underlying social structure.

In a previous work (Ghawi et al. 2019), we addressed the analysis of such a social network of intellectual influence, incorporating over 12,500 scholars from international origins since the beginning of historiography. In Petz et al. (2020), we also extended the analysis of that network by incorporating a temporal dimension, analyzing the network of scholars dependent to their time, and adding a longitudinal perspective on how scholars formed networks. By doing so, we opted for an inclusive, global perspective on the history of intellectuals. This perspective of a vast longitudinal global network of intellectuals is a response to recent discussions on not-global-enough research within intellectual history (Haakonssen and Whatmore 2017). We thus attempt to go beyond the traditional "master narratives" (Gänger and Lewis 2013) of a Western European centrist view on intellectual history (Subrahmanyam 2017).

The goal is not only to understand how the influence relations among scholars evolved over time, but also to get deep insights on their influence on historical periods. With this kind of longitudinal analysis, we can answer questions like: how did these influence networks evolve over time? who were the most influential scholars in a period? and which patterns of influence did emerge?

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Published online: 10 July 2021

In this paper, we build upon (Petz et al. 2020), and extend the analysis of the social network of scholars by addressing the diffusion dynamics of influence among scholars over the history. As scholars get influenced by other scholars, who are influenced by others, and so on, the influence of scholars spread over time, and takes the form of *cascades*. Influence cascades can be characterized using several properties, such as size, depth, and breadth. For all scholars in the social network, we measure and analyze these properties, and categorize the scholars based on the properties of their influence cascades.

Moreover, we analyze the community structure within the network of scholars. By applying a community detection algorithm, we are able to identify the major communities of scholars who densely influence each other, forming knowledge clusters.

Our contributions are as follows:

- We incorporate a longitudinal perspective on the social network analysis of intellectuals based on a global periodization of history.
- We identify patterns of influence and their distribution in within-, inter-, and accumulated-era influence networks.
- We identify influence signatures of scholars and eras.
- We identify scholars with various knowledge broker roles.
- We construct influence cascades of scholars, and measure and their properties.
- We analyze the cascade properties over eras, and characterize them into two clusters of small- and large cascades.
- We analyze the community structure within the network of scholars, and how the identified communities influence each other.

This paper is organized as follows. Section 2 reviews related works. In Sect. 3, we briefly outline the dataset's characteristics and pre-processing. Section 4 presents the network analysis of the entire network, and its time-sliced projections into partial influence networks (within-era, inter-era, and accumulated-era), featuring their basic network metrics, degree distribution, and connectivity. In Sect. 5, we identify different influence patterns of scholars and eras. Section 6 is devoted to the longitudinal analysis of brokerage roles of scholars. In Sect. 7, we address the diffusion dynamics of influence through the analysis of influence cascades of scholars over different eras. Finally, in Sect. 8, we address the communities of scholars, and the influence between them.

2 Related work

The term of intellectual history combines a plethora of approaches on discourse analysis, evolution of ideas, intellectual genealogies, and the history of books, various scientific disciplines, political thought, and intellectual social context (Wickberg 2001; Gordon 2013). These studies are usually limited to specific regions or time spans as a trade-off for thorough comparative and textual analysis. Endeavors to write a "Global Intellectual History" (Moyn and Sartori 2013) were criticized for focusing on the more well-known intellectual thinkers despite including a transnational comparative perspective (Subrahmanyam 2015).

Network methodologies allow analyzing intellectual history and as such the history of intellectuals as big data, encompassing time and space with a focus on their inter-connections. Notably, computational methods have been used in the study of communication networks of the *respublica litteraria* of the late 17th and 18th century, in which various studies modeled the Early Modern scholarly book and letter exchanges as formal networks. Since 2008, the project "Mapping the Republic of Letters" at Stanford University spearheaded the digitization of Early Modern letters and systematically modelled the metadata on who is connected to whom in correspondence networks mapped into spatial realm, similarly to a "traffic analysis" (Edelstein et al. 2017 p. 403). More recent studies have incorporated a temporal perspective on these epistolary networks, and studied their change in time, as well as differentiated between the types of correspondence exchanged in a multi-layered perspective (Vugt 2017). While the *Republic of Letters* contains a multitude of scholarly actors in an imagined intellectual community—the so-called republic—consisting of "a palimpsest of people, books, and objects in motion" (Grafton 2009 p. 6), it is confined to the Early Modern period, and primarily studied through the in-depth analysis of selected ego networks, such as e.g. the correspondence network of Benjamin Frankling during his "London Decades" (1757–1775) Winterer (2012), or the influence of English authors on the Enlightenment philosophy of Voltaire (Edelstein and Kassabova 2020).

A recent study (Ghawi et al. 2019) proposed to research the entire history of intellectuals with the means of a network approach. This paper defined the most influential as those with the longest reaching influence (influence cascades), and identified as such Antique and Medieval Islam scholars, and Karl Marx as the one with the most out-going influences. In this paper, we extend this analysis by incorporating a temporal dimension in order to establish a deeper insight on how these influences evolved in time. Much research has been devoted to the area of longitudinal social networks (Newcomb 1961; Huisman and Snijders 2003; Snijders et al. 2010; Holme and Saramäki 2019). Longitudinal network studies aim at understanding how social structures develop or change over time, usually by employing panel data (Hennig et al. 2012). Snapshots of the social network at different points in time are analyzed in order to explain the changes in the social structure between two (or more) points in time in terms of the characteristics of the scholars, their positions in the network, or their former interactions.

3 Data

3.1 Data acquisition and preprocessing

The source of information used in this paper originated from YAGO (Yet Another Great Ontology) (Mahdisoltani et al. 2015), which is a pioneering semantic knowledge base that links open data on people, cities, countries, and organizations from Wikipedia, WordNet, and GeoNames. At YAGO, an influence relation appears in terms of the `influences` predicate that relates a scholar to another when the latter is influenced by the ideas, thoughts, or works of the former. The accuracy of this relation was evaluated by YAGO at 95%. We extracted a dataset that encompasses all influence relationships available in YAGO, using appropriate SPARQL queries that implement mining techniques of social networks from Linked Open Data (Ghawi and Pfeffer 2019). The result consisted of 22,818 directed links among 12,705 intellectuals that made up the nodes and edges of our target social network of influence. In order to incorporate a time dimension to our analysis, we extracted birth and death dates of each scholar. Some scholars had missing birth and/or death dates, which we deduced by subtracting 60 years from the death date, and vice versa, up to the symbolic year of 2020. When both dates were missing, we manually verified them. During this process we had to remove some entities, as they did not correspond to intellectuals. These were either (1) concepts, e.g., 'German_philosophy' and 'Megarian_school', (2) legendary characters, e.g., 'Gilgamesh' and 'Scheherazade', or (3) bands e.g., 'Rancid' and 'Tube.' To this end, we obtained a new dataset of 12,577 scholars with complete birth and death dates.

3.2 Periodization

In this paper, we do not use the classical concept of network snapshot, which is a static network depicted at a given point in time. Rather, we split the time span (i.e., the history) manually into consecutive periods (eras), and embed the network nodes (actors) into the eras in which they lived. This way, the micro-level influence among scholars can be viewed as a macro-level influence among periods of history. This enables the analysis of the influence network within each era (= within-era), between different eras (= inter-era), and in an accumulative manner (= accumulated-era). By introducing a longitudinal perspective, we split the time-span using a periodization that takes global events into account. Any periodization is a construct of analysis, as each field of research has its own timeline characterizing periods (Pot 1999) which are dependent on different caesura for the respective object of research (Osterhammel 2002). This complicates an overarching longitudinal perspective on a global scale. In order to match the internationality of scholars, we used Osterhammel's global periodization (Osterhammel 2002) and worked with six consecutive periods (eras): Antiquity (up to 600 AD), Middle Ages (600–1350), Early Modern Period (1350–1760), Transitioning Period (1760–1870), Modern Age (1870–1945), and Contemporary History (1945–2020). We have given each of these eras an abbreviation to easily referring it throughout the paper as shown in Table 1.

Table 1 Eras and their start- and end dates

	Era	Start–end years	Length
`AN`	Antiquity	(up to 600 AD)	~ 2000
`MA`	Middle ages	(600, 1350)	750
`EM`	Early modern period	(1350, 1760)	410
`TP`	Transition period	(1760, 1870)	110
`MR`	Modern age	(1870, 1945)	75
`CH`	Contemporary history	(1945, 2020)	75

One conceptual challenge was to map scholars into eras. Many scholars fit to more than one period's timeline. We opted for a single era membership approach since it is more intuitive and easier to conceptualize. A single era membership of each scholar reduces the complexity of analysis and computations, while encompassing the essential membership of each scholar to a single era. It also offers adequate results when we compare eras, since it avoids redundancy. This approach does not change the influences of the scholar to scholars of other periods.

In order to assign a single era to a scholar, we used the following method: We calculated the midpoint of the scholar's lifespan ignoring the first 20 years of their age, as we assumed that scholars in general would not be active then. Then we assigned the era in which this midpoint occurs as the scholar's membership to an era. After this initial assignment process, we verified the global validity of assignments by counting the number of influence links from one era to another. We observed that there were some reverse links of eras, i.e., an influence relation from an actor in a recent era toward an actor assigned to an older era. Those anomaly cases (about 200) were basically due to:

1. Errors in dates: Some dates were stated in the Hijri calendar, instead of the Gregorian calendar, and some dates were BC and missing the negative sign.
2. Errors in direction of the relationship: Source and target actors were wrongly switched.
3. Inappropriate era-actor assignments.

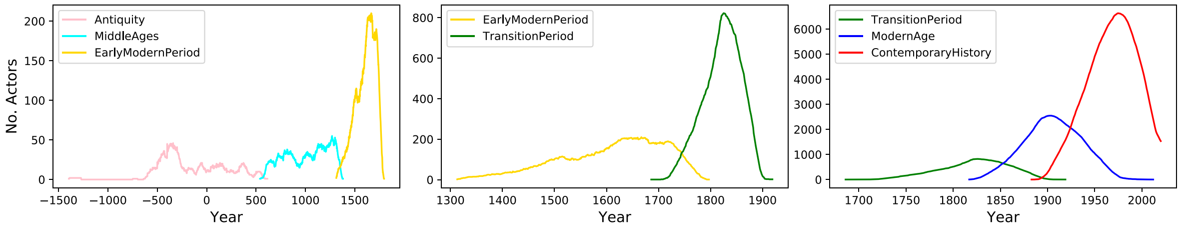


Fig. 1 Number of scholars alive in each year based on their assigned eras

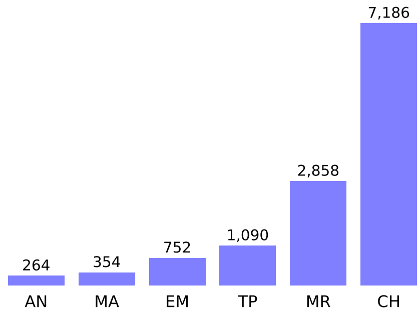


Fig. 2 Number of scholars per era

	AN	MA	EM	TP	MR	CH
AN	319	87	145	66	114	177
MA		387	144	36	62	121
EM			694	432	269	432
TP				927	1,373	1,041
MR					2,806	4,885
CH						7,960

Fig. 3 Number of influence links from preceding periods (rows) to target eras (columns)

The anomalies due to errors have been manually corrected. The cases of inappropriate assignment were technically not erroneous. This usually happened when the influencer lived much longer than the influenced, elevating the influencer's period into a more recent one. We solved this by iteratively reassigning either the influencer backward to the era of the influenced, or the influenced forward to the era of the influencer. As a result, each scholar is assigned to exactly one era, such that no reverse links of eras exist. The final cleaned dataset consists of 22,485 influence links among 12,506 intellectuals. Figure 1 shows each era's continuous density of scholars based on their lifespan; whereas Fig. 2 shows the number of scholars assigned to each era.

4 Analysis

With scholars embedded in their respective eras, the entire influence network can be time-sliced: we projected it into several partial networks based on the source era (of the influencer) and target era (of the influenced scholar). When the source and target eras are the same, we call the partial network a *within-era* influence network. When the source and target eras are different, we call the partial network an *inter-era* influence network. There are no reverse links from a later era to a previous one due to preprocessing.

As a result of time-slicing the whole network, we obtain six within-era networks corresponding to all the six eras, and 15 inter-era networks, corresponding to all chronologically ordered (but not necessarily consecutive) pairs of different eras. Moreover, we constructed six *accumulated-era* influence networks of scholars living up to and including a target era.

Figure 3 shows the distribution of influence links over pairs of eras, where the rows represent source eras, and the columns represent target eras, i.e., each cell displays the number of influence links incoming from (actors in) the row era, outgoing to (actors in) the columns era. One can easily observe that the greatest deal of links occur within the Contemporary era, followed by the links from Modern Age to Contemporary, and within Modern Age. This is obviously because those recent eras comprise the largest deal of scholars in our dataset.

Figure 4 shows the proportion of influence links among all pairs of eras. There, we can already make two major observations for inter- and within-era influence relations: For one, the highest fraction of influence received by scholars of each era comes from its own era. This means that the internal impact of any era is in general higher than its external impact. In absolute numbers, the vast majority of links occur within the Contemporary era, followed by links from the Modern Age to the Contemporary period, and within the

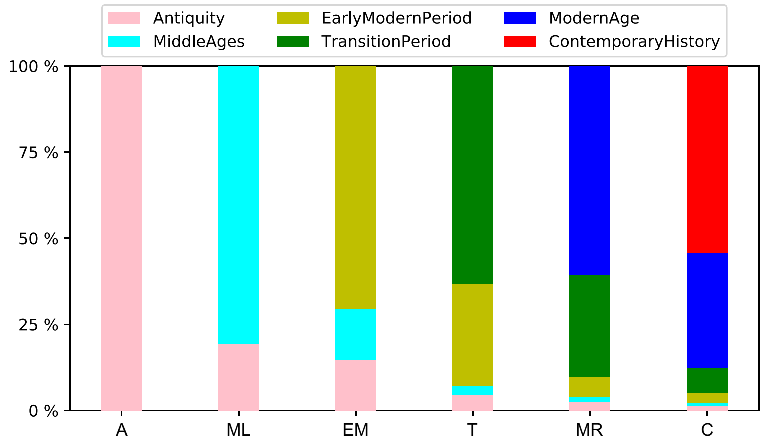


Fig. 4 Percentage of received influences in each era

Table 2 Metrics of within-era networks

Era	AN	MA	EM	TP	MR	CH
N	219	303	610	761	2102	6081
N/A	82%	86%	81%	70%	73%	85%
E	327	387	694	927	2806	7960
Density	.0068	.0042	.0019	.0016	.0006	.0002
avg. d_{out}	1.49	1.28	1.14	1.22	1.33	1.31
max d_{in}	12	9	17	27	21	26
max d_{out}	20	16	23	32	68	58
max d	32	20	32	41	73	58
WCC	11	21	94	108	208	582
LWCC	179	233	245	436	1495	4379
	82%	77%	40%	57%	71%	72%
SCC	0	2	6	8	31	38
R	0	0.005	0.023	0.028	0.036	0.014
T	0.064	0.066	0.071	0.042	0.029	0.017

Modern Age, which is clearly owed to the increased amount of scholars in these periods.

The inter-era influences of each period is strongest on its consecutive period. As our earliest period, Antiquity receives only influence links from itself, whereas the influence received in the Middle Ages are 82% internal, and 18% from Antiquity. Subsequently, the amount of the within-era influence shrinks throughout the consecutive periods, but still remains the biggest influence. Noteworthy here is the high proportion of influences of Antiquity on the Early Modern period, which represents their increased reception during the Renaissance. However, the proportionately many links of Antiquity to the Middle Ages reassert the shift in historical research that the Renaissance did not “rediscover” Antiquity, but was received before in the Middle Ages as well (Fejfer et al. 2003 p. 3–4).

4.1 Within-eras influence networks

In the following, we analyzed the six *within-era* influence networks, which represent the internal impact of an era. We extracted the following metrics, as shown in Table 2:

- Number of nodes N, and edges E, and density D.
- Average out-degree (= avg. in-degree due to the properties of a directed graph).
- Max. in-degree, max. out-degree, and max. degree.
- WCC: number of weakly connected components.
- LWCC: size of the largest weakly connected component.
- SCC: number of strongly connected components, when the number of nodes is > 1).
- Reciprocity (R) and transitivity (T).

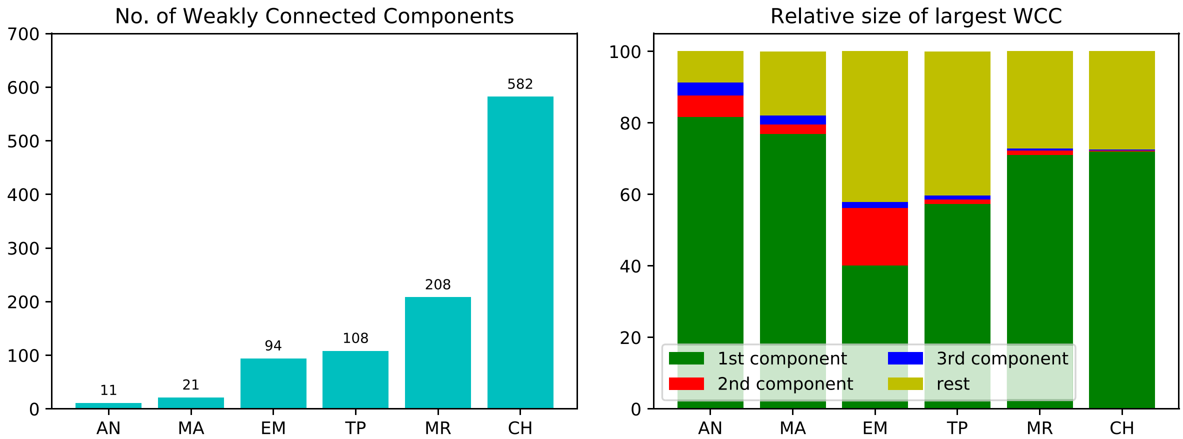


Fig. 5 Weakly connected components in within-era influence networks

We included $\frac{N}{A}$ in Table 2 in order to contain that the number of nodes N in a within-era network could be less than the number of actors of that of era A. This is owing to the fact that not all scholars of an era necessarily participated in its within-era influence network. Some scholars influenced or were influenced by actors of different eras only. However, around 80% of scholars in each era were active in these within-era networks. The highest value of 86% of the Middle Ages refers to their relative self-containment as an era, as well as the lowest value in the Transitioning period of 70% refers to its high out-going influences.

Over all eras, the amount of nodes and edges steadily increased, while the density of networks decreased. On average, the out-degree revolves around 1.25, where the highest value of 1.5 occurs in Antiquity, and the lowest of 1.14 in the Early Modern period. When we compare the evolution of the max. out-degree in time, we find that the expected continuous increase did not always hold due to two exceptionally high observations at Antiquity and the Modern Age. Mutual ties among contemporaries were in general very low. We can report none in Antiquity, and only one in the Middle Ages between Avicenna and Al-Bīūī. In the Early Modern period, eight mutual relations were observed, including, e.g., Gottfried Leibniz (1646–1716) and David Bernoulli (1700–1782), whereas 13 mutual relations in the Transitioning period, such as Friedrich Engels (1820–1895) and Karl Marx (1818–1883), or Johann Goethe (1749–1832) and Friedrich Schelling (1775–1854). In the Modern Age, the number of mutual ties increased to 51 (e.g., Jean-Paul Sartre (1905–1980) and Simone de Beauvoir (1908–1986)); and to 54 in the Contemporary period.

Figure 5 shows the number of weakly connected components (WCCs) in the within-era networks of each era, and the relative size of the largest ones w.r.t the whole corresponding network.

The number of WCCs increased gradually over the consecutive eras. In general, the networks consisted of one giant component, which encompassed the majority of nodes, while the rest of components were relatively smaller. This was particularly developed in Antiquity and the Middle Ages, where the giant components constitute of 82% and 77% of the nodes, while the second largest were at 6% and 3%, respectively. The Early Modern period constitutes an exception to this giant component rule: the largest one was only at 40%, and the second largest at 16%. Looking at their composition, the first consisted of natural scientists, mathematicians, and philosophers, such as Descartes, Newton, and Leibniz, while the smaller one was compromise of artists and painters, such as Rembrandt and Raphael. The single giant component phenomenon appeared again in subsequent eras. For instance, in the Transitioning period, there were 108 WCCs, where the largest two incorporated 57% and 1.3% of the nodes. In the Modern and Contemporary Age, the largest components comprised about 70% of nodes.

Who was most influential on their contemporaries? Table 3 lists the top five scholars per era based on their out-degree in the within-era influence networks. The highest within-era out-degree over all times was achieved by Friedrich Nietzsche (1844–1900) of the Modern Age with 68 outgoing influence links to other scholars of his era.

4.2 Inter-era influence networks

Inter-era influence networks are partial networks where the source era precedes the target era. We interpreted these networks as bipartite, as the actors belong to different groups; the source era and the target era. Therefore, only edges between nodes sets are possible.

Table 3 Top 5 actors, per era, based on out-degree in within-era influence networks

Antiquity		MiddleAges	
Plato	20	Avicenna	16
Aesop	13	Muhammad	11
Pythagoras	10	Al-Ghazali	11
Plotinus	10	BanūMūsā	8
Euhemerus	10	J. S. Eriugena	8
EarlyModern		**Transition**	
John Locke	23	Goethe	32
René Descartes	22	Hegel	29
Isaac Newton	15	Lord Byron	24
Hugo Grotius	13	Immanuel Kant	22
Leibniz	11	von Schelling	17
Modern		**Contemporary**	
Nietzsche	68	Vladimir Nabokov	58
Jules Verne	35	Friedrich Hayek	50
Henri Bergson	35	Richard Pryor	50
Leo Tolstoy	24	Jacques Derrida	48
Edmund Husserl	22	Michel Foucault	47

Table 4 shows the metrics for those inter-era influence networks. In general, each era had the most links with its consecutive era, and additionally with the Contemporary period's scholars. Exception to this was Antiquity, which saw its first peak with the Early Modern period relating to Renaissance interests.

Their densities were again decreasing through the combinations, except for those periods that had less links to other periods, such as the Middle Ages to the Transitioning period.

Which scholar influenced a successive era the most? Table 5 shows the scholars with the highest degrees in the inter-era networks. Noteworthy here is Karl Marx, who had the highest out-degree over all times from the Transitioning period to the Contemporary age, followed by modern philosopher Friedrich Nietzsche and Martin Heidegger on Contemporary scholars.

4.3 Accumulative influence networks

For each era, we constructed an accumulative network of all influence links among scholars who lived up to and including that era. We performed essential social network analysis on these six *accumulated-eras* networks, which combine the internal and external impact of eras. The final network of the Contemporary Age is the same as the complete network over all periods (Ghawi et al. 2019).

Figure 6 shows the best connected scholars for each era those that influenced at least 10 others - in the final accumulated network. We clearly see two joined networks of hubs. The right section is very diverse in terms of including different eras and different fields such as philosophy, theology, and science scholars. The left section consists mainly of writers since the Long 19th Century (1789–1914); Alexander Pushkin (1799–1837) is one of the eldest nodes there. This writers' network shows little diversity in comparison to other historical periods and consists mostly of Modern and Contemporary age writers. That writers are less connected to the philosophy, theology, and science scholars show that these groups referenced themselves more consistently.

Table 6 shows the metrics of accumulated-era networks. Regarding node degrees change over consecutively accumulated eras, we observe that at all eras the maximum

Table 4 Metrics of inter-eras influence networks

Source → Target	N	E	N_s	N_t	D	In-degree avg	In-degree max	Out degree avg	Out degree max
AN → MA	82	87	38	44	.052	1.98	7	2.29	12
AN → EM	117	145	46	71	.044	2.04	7	3.15	19
AN → TP	66	66	29	37	.062	1.78	5	2.28	11
AN → MR	101	114	42	59	.046	1.93	11	2.71	23
AN → CH	169	177	49	120	.030	1.47	6	3.61	46
MA → EM	149	144	66	83	.026	1.73	9	2.18	21
MA → TP	52	36	22	30	.055	1.20	5	1.64	6
MA → MR	77	62	27	50	.046	1.24	4	2.30	12
MA → CH	146	121	50	96	.025	1.26	6	2.42	34
EM → TP	392	432	159	233	.012	1.85	16	2.72	24
EM → MR	262	269	101	161	.016	1.67	13	2.66	15
EM → CH	437	432	125	312	.011	1.38	7	3.46	35
TP → MR	1111	1373	436	675	.005	2.03	19	3.15	53
TP → CH	888	1041	212	676	.007	1.54	9	4.91	112
MR → CH	3817	4885	1271	2546	.002	1.92	17	3.84	78

Table 5 Top scholars w.r.t out-degree in inter-era networks

source → target	First rank		Second Rank	
AN → MA	Aristotle	12	Augustine of Hippo	6
AN → EM	Aristotle	19	Plato	14
AN → TP	Aristotle	11	Plato	9
AN → MR	Plato	23	Aristotle	16
AN → CH	Aristotle	46	Plato	32
MA → EM	Ibn Tufail	21	Thomas Aquinas	9
MA → TP	Petrarch	6	Dante Alighieri	5
MA → MR	Dante Alighieri	12	Thomas Aquinas	11
MA → CH	Thomas Aquinas	34	Dante Alighieri	10
EM → TP	J. J. Rousseau	24	Shakespeare	21
EM → MR	Baruch Spinoza	15	Shakespeare	15
EM → CH	Shakespeare	35	David Hume	25
TP → MR	Immanuel Kant	53	Karl Marx	43
TP → CH	Karl Marx	112	Hegel	67
MR → CH	Nietzsche	78	Martin Heidegger	73

out-degree is greater than the maximum in-degree. Moreover, those maximum degrees continuously increase over eras, in contrast to within-era networks. The average out-degree changes slightly over time, taking its lowest value of 1.45 at Middle Ages, and highest value of 1.8 at Contemporary age. Noteworthy is the drastic collapse of the largest Weak Component in the Early Modern period, which has steadily risen since.

Who was the most influential intellectual in an era? Figure 7 shows the evolution of the 10 most influential scholars in the complete network based on their out-degree progression in the accumulative networks.

The top two ranks of the most prolific scholars were consistently taken over by Antique philosophers Plato, and Aristotle (who among contemporaries was only in rank 6). Contemporary scholars came on third rank in the Middle Ages (Avicenna), in the Early Modern period (Ibn Tufail, John Locke, René Descartes), and in the Transitioning period (John Locke, Johann Goethe). This changed in the Modern Age, when Transitioning period scholars Immanuel Kant and Hegel took the first ranks. Aristotle still remained in the top five. The highest out-degree over all times is observed at the Contemporary Age, where Karl Marx had 158 outgoing influence links to other scholars of all eras, followed by Nietzsche, Hegel, and Kant.

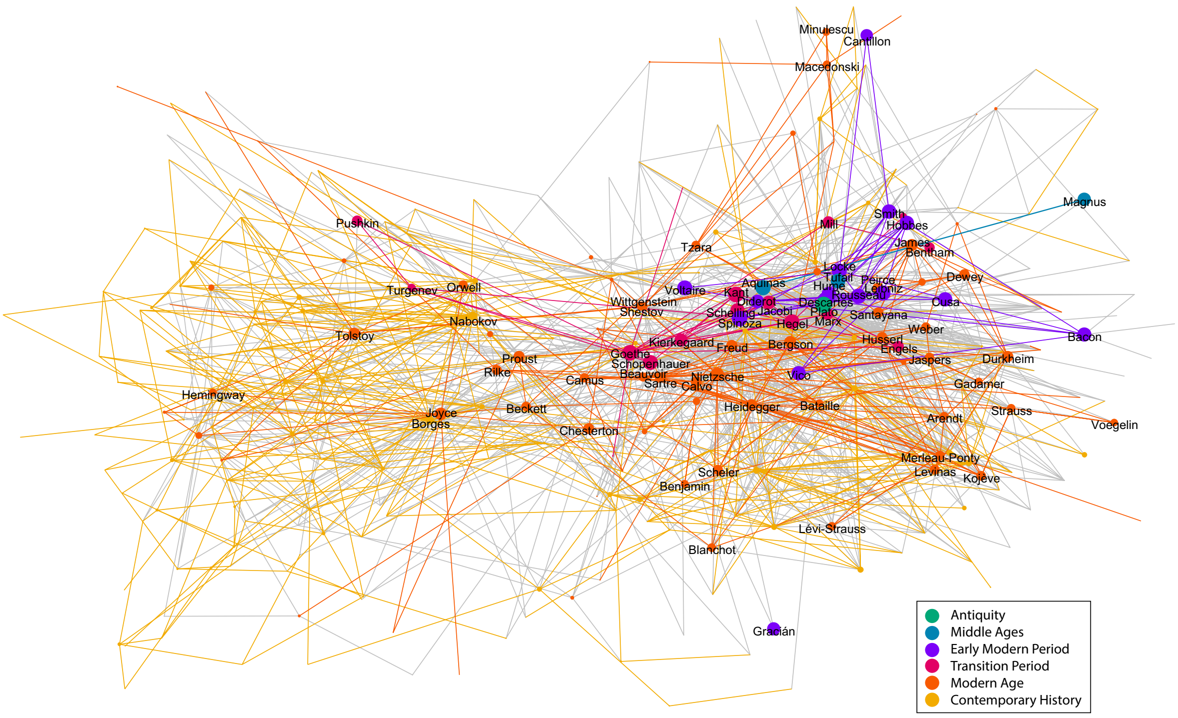


Fig. 6 Network of the most influential actors with at least 10 out-going influences. Node size = proximity prestige, node color = era, links within an era are colored with the color of the era, the other links are gray

Table 6 Metrics of accumulative-era networks

Era	AN	MA	EM	TP	MR	CH
N	219	552	1227	2141	4697	12,506
E	327	801	1784	3245	7869	22,485
N_{source}	54	155	388	677	1501	3890
N_{inner}	71	178	353	597	1331	3080
N_{sink}	94	219	486	867	1865	5536
Density	.0068	.0026	.0012	.0007	.0004	.0001
avg. d_{out}	1.49	1.45	1.45	1.5	1.68	1.80
max d_{in}	12	16	26	38	48	48
max d_{out}	20	24	41	52	75	158
max d	32	36	50	60	116	196
WCC	11	30	110	211	390	817
LWCC	179	441	797	1513	3550	10192
	82%	80%	65%	71%	76%	81%
SCC	0	2	8	16	47	85
R	0	0.002	0.010	0.014	0.019	0.011
T	0.064	0.067	0.064	0.056	0.039	0.021

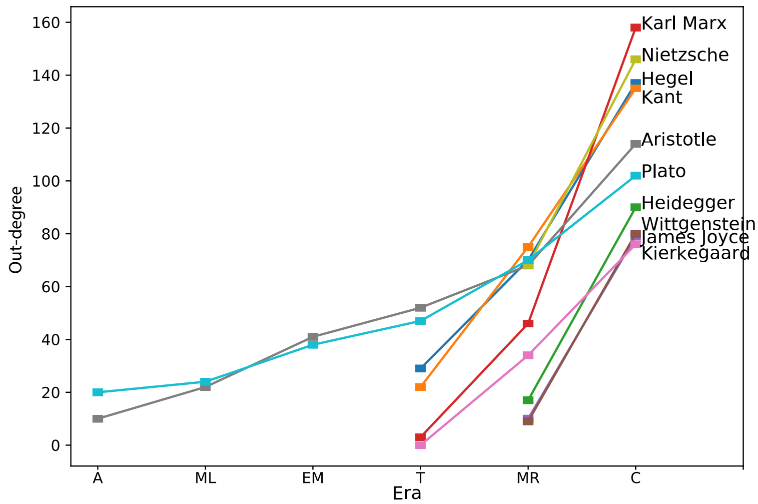


Fig. 7 Top 10 of the most influential intellectuals of the complete network based on their out-degree, and their progression in the accumulated-era networks

5 Patterns of influence over eras

In this section, we study the influence patterns of scholars over eras. We construct influence signatures based on how much on average a scholar influenced an era, and which patterns of directed influences characterize an era.

5.1 Influence power of scholars

For each scholar, we construct their influence signature as a sequence of their influence links toward each era, starting from their own. For example, the influence signature of Aristotle was [10, 12, 19, 11, 16, 46], which meant he had 10 influence links within Antiquity, 12 links toward the Middle Ages, etc. Using those signatures, we define the *longitudinal influence power* of a scholar as the average of their influence signature. A scholar would have a high influence power when he has (1) a high number of influence links, (2) over all or many eras. In contrast, having few influence links over several eras, or many links over few eras would give a low value of this influence power measure. For example, with an average around 19 both Aristotle and Shakespeare had similar influence powers. In absolute numbers, Aristotle had almost twice the number of Shakespeare's influence links (114 to 73, respectively). While Aristotle influenced all 6 eras, and Shakespeare only 4, the ratio of the links per era decreased for Aristotle, resulting in their similar influence

Table 7 Top scholars, in each era, with respect to *longitudinal influence power*

Antiquity		MiddleAges	
Aristotle	19.0	Thomas Aquinas	12.6
Plato	17.0	Dante Alighieri	6.0
Augustine of Hippo	6.0	Ibn Tufail	5.8
Plotinus	4.7	Avicenna	4.6
Heraclitus	4.2	Al-Ghazali	3.6
EarlyModernPeriod		TransitionPeriod	
William Shakespeare	18.2	Karl Marx	52.6
Baruch Spinoza	14.8	Hegel	45.7
René Descartes	14.0	Immanuel Kant	45.0
John Locke	13.0	Søren Kierkegaard	25.3
David Hume	12.5	Fyodor Dostoyevsky	23.0
ModernAge		ContemporaryHistory	
Friedrich Nietzsche	73.0	Vladimir Nabokov	58.0
Martin Heidegger	45.0	Friedrich Hayek	50.0
Ludwig Wittgenstein	40.0	Richard Pryor	50.0
James Joyce	39.5	Jacques Derrida	48.0
Sigmund Freud	32.0	Michel Foucault	47.0

powers. This measure provides an indicator of the influence power of an intellectual throughout history, and combines both the intensity and the diversity of influence.

Influence power also allows us to compare scholars from different eras. Table 7 shows the top 5 scholars based on the longitudinal influence power. Here, Aristotle, Thomas Aquinas, William Shakespeare, Karl Marx, Friedrich Nietzsche, and the writer Vladimir Nabokov (1899–1977) are identified by their influence power as the most influential intellectuals of their respective periods. The highest longitudinal influence powers over all times had Nietzsche (73), followed by Nabokov (58) and Marx (52).

5.2 Influence patterns

Which directed influences were most common in an era? We derive these influence patterns of eras by replacing any nonzero entries by X of the scholar's influence signatures, and aggregate all occurrences of each pattern for each era. We thus ignore the actual values of influence (intensity), but keep the temporal effect (diversity). For example, the influence pattern $[X, 0, \cdots, 0]$ means that the scholarly influences goes to the first (own) era only, with no influence on other eras. The pattern $[X, X, \cdots, X]$ signifies that the influence is distributed over all applicable eras, regardless of the actual values. Table 8 gives the top patterns of each era with the pattern's frequency of occurrence with regard to the respective era.

For example, for the Middle Ages the most frequent pattern is $[-, X, 0, 0, 0, 0]$, which represents that 56% of scholars only influenced contemporaries with no influences on other eras. Over all eras, the most common pattern was within-era influence, followed by the influence on the consecutive period. Exception to this rule is the Modern period, which experienced the reverse, and had a higher influence on the Contemporary period than on its own. Since the Early Modern period, the pattern of influencing all successive eras including its own becomes more frequent (from 7% on), and rises with each successive period.

6 Brokerage roles

Which roles had scholars in regard to their influence on others? By following the brokerage approach by Gould and Fernandez (Gould and Fernandez 1989), we infer on the roles of scholars by analyzing the non-transitive triads, in which node A has a tie to node B, and B has a tie to node C, but there is no tie between A and C. In these triads, B is thought to play a structural role called a *broker*.

The possible brokerage roles are shown in Fig. 8, which are adapted from the work of Gould and Fernandez in Gould and Fernandez (1989), and Everett and Borgatti (2012). These brokerage roles are:[1]

1. *Coordinator*, where A, B and C all belong to the same group;
2. *Representative*, where A and B belong to one group, and C belongs to another;
3. *Gatekeeper*, where A belongs to one group, and B and C belong to another;
4. *Liaison*, where A, B and C each belong to a different group.

In this paper, we interpret nodal membership in groups as eras. This allows us to consider to what extent a node's importance is based on joining two nodes that are members of the node's own era, or on joining others outside their era.

Table 9 shows, for every type of brokerage roles, and for each era, the top three scholars with that role in that era. The number besides each scholar is the number of non-transitive triads of that scholar w.r.t the specified brokerage role and the specified era. Since reverse links, from an era to an older one, are not allowed (as per preprocessing), some brokerage roles are not possible in some eras. Namely, Representative

[1] There is a fifth brokerage role, the *Consultant*, where A and C belong to one period, and B belongs to another. This role is not possible in our network, as we did not allow reverse influences of a more recent period onto a previous one.

Table 8 Top frequent influence patterns of eras

	AN	MA	EM	TP	MR	CH	
Antiquity	×	0	0	0	0	0	43%
	0	0	0	0	0	×	8%
	0	×	0	0	0	0	7%
	0	0	×	0	0	0	7%
MiddleAges		×	0	0	0	0	56%
		0	×	0	0	0	9%
		×	×	0	0	0	7%
		0	0	0	0	×	6%
EarlyModern			×	0	0	0	51%
			0	×	0	0	13%
			0	0	0	×	7%
			×	×	×	×	7%
Transition				×	0	0	35%
				0	×	0	29%
				×	×	×	11%
				×	×	0	9%
				0	0	×	8%
				0	×	×	7%
ModernAge					0	×	38.8%
					×	0	36.7%
					×	×	24.5%
Contemporary						×	100%

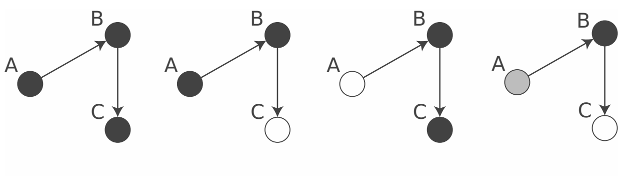


Fig. 8 Brokerage Roles of the top right node of each triad, adapted from Gould and Fernandez (1989) (Gould and Fernandez 1989)

and Liaison brokerage roles are impossible for Contemporary, as well as Liaison and Gatekeeper brokerage roles for Antiquity.

For Coordinator role, A, B and C belong to the same era. Hence, a scholar with this role gets influence from- and influences other scholars from the same era. The scholars with the highest scores for Coordinator in their respective periods are: the ancient Greek philosopher Plato, the medieval polymath Avicenna (980–1037), the Early Modern philosopher John Locke (1632–1704), Johann Goethe (1749–1832), Friedrich Nietzsche (1844–1900), and the contemporary horror writer Stephen King (born 1947).

For Representative role, A and B belong to one era, and C belongs to another (more recent) era. Hence, a scholar with this role gets influence from other scholars from his own era, and influences other scholars from another era. The top scholars with this role are: Plato and Aristotle in Antiquity, Ibn Tufail (1105–1185) and Tomas Aquinas (1225–1274) in Middle Ages, David Hume (1711–1776) and Leibniz (1646–1716) in Early Modern period, Karl Marx (1818–1883) and Hegel (1770–1831) in Transition period, and the modern philosophers Martin Heidegger (1889–1976) and Ludwig Wittgenstein (1889–1951).

For Gatekeeper role, A belongs to one era, and B and C belong to another more recent era. Hence, a scholar with this role gets influence from other scholars from an older era, and influences other scholars from his own era. The top scholars with this role are: Avicenna and Tomas Aquinas in Middle Ages, René Descartes (1596–1650) and John Locke in Early Modern period, Immanuel Kant (1724–1804), Hegel, and Goethe in Transition period, Nietzsche in Modern Age, and the contemporary French philosopher Michel Foucault (1926–1984).

For Liaison role, A, B and C each belong to a different group. Hence, a scholar with this role gets influence from other scholars from an older era, and influences other scholars from another more recent era. The top scholars with this role are: Tomas Aquinas in Middle Ages, the Early Modern

Era	Coordinator		Representative		Gatekeeper		Liaison	
AN	Plato	207	Plato	970				
	Aristotle	71	Aristotle	770				
	Zeno of Citium	47	Augustine of Hippo	137				
MA	Avicenna	61	Thomas Aquinas	503	Avicenna	40	Thomas Aquinas	351
	Thomas Aquinas	50	Ibn Tufail	203	Pseudo-Denys	37	Dante Alighieri	88
	Al-Ghazali	33	Rumi	85	Thomas Aquinas	37	Meister Eckhart	43
EM	John Locke	194	David Hume	686	René Descartes	221	Baruch Spinoza	559
	Leibniz	171	Leibniz	603	John Locke	125	Shakespeare	353
	René Descartes	146	J.J. Rousseau	461	Leibniz	91	René Descartes	351
TP	Goethe	262	Karl Marx	4,094	Immanuel Kant	467	Immanuel Kant	2,496
	Hegel	247	Hegel	901	Hegel	416	Karl Marx	1,666
	Alexander Pushkin	124	Søren Kierkegaard	715	Goethe	361	Hegel	1,532
MR	Nietzsche	339	M. Heidegger	971	Nietzsche	2,808	Nietzsche	3,242
	A. Macedonski	255	L. Wittgenstein	682	A. Macedonski	386	Martin Heidegger	1,243
	Bertrand Russell	223	J.P. Sartre	597	Henri Bergson	365	Samuel Beckett	770
CH	Stephen King	480			Michel Foucault	1,085		
	Gilles Deleuze	400			Jacques Derrida	1,084		
	Michel Foucault	395			Friedrich Hayek	1,007		

Fig. 9 Brokerage Roles

philosopher Baruch Spinoza (1632–1677), Immanuel Kant in Transition period, and Nietzsche in Modern Age.

7 Diffusion dynamics of influence

In order to get insight on how the influence spread throughout the network, and how this spread change over time, we study the diffusion of influence throughout the network, similarly to Ghawi et al. (2019).

We refer to the influence path formed as scholars, influenced by an original scholar, influence other scholars, as a *cascade*; and we refer to the original scholar as the *root* (see Fig. 10). For each scholar, we construct his influence cascade, by considering out-going edges starting from that scholar. However, in order to avoid exhaustive search (due to cyclicity), we construct scholar's cascade as a directed acyclic graph (DAG), i.e., in case of reciprocal edges between a pair of nodes, we arbitrarily choose one of the reciprocal edges. Thus, the result we obtain is a directed acyclic graph (DAG), which we call henceforth a *cascade*.

In order to characterize the influence cascades, we employ the following features as used in Mathew et al. (2018); Vosoughi et al. (2018):

- **Size**: the number of nodes in the DAG which are reachable from the root node, i.e., the total number of unique nodes involved in the cascade.
- **Depth**: the length of the longest path from the root node of the cascade. The depth of a cascade, D, with n nodes is defined as

$$D = \max(d_i), 0 \leq i \leq n$$

where d_i is the distance (length of the shortest path) from the root to node i.

- **Average depth**: the average path length of all nodes reachable from the root node.

$$AD = \frac{1}{n-1} \sum_{i=1}^{n} d_i$$

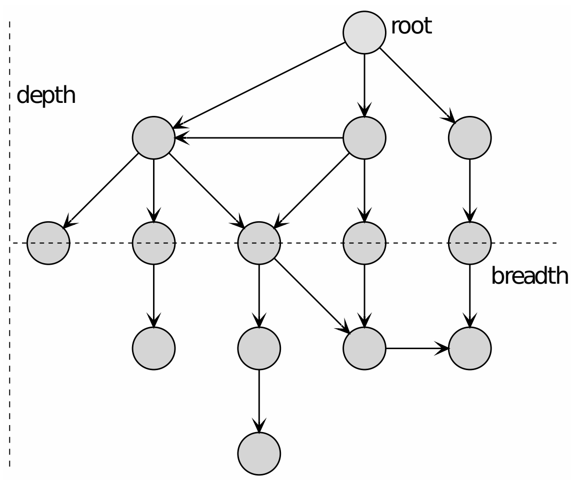


Fig. 10 Influence cascade

Era	Size		Depth		Avg. Depth		Breadth	
Antiquity	Thales	5,725	Moses	17	Moses	9.4	Aesop	2,167
	Anaximander	5,724	Aaron	17	Aaron	9.4	Philo the Dialectician	2,163
	Hesiod	5,723	John the Evangelist	15	John the Evangelist	8.0	Pasicles of Thebes	2,163
	Pherecydes of Syros	5,722	Clement of Alexandria	15	Speusippus	7.8	Diodorus Cronus	2,163
	Pythagoras	5,721	Athanasius of Alexandria	15	Pasicles of Thebes	7.4	Thrasymachus of Corinth	2,163
MiddleAges	Ja'far al-Sadiq	5,478	Abū Ḥanīfa	20	Abū Ḥanīfa	12.1	Al-Ghazali	2,125
	Harbi al-Himyari	5,434	Abu Suhail an-Nafi	20	Abu Suhail an-Nafi	12.1	Al-Juwayni	2,125
	Jābir ibn Hayyān	5,433	Hisham ibn Urwah	20	Hisham ibn Urwah	12.1	Abu Talib al-Makki	2,125
	Muhammad	5,402	Malik ibn Anas	19	Al-Juzajani	11.2	Harith al-Muhasibi	2,125
	Al-Kindi	5,401	Al-Shaybani	19	Ibn Jurayj	11.2	Al-Balkhi	2,104
EarlyModern	Nicholas of Cusa	5,203	William Derham	17	Jan van Scorel	9.2	Samuel Richardson	2,126
	Michel de Montaigne	5,180	John Ray	17	William Derham	8.5	Denis Diderot	2,118
	Francisco Suárez	5,175	Giulio Cesare Croce	17	John Ray	8.5	G-F. Rouelle	2,118
	Gemistus Pletho	5,172	N. Boileau-Despréaux	16	Giulio Cesare Croce	8.5	Pierre Bayle	2,114
	Basilios Bessarion	5,170	Thomas Gray	15	M. van Heemskerck	8.2	John Selden	1,965
Transition	J. N. Tetens	4,699	H. T. Buckle	18	F. K. Forberg	9.9	Oliver Goldsmith	1,960
	J. H. Lambert	4,699	J-F. Millet	18	J-F. Millet	9.3	Goethe	1,895
	Immanuel Kant	4,698	Monticelli	17	H. T. Buckle	9.1	James Macpherson	1,866
	Thomas Reid	4,644	F. K. Forberg	17	Bettina von Arnim	8.9	F. G. Klopstock	1,844
	J. G. Hamann	4,641	Costache Caragiale	16	A. P. de Candolle	8.6	Friedrich Schiller	1,838
ModernAge	Hippolyte Taine	3,675	Anton Mauve	17	Alfred Binet	9.1	Hippolyte Taine	1,357
	African Spir	3,536	Edmund John	17	James Mark Baldwin	9.1	African Spir	1,283
	Jean-Marie Guyau	3,256	Thomas Mann	17	Jacob L. Moreno	9.1	Herbert Spencer	1,071
	Paul Bourget	3,253	Georges Seurat	17	E. E. Cummings	9.0	Nietzsche	1,008
	Paul Rée	3,253	Vasile Pogor	17	Hans Vaihinger	8.9	Paul Bourget	1,008
Contemporary	R. E. Schultes	884	Witold Gombrowicz	15	Kenneth Patchen	8.0	Jean Genet	214
	Witold Gombrowicz	857	Kenneth Patchen	15	Witold Gombrowicz	7.9	Henry Miller	193
	Kenneth Patchen	857	Thomas Bernhard	14	Robert Duncan	7.2	R. E. Schultes	155
	Robert Duncan	856	Allen Ginsberg	14	Allen Ginsberg	7.1	J-T. Desanti	154
	Thomas Bernhard	853	Robert Duncan	14	Thomas Bernhard	6.9	J. L. Austin	148

Fig. 11 Analysis of influence diffusion cascades of scholars. Table shows the top 5 scholars of each era

– **Breadth**: the maximum number of nodes present at any particular depth in the cascade.

$$B = \max(b_j), 0 \le j \le D$$

where b_j denotes the breadth of the cascade at depth j and D denotes the maximum depth of the cascade.

For all scholars, we extracted their cascades, and computed the properties of cascades: size, depth, average depth and breadth. Clearly, there are some nodes that do not have cascades, since they do not have successors (they are not influencers), thus, we had to exclude those scholars. We also excluded cascades of size 1 (scholars who influence one another only). Therefore, we end up with 4,537 cascades (36% of all scholars).

Table 11 shows for each era the top 5 scholars based on the four features of cascades. We observe that top cascades by size and by breadth correspond to Antiquity intellectuals, whereas, top cascades by depth (and avg. depth) correspond to intellectuals of the Middle Ages (Islam theologians).

However, in order to get insight on how the features of those cascades evolve over time, we compare them over the consecutive eras. Figure 12 shows the distribution of the four features (size, breadth, depth, and avg. depth) over the eras; whereas Table 9 provides, for those features, a statistical summary including the mean, median (50% quantile) and maximum, over the different eras.

At a glance, one can see that the size and breadth features exhibit similar behaviors; while the depth and avg. depth features exhibit similar behaviors as well. We observe that the size of cascades decreases over time until it almost vanishes at Contemporary period. At the first four eras (up to Transition Period) this decrease in size is smooth (average size is above 1500 on average), but it becomes more sharp in the last two eras (average size of less than 500 in Modern Age, and only 40 in contemporary). Moreover, we can see from Table 9, that in the first two eras (AN and MA) the mean size is less than the median, which means that the distribution is negatively skewed; but starting from Early Modern Age, the mean becomes greater than the median, hence, the

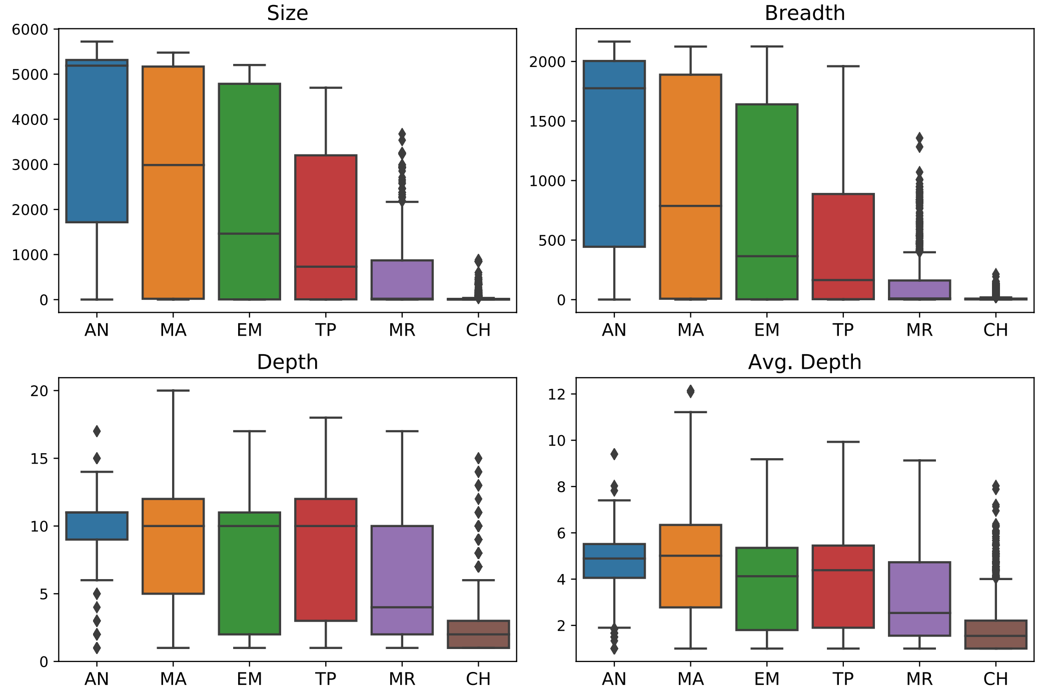


Fig. 12 Distribution of cascades features over eras

Table 9 Statistical summary (average, median and max) of cascade features over the different eras

Era	#	Size			Breadth		
		avg	50%	max	avg	50%	max
AN	177	3857	5189	5723	1371	1775	2167
MA	199	2493	2985	5478	882	787	2125
EM	400	2237	1463	5203	752	365	2126
TP	594	1568	731	4699	455	165	1960
MR	1437	477	20	3675	122	10	1357
CH	1730	40	5	884	13	4	214
Era	#	Depth			Avg. depth		
		avg	50%	max	avg	50%	max
AN	177	9.3	11	17	4.6	4.9	9.4
MA	199	9.1	10	20	5.0	5.0	12.1
EM	400	7.6	10	17	3.9	4.1	9.2
TP	594	7.9	10	18	3.9	4.4	9.9
MR	1437	6.0	4	17	3.2	2.5	9.1
CH	1730	2.9	2	15	1.9	1.5	8.0

distribution is positively skewed. A similar behavior can be observed for the breadth of cascades.

The depth, and avg. depth features also decrease smoothly over time. The median depth is constant (at 10) over three eras, from MA until TP, and drops afterward. We can observe a slight increase in depth and avg. depth in Middle Ages comparing to Antiquity: maximum depth goes from 17 to 20, mean avg.depth goes from 4.6 up to 5.0, and maximum avg-depth goes from 9.4 up to 12.1. Another slight increase in depth and avg. depth is also observed in Transition period

Table 10 Correlation of cascade features

	Breadth	Depth	Avg. depth
Size	0.98	0.71	0.64
Breadth		0.63	0.57
Depth			0.97

comparing to Early-Modern period: mean depth goes from 7.6 to 7.9, maximum depth goes up to 18, median avg-depth goes from 4.1 to 4.4, and maximum avg-depth goes from 9.2 up to 9.9. Moreover, in the first four eras (until TP) the mean depth is less than the median, which means that the distribution is negatively skewed; but starting from Modern Age, the mean depth becomes greater than the median, hence, the distribution becomes positively skewed, with many outliers to the right (high values). The same applies for avg. depth.

Table 10 shows the correlation values between the different features. We can see that there is a very strong correlation between size and breadth (0.98), and between depth and avg. depth (0.97). On the other hand, the correlation between Those values are almost the same over all eras.

In order to get insight on how the cascades evolve over the different eras, Fig. 13 shows scatter plots of several pairs of cascade features.

Figure 13-a shows the relation between the size and the breadth of cascades over time. Besides the linear relation that we can clearly see between these features, we can also observe that in early eras, starting from AN, these features tend to have large values, and over time the values decreases gradually until they become relatively very small at CH. For instance, if we consider the cascades with size $\geq$ 4500 and breadth $\geq$ 1500, the fraction of such large cascades is 66% in Antiquity. This fraction drops to 39% in Middle Ages, 31% in Early Modern, and only 3% in Transition period; then it becomes 0% in Modern and Contemporary periods.

Figure 13-b shows the relation between the size and the depth of cascades over time. We can see that at Antiquity most of the cascades have large values of size and depth, while some cascades have small size and small depth. On the one hand the fraction of large cascades with size $\geq$ 4500 and depth $\geq$ 9 is 69% in Antiquity, and it drops to 39% in MiddleAges, 33% in EarlyModern, and 3% in Transition period, and 0% afterwards. On the other hand, we observe that cascades that have a small depth ($\leq$ 7) have always a very small size ($\leq$ 400). In other words, we can say that the necessary condition to have a non-small size cascade, is to have a depth of at least 8. The fraction of such small cascades increases over time from 23% in Antiquity, to 93% in Contemporary period.

Figure 13-c shows the relation between the depth and the avg. depth of cascades over time. We can clearly see the linear relation between these features (correlation 0.97) over all eras.

Now, in order to characterize this linear relation we apply a linear regression model, using depth as a dependent-, and avg. depth as independent variable. The result is:

$$\text{depth} \sim -1.17 + 2.22 \times \text{avgdepth}$$

Similarly, if we use avgdepth as a dependent-, and depth as independent variable, the result is:

$$\text{avgdepth} \sim 0.67 + 0.42 \times \text{depth}$$

In both cases, the prediction accuracy is pretty high, with $R^2 = 0.94$.

Moreover, in order to characterize the relation between the size of cascades and the other features, we apply a multiple regression model using size as a dependent variable, and depth and breadth as independent variables (we exclude avg. depth to avoid multicollinearity, due to its linearity with depth).

The result of this model is:

$$\text{size} \sim -139 + 52.1 \times \text{depth} + 2.61 \times \text{breadth}$$

with a very high accuracy of $R^2 = 0.98$.

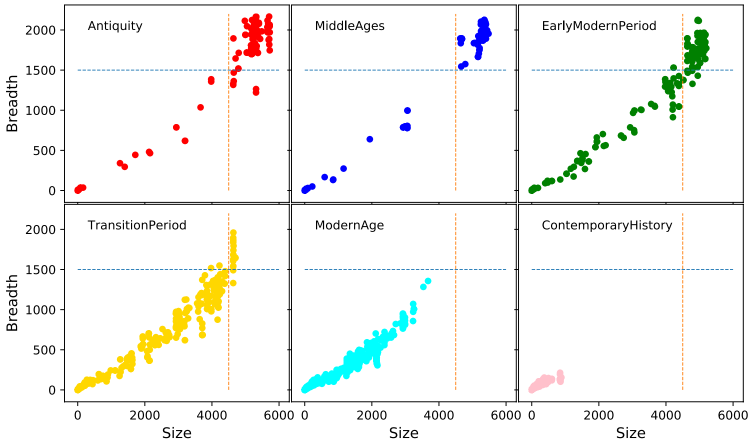
7.1 Clustering of cascades

Based on previous discussion, we notice that most of the cascades tend to have either pretty small values of features, or pretty large values; while intermediate values are little frequent.

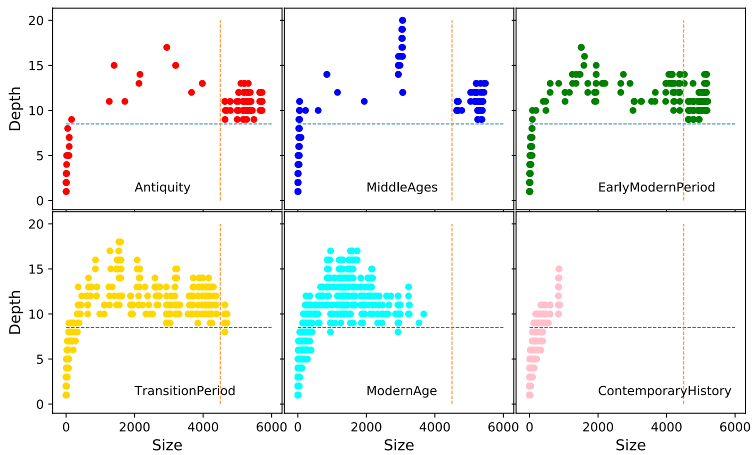
This observation can be verified be looking at Fig. 14 which depicts a kernel density estimate (KDE) plot of each feature, showing the data using a continuous probability density curve. All the four features exhibit two dense regions, that are clearly distinguishable (we approximately separate them using a vertical dashed line), that correspond to small and large cascades.

Moreover, Fig. 15 depicts a violin plot of each feature over all eras, showing the full distribution of features. Here also we can clearly see the two regions, that distinguish small- and large cascades, over the different consecutive eras.

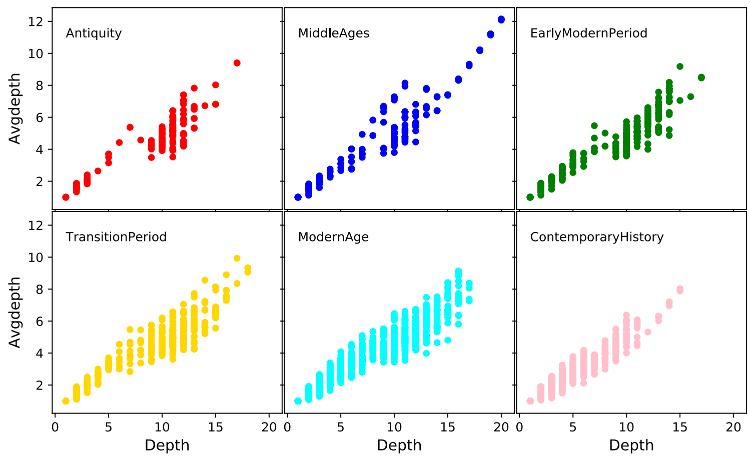
In order to categorize influence cascades based on their aforementioned features, we apply a clustering algorithm, namely K-Means (Lloyd 1982; MacQueen 1967), using the four features of cascades: size, breadth, depth, and avg. depth. The goal is to obtain two clusters of cascades, namely small- and large cascades. Hence, we use $k = 2$ as the number of desired clusters. However, as we have seen, the features are on different scales, for instance, the depth and avg. depth are below 20, while the size and breadth can be above 5000. Therefore, we need to normalize the features



(a) Size, Breadth



(b) Size, Depth



(c) Depth, Avg. Depth

Fig. 13 Relation between features of cascades over eras

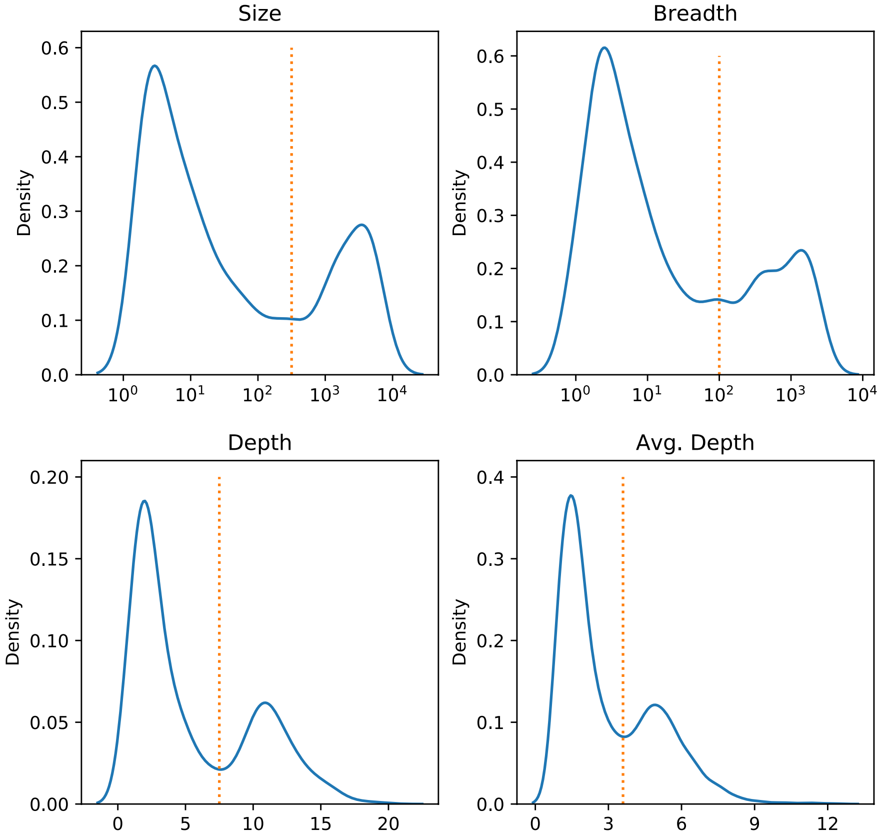


Fig. 14 Density of cascade features, showing a clear distinction between small and large cascades

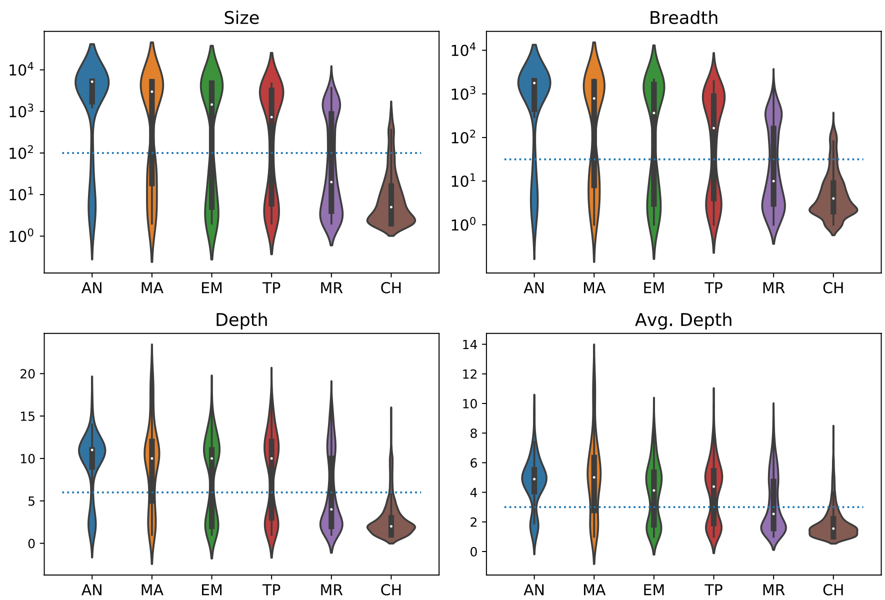


Fig. 15 Distribution of cascade features over eras

Table 11 Statistical summary of the features of small- and large cascades

	Small cascades			Large cascades		
count	3425 (75.5%)			1,112 (24.5%)		
	avg	min	max	avg	min	max
Size	54.4	2	1425	3214.4	653	5723
Depth	3.3	1	13	12.1	8	20
Avg. depth	2.1	1	8.1	5.6	3.4	12.1
Breadth	17.3	1	389	1013.8	102	2167

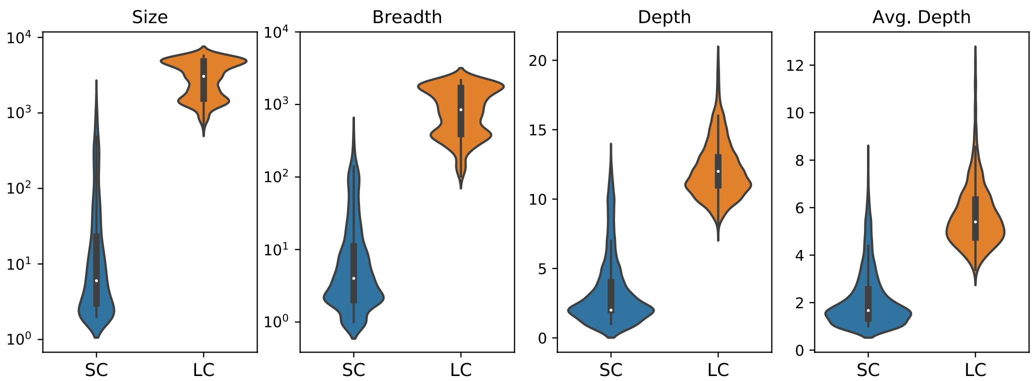


Fig. 16 Feature distribution of the 2 clusters of cascades

to put them on the same scale. This is done by dividing each feature by its maximum, thus each feature becomes in the range [0,1].

As a result of the clustering, we obtain two clusters of cascades, that can be indeed categorized as small cascades (CS), and large cascades (LC). As shown in Table 11, SC cluster comprises 3425 cascades (75.5%), while the remaining 1112 cascades (24.5%) belong to LC cluster.

The differences between the two clusters are clear. For instance, the size of small cascades is 54.5 on average (median = 6), and 3,214.4 for large cascades (median = 3,056). On the other hand, the depth of small cascades is 3.3 on average (median = 2), and 12.1 for large cascades (median 12).

Figure 16 depicts a violin plot for each feature showing its distribution. One can easily see how distinct the two clusters of small- and large-cascades are.

Moreover, we can also look more closely at these two clusters by looking at the scatter plots of Fig. 17, that show the relation between different pairs of cascade features. For instance, when we look at the relation between size and breadth, we see the cluster of small-cascades (blue) located in a small area at bottom-left (size ≤ 1000, and breadth ≤ 400); however, this small area comprises all small cascades that are more than 75% of all cascades!

Finally, it is of great importance to look at how these two clusters of cascades evolve over time. Table 12 shows the number and fraction of cascades in the small- and large-cascade clusters, over the different consecutive eras. We see that, although the raw number of cascades in both clusters gradually increases over time (except for LC in MA and CH), the fraction of small cascades increases, while the fraction of large cascades decreases over time.

This change in the fractions of SC and LC clusters over time is also reflected in Fig. 18. We observe that in Antiquity, about 75% of cascades are classified as large, and 25% as small. In the next three eras, Middle Ages, Early Modern period, and Transition period, small- and large cascades are almost equally distributed (about 50% each). Then, in Modern Age, large cascades make only 25% of cascades, and the remaining 25% are small. During Contemporary History, almost all cascades (99.4%) are small.

This result makes sense and is pretty reasonable. The longer history a scholar has, the more influence he can give, the bigger his legacy is; and the larger his chains of influence become. In other words, the influence cascade of a scholar is somewhat proportional to how long his history is. On the other hand, recent scholars have not yet enough time to develop large cascades of influence.

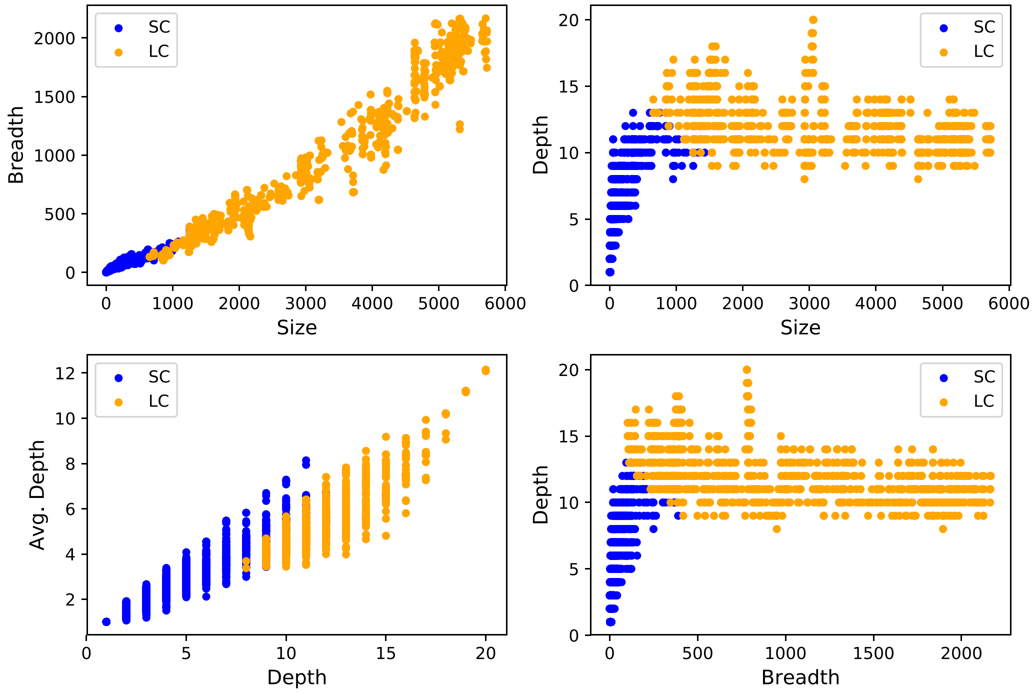


Fig. 17 Distribution of the two clusters of small- and large cascade w.r.t different pairs of features

Table 12 Number and fraction of cascades in small- and large clusters, over eras

	AN	MA	EM	TP	MR	CH
SC	42	87	190	296	1090	1720
	23.7%	43.7%	47.5%	49.8%	75.9%	99.4%
LC	135	112	210	298	347	10
	76.3%	56.3%	52.5%	50.2%	24.1%	0.6%

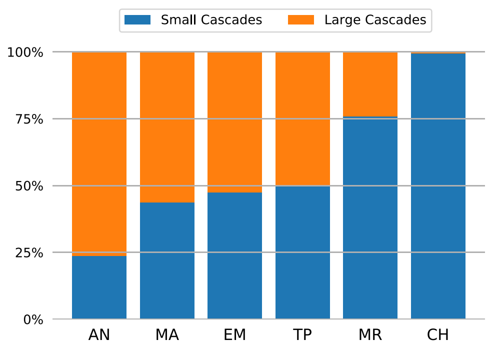


Fig. 18 Fraction of SC and LC clusters over eras

8 Communities of scholars

In order to get deep insights on how the scholars influence each other, we analyze the community structure in the social network of scholars. A community in a social network is a group of nodes that are relatively densely connected to each other but sparsely connected to other dense groups in the network (Porter et al. 2009).

For this purpose, we applied a community detection algorithm, namely InfoMap[2] algorithm (Bohlin et al. 2014), on our complete influence-based social network of scholars (over all eras). As a result, we obtained 1,772 communities. However, since many of those communities are of small size,

[2] InfoMap algorithm is a commonly used community detection algorithm that suits directed networks; it is implemented in the map equation framework.

Table 13 Communities of scholars, top 10 by size. Distribution of member scholars over eras, and notable scholars

#	size	AN	MA	EM	TP	MR	CH	Notable scholars
1	180	0	0	0	0	6	174	R. Pryor, L. Bruce, G. Carlin
2	91	2	2	13	47	12	15	Hegel, Immanuel Kant, Kierkegaard
3	88	2	0	12	14	21	39	F. Hayek, Ludwig von Mises, Adam Smith
4	87	0	0	0	5	28	54	E. Kocbek, F. Prešeren, S. Kosovel
5	65	18	27	13	0	3	4	Thomas Aquinas, René Descartes, Augustine of Hippo
6	60	0	1	0	11	43	5	A. Macedonski, E. Lovinescu, Ion Minulescu
7	60	2	0	0	15	14	29	Karl Marx, L. Althusser, Friedrich Engels
8	60	5	0	19	16	9	11	John Locke, David Hume, John Stuart Mill
9	49	0	0	0	0	21	28	Ludwig Wittgenstein, Bertrand Russell, Rudolf Carnap
10	48	0	0	1	7	25	15	Pablo Picasso, Paul Cézanne, Henri Matisse

we opted to exclude communities that have 5 or less scholars; hence, we have 716 remaining communities.

In each of such detected communities, most of the influence of member scholars goes toward other members of the same community. This means that those scholars belonging to the same community, while influencing each other, are forming a cluster of knowledge, that simulates a school of thought.

It is noteworthy that each of those communities comprises scholars who belong to different eras. This means that the communities are mostly diverse, and open (rather than closed), and evolved over time.

Table 13 provides an overview of the largest 10 communities, sorted by community size (number of member scholars). This table also shows the distribution of member scholars over the different eras, and lists few of notable scholars belonging to that community (top 3 scholars based on out-degree).

The largest community consists of 180 scholars, who are mostly contemporary American actors (mainly comedians). The second largest community comprises 91 scholars, who are mostly philosophers of Transition period, including Hegel, Kant and Kierkegaard. Third and fourth communities, respectively, comprise economists and poets from modern and contemporary periods.

The fifth community mainly comprises scholars from Antiquity and Middle Ages, including Descartes and Tomas Aquinas. Among other noteworthy communities, the community no. 7 which mainly represents the communism school of thought comprising modern and contemporary philosophers such as Marx and Engels; and the community no. 10 which comprises a group of modern famous painters, including Picasso, Cézanne and Matisse.

However, although most of the influence of communities is internal, there is still some observable external influence. That is, in some communities the scholars have influence on other scholars of other communities. Thus, we can measure how a community influences another one by aggregating the influence of individual scholars of the first community on the scholars of the second. In other words, we define the influence of a community A on another community B, denoted $f(A, B)$ as the sum of individual scholar influence over all scholars of A and all scholars of B:

$$f(A,B) = \sum_{a \in A} \sum_{b \in B} f(a,b)$$

where $f(a, b)$ is a function defining the influence of a scholar a on another b, and is given by:

$$f(a,b) = \begin{cases} 1 & \text{if scholar } a \text{ influences scholar } b \\ 0 & \text{otherwise} \end{cases}$$

Using this formula, we calculated the community influence over all possible pairs of the 716 detected communities in our social network of scholars. In fact, there are more than a half million of such pairs of communities; however, only 1% of those pairs exhibit a nonzero influence (about 5 thousand pairs). Even in this tiny portion, for many of these community pairs, the influence was negligible, with value 1 for 73% of cases (i.e., only 1 scholar from one community influences 1 scholar from the other), and value 2 for 16% of cases.

Thus, we opted to retain only the pairs of communities where the value of community influence is greater than or equal 15. The result can be expressed as a directed and weighted network of communities, where the nodes represent the communities, and the directed edges represent the community influence, and the weights represent the aggregated value of individual scholars (of one community towards another). This network of communities is shown in Fig. 19, where each node is labeled by the id of the community, the node size is proportional to the size of the community, the color represents the dominant era of the

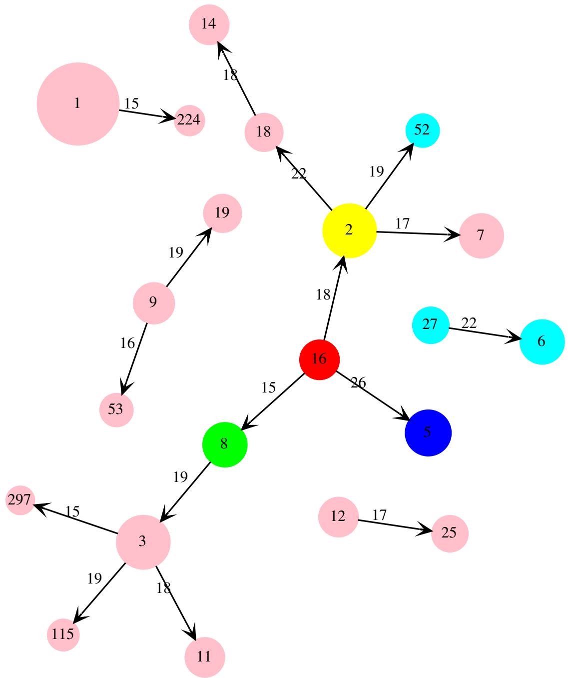


Fig. 19 Network of communities influencing each other

community scholars, and the edges are labeled by the aggregated influence.

For instance, we realize that one of the central communities in this network is the community no. 16, which comprises a group of famous Antiquity scholars, including Aristotle and Plato. This community has a great influence on several other communities, including: community no. 5 (Middle Ages, incl. Descartes and Aquinas), community no. 8 (Early Modern age, incl. John Locke and David Hume), and community no. 2 (Transition period, incl. Hegel and Kant).

9 Conclusion

In this paper, we incorporated a longitudinal aspect in the study of the influence networks of scholars. First, we extracted their social network of influence from YAGO, a pioneering data source of Linked Open Data, which records the main influences of and by intellectuals We opted for a global approach for the periodization of history to match the internationality of scholars, resulting in six consecutive eras to study.

Our main question was whether we could identify patterns of influence, and their change over time. Therefore, we performed essential network analysis on every time-sliced projection of the entire network in within-era, inter-era, and accumulated-era influence networks. We investigated their social network metrics, degree distribution, and connectivity. An influence pattern throughout all eras was that the internal impact of any era was higher than its external impact. The vast majority of scholars influenced scholars of their own period (= within-era influence) with a relatively stable average out-degree. There were only a few instances of reciprocity. When accumulating eras, the max. degrees drastically increased. However, over all eras the maximum out-degree stayed greater than the maximum in-degree. In inter-era influence networks, each era has the most influence on the consecutive one, and the Contemporary period. The exception to this rule was a spike in the absolute links of antique influences on the Early Modern period, representing the increased reception of antique scholars during the Renaissance. However, proportionally Antiquity's influence on Early Modernity was as high as on the Middle Ages, which reasserts the shift in historical research that the Renaissance thinkers did not "rediscover" Antiquity, but that medieval scholars also received it (Fejfer et al. 2003 p. 3–4).

With a longitudinal perspective, we can add a more pronounced view on who the most influential intellectuals are. The scholar with the highest out-degree over all periods on contemporaries (= within-era) was Modern age scholar Friedrich Nietzsche. Plato in Antiquity, Avicenna in the Middle Ages, John Locke in the Early Modern period, Johann Goethe in the Transition period and Vladimir Nabokov in the Contemporary period were the most influential on the contemporaries of their respective periods.

When accumulating eras, the most influential intellectuals of an era change: here, Plato was the most influential for Antiquity and the Middle Ages, Aristotle for the Early Modern and Transitioning period, Immanuel Kant for the Modern Age. In the Contemporary period, and therefore for the complete network of intellectuals, Karl Marx.

In the inter-era network analysis, Transitioning period scholar Karl Marx had the highest out-degree over all times to the Contemporary age. Modern intellectuals Friedrich Nietzsche and Martin Heidegger took second place over all time for the Contemporary period.

To understand the diffusion dynamics of influence, we constructed influence cascades of scholars, and measured their properties, such as size, depth and breadth. First, we found that those properties decrease over time, which means that the influence cascades are larger for older scholars than for more recent ones. We also analyzed the inter-relations between the properties of cascades, and found that they are positively correlated, in particular, size with breadth, and depth with average depth. We also characterized such relations in form of different linear models, with high accuracy.

Moreover, we found out that the cascades are clustered into two categories, namely small- and large cascades. An interesting finding here is that the fraction of small cascades increases over time, while the fraction of larges cascades decreases. In particular, the majority of the cascades in Antiquity belong to the large category, whereas in Middle Ages, Early Modern, and Transition periods the cascades were evenly distributed into the small and the large categories. The large cascades became the minority in Modern Age, and almost disappeared in Contemporary History. Hence, we could conclude that the influence cascade of a scholar is somewhat proportional to how long his history is. The longer history a scholar has, the more influence he can give, the bigger his legacy is; and the larger his chains of influence become.

This study of the longitudinal patterns of influence is such suited to further the insights on the interconnections of influence of thinkers and the dynamics of eras alike. Therefore, we plan to study the evolution of communities in these accumulated networks in future work. Another direction of research would be to study the effects of different periodizations on the importance of scholars, as well as deriving an automated periodization based on the dataset. In addition, we would like to compare this YAGO network of intellectual influence with a more detailed network of scholars based on the main books on intellectual history, in order to establish their differences and insights in this field of study.

Funding Open Access funding enabled and organized by Projekt DEAL.

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Tracking the Evolution of Communities in a Social Network of Intellectual Influences

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In

Journal for Historical Network Research 2021, accepted for publication Sept. 18, 2021.

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Contribution of thesis author

Theoretical operationalization, data preparation, iterative evaluation of computational implementation and analysis, qualitative evaluation and contextualization, as well as manuscript writing, revision, and editing.

Journal of Historical
Network Research

Tracking the Evolution of Communities in a Social Network of Intellectual Influences

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Accepted for publication Sept. 18, 2021.
Manuscript version Sept. 20, 2021.

Abstract

The history of intellectuals consists of a long spanning entangled web of influences, interdependencies, and inspirations. In this paper, we construe the history of intellectuals with the means of a formalized network approach, and analyze structurally how communities form and develop based on their intellectual influences. We are working with a unique data set of Linked Open Data, which we critically reflect on. In this paper we tackle the question if community detection can help us to identify schools of thought, as well as patterns in the influence relations of scholars. We provide a detailed description of the process of extracting Linked Open Data, the construction of longitudinal networks, and the methodology of identifying and evaluating intellectual communities in the dataset using a community detection algorithm. Finally, we track the dynamic evolution of these communities in time, and characterize the structural patterns of their evolution, and the mechanisms of their development. We contextualize the changes in selected network structures in order to establish the merit of this method for a new perspective on the history of intellectuals, their influences, and their ideas.

Keywords longitudinal analysis, social network analysis, history of intellectuals, dynamic networks, community detection, community evolution, big data

1 Introduction

The history of intellectuals consists of a long spanning and entangled web of influences, interdependencies, and inspirations. In this paper, we work with a unique dataset on the influence relations of intellectuals, and explore their communities' formation, development, and dissolution. The history of intellectuals encompasses an abundance of interdisciplinary research fields, including the history of scientific disciplines and methodologies, the history of ideas and of books, and the origins and the anterior social contexts of intellectuals and intellectual thought (Wickberg 2001; Gordon 2013). Research on intellectual history mostly employs a regionally limited perspective within a closed time-frame in order to develop a comprehensive comparative analysis, but lacks an inclusive, global perspective (Haakonssen and Whatmore 2017), as well as focuses on the "usual suspects" of an Eurocentrist view (Subrahmanyam 2017). Attempts to rectify this in a *Global Intellectual History* as by Moyn and Sartori (2013) were criticized to focus on the already well-researched intellectuals despite their transnational approach (Subrahmanyam 2015).

A formalized network approach on the influences of and on intellectuals allows us to re-frame historical research beyond Lovejoy's "unit-ideas" (1936) and extending on Skinner's "contextual history" (1969), focusing on the personal relations and interdependencies of scholars. This follows the idea of philosophers such as Pierre Bourdieu, Karl Mannheim, or Erwin Panofsky on the relational situateness of ideas and intellectuals in their historical and cultural context of the time in a social history of ideas (Ringer 1990, pp. 270–4), as well as on the "conditions and modalities of 'knowledge production'" (Goldman 1994, p. 266). This kind of research is facilitated with the methodologies and tools of the Digital Humanities, which Edelstein (2016) considered a "boon for intellectual history".

In order to answer to the requirements of a global perspective on the history of intellectuals and to harness the prospects of formal network analysis on the study of intellectual history, Ghawi et al. (2019) proposed to study this as a network from a global perspective, and identified, among other things, the most influential scholars in time as those with the longest reaching influences (influence cascades). This analysis was extended in recent work, which introduced a longitudinal perspective on the most central scholars within each period (Petz et al. 2020). In social sciences, longitudinal network analysis is used on panel data to facilitate understanding on the development of and changes in social structures and node characteristics in time by studying temporal snapshots of social networks (Hennig et al. 2012; Newcomb 1961; Huisman and Snijders 2003; Snijders et al. 2010; Holme and Saramäki 2019). In historical studies, panel data are usually not available. In the study by Petz et al. (2020), this was solved by constructing temporal snapshots of networks by dividing the time span of history into periods.

In related work, the epistolary exchanges of Early Modern scholars were mapped as spatial networks (compare, e.g., Edelstein et al. 2017, p. 237). More recent projects on the *Republic of Letters* have incorporated a temporal perspective on them as well (Vugt 2017), which provide challenges to model discrete and continuous time of fuzzy dating (Kudella 2019, p. 50).

Recently, community detection in historical network research gained traction in the analysis of conflict and coalition politics of Medieval sovereigns using the concept of Georg Simmel's Social Circles (Dahmen et al. 2017; Gramsch-

Stehfest 2020) or the identification of communities in the transmission of medieval manuscripts with Gephi as by Férnandez Riva (2019).

In this paper, we are interested in the formation and evolution of intellectual communities in time. In order to study the patterns and mechanisms of intellectual community evolution in time, we test whether we can computationally identify trends in the history of intellectuals. Can we identify schools of thought? Can we identify hidden patterns in the influence relations of scholars? How do these structures change in time? The perspective on the history of intellectuals as organized in network communities serves as a starting point for an analysis of the transformation and evolution of thought.

2 Data and Method

Our dataset is extracted from YAGO[1], a large semantic knowledge base developed by the Max Plank Institute for Informatics in Saarbrücken. YAGO is one of the pioneering contributors of Linked Open Data (LOD), and was alongside DBpedia (Bizer et al. 2009) one of the first to extract semantic knowledge at a large scale from Wikipedia (Suchanek et al. 2007). YAGO compiles information about millions of entities (such as on people, cities, countries, and organizations): mining data from Wikipedia's[2] categories, redirects, and infoboxes, covering synsets or hyponymy from WordNet[3], and matching spatial and topographical entities from GeoNames[4] (Mahdisoltani et al. 2015). These information were compiled with web scraping and text mining techniques which were employed on Wikipedia's infoboxes and categories, as well as natural language processing applied on e.g., entity disambiguation and result filtering. In YAGO, the resulting data were merged with the DBpedia ontology[5] and the SUMO ontology[6]. The accuracy of YAGO's data has been manually evaluated above 95%. We work with the YAGO3 version (released in 2015, which we extracted in 2018), which features over 10 million entities and over 120 million entries on their attributes.
In the following, we will first describe the extraction process of the YAGO influence relation and the pre-processing of the dataset, in which we enriched the dataset with a temporal, spatial and disciplines dimension, as well as the process of constructing longitudinal networks. Subsequently, we will discuss the peculiarities and possible biases of the dataset presented.

Mining a social network of intellectuals from YAGO

Most LOD sources, including YAGO, are typically represented using RDF (Resource Description Framework), which is the W3C[7] standard for representing information in the Semantic Web (Manola and Miller 2004). RDF is a data

1. Yet Another Great Ontology
2. https://www.wikipedia.org
3. https://wordnet.princeton.edu
4. https://www.geonames.org
5. http://www.mpi-inf.mpg.de/departments/databases-and-informationsystems/research/yago-naga/yago/linking/
6. http://www.mpi-inf.mpg.de/ gdemelo/yagosumo/
7. World Wide Web Consortium https://www.w3.org/

Table 1: Examples of influence relations

Ibn_Tufail	yago:influences	Christiaan_Huygens
Ibn_Tufail	yago:influences	Immanuel_Kant
Ibn_Tufail	yago:influences	Isaac_Newton
René_Descartes	yago:influences	Christiaan_Huygens
René_Descartes	yago:influences	Immanuel_Kant
René_Descartes	yago:influences	Isaac_Newton
Johannes_Kepler	yago:influences	Isaac_Newton
Maimonides	yago:influences	Isaac_Newton
Christiaan_Huygens	yago:influences	Isaac_Newton
Francis_Bacon	yago:influences	Isaac_Newton
Isaac_Newton	yago:influences	Abraham_de_Moivre
Isaac_Newton	yago:influences	Immanuel_Kant
Isaac_Newton	yago:influences	Voltaire
Baruch_Spinoza	yago:influences	Immanuel_Kant

model, where each piece of information (called statement or fact) is structured in a triple of the form:

$$(\text{subject}, \text{predicate}, \text{object})$$

where subject and object are labeled as noted, connected by an edge labeled predicate. The standard query language for RDF is SPARQL (Prud'hommeaux and Seaborne 2008; Harris and Seaborne 2013), which became a W3C recommendation in 2008. As argued by Ghawi and Pfeffer (2019, 2020), Linked Open Data can be used as a source of information to extract social networks among entities, using various extraction patterns expressed in the SPARQL query language.

YAGO includes a predicate labeled `yago:influences`, that relates intellectuals based on their influence relationships as recorded in Wikipedia's infoboxes. The accuracy of the `yago:influences` relation was evaluated with a confidence score of 0.96 by YAGO. We are particularly interested in this predicate to extract an influence social network among intellectuals. Table 1 shows a sample of RDF triples from YAGO, depicting the influence relation among several intellectuals. To extract our target influence social network, we used a SPARQL query as shown in Figure 1. The query has been executed over YAGO's SPARQL endpoint.[8]

Figure 1: SPARQL query used to extract the influence social network

```
SELECT ?u ?v
WHERE {
  ?u yago:influences ?v.
}
```

This query returns all pairs (u, v) of entities (scholars in our case) that are connected via the `yago:influences` relation, or in other words, if entity u influences entity v. We then use the result of this query as the basic edge-list for the influence network of intellectuals, in which nodes constitute the raw data

8. https://linkeddata1.calcul.u-psud.fr/sparql, as of July 2019.

base of intellectuals available. The raw dataset comprises 12,705 nodes and 22,818 edges, as reported in Ghawi et al. (2019).

Intellectuals and their influences in YAGO

As the influence relations in YAGO are originating from Wikipedia, any findings of this study using a dataset extracted from YAGO3 perforce reflect the knowledge hosted there. There are several important points to reflect on the type of intellectuals and influence recorded. Intellectual is a broad category in YAGO following its historical dimensions that there is no "single definition of the intellectual's condition that applies universally" as Ringer (1990, p. 281) noted, and we might add with Wickberg (2001, p. 387) that a generalization of intellectuals as a social type would not be historically correct. YAGO's intellectuals entail philosophers, writers, and scholars of the natural sciences as well as artists, mathematicians, physicians, polymaths, musicians, and more, among which an illustrious list of polar explorers. These intellectuals appear in our dataset if there was a known influence from and to other intellectuals; the influences recorded are based on their main influences, and are therefore not exhaustive.[9] The information on such included intellectuals and their main influences are originating from Wikipedia, and as such represent a crowd-sourced and semi-popular knowledge on intellectuals in history. Wikipedia is an online encyclopedia that provides the "primary source of knowledge for a huge number of people around the world" (Anderka 2013, p. 12), which reliability of information is ensured with consistent "major peer review activity" (Viseur 2014, p. 3). Due to the professionalization of Wikipedia in the last decade[10] , this collection of scholars closely represents the current state of research, and encompasses what can be considered the main intellectuals in history (though not exhaustive). The intellectuals recorded in YAGO can be considered biased as they are focused on major figures, and specifically, on men.[11] While scholars like pioneering psychologist Leta Stetter Hollington (1886–1939) are missing from our dataset[12], the philosopher Émilie Du Châtelet (1706–1749) actually is included. Of seven female philosophers from the Early Modern Period highlighted by *Project Vox* (Duke University Libraries), three appear in our dataset.[13]
To conclude, the dataset offers an *abstract* form of the history of intellectuals, which records the most important influences of the most important intellectuals reflecting closely the current state of research as added by the crowed-sourced Linked Open Data community – similar to the broad strokes of a *Meistererzählung* (master narrative). Any findings necessarily iterate the representation

9. So for example, the Medieval writer Bernardus Silvestris (1085–c. 1160) is not included in the dataset, whose allegorical philosophical work on the birth of the universe ("Cosmographia") heavily influenced the "father of English poetry" Geoffrey Chaucer (c. 1340–1400). The latter is actually included in the dataset, but his main influence is recorded as Ovid.

10. This entails regular proof-reading, peer-reviewing, and facilitated reversals of vandalized articles using the MediaWiki software (Anderka 2013, p. 9).

11. WikiProject *Women in Red* by Roger Bamkin (Wikipedia) and *Project Vox* at Duke University Libraries are initiatives designed to raise awareness about the "gender gap" in Wikipedia: the absence of female scientist's entries, and their higher probability to be deleted (Krämer 2019). In 2016, 16.72% of English entries in Wikipedia were about women (Stephenson-Goodknight 2016); by 2019, this number was raised to 18% (Krämer 2019). These more recent developments are not included in YAGO3, which was created in 2015.

12. Whose Wikipedia page was introduced later than the YAGO3 database from 2015.

13. These are Mary Astell, Du Châtelet, and Anne Conway

on YAGO, and as such on Wikipedia.

Adding a temporal dimension

We expanded the dataset with birth and death dates of each scholar in order to incorporate a temporal dimension to analysis.[14] We used the SPARQL query shown in Figure 2, where the predicates `wasBornOnDate` and `diedOnDate` were used to retrieve birth and death dates of the scholars in our dataset. Since a scholar could be an influencer or be influenced, their entity would appear in the subject or object positions of the triple pattern. Therefore, the query contained a combination of both patterns using an `UNION` operator. Since the data set may not have information about the birth date or the death date (or both) of some scholars, the triple patterns to retrieve those dates are stated as optional.

Figure 2: SPARQL query to extract birth and death dates

```
SELECT ?u ?birthDate ?deathDate
WHERE {
  { SELECT DISTINCT ?u WHERE {
      { ?u yago:influences ?v. }
       UNION
      { ?v yago:influences ?u. }
  } }
 OPTIONAL {?u yago:wasBornOnDate ?birthDate.}
 OPTIONAL {?u yago:diedOnDate    ?deathDate.}
}
```

The results of this query are as follows:

- 8,073 entities have both dates (119 of them had errors: death dates before birth dates, which had to be manually corrected).
- 4,030 entities have birth date, but no death date.
- 82 entities have death date, but no birth date.
- 520 entities have neither dates.

Some entities had no birth or death dates recorded; we corrected such missing information by schematically adding/subtracting 60 years from the birth/death date[15] up to the symbolic year of 2020, in order to get a broad estimation of their lifetime and later periodization. When both dates were missing, we verified those manually. In the course of the data processing, we removed entities that were either conceptual actors, legendary figures, or groups, as e.g., the "Megarian_school" or "Gilgamesh". The interim dataset consisted of 12,577 scholars with complete birth and death dates.

14. Compare the following data preparation and cleaning procedures to Petz et al. (2020).
15. This process is then followed by another data verification, when introducing a periodization into which the scholars are mapped, as described in the following parts.

Table 2: Overview on Eras

Abbrv.	Era	Start	End
AN	Antiquity		600
MA	Middle Ages	600	1350
EM	Early Modern Period	1350	1760
TP	Transitioning Period	1760	1870
MA	Modern Age	1870	1945

Mapping scholars into a periodization of time

In order to derive to a longitudinal perspective on a static network, we compartmentalized the time-span of history manually into consecutive periods (or: eras) into which we embedded the scholars. From this perspective, influences on the micro-level can be studied as influences on macro-level among periods of history. We used the global periodization introduced in Petz et al. (2020) to map scholars into eras that inferred five consecutive eras based on Osterhammel's global periodization (2006), as seen in Table 2. We decided for a global perspective on the periodization in order to cater to the internationality of intellectual networks and their heterogeneous origins, and to satisfy the criticized lack of international outlook in intellectual history.[16] We left out the Contemporary period starting in 1945, as for this study we focused on the periods up to the Contemporary age. Of course any periodization is a construction to facilitate research, and as such dependents on the specific caesura for the respective research field (Pot 1999, p. 63; Osterhammel 2006, pp. 50–51).

Then, every intellectual was assigned to an unambiguous period. In the process of this, we corrected outliers that resulted from different dating (e.g., dates recorded in YAGO in the Hijri calendar instead of the Gregorian, or missing negative signs for BC). We rectified some outliers of impossible influence relations from a later period to an earlier one, which resulted from wrongly switched influence relations and/or when the lifespans of a scholar influencing another were drastically different, thus eliciting chronologically reverse links of eras. Finally we mapped ambiguous period membership of scholars, who fit more than one era, into a single essential period. The approach of a single period membership avoids redundancy, and offers a more intuitive perspective to the longitudinal structure of the networks in order to grasp macro changes in their influence relations.

Adding a spatial dimension, and disciplines

As we are interested in identifying schools of thought, we manually established the geographic domain of agency for each intellectual in the dataset (compare to Table 3), and surveyed their main disciplines, which we structured into 14 container categories[17] (see Table 4). These disciplines entail the main area of

16. Compare this also to the discussion.

17. These container categories are sometimes of anachronistic nature as e.g., "social studies" as a field developed only in modern time, but which term we used to group historians, anthropologists, and social scientists into. Also while "writer" as a category could be used for each intellectual in the dataset, we only grouped those in there that worked as poets, journalists, or essayists, and who did not work more prominently in the other fields.

Table 3: Overview on Geo-categories

Abbrv.	Geo-Category	Notes
GR	Ancient Greeks and Romans	
EU	Europe	
AR	Arab world	including Near and Middle East, "Al-Andalus", Ottoman Empire, and Modern Turkey
AS	Asia	e.g., India, China, and Japan
AM	North America	
OT	Others	Oceania, Africa and South America

Table 4: Overview on Disciplines

Abbrv.	Discipline	Notes
wrt	writer	poets, journalists, essayists
art	art	painters, sculptors
phl	philosophy	
bio	bio-sciences	e.g. biology, physics, chemistry, geology
rel	religious studies	e.g., theology, mystics
soc	social studies	e.g., sociology, anthropology, history
med	medicine	
pol	political field	e.g., politicians, military, statesmen
mat	mathematics	including statistics
eco	economy	including businessmen
leg	legal studies	e.g. judges, jurists, lawyers
lan	language studies	e.g., linguistics, translation, grammar
eng	engineering	including architecture
ply	polymath	

Table 5: A snippet of the final dataset of scholars.

actor	dob	dod	era	region	discipline
Ibn_Tufail	1105	1185	MA	AR	ply
Maimonides	1135	1204	MA	AR	ply
Francis_Bacon	1561	1626	EM	EU	phl
Johannes_Kepler	1571	1630	EM	EU	bio
René_Descartes	1596	1650	EM	EU	phl, mat
Christiaan_Huygens	1629	1695	EM	EU	med
Baruch_Spinoza	1632	1677	EM	EU	phl
Isaac_Newton	1642	1727	EM	EU	ply
Abraham_de_Moivre	1667	1754	EM	EU	mat
Voltaire	1694	1778	EM	EU	phl
Immanuel_Kant	1724	1804	TP	EU	phl

Table 6: Accumulated-Era Networks.

Era	Nodes	Edges
Antiquity	209	313
Middle Ages	5,41	786
Early Modern Period	1,212	1,765
Transition Period	2,123	3,223
Modern Age	4,666	7,803

work of a scholar.

For the survey of these attributes, we employed a human annotation process, which involved dividing the dataset into ten chunks and manually classifying the main disciplines and geo-location for each intellectual. These annotations were then manually verified. We found further 32 entities to be either non-intellectual inspirations[18] or groups which members already existed in the dataset, which we removed. The final cleaned dataset consists of 5,287 intellectuals in the network with 7,803 influence relations. Table 5 shows a snippet of our final dataset of scholars, where each scholar is associated with his birth and death dates, era, geo-category, and main discipline(s).

Constructing Longitudinal Networks

We constructed longitudinal network snapshots of the original complete network by subsampling the dataset according to the five consecutive periods (also referred to as eras, compare to Table 2) in order to transform the static final network into a series of time-steps. By adding these time-slices of the original network in consecutive order, we derive to five progressively *accumulated networks*, which consist of all influence links of scholars up to and including a target period. For example, the first accumulated network (the Antiquity network) consists of all scholars from Antiquity era only; whereas the second accumulated network (the Middle Ages network) consists of all scholars from Antiquity and the Middle Ages, and so on. The last accumulated network (the Modern Age network) consists of all scholars of all eras, hence, it is equivalent

18. Such as the sailor Owen Chase, whose biography inspired the story of Moby Dick by Hermann Melville.

to the original (complete) network. Table 6 gives an overview on the number of nodes and edges in each accumulated network.

In the following, we describe the network properties of the influence relations of scholars and their time-sliced network projections, and investigate on their communities detected trough a community detection algorithm. For analysis, we created directed graphs for each time-sliced network with the *Python::NetworkX* library (Hagberg et al. 2008).

3 General Data Exploration

After enriching of the dataset in preprocessing, we are able to characterize the dataset of international scholars more thoroughly. In the following we examine the characteristics of scholars in the three dimensions of disciplines, regions, and eras (compare to Figure 3).

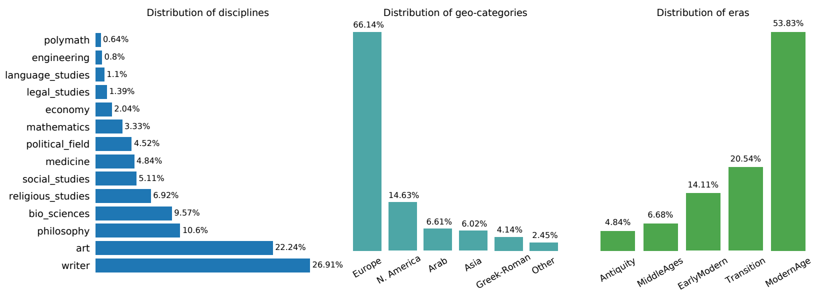


Figure 3: Distributions of Disciplines, Regions, and Eras

The most frequent profession in the database of scholars is *writer* (27%), followed by *arts* (22%), and *philosophy* (11%). The least frequent disciplines are *polymaths* and *engineering* with $< 1\%$ each, catering to the relative rarity of polymathy and the recentness of the engineering as a discipline. While the dataset takes a global stance, the majority of scholars are from Europe (EU, 66%), followed by North America (AM, 15%) and the Arab world (AR, 7%). The least frequent geo-categories of Oceania, South America, and Africa, which we summarized in the container category OT, constitute together less than 3% of all scholars.
Despite its global representation, we can observe a relative bias of favoring the West in the dataset. For what we defined as the Arab World intellectuals are relatively well represented for the Medieval era (as a nod to the Islamic Golden Age, in Baghdad as well as in Cordoba), for most of Africa there are almost no scholars, as well as for South America, and only a scrape on the surface of the rich intellectual history of Asia. There is also a prevalence of more recent scholars in the dataset: the percentage of scholars per era continuously increased in time from 4.8% of all scholars in Antiquity to 53.8% in Modern Age.

In order to explore the interdependencies among the three dimensions (eras, regions and disciplines), we examine the frequency distribution of scholars over the different combinations of dimensions. Figure 4 shows three 2-dimensional matrices, in which each corresponds to a pair of dimensions: era–discipline,

Era × Discipline (top)

	wrt	art	phl	bio	rel	soc	med	pol	mat	eco	leg	lan	eng	ply
AN	48	4	134	11	28	14	27		14		4	3		1
MA	61	23	57	41	154	30	19	9	30		27	17		17
EM	149	271	101	68	99	26	29	13	42	7	20	7	6	13
TP	319	219	116	204	50	67	78	60	44	26	21	13	12	9
MR	954	688	255	264	117	208	170	212	87	93	34	36	33	10

Region × Era (left)

Region	AN	MA	EM	TP	MR
GR	217	3			
EU		75	655	892	1907
AR	13	232	37	17	54
AS	28	44	43	27	179
AM			9	139	652
OT			2	22	112

Region × Discipline (center)

	wrt	art	phl	bio	rel	soc	med	pol	mat	eco	leg	lan	eng	ply
GR	44	4	122	9	19	13	18		14		4	2		
EU	1005	886	422	416	193	224	174	233	161	84	44	47	36	28
AR	91	4	37	42	159	41	27	9	21		31	16		17
AS	140	44	41	10	60	10	37	3	8	3	4	6		2
AM	186	258	39	113	19	57	56	59	16	39	19	5	14	2
OT	74	28	8	16	2	7	15	4		1	4		2	2

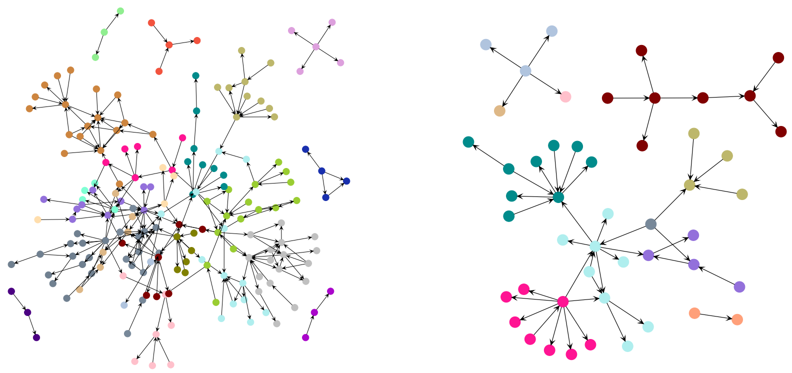
Figure 4: Frequency distribution of scholars per Region–Era (left), per Era–Discipline (top), and per Region–Discipline (center). Read like: Frequency of scholars with characteristics *row* and *column*.

region–era, and region–discipline.

The first matrix (top) shows the distribution of scholars per era–discipline combination. We can see that the dominant discipline in Antiquity was *philosophy*, while in the Middle Ages it was *religious studies*, and in the Early Modern period *arts*. In all three eras, the second most prominent profession was *writer*, which became the dominant discipline in the Transitioning period and Modern age.

The second matrix (left) shows the distribution of scholars per region-era combinations. We can see that the majority of scholars in Antiquity were from Greek and Roman Antiquity (GR), while in the Middle Ages they were from the Arab world (AR). This reveals another peculiarity of the dataset: we located Greek and Roman Antique thinkers in this category, and not counted them toward European scholars.

The Arab regional subset has most of its information on Medieval scholars, therefore showing a relative increase during the Medieval period. This could be owed to the circumstance that Medieval research in the Arab world was more centralized than in Europe at the time. In Europe, decentralized Monastic learning was only replaced by the establishment of universities in an intellectual revolution during the 12th century (Burke 2000, p. 36; Lutz-Bachmann 2003, p. 133), therefore resulting in differences in intellectual influence genealogies. In the Arab world, college-like institutions already existed before that – who are thought to have been influential on the creation of the first colleges in Europe, albeit with the difference that they were "fluid system[s]" with an informality to teaching (Burke 2000, pp. 49-50, Quote on p. 50) and a focus on prominent teachers instead of institutions (Berkey [1992] 2014, p. 16).[19] When



(a) AR (b) EU

Figure 5: Medieval period influence networks of two sub-samples of scholars located in AR and EU, respectively. Communities are indicated in colors; communities of size < 3 are not shown (for the community detection process, please refer to section 4).

comparing the networks of a sub-sample of AR and EU, respectively, the thesis on the greater centralization and interconnection of scholarship in AR during the Middle Ages finds further support: of the AR sub-sample, 79% of scholars (171 out of 215 in total) cluster in the largest weakly connected component – in comparison to the 69% scholars (34 out of 49 in total) in the EU sub-sample graph (compare to Figure 5). This difference is even more remarkable, when the difference in the amount of scholars is put into account: the AR sub-sample hosted more than 4 times the amount of scholar than in the EU sub-sample.

In order to explore the influence relations among aggregated scholars in the different categories of each dimension (era, region, discipline), we look at the distribution of influence relations of a scholar over the different combinations of those categories, i.e. the characteristics of a scholar influencing another one. Figure 6 shows three 2-dimensional matrices, each corresponds to one of the dimensions, and iterates the absolute frequency of scholars in each category. These matrices show the aggregated frequency of intellectuals (with characteristic in *row*) dependent on the three dimensions (era, region, discipline) influencing likewise aggregated intellectuals (with characteristic in *column*), i.e. the number of scholars from the AR that influence scholars in AS. The first matrix (Figure 6, top-left) shows the influence relations between the different eras. We can see that each period was mostly influenced by (scholars from) itself, except for the Transitioning period which had more out-going influences to Modern Age. The second matrix (Figure 6, bottom-left) shows the influence relations between the different regions. We can see that the influence received by each region comes

19. It might be noted here, that Medieval European universities were also much less formalized before 1800 (Burke 2000, p. 50).

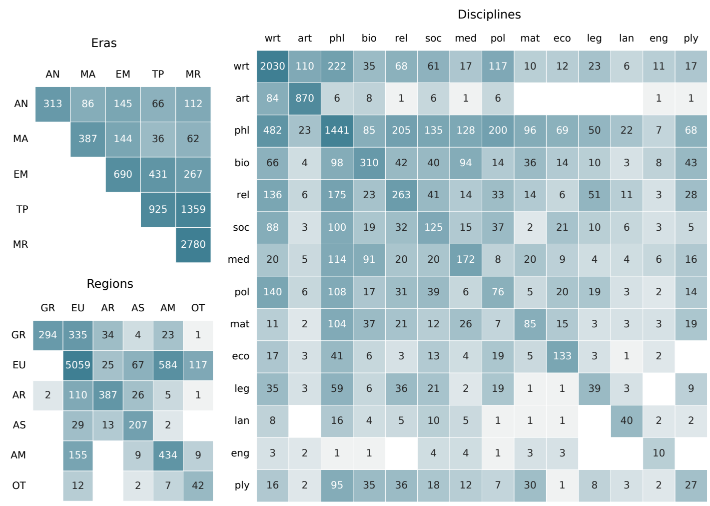


Figure 6: Influence relations between eras (top-left), between regions (bottom-left), and between disciplines (right). Read like: Frequency of scholars with characteristic (in *row*) who influence scholars with characteristic (in *column*).

from that region itself, except for AM and OT, which received more influences from EU than from themselves. We can also note that each era influenced itself the most, except for GR, which influenced EU more than itself.

The third matrix (Figure 6, right) shows the influence relations between the different disciplines. There, scholars usually influence other scholars from their own disciplines, as well as *writers*.

In the following sections, we develop a method to detect communities and study the patterns of community evolution of intellectuals over time, space and disciplines, as well as the structural dynamics of eras, and identify mechanism regarding their development.

4 Community Detection

Most social networks exhibit community structures: their nodes are organized into groups, called communities or clusters, where each group's nodes have a higher probability of being connected to each other than to members of other groups (Fortunato 2010). Pairs of nodes are more likely to be connected if they are both members of the same community, and less likely to be connected if they do not share communities. Identifying communities may offer insight on how the network is organized; it helps to classify nodes based on their role with respect to the communities they belong to. The problem of detecting communities in a network has been extensively studied in the literature, and several methods for community finding have been developed.[20]

In a social network, a community can be considered a set of entities closer con-

20. We refer to Fortunato (2010) for a comprehensive survey.

nected to each other than to the rest of the entities in the network (Girvan and Newman 2002), e.g., through more intense interaction with each other (Leskovec et al. 2008). This closeness is based on similarity, and implicitly assumes an underlying structuring principle of homophily (Dakiche et al. 2019, p. 1085; see also McPherson et al. 2001).

As discussed before, we constructed five accumulated networks of scholars over the five eras. In this paper, our goal is to study the evolution of communities of scholars over time. The method to do so consists of the following steps:

- First we apply a community detection algorithm on these accumulative networks, and
- Then we apply an algorithm to track the evolution of communities over time in the five consecutive eras.

In this section we present the first step of community detection, whereas we present the second step of tracking the community evolution in the next section.

Finding communities with the InfoMap algorithm

We opted to use the *InfoMap community detection algorithm* for directed networks as implemented in the map equation framework by Bohlin et al. (2014). The core of the InfoMap algorithm follows closely the Louvain method (Blondel et al. 2008), where neighboring nodes are joined into modules (clusters), which subsequently are joined into supermodules. The InfoMap algorithm allows to detect communities in directed networks, which we applied on the accumulated influence networks of intellectuals, consisting of all influence links among scholars who lived up to and including target era.

Since the InfoMap two-level algorithm is based on random walks, it would provide different results each time when executed on the same network. Accordingly, we developed an evaluation method to choose the most coherent results: We opt to base such evaluation on the homogeneity of these communities based on the attributes we surveyed in preprocessing. Thus, we define the following *diversity measure*:

Let A be a group of items (duplicates allowed) of size L (number of all items), and let N be the number of unique items in A, we define the diversity of this group as:

$$\text{diversity}(A) = \begin{cases} 0 & \text{if } L = 1 \\ \frac{N-1}{L-1} & \text{otherwise} \end{cases} \tag{1}$$

This measure will equal 1, when the group is completely heterogeneous (e.g., if all items are different: $N = L$), and will equal 0 when it is completely homogeneous (e.g., all items are the same: $N = 1$). We can use this measure to assess the diversity of a group of scholars with respect to any dimension, where the items are the categories of that group's members according to the given dimension. For instance, if a community consists of two scholars from Antiquity, and three scholars from the Middle Ages, its diversity according to this measure is: $\frac{2-1}{5-1} = 0.25$.

In the process of detecting communities, we used this diversity measure to evaluate the obtained results. For each era, we executed the community detection algorithm 10 times with a different randomization seed[21] each (henceforward referenced as clustering run). For each run, we established the diversity of the clustering results by calculating the diversity of each community with regard to their homogeneity in disciplines, regions, and eras. These results we combined with a weighted average, using the weights of 45% for disciplines, 30% for regions, and 25% for eras respectively.[22] The diversity of the clustering run is then calculated as the average diversity of the communities detected in each accumulated network.[23] Out of this sample of 10 randomized clustering runs, we chose the initial seed of the clustering run that minimized diversity, namely, the run with the most homogeneous set of communities.

Characterising these communities

When applying the community detection algorithm, we obtain a set of communities for each accumulative-era network. Table 7 shows for each era the number of detected communities (C), the number of communities with size > 3 (C'), the size (number of nodes) of the top three largest communities (LC_1, LC_2, LC_3). and the average number of members per community M. We clearly observe an increase in the number of communities, which is a result of the increasing number of scholars in the longitudinal accumulation.

Table 7: Overview on the sizes of detected communities per era. N: No. of nodes, C: No. of communities, C': No. of communities with size > 3, LC_i: i^{th} largest community, M: average members per community, D_e, D_g, D_d: diversity of eras, regions and disciplines, respectively. When the diversity measure is closer to 0, the community is more homogeneous.

Era	N	C	C'	$\|LC_1\|$	$\|LC_2\|$	$\|LC_3\|$	M	D_e	D_g	D_d
Antiquity	209	31	21	19	13	13	6.74	0.00	0.085	0.31
MiddleAges	541	80	53	21	19	19	6.76	0.05	0.089	0.50
EarlyModern	1212	201	103	41	29	29	6.03	0.07	0.072	0.37
TransitionP.	2123	361	179	51	50	42	5.88	0.12	0.063	0.36
ModernAge	4666	726	365	66	52	48	6.43	0.14	0.103	0.33

For each era and over all communities of each era, Table 7 shows the average diversity with respect to eras (D_e), geo-categories (D_g), and disciplines (D_d). We observe that the communities of scholars exhibit a very low diversity with respect to eras and regions over all the consecutive eras, i.e. in any community there is one major era and one major region to which most of the members belong. On the other hand, communities exhibit a relatively intermediate level of diversity with respect to disciplines over all eras even though this

21. The randomization seed is the entry configuration of the algorithm.

22. We weighted disciplines the highest, as these we found the main reason for community formation, following the observations in Figure 6. Regional location influences the formation of ties; however these spatial distances are not unbridgeable, and following the line of thought of Baring (2016), connection should weight more in a truly transnational perspective. We weighted the influence of eras the least as we perceived this is an trivial difference between scholars from different time frames.

23. In future work, a robustness analysis could evaluate changes in the diversity measure, if different or multiple disciplines would be recorded for each intellectual (instead of this analysis' focus on only one main discipline), as. e.g. Voltaire in the category *writer* as a poet instead of (or including) *philosophy* as an Enlightenment philosopher.

Table 8: Overview on the composition of the largest communities in each era.

Era	#	$\lvert C\rvert$	eras	regions	disciplines	notable scholars
Antiquity (AN)	1	19	AN 100%	GK 95%	phl 95%	Plato, Aristotle, Socrates
	2	13	AN 100%	RO 65%	wrt 88%	Virgil, Ovid, Theocritus
	3	13	AN 100%	IN 77%	pol 77%	Buddha, Ashoka, Mahavira
	4	12	AN 100%	GK 58%	phl 88%	Augustine of Hippo, Proclus, Boethius
	5	11	AN 100%	GK 100%	phl 100%	Arcesilaus, Carneades, Xenocrates
MiddleAges (MA)	1	21	AN 95%	GK 90%	phl 95%	Plato, Aristotle, Socrates
	2	19	MA 100%	AR 95%	wrt 64%	Ganjavi, Al-Hallaj, Omar Khayyám
	3	19	AN 89%	GK 55%	phl 71%	Plotinus, Augustine of Hippo, the Areopagite
	4	17	MA 100%	AR 100%	rel 76%	Ahmad ibn Hanbal, al-Bukhari, Abu Dawood
	5	17	MA 94%	AR 71%	phl 30%	Ibn Tufail, Averroes, Maimonides
EarlyModern (EM)	1	41	MA 51%	EU 54%	phl 48%	Thomas Aquinas, Plotinus, Augustine of Hippo
	2	29	EM 93%	EU 93%	phl 39%	John Locke, Francis Bacon, Thomas Hobbes
	3	29	MA 69%	AR 86%	wrt 71%	Ganjavi, Al-Hallaj, Attar of Nishapur
	4	29	AN 90%	GK 83%	phl 83%	Plato, Aristotle, Socrates
	5	29	MA 62%	AR 48%	phl 23%	Ibn Tufail, Averroes, Maimonides
Transition (TP)	1	51	MA 51%	EU 53%	rel 47%	Thomas Aquinas, Plotinus, Augustine of Hippo
	2	50	EM 66%	EU 96%	phl 44%	René Descartes, John Locke, David Hume
	3	42	AN 90%	GK 79%	phl 67%	Plato, Aristotle, Socrates
	4	33	TP 55%	EU 67%	wrt 77%	Goethe, Friedrich Schiller, Ganjavi
	5	31	MA 58%	AR 45%	phl 31%	Ibn Tufail, Averroes, Maimonides
ModernAge (MR)	1	66	MR. 79%	EU 78%	art 100%	Pablo Picasso, Paul Cézanne, Claude Monet
	2	52	MA 52%	EU 62%	rel 46%	Thomas Aquinas, Plotinus, Augustine of Hippo
	3	48	MR 56%	EU 83%	phl 35%	Hegel, Karl Marx, Friedrich Engels
	4	45	MR 78%	EU 100%	wrt 87%	A. Macedonski, B. Fondane, Ion Minulescu
	5	41	TP 59%	EU 98%	phl 61%	Immanuel Kant, Baruch Spinoza, Schelling

had the strongest weight in the optimization of communities homogeneity in the community detection process.

Table 8 shows the composition of the largest communities per era. These show clear thematic distinctions.
The biggest three communities in Antiquity are a group of 19 Classical Philosophers around Aristotle, Plato and Socrates, a cluster of 13 Greek and Roman poets (Virgil, Ovid, Ennius) and Cynic philosophers (Menippos of Gadara) as seen in Figure 8 on top, and a community mirroring the political influences on Ashoka the Great of the Mauryan dynasties, and the Seleucid empire. This community is identifiable in the top right of Figure 7, which shows the influence network of intellectuals during the Antiquity era and their communities distinguished in colors. On the top right, there are two communities not connected to the others: on the right, the community surrounding Ashoka the Great, and on the left one of Chinese scholars.

The Classical Philosophers community survived into the Middle Ages as the biggest cluster (of 21 scholars) influencing Medieval Georgian Neoplatonist philosopher Ional Petrisi, followed by a two communities of equal size (19) of Persian poets, Sufi mystics, Sunni poets and philologists dating from 9th to the 13th century (Rumi, Saadi Shirazi, see Figure 8 second from top), and a community of Neoplatonic philosophers influencing Christian theologians (Plotinus, Augustine of Hippo, Anselm of Canterbury)

In the Early Modern period, the biggest community (41 scholars) is formed by mostly Medieval Christian theologians and mystics (Thomas Aquinas, John Calvin) and Renaissance humanist Nicholas of Cusa, followed by three communities (29) of Enlightenment scholars of political theory and statesmen (John Locke, Thomas Hobbes, Edmund Burke, compare to Figure 8 second from below), a Persian theosophic poets community (Rumi, Hafez), and a community of Classical philosophers of Antiquity influencing Renaissance Greek philosophers Ioannis Kottounios and surgeon Marco Aurelio Severino. Noteworthy

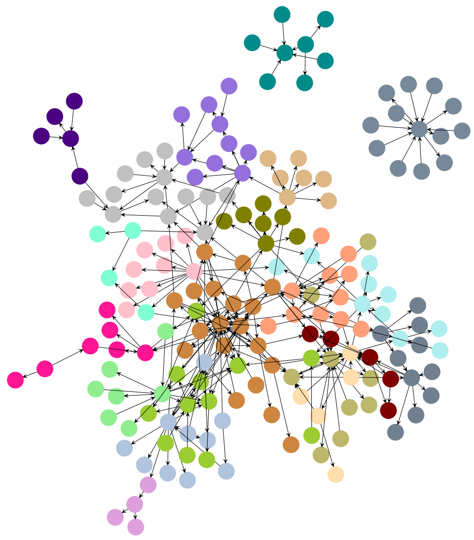


Figure 7: Influence network of intellectuals in the Antiquity period with communities highlighted.

here are also the international and heterogeneous community around Andalusian Medieval scientist/philosophers (Abu al-Quasim al-Zahrawi, Maimonides), and the political theoretical influences of polymath Ibn Tufail on Early Modern scientists, politicians, and religious scholars. The sixth biggest cluster (20) is merged from the Roman Poets with contemporary early Modern Poets of the Renaissance (Ludovico Ariosto), representing their interest in the Classical antiquity. An interesting configuration provides the seventh biggest cluster (18), too, which consists mainly of natural philosophers and mathematicians, and a surprising high concentration of polymaths (Gottfried Leibniz, Roger Joseph Boscovich, Benjamin Franklin).

The biggest community of the Transitioning period (51 scholars) consists of Christian Theologians and Mystics, again headed by Thomas Aquinus. The second biggest community (50) consists of Early Modern Enlightenment scholars of political theory and economy (Francis Bacon, John Locke, David Hume, Adam Shmith), influencing science philosophers such as August Comte. The Classical Philosophers constitute the third biggest cluster (42) here, too, in almost unchanged composition. Fourth biggest cluster of size 33 shows an interesting community of Persian theosophic writer Hafez's influence on German Romantic literature (Goethe, Kleist, Schiller) as seen in Figure 8 below.

In Modern age, a community of 66 Modern artists emerges ranging from Impressionism (Cezanne, Matisse) to Kubism (Braque) and Social Realism (Ben Shaw). Second biggest community (52) of Antique and Medieval Christian religious philosophers (Plotinus, Thomas Aquinus) with few links to Early Modern and Modern theologians (Nicholas of Cusa, Joseph Maréchal). Third biggest community (48) consists of a political philosophers influenced by Hegel and So-

cialist thinkers formed around Max Stirner, Bruno Bauer and Karl Marx, and Modern influences ranging from Vladimir Lenin, to the political "father of Indonesia" Tan Malaka, and Bertold Brecht.
The communities detected revolve around the main influences of each scholar, and comprise of reasonable thematic groups, which allows us to identify various schools of thought.

5 Evolution of Communities

In order to track the evolution of these communities computationally and to identify their structural changes, we follow the approach of Greene et al. (2010). They proposed to identify a set of *dynamic communities*, a type of "evolving complex networks" (Qiu et al. 2010; Dakiche et al. 2019, p. 1085) that are present in the network across one or more time steps, which compositions change according to the behavior of its members, i.e. joining, leaving, or establishing new relations. Communities identified at an individual time step are referred to as *step communities*: they represent specific observations of a dynamic community at a given point in time. Each dynamic community D_i can be represented by a time-line of its constituent step communities, ordered by time and with at least one step community for each step t. The most recent observation in a timeline is referred to as the *front* of the dynamic community.

Their model for dynamic community analysis is focused around the life cycle of communities, and the key events that characterize the evolution of dynamic communities, such as

- Birth: The emergence of a step community observed at time t for which there is no corresponding (preceding) dynamic community.
- Death: The dissolution of a dynamic community D_i occurs when it cannot be observed anymore (i.e. there is no corresponding step community to be observed) for several consecutive time steps. D_i is subsequently removed from the set D of dynamic communities.
- Merge: A merge occurs if two distinct dynamic communities (D_i, D_j) observed at time $t-1$ match to a single step community C_{ta} at time t. The pair subsequently shares a common timeline starting from C_{ta}.
- Split: It may occur that a single dynamic community D_i present at time $t-1$ is matched to two distinct step communities (C_{ta}, C_{tb}) at time t. A branching occurs with the creation of an additional dynamic community D_j that shares the timeline of D_i up to time $t-1$, but has a distinct timeline from time t onward.
- Continuation: Trivial one-to-one matching where a dynamic community observed at time t also has an observation at time $t+1$.

This results into the need for tracking communities over time (p. 1085). The strategy of tracking communities across time steps is a heuristic threshold-based method, which allows for many-to-many mappings between communities across

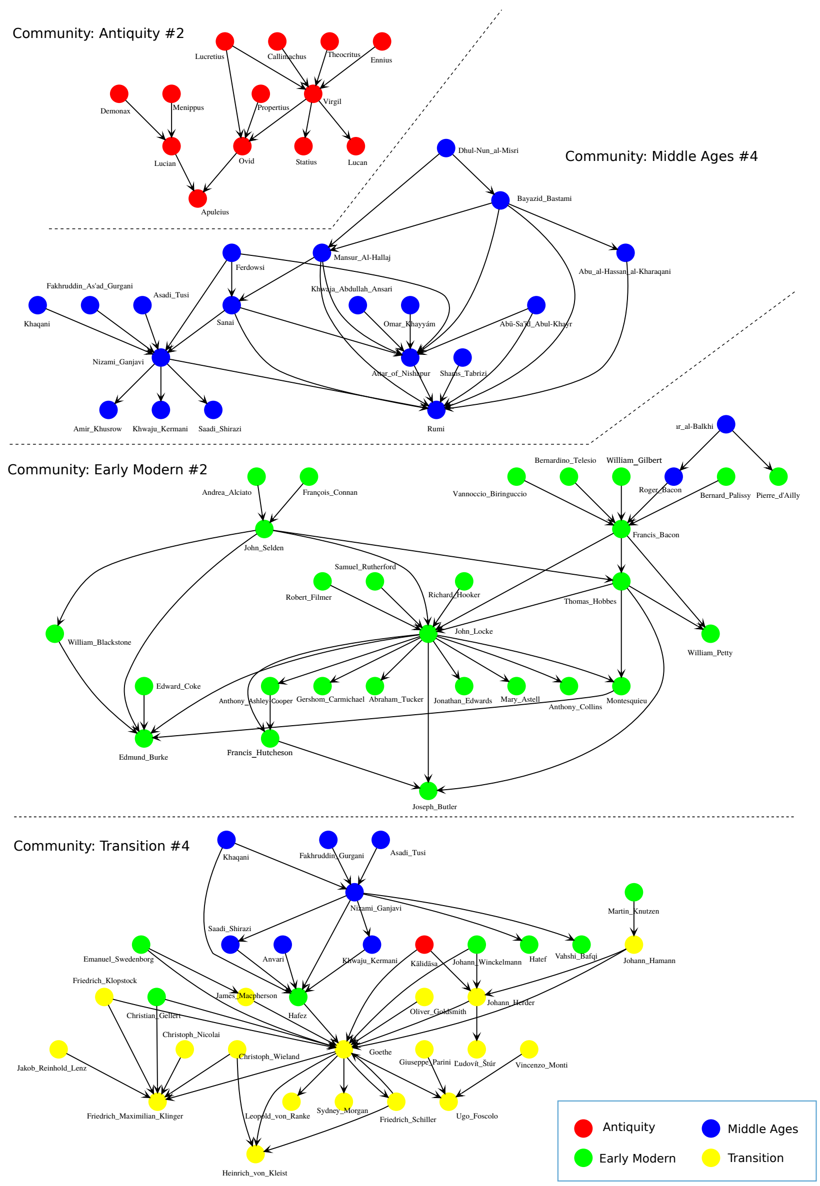


Figure 8: Tracking influence relation compositions of various exemplary communities.

different time steps.[24] The strategy proceeds as follows: Given the first step grouping $\mathbb{C}_1$ (communities of the first time step) a distinct dynamic community is created for each step community. Then, with the next grouping $\mathbb{C}_2$, an attempt is made to match these step communities with the fronts $\{F_1, \cdots, F_{k'}\}$ (i.e. the step communities from $\mathbb{C}_1$). All pairs (C_{2a}, F_i) are compared, and the dynamic community timelines and fronts are updated based on the key event rules described previously. The process continues until all step groupings have been processed and classified.

Matching front and step communities

To perform the actual matching between C_t and the fronts $\{F_1, \cdots, F_{k'}\}$, we need a measure of similarity between sets. Greene et al. (2010) proposed to use the widely-adopted Jaccard index[25]. The similarity of a united set of communities however provides trivial results in our study, as it focuses on the overlap in two communities instead of how much of one community is integrated into the next.

Boujlaleb et al. (2017) proposed to use another measure, Quantity Insertion (QI), which reflects the quantity of members of front community F_i that are inserted into the step community C_{ta}:

$$sim_{\mathrm{QI}}(C_{ta}, F_i) = \frac{|C_{ta} \cap F_i|}{|F_i|}$$

We opt to use this QI measure in our study as it is more robust and provides better interpretable results. If the similarity exceeds a matching threshold $\theta \in [0, 1]$, the pair is matched and C_{ta} is added to the timeline for the dynamic community D_i. The output of the matching process will naturally reveal a series of community evolution events. A step community matching to a single dynamic community indicates a *continuation*, while the case where it matches multiple dynamic communities results in a *merge* event. If no suitable match is found for a step community above the threshold θ, a new dynamic community is created for it.

Characterization of community tracking results

We applied this tracking method on the detected communities over the five eras as time steps. We excluded small communities with 3 or less scholars, hence the number of remaining communities of the five eras are [21, 53, 103, 179, 365]. For matching we used a similarity threshold $\theta \geq 0.5$, that is two communities are considered a match when at least 50% of common members belong to the front dynamic community.

24. Many-to-many mappings are a method of system analysis, and refer to the mapping of relationships of entities' instances. An entity can contain a parent instance for which there are many children instances in another entity, and vice versa. In our context this means that a community can consist of scholars, that are also present in a subsequent/preceding community of a later/earlier era, which relationship is observed or tracked by this method. A mapping occurs when the similarity of both entities passes a certain threshold.

25. The Jaccard index or coefficient calculates the similarity of a sample set (in this case: of communities) by dividing the size of overlap of the sample set by the size of the united sample set, i.e. the overlap of two communities divided by the size of the two communities combined.

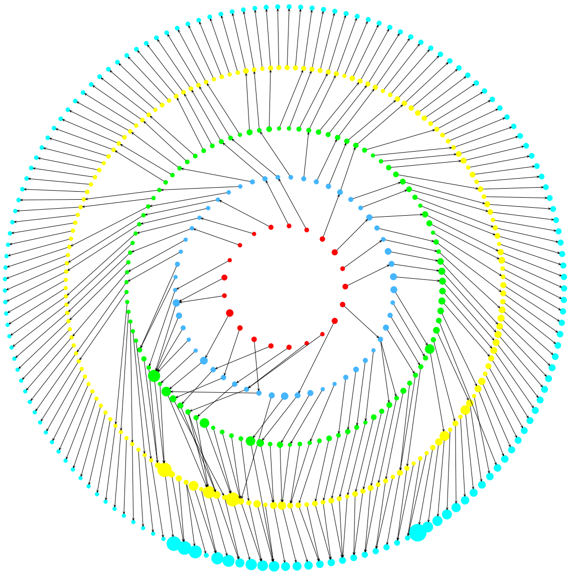


Figure 9: Evolution of dynamic communities with more than 3 members over eras, starting with Antiquity from the center outwards. The size of nodes represents the amount of memberships.

The results of the process of tracking community evolution are 154 dynamic communities in time, among them 132 continued communities (with continuation events only) and 22 merged communities (with merge/split events). Figure 9 shows an overview on the evolution of dynamic communities over all five periods.

We recorded 4 split events (1 at EM, 2 at TP, and 1 at MR), and 36 merge events (2 at MA, 4 at EM, 10 at TP, and 20 at MR). On average, each dynamic community consists of 14.3 members (median: 10 members). For each dynamic community, we calculated the number of constituent step communities (denoted N), the number of distinct scholars (across all step communities, denoted M_1), and the average number of scholars per step community (denoted M_2). Note that in any dynamic community, the constituent step communities are not disjoint in general[26]; thus, a scholar can belong to a different step community in different eras. Therefore, M_2 is not the same as M_1 divided by N. In fact, M_2 is the sum of the sizes of step communities divided by their member count N. M_1 is the count of distinct scholars in all step communities of an entire dynamic community over all eras.

The difference $M_1 - M_2$ provides an indication of the change behavior of a dynamic community. The lower this difference is, the more static the community is; for instance, when this difference is 0 (i.e., $M_1 = M_2$), the community is self-contained and does not change its members); whereas the higher the difference is, the more changes in the community.

26. They are disjoint only when they are of the same era.

In continued dynamic communities, the number of constituent step communities N is the same as the number of corresponding eras, because in such continued dynamic communities only one step-community is observed at each era. This is not the case in merged dynamic communities, where multiple step-communities can be observed at a given era (e.g., get merged in a later era, or got split in a former era).

Table 9 summarizes the largest 5 merged dynamic communities. It shows for each one the number of constituent step-communities N, the number of distinct scholars M_1, and the average number of scholars per step-community M_2. It also shows the number of step-communities from each era. For instance the largest dynamic community consists of 23 step communities (7 from AN, 6 from MA, 5 from EM, 3 from TP and 2 from MR). It comprises 100 distinct scholars (many of which belong to multiple step communities at different eras), their step communities contain 15.3 scholars on average. This community is described in detail later.

Table 9: Summary of the top 5 merged dynamic communities. N: number of step communities, M_1: number of distinct scholars, M_2: average number of scholars per step community, N_e: number of step communities from era e.

N	M_1	M_2	N_{AN}	N_{MA}	N_{EM}	N_{TP}	N_{MR}
23	100	15.30	7	6	5	3	2
11	63	19.64	2	5	2	1	1
10	25	8.50	0	3	3	3	1
7	38	13.29	0	1	3	2	1
7	19	10.29	1	1	2	2	1

Patterns of dynamic communities

Table 10: Patterns of dynamic communities over eras. $\overline{N}$: average number of step communities, $\overline{M_1}$: average number of distinct scholars, $\overline{M_2}$: average scholar-per-community ratio.

Eras					Continued				Merged				
AN	MA	EM	TP	MR	#	$\overline{N}$	$\overline{M_1}$	$\overline{M_2}$	#	$\overline{N}$	$\overline{M_1}$	$\overline{M_2}$	#
× →	× →	× →	× →	×	9	5	10.4	8.7	4	11.75	55.5	15.3	13
× →	× →	× →	×						1	5	19.0	7.0	1
	× →	×			1	2	9.0	7.5	1	3	12.0	7.0	2
	× →	× →	× →	×	16	4	11.0	9.8	8	6.13	25.9	12.3	24
		× →	× →	×	37	3	10.7	8.5	4	4.25	32.0	15.6	41
		×	⟶	×	1	2	22.0	15.5					1
			× →	×	68	2	11.0	8.5	4	3	42.8	19.3	72
					132				22				154

The pattern of communities per era is depicted in Table 10; along with some statistics about their occurrence in both continued and merged cases.

For instance, the first pattern represents step communities from all five eras. This pattern occurs in 13 dynamic communities; 9 out of them are continued, while 4 are merged. In those 9 continued ones, the average number of step communities is $\overline{N} = 5$ (in accordance to the five periods we have), the average number of distinct scholars is $\overline{M_1} = 10.4$, and the average of scholar-per-community ratio is $\overline{M_2} = 8.7$. Whereas in the 4 merged ones, the average number of step communities is $\overline{N} = 11.75$, the average number of distinct scholars is $\overline{M_1} = 55.5$, and the average of scholar-per-community ratio is $\overline{M_2} = 15.3$.

The most frequent patterns are:

- TP→MR: this pattern occurs 72 times (68 continued, and 4 merged).
- EM→TP→MR: this pattern occurs 41 times (37 continued, and 4 merged).
- MA→EM→TP→MR: this pattern occurs 24 times (16 continued, and 8 merged).

There is another interesting pattern, EM→MR, which consists of a step-community from EM that disappears in TP and reappears again in MR.

In order to be able to better interpret these patterns, we investigated in the similarity of communities in each time-step, and inspected their loss/gain of members.

Step-wise similarity of communities

Over all dynamic communities, we calculated the similarity between matching step communities (inter-period similarity) regarding their common scholars using the Jaccard and the QI measures, and their similarity in terms of the three dimensions: era, geo-categories and disciplines using the cosine similarity[27]). Table 11 shows the results, where we can observe a very high average similarity of around 92% (based on the QI measure) over all time-steps, revealing that most communities are relatively constant in their composition.

Table 11: Similarity between step communities

step	#	common scholars		dimensions		
		Jaccard	QI	era	region	discipline
AN → MA	21	0.795	0.921	0.995	0.994	0.990
MA → EM	53	0.725	0.894	0.954	0.963	0.962
EM → TP	97	0.754	0.916	0.955	0.975	0.969
TP → MR	166	0.718	0.911	0.918	0.988	0.975
MA → TP	1	0.450	0.692	0.874	0.949	0.965
EM → MR	2	0.604	0.892	0.882	0.999	0.968
All		0.746	0.920	0.916	0.987	0.976

In a dynamic community, a constituent step community does not necessarily contain all the members of its preceding step communities; and it does not necessarily contain all the members of its succeeding step communities. In general, the members of a step community X at some era will be members of different communities Y_i at the next era. If the similarity between X and Y is above a threshold, it matches, and the two communities will be identified as belonging to the same dynamic community. However, if the similarity is below

27. For each step community, each dimension is described as a vector; for example, a community with 6 scholars from EU and 4 scholars from AM, is represented as (0,6,0,0,4,0).

the threshold (and $\neq 0$), this means that there are some of X members who moved to Y without having an observed connection between X and Y. Thus, there is an unobserved exchange of members, which means a loss of members for X, and a gain/introduction of new members for Y.
In order to analyze this behavior of gaining/loosing scholars in communities, we calculate several measures for a step community:

- Loss number ($\text{Loss}_N(x)$): the number of lost members, i.e., number of X members, who are not present in its successors. We also calculate Loss ratio ($\text{Loss}_r(x)$) via dividing $Loss_N(x)$ by the size of X.
- Gain number ($\text{Gain}_N(x)$): the number of newly-introduced members, i.e., number of X members, who are not present in its predecessors. We also calculate Gain ratio ($\text{Gain}_r(x)$) via dividing $\text{Gain}_N(x)$ by the size of X.
- Forward Stability ($\text{FS}(X)$): ratio of X members, who are present in its successors.
- Backward Stability ($\text{BS}(X)$): ratio of X members, who were present in its predecessors.

Note that $\text{Loss}_r(x) + \text{FS}(X) = 1$, and $\text{Gain}_r(x) + \text{BS}(X) = 1$.
The average loss per dynamic community is 2.2 members, where 90 out of the 154 (58%) communities have 0 loss; the maximum gain is 44. The average gain per dynamic community is 3.3 members, where 61 out of the 154 (40%) communities have 0 gain, and the maximum is 60. The average forward stability is 0.92, while the average backward stability is 0.85; which means that we expect that 92% of the members of a step community will be observed in its successor communities; while 85% of the members were observed in its predecessor communities. Table 12 provides a summary of these measures over all eras. These figures suggest again little structural change in communities on average, and relatively stable communities in time.

Table 12: Summary of loss and gain of scholars per dynamic community

	loss_N				$\overline{FS}$	gain_N				$\overline{BS}$
Era	#	sum	avg	max		#	sum	avg	max	
AN	21	16	0.76	5	0.921					
MA	53	50	0.94	5	0.907	19	19	1.00	6	0.925
EM	98	87	0.89	9	0.925	48	97	2.02	12	0.858
TP	165	186	1.13	24	0.917	86	141	1.64	26	0.888
MR						153	538	3.52	60	0.819

Given a dynamic community, there is a very strong correlation between the difference between the distinct scholars and the average amount of scholars in a step community $M_1 - M_2$ on one hand, and the sum of Loss_N as well as the sum of Gain_N over its constituent step communities:

$$\text{corr}(M_1 - M_2, \sum \text{Loss}_N) = 0.868$$

$$\text{corr}(M_1 - M_2, \sum \text{Gain}_N) = 0.844$$

A low difference in the number of distinct scholar and the average amount of scholars in a step community ($M_1 - M_2$) means little loss and/or little gain, therefore communities have a high stability, and can be considered almost static, whereas a high $M_1 - M_2$ signifies more loss and/or more gain, characterizing low stability in a highly changing community.

An interesting sub-class of dynamic communities are those who are *self-contained*. We say a dynamic community is self-contained if its constituent step communities consists consistently of the same set of scholars. This means that there is no exchange of scholars with other communities at all. Based on this definition, a self-contained community has the following characteristics:

- It is necessarily a *continued* community.
- $M_1 = M_2$, i.e., the number of distinct scholars equals the ratio of scholars per step-community.
- The similarity of step-wise communities is 100% in terms of scholars and in terms of the three dimensions.
- Both the loss number, $\text{Loss}_N(x)$, and the gain number, $\text{Gain}_N(x)$, are 0.
- Both forward- and backward- stability (ratio of common scholars) is 100%.

We found that there are 52 of such self-contained communities (2 start at Antiquity, 8 at MA, 16 at EM, and 26 at TP). All of them survive intact until Modern Age. Table 13 shows the patterns of self contained communities with their average sizes.

Table 13: Self-contained communities

Eras						$M_1 = M_2$		
AN	MA	EM	TP	MR	#	avg	min	max
× →	× →	× →	× →	×	2	5.50	4	7
	× →	× →	× →	×	8	7.50	4	17
		× →	× →	×	16	5.81	4	11
			× →	×	26	5.58	4	10
					52	5.94		

Description of the largest dynamic community

The largest merging dynamic community consists of two clusters on the left and right, and one intermediate branch merging in each of those two.

The cluster of the left side of Figure 10 consists of two sub-branches meeting during the Transitioning period, the first of which consists of a community of the influence of the Greek poet Aesop (6th BC) on later writers of fables (Avianus, Babrius), tragedians (Sophocles), historians (Herodot), rhetoricians (Himerius), and grammarians (Dositheus Magister) continuing as such in the Middle Ages and in the Early Modern period.

The left cluster's second sub-branch consists of two separate branches, which merge in the Early Modern period. One part of this (sub-)sub-branch consists

of a community of philosophers and mathematicians around Ionian philosopher Pythagoras, which continues as such into the Medieval era. The other part of this (sub-)sub-branch consists of the group of Classical Philosophers of Socrates, Plato, and Aristotle. This community continues self-contained into the Medieval period, and finally merges with the Antique mathematical philosophers community of Pythagoras in the Early Modern period joined through Parmenides. This joined community influences various Early Modern Neoplatonian philosophers and the Greek scholar Ionnais Kottounios (17th century).
Finally, both sub-branches of the left cluster join in the Transit period, which include the poetic influences on Socrates, and merge with another Sophist community from the intermediate branch into a combined community of Sophist, poetic, mathematical, and Stoic influence network on Plato and Aristotle, which continues into the Modern period, loosing the poet's branch, but incorporating the Aristotelian influence on Francis Bacon.[28]
The intermediate branch consists of community of Socrates student Antisthenes's influences on Cynicism (Diogenes of Sinope, Crates of Thebes) merging with a community of Stoic philosophers surrounding Zeno of Citium into a joined community of Cynics' influence on Stoicism through the Megalarian School. These continue into a community, which incorporates early Sophist influences of Cynicism as well. A split event leads to the Sophist part of the community to merge with the aforementioned Classical philosopher's community around Socrates, and the Cynics part to merge to community of Cynics around Zeno of Citium and Stoics around Epictetus. The Stoics in turn influence a cluster of Jansenists around Early Modern scientist Blaise Pascal of the second cluster on the right, who after his religious epiphany in the 1650s was influenced by Epiktet and turned to Jansenism, a heretic branch of Catholic Popedom in fight against the Jesuits.
The second cluster on the right consists of two continuing communities, a Stoic community of the school of Athen around Cleanthes and Epictetus and another Stoic community in the Roman Republic around the teacher-student pair of Panaetius and Posidonius that continue until Modern age, with exception to the merge event with the intermediate branch of Cynics, Stoics and Jansenists. This group then merges into a combination of both branches of Stoicism of Panaetius and Cleanthes via Zeno of Citium, loosing the Early Modern Jansenists group around Pascal.

In order to infer on the question why these groups show these evolution dynamics in communities, it is of equal importance to look for who is part of a community as it is for who is not. The scholars part of a community show a greater homogeneity than in other possible communities in regards to their disciplines, regions, and periods – as this was optimized in the clustering algorithm. We can clearly identify schools of thought and reasonable thematic clusters. These communities are structured again by sub-group of cores – members of communities that stay together even though the group changes communities in time, such as the Cynics genealogy of Diogenes of Sinope, Crates of Thebes,

28. Bacon's work on natural philosophy drew heavily from ancient sources, and as Pesic (2014) argues, his terminology – such as the contested usage of "violence" of nature and the dominion of man (compare to Merchant 2008 – can only be understand "depend[ent] on their Aristotelian context", which Bacon developed his "new philosophy" on (Pesic 2014, p. 79), though he also departed from his ancient sources (see also Cushing 1998, pp. 15-28).

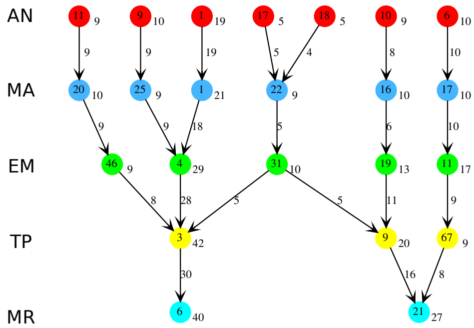


Figure 10: Largest dynamic community with merge/split events ($\theta = 0.5$).

his wife Hipparchia of Maroneia, and her brother Metrocles, which closely resemble schools and fields within the communities. The changing composition of communities, exchanging core sub-groups and floating members, leads to these core-groups integrating into other groups that provide a stronger homogenity in relation to the possible other groups in that era.

6 Conclusion

This study is founded on a database encompassing the influence relations of intellectuals in the broad strokes of a "*Meistererzählung*": an abstract view on the main influences of the main intellectuals as collected in the Linked Open Data base YAGO3 – and as such as recorded in Wikipedia, the biggest and most accessible encyclopedia of crowd-sourced origin[29]. This view on the history of intellectuals closely iterates the state-of-knowledge compiled in the knowledge base YAGO3/Wikipedia, and consequently represents a crowd-curated contemporary view on the history of intellectuals and their main influences on another. Despite the focus of the database on main influences and biases in representation favoring male European intellectuals notwithstanding a general global stance of the dataset (as described in Sections 2 and 3), this unique dataset constitutes still the most complete dataset available on the history of intellectuals albeit in the broad strokes of a master narrative.
In this study, we offered a network methodology to analyze the history of intellectuals. We provided a detailed description of the process of creating, enriching, and preparing an extracted dataset from YAGO with SPARQL, and how to create longitudinal networks of such data based on a global periodization. We investigated the community formation processes of scholars in time and developed a method to evaluate the quality of resulting communities by taking their diversity into account. The community detection helps to understand the genealogy of scholars, and the variety of relational influence, and provides a means to computationally identify schools of thought. We traced the evolution of these communities as a dynamic process throughout time and differentiated between

29. Wikipedia grows by approx. 1,500 articles per day and offers an unparalleled quick potential correctional prowess of an average of 1,9 edits per second (Wikipedia).

154 dynamic communities of size 4 or greater, and tracked the continuation and merge of communities throughout their evolution, as well as their similarity in each time step. We described exemplary the mechanisms and characteristics of their development based on the largest merging community in the dataset, exemplifying the change in core groups and floating members.
These approaches helped to bring more quantitative/computational evidence for some assumptions derived from qualitative research, and offer the potential for further falsification. In order to achieve this potential, a more "fine grained" database would be necessary. As the above analyses iterate the abstract "broad stroke" representation in YAGO/Wikipedia, ideally we would like to broaden the database to include a representative and global outlook, and apply the established methodology of analyzing the YAGO network on a more "fine grained" influence network that takes more than the most important influences of the most important scholars into account. This could be based on a selection of primary sources from within intellectual history, which we would like to evaluate differences and insights on the dynamics of intellectual influences, and to compare those with the results of the extracted YAGO3 dataset. A community analysis based on a more fluid interpretation of the disciplines of each scholar, taking multiple heterogeneous disciplines into account, would elevate on the robustness of the formation of computationally detected communities. There, we would like to add on this study in an extended in-depth analysis of the various interrelations of the core groups these communities consist of, and their interactions (and exchange) with other communities.

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Chapter 6

Discussion

6.1 Becoming DH

6.1.1 Discourses of subjectivisation

The constant discussions on what belongs to the digital humanities, the negotiation of their framework(s) and place within the established disciplines and in the institutionalized academia – be it either in permanent and temporary institutions – we can consider a "discourse of subjectification" ("*Subjektivierungsdiskurs*") following the conception of Foucault ([1969] 1973). The discussions on the nature and place of the DH act as a means to formally establish their disciplinary independence, and as such a means for agency.

Foucault interpreted the participation in discourses as "practices of subjectification" ("*Praxis der Subjektivierung*"). The individual participates in a discourse that revolves around power (i.e. shaping the acceptable content in negotiation processes) and position (i.e. the integration vs. opposition to the group of discourse), which allows a means of agency of the individual. Foucault regarded the membership in these discourses in as a form of reduction of complexity: Participation practices are based on time-dependent epistles (the so-called "truths," that are subject to change in time), and are structured by a distinct set of rules (practices called "technologies of self"), which set the possible range of behavior in the discourse, thus providing finite limits to complex interactions, hence reduce complexity.[1] In his later work, Foucault differentiated more on the possible degrees of surrender of the subject to the discourse, taking more variation in behavior into account.

We argue that many discussions in the DH can be characterized as discourses of subjectification – specifically in the discussions on their definition – in order to become a subject in the Foucauldian sense, establishing a means of agency. This process thus enables the DH to become an independent field, of which individuals position themselves

1. A common example of these "technologies of self" in the social sciences would be practices of masculinity that allow an individual to be perceived as a man. In the context of this thesis, "technologies of self" entail what belongs to the digital humanities, which kind of methods are part of this, how these methods are supposed to be applied, etc. These practices are subject to constant calibration in the discourse community, and as such submitted to change.

to be a part. The specific practices of subjectification of individuals in this discourse would then entail e.g., publishing in specific DH journals, participating in discussions on DH, or declaring to belong to the DH community as a 'Digital Humanist', with which the individual researcher becomes part of the DH discourse(s) and therefore subject themselves to a distinct set of rules, such as research behavior.

Foucault pointed to the changing epistles in the discourses, which are evident as well in the discourses of DH. So far, no unified answer–or singular practice in the Foucaldian sense–has been found in the last decades that would yet remain uncontested. Instead, these are subjected to a high degree of change, following the Foucauldian idea of constant calibration of practices in negotiation process within the subjectification discourses.

6.1.2 On the need to define DH – Differentiation and definiteness

The continuing disagreements on a unifying definition of the DH or on common frameworks resulted in a multitude of different (and changing) research approaches, research objects, and fields of study.

Addressing the heterogeneity of the DH, the term of the"big tent" was coined[2]: all digitizing and digitalizing advances in the humanities are part of the DH in a maximum inclusive or even "ecumenical" way (Terras 2011). It was argued that a concise definition of the DH would neither be necessary nor feasible, and that it could endure the tension of the heterogeneity of the multitude of fields, concepts, ideas, methods, and approaches, and ultimately, its indefiniteness (see e.g., Mathew Kirschenbaum 2014, p. 59; Nyhan and Flinn 2016) or "definitional openness" (Ernst 2015, p. 1). Instead, the DH were interpreted as a "phenomena" (Sahle 2015, p. 55) or "intersection" (Baum and Stäcker 2015, p. 4) of digital technology, computational prowess, and the humanities disciplines (Terras 2011; Thaller 2017b).

This "big tent"-perception of the DH was heavily criticized: a clear grasp on the status of DH would be necessary to stake the field, and its position within academia. "If everyone is a Digital Humanist, then no-one is really a Digital Humanists," Terras (2011) criticized the overly inclusive and generalist stance on the DH. This criticism was fueled also by science-political considerations, such as to secure funding, a permanent place within the academia, and a sustained permanence of professional positions and non-temporary institutions in a situation of increasingly shrinking funding and financial cuts in the humanities' departments, and alternative career paths of the "alt-ac" trajectories of unsecured part-time employment (ibid.; Nyhan et al. 2013, p. 1; Sahle 2015; Piotrowski 2020, pp. 2, 13; Jannidis 2019, p. 70). In contrast to this assertion, Matthew Kirschenbaum (2012) called it a "tactical" decision to consider everything digital as part of the DH to opportunistically secure funding more easily (compare also Baum and Stäcker 2015, p. 7). Similar also voiced this Gerhard Wolf (quoted in Nerbonne 2015,

2. Attributed to have been used first by Pannapacker at the conference of Alliance of DH Organizations (ADHO) at Stanford University in 2011 (Crymble 2021, p. 6).

p. 33): dispensation of funding would favor the digital or computational application instead of a more traditionally-minded one; as such embracing a digital methodology can be interpreted to provide an attempt to escape the "chopping block" (Zelizer 2013).

Many attempts[3] have been made to find a common definition of the DH intended to counteract the danger of a meaningless umbrella term (see e.g., Matthew Kirschenbaum 2012; Terras 2011, 2013), which led to both the differentiation in more sub-fields and model interpretations, but also to the abandonment of finding a common definition. Still in 2021, Crymble (p. 5) argued that the different strands within the DH are inconsolable as for their "different research realities."

This development of not necessarily needing a unified definition was interpreted as a testimony to the greater "self-consciousness," independence and general disciplinary security of the field (König 2021, p. 40), which led to abandon the earlier need for justification of the new digital perspectives. This security stems from the ongoing professionalization and institutionalization of the DH in the physical academic landscape, even though these institutions are usually in the non-traditional and impermanent form of focus groups or centers as well as temporary academical positions.[4] Instead since around the mid-2010s, the DH discourses focus more on establishing best research practices and applications.

Definiteness. In parallel, the perceived "big tent" of DH tended to split up: increasingly the DH are differentiated into separate and more specialized sub-fields. This catered to the wish for a more definitive grasp on the goals, outlooks, and specific approaches of digital research, i.a. a distinct set of research rules, and to reverse the meaninglessness of a term too broad. Examples for this are the exclusion strategy of computational lingusitics and corpus linguistics to be regarded a separate discipline from the DH[5] (Sahle 2015, p. 54; Baum and Stäcker 2015, p. 7), or the tendency of new field and sub-fields emerging from replacing the adjective 'digital' with 'computational'. Computational history emerged from digital history; the former stressing a different research focus on computational methodology in contrast to the perceived main occupation with digitization of sources and their online presentation of the digital history. In the broader DH, similar developments show up recognizing a computational humanities as a distinct discipline from the DH, as seen in a recent surge in activity ranging from seminars and workshops, such as e.g., the "Dagstuhl-Seminar" on Computational Humanities (Biemann et al. 2014, p. 81); or the change in focus at Heidelberg University from hosting the "1st Summer School of Digital Humanities" in 2017 first[6], which was then succeeded with the "2nd Computational Humanities Summer School" in 2019[7]; the

3. Compare to section 2.1.
4. Compare to chapter 2 on "DH as an independent discipline vs. sub-field."
5. Or, humanities computing as this started already in the 1980s, compare to section 2.2.
6. https://www.uni-heidelberg.de/fakultaeten/theologie/forschung/distant-reading/programm.html
7. https://hch19.cl.uni-heidelberg.de/

"Computational Humanities Research Workshop"[8] in 2020 alongside a discourse forum[9] of the same name; or arguments for the further sub-differentiation of the computational humanities as either focusing on applied or theoretical advances (Piotrowski 2020; similarly, also Jäger and Winckler 2013 argue for a separate discipline). Famously, Franco Moretti–the "father" of distant r,eading–is quoted Hackler and Kirsten (in 2016, p. 5) as supporting this development of differentiation by criticizing the unilateral usage of the term DH:

> "I use it only because everybody uses it [...]. But, frankly, I don't like it. I think it means nothing, whereas 'quantitative' and 'computational' means something."

Despite these developments the vast majority of the DH are still predominantly concerned with digitization, whereas only a minority can be considered part of the computational or "numerical humanities," as Roth (2019, p. 12) ascertained in a study on the focus of recent publications in the DH.

Petitioning for an alternative approach for more definiteness while staying within the 'big tent' of DH, Crymble (2021, pp. 7, 44, 161) suggested for a more distinct language in order to identify the different strands within the DH, their unique approaches, and "different intellectual aims." Addressing specific professions such as e.g., (digital) editors, (digital) archivists, digitizers, computational analysts, and more, would properly reflect on the stark differences in their "research realities" beyond specific sub-fields (ibid., p. 5).

6.1.3 Historicity of DH discourses – History on repeat

These on-going discussions and issues of the DH have to be historicized[10] and contextualized as part of constant reform and innovation in the humanities–following the familiar aphorism "Those who cannot remember the past are condemned to repeat it" written by the philosopher George Santayana ([1905] 2011, p. 172). "Considering that history as a modern academic discipline and profession arguably dates back to the second half of the nineteenth century, it follows that 'digital history' has been a part of the practice of doing history for a substantial period of time and is certainly less new than the current buzz surrounding digital humanities (DH) might suggest," argued Zaagsma (2013, p. 4).

In 1966, William O. Aydelotte published a rebuttal on the criticism brought forward against quantitative history, that targeted its limited applicability[11], the dichotomous extremes of either trivial or revolutionary results in falsification or replication studies

8. https://2020.computational-humanities-research.org/cfp/
9. https://discourse.computational-humanities-research.org/
10. Crymble made this point one of the core arguments in the monograph "Technology and the Historian", published only in mid-2021.
11. Due to the nature of historical sources as fuzzy or unreliable (Aydelotte 1966, pp. 805, 811, 820).

that could revise previously conventional knowledge (Aydelotte 1966, p. 820)[12] and the erroneous methodological application and spurious interpretation of results due to the lack of adequate education of historians in statistics – from the side of the applicants ("dilletantism") as well as of the readers (Reynolds 1998, pp. 146-7).

The points brought forward by William O. Aydelotte in 1966 mirror discussions still seen 60 years later, and proof to be still up-to-date when replacing the word 'quantitative' with 'digital': the fear of traditional history that the quantitative might replace the qualitative methodology[13], and concerns about the missing adequate education of a new generation of historians in statistics. Aydelotte (1966, p. 804) bemoaned that cliometrics possibly "has been pushed too far," as the fundamental knowledge of quantitative methods and statistics were not widespread enough in the historical studies. Therefore, there is not enough mathematical foundation to prevent wrongly used techniques due to lack of knowledge resulting in erroneous studies (ibid., pp. 809–10), or the ever prominent believe in numbers[14] (ibid., p. 812), and the assumption that it would be possible to give "proof with figures" (ibid., p. 816), or that a quantitative approach would be more accurate *per se* even if not employed thoroughly and sensibly (compare to ibid., p. 811). This general lack of statistical knowledge (the "training gap", Anderson 2007) would not prevent spurious interpretation of numbers and figures from both the side of the applicator and the side of the reader. This puzzled Aydelotte (1966, p. 804) as quantitative assumptions are to be found almost everywhere, e.g.,"implicitly in any generalization." He criticized the "hostility" of more traditional scholarship[15] regarding the feasability, reliability, and general usefulness of quantitative methods (ibid., p. 809). At the same time, Aydelotte (1966, p. 824) described the same "starry-eyed" fascination with the possibilities of the quantitative methods , and suggested the advantages of quantitative analysis of a (proto-) 'big data'-like amount of historical sources, offering greater objectivity and accuracy using the then-modern tool of punch cards, identifying fruitful research questions, and mining the "gold [...] still near the surface." "Such manipulations of the data would take an immense amount of time to do by hand, but ordinarily, they can readily be performed by machines," Aydelotte (1966, p. 806) summarized.

12. Aydelotte (1966, pp. 807, 815) mentioned in this context the study on the importance of infrastructure for the industrial advancement of the US by Fogel (1964), that challenged the "conventional wisdom on the centrality of railroads" and highlighted that "canals would have also succeeded as a transportation system" (Anderson 2007, pp. 247–8)

13. "There is no single methodology in history," tried Aydelotte (1966, p. 804) to rebut such concerns as e.g. voiced by Reynolds (1998, p. 147) (much later) that the increased interest from the social sciences would lead to replace historians.

14. Following the reprimand by S. B. Warner ([1962] 1978, p. 173) that the "past tendency to [...] accept statistics as prima facie fact must be abandoned." Instead he advises to use "cross-information" to assess the "reliance [...] place[d] upon a given set of statistics" (ibid., p. 174).

15. As e.g., a commentary by Arthur Schlesinger Jr. (1962, p. 770) that "[a]lmost all important questions are important precisely because they are *not* susceptible to quantitative answers." As well as the reference to the "dubious reputation" of cliometricians described by Reynolds (1998, p. 141) resulting in their distance from the general field of history,

Contemporary discussions mirror these historical ones in a fashion of history on repeat, while many of these remarks concerning the limitations and reservations of the machine-based methodology still persist. This repeats also in more current discussions. In the late 1980s, the necessity for "computing humanists to learn to program" was critically discussed, characterized by "anxiety over which direction that should take if needed", as noted Black (2010) on a re-reading of mails traded on the HUMANIST BITNET list server from 1987 (see also Hockey 2004, p. 9). Black (2010) expressed surprise on the familiarity of the issues brought forward then.

Differences pertain in the scope of feasible future research enterprises. Avner Greif (1997, p. 400) purported in the late 1990s new possibilities for cliometrics using computers, in "cross-section studies" using longer timeframes and "data sets that could not have been assembled or analyzed before." This was similarly voiced since the 2010s on the prospects of big data research (e.g., in "*Exploring Big Historical Data. The Historian's Macroscope*" by Graham et al. 2016; see also Crymble 2021, p. 26) and shows the ever changing perspectives on what is to be considered big and feasible, as well as which methods would be best suitable for this. Ironically, the question of establishing a mathematical foundation in humanities' (especially historical) students remains unsolved since the requests of the early cliometricians.

These outlined points in past discussions show a clear tendency in the DH of being "unaware that the same points may have been debated" decades before Crymble (2021, p. 3). The historical contextualization of methodological debates in the past offers a multiple advantages: this establishes an awareness of past results (and open questions), situates the new insights in a tradition of past accomplishments (Sula and Hill 2019, p. 192), avoids the seasonal re-issuing of old debates (criticized as "eternal September" by Nowviskie 2010), and paves the way for both new and original contributions (Crymble 2021, p. 3). Crymble (2021) argued to place digital history–and consequently DH as well–into a long "history of technology impact on historical studies" (ibid., p. 2) in order to actually draw from the experiences of the past, instead of "operating in an eternal present, both ignoring and being ignored by the histories of the field of which they should have been a part" (ibid., p. 3). "The key to its future–and in some measure the future of all the related humanities–is its history. This history we must remember," stressed McCarty (n.d.) in the Roberto Busa Award lecture in 2013. This forgetful historiography of the achievements and reservations of the generations prior is maybe owed to the outsider status of the computer-based methodology within historical studies' "disciplinary mosaic" (Fridlund 2020, p. 73). Still, a concise, encompassing critical historiography of the origins of the digital humanities and digital history remains to be written, taking into account all of the issues sketched out as part of this thesis.

6.1.4 Theoriezation

Alongside the forgetful historiography of the DH, a general problem in the DH are their perceived theorylessness. This picks up on the "more hack less yack" debate in the 2010s, which heavily focused on the application of methodologies instead of the theoretical implications and theorization of the DH, reminiscing the proclaimed end of theories by Felsch (2015) since the 1970s (Radtke 2015). This was heavily criticized: more methodologies than theories were discussed within the DH (as e.g., Scheinfeldt 2012, p. 125), favoring the "epistemologies of doing and building" as coined by Stephen Ramsay in a MLA panel in 2011 (Cecire 2011).

Undoubtedly, science theories exist in the DH already, such as e.g. hermeneutics, which is updated to include a wider variety of and digital sources; as such the critique on a focus on methodologies instead of a 'theory of the DH' provides a "false focus" as Piotrowski and Fafinski (2020, p. 5) stressed. "[T]heory and digital humanities aren't two separate enterprises that my be able to collaborate fruitfully. They are much closer to being one and the same thing", as B. M. Schmidt (2011) has argued.

In general, the DH use established theories from humanities' disciplines (e.g. literary studies) and apply them to a data source with computer-based methodology, such "renewing [...] theoretical traditions in humanities research" (ibid.).

The recent search for an again unifying and identity forming theory[16] for the DH culminates in various workshops and initiatives, such as e.g., the Workshop "Theorytellings" organized by the *Forum Digital Humanities Leipzig* in 2021[17], or the "AG Digital Humanities Theorie" founded in 2019[18], and more (e.g., Piotrowski 2020). The question remains if there are DH-specific theories to be found; or whether the DH automatically apply and refine theories of other disciplines that they combine interdisciplinary. Establishing a DH immanent theory would provide further independence of the field, and provide a way out of the perceived status as an auxiliary science–which has no theories on its own and offers application as a service only.

Network Theories

Similarly to the general digital humanities, network research is criticized lacking a conclusive theory of social networks (compare to M. Granovetter 1979; Wellman 1983, p. 179). Despite this assessment, network research is based on assumptions–either explicitly, and much more often implicitly–why and how people form connections in networks (Fuhse 2010, p. 167). Even though it is not the goal of network research to derive to a sociology of human nature, these assumptions are still rooted in such sociological concepts. These greatly influence how network research is analyzing social phenomena that emerge from structures of social relations of human (and non-human) actors. We want to identify

16. Theories constitute models and feature the premises needed to answer a research questions by offering a *modus operandi*. Merton ([1949] 1968) argued that theories should not be applicable in each and every situation; they could explain a lot, but not everything nor a single phenomena only. Instead, theories should facilitate the understanding of a broader phenomena, which Merton ([1949] 1968) called "middle range theories" in contrast to universally applicable theories that he deemed not suitable for the humanities.

17. https://fdhl.info/theorytellings/

18. https://dhtheorien.hypotheses.org/

three major frameworks of network theories following Fuhse (2020): that of action theory, pragmatist/interactionist theory, and relational sociology, supplemented by White's phenomenological relational sociology, and as argued by (Fuhse 2010), system theory.

Sociologists like Gehlen or Luhmann thought of human systems as a form of complexity reduction, producing stability and orientation. This focus on embeddedness in social networks offers a more interactive perspective in contrast to the more economical gain oriented approaches by Marx, Bourdieu, or within the rational choice theory (ibid., p. 173). Phenomenological network theory offers explanations for still heterogenous diverse network contexts, by recognizing the influence of few intensive relationships, rendering culture (and other systems) a "tool-kit" of possible social behavior and opinions, of which individuals can draw from creatively (ibid., p. 173). Transactions lead to the development of hierarchical roles, which serve as orientation of behavior and again reduce thus social complexity. This provides not a complete new theory on the interrelations of humans and interhuman structures, but closely follows empirical research.

While Borgatti and Lopez-Kidwell (2011) suggested to differentiate between effects of social networks as "network theory" and impacts on networks as "theory of networks," these can be regarded as mere recurring patterns/mechanisms in networks but not theory in the sense of explaining the nature and constitution of networks and their reflection on social phenomena (Wimmer and Lewis 2010, 139ff; Fuhse 2020).

Fuhse (2010, p. 173) noted that a macro level on society is still missing, as these theories cover the meso level of structures only. For a theory on the level of societies, Luhmann theorized that communication transforms these meso structures to bigger societal structures, while Foucault claims "discourse" results this.

6.2 Impact of the DH

6.2.1 Prospects

The lure of the DH is to 'update' traditionally analogue humanities' methodologies and approaches to the opportunities of the technological and digital changes. As such the DH wields the promise of a transformative power:

- The prospect to generate new insights on the research fields of the humanities on "deeper, less obvious connections" (Sternfeld 2014), latent structures (e.g., Nerbonne 2015, p. 35) or invisible trends hidden for the human eye, but detectable with the help of the computer (Underwood 2014).

- This entails the aspect of being more efficient and saving time: big data sets can be such analyzed that cannot be covered by an individual researcher in reasonable time.

- As well as an approach for falsification, re-testing, and refinement of established knowledge in replication studies (Edelstein et al. 2017, p. 408), increasing the validity of research and testing the robustness of results (Baum and Stäcker 2015, p. 10), and minimizing (or counteracting) the "authority of the wise" few as phrased by Nerbonne (2015, p. 38),

- suitable to provide new (or at least a change in) perspectives and new answers and inferences on traditional and new research questions and even well-known phenomena (a new "historical understanding for a new era," Sternfeld 2014),
- as well as offer "new avenues of inquiry and [...] springboards for further research" (Edelstein et al. 2017, p. 409),
- utilizing a large scale of sources "in a much broader space of possibilities" (ibid., p. 420), making "previously impossible or implausible research" approachable (Milligan 2013, p. 1).
- This bears the potential of innovation in the respective fields, and
- ultimately advances domain specific knowledge,
- and furthers a methodological awareness that "force[s] us to look closely at the information we have" and that information taken "for granted" (Edelstein et al. 2017, p. 408).

These promises require new "frameworks" of thinking (Sternfeld 2014) in order to ensure that the implications of the digitally-framed research are understood "as fully as possible" (Ayers 1999, p. 8), and to be made applicable for the humanities (Thaller 2017a, p. 16). Part of these frameworks are the various forms of literacies have to be counted: data literacy, computational literacy, and in general an updated digital hermeneutics that includes analogue and digital sources.[19]

Similar promises have been made for the gains of applying a network methodology on humanities' research objects: the potential for innovation, and the flexibility that a relational perspective offers to both reduce complexity (in an abstract view on an object of research), but also to grasp a certain complexity in analysis (Stegbauer and Häußling 2010b; Düring et al. 2016; Düring et al. 2020). In general, the complexity of a research object can be reduced in network analysis by focusing only on specific parts of relations of entities, and provide an abstract view in the form of a model of relations. But this complexity can be enhanced or better differentiated, too. In order to increase the validity of the results, it is possible to add more layers of metadata to the edge relations: by discerning between different types and qualities/qualitative assessments of relations, ranges of assuredness in regards to the factuality of an edge, as well as the temporal evolvement[20] of relationships. A relational perspective could thus bridge

19. See section 6.3.1.
20. Such as e.g., in novel forms of modeling in layers of time to show temporal developments of succession and sequences (Baum and Stäcker 2015, p. 10).

differences between theory and empiricism, the micro and the macro perspective, and could bridge gaps between structural and performance levels (Stegbauer and Häußling 2010a, p. 14), and might consolidate and generalize heterogeneous methodologies from the communities themselves (Rehbein 2020, pp. 256-7).

6.2.2 Criticism

These aforementioned promises in DH, digital history, and HNR are summoned again and again, usually characterized by a language full optimism and pathos. The promise for greatness is often perceived to have fallen short–"over-promised and under-delivered" (Arguing with Digital History working group 2017, p. 2)–, and has attracted lots of criticism: The DH would not 'save' the humanities (Kirsch 2014; Keeney 2016; Koh 2018; Hohls 2018, A.1-20–21; Piotrowski 2020, p. 3), the constant conjuration of new insights within the "revolution rhetorics" of the "apostles of the 'big data revolution"' (Fickers 2020) would be bordering close to magical thinking.

"[W]hy should new methods produce radically different results? We are studying the same objects that scholars have been painstakingly exploring for hundreds of years," asked Edelstein et al. (2017, p. 408). This rhetorical question picked up on the general resistance against new tools and methods, which are met with skepticism and criticism[21] until they are eventually accepted into mainstream (Rehbein 2018, p. 33). Hiltmann et al. (2021, p. 123) tried to explain the resistance to the digital turn due to it coming from "outside" (i.e., computer science) unlike the "internal" turns before from within humanities, e.g., the cultural or the linguistic turn, among many more *turns* (compare to Bachmann-Medick 2016).

6.2.3 Keeping promises

At the same time, these promises (especially on new insights on humanities' research objects) are perceived as requisite for the successful acceptance of the digital or computational methodology in the broader humanities and of the field of DH itself, as Nerbonne (2015, p. 32) pointed out. Therefore the questions stands: *Did the DH manage to fulfill their promises?*

Transforming humanities' research. The promise for reformation of the humanities through technology goes back to at least the 1970s.[22] Then, the transformative power of technologically assisted scholarship was described as "more convenient" and as fundamentally changing the possible scope of research (Wulf 1997, p. 111). It would change the

21. Compare to sections 6.1.3 and 6.3.2.
22. And actually even further. The *topos* of transformation of scholarship via technology can be traced back centuries. One of the most influential technological innovations in this regard was the invention of the printing press (Eisenstein 1979).

"representation of and access to information," allowing it "to organize kinds and quantities of information that weren't possible [before], hence to ask and answer questions about the human record that couldn't be answered before" (ibid., p. 111).

On the one hand, the promises on transforming research came true: the humanities (alongside all other areas of research, and life in general) were fundamentally changed by the digital revolution in the digital age[23] and the vast possibilities of the ever-present personal computers and the internet (e.g., Nerbonne 2015, p. 31; Arguing with Digital History working group 2017, p. 12; Guldi 2020, p. 328)–the most successful information technology since the the letterpress printing (Eisenstein 1979), and through the digitalization as influential in effect as the industrialization (Bunz 2012). Berry's argument goes as far that computer technology changed humanity (and the humanities) similarly to the domestication of humanity through pen and paper (Latour 1986), which he called the "computational turn."

Research practices were irrevocably changed even for 'traditional' humanities that do not consider themselves working digitally.[24] This includes the ways information is retrieved[25], stored[26], written[27], or published[28], to name only few instances. The successful digitization of analogue sources led to a hegemony of online resource citations in the humanities, and an ongoing replacement of the on-site archive in favor of the remote (digital) archive (Fridlund 2020, p. 75). This solved many issues of accessibility, which traditionally restricted or at least hampered humanities' research, as dependency on printed editions of primary sources or personal visits to archives aren't a necessity anymore when those sources are available digitally[29] (Rehbein 2020, pp. 259–60), and (at least in theory) democratically[30].

In this context, the trope of going from "scarcity" to "abundance" of sources (as coined e.g., by Rosenzweig 2003) through mass digitization is oftentimes referred. The amount of (analogue) sources however did not change; only their access did. Graham et al. (2016) argued accordingly that historical studies have always been a big data project in their core, calling the impression of the scarcity of (historical) sources a myth. Mass

23. Which is considered a new epoch (Schmale 2017; Gugerli 2018, p. 8; Hohls 2018, A.1-1).

24. In fact, it is arguable what can be considered 'traditional' in the humanities, as new methods and research perspectives are continuously introduced, and usually met with skepticism at first. Crymble (2021, p. 162) stressed that there is no stoic traditionalism in the humanities: "Neither can historians continue to pretend that their field has been left untouched."

25. Key word search in search engine and bibliographic online catalogues instead of surveying physical finding books in archives or bibliographical catalogues stored in cupboards in libraries.

26. Usually digitally instead of in physical copies in order to make them further processable.

27. Word processing programs on a personal computer instead of on a typewriter, as well as in solitary as much as in collaborative ventures, who cooperate through digitally accessible writing formats (see e.g., Walsh 2017, p. c), or through crowdsourcing efforts such as social editing (see e.g., Price 2016).

28. E.g., using Hypertext, multimedia representation, or new publishing formats such as Open Access

29. As a side effect, collection differences in memory institutions are blurred in digital supra-collections. Before, collection habits were divided between libraries (for reprintable serial sources) and archives (unique sources).

30. However practically restricted by various copyright and privacy laws.

digitization reversed the access-scarcity to an access-abundance, which still is characterized by scarcity, i.e. missing documents, incomplete sources, a general fuzziness of data; this constitutes a scarcity paradox.

Some authors such as Cohen and Rosenzweig (2005) claimed that already working with a computer would constitute part of the DH–without needing a conscious reflection on belonging to the DH community or the epistemic implications of the media used (compare to König 2021, p. 40). Similarly, also Berry (2011, p. 1) regarded the usage of e-Mails, online search, and virtual bibliographies as part of the successful digitalization of the humanities through DH. As for the "*Clio-Guide. Ein Handbuch zu digitalen Ressourcen für die Geschichtswissenschaften*", too, Hohls (2018, A.1-3) referred to the *"Selbstverständlichkeit"* of digital methods in the humanities, but essentially means the digitization of sources, and changes in writing and publishing behavior through personal computers.

On the other hand, this transformation of the humanities was not absolute. Despite the profound changes in common research behavior of searching, finding, and editing, the digital mediasation of sources and workflows is hardly reflected on in the 'traditional' humanities and remains too often "almost methodologically invisible" (Fridlund 2020, p. 76). The computer serves in an auxiliary position and only assists in the research workflow, while research itself pertained traditional and analogue methods. Common problematic behavior entails that the print resource is cited even though the digitally-accessible version was used (Blaney and Siefring 2017; Arguing with Digital History working group 2017), thus neglecting the epistemic and source critical implications of the digital version.

Instead, these changes in research behavior can be regarded as part of the digital turn in society and general sciences, and not necessarily part of the DH's influence. It can be argued that also the DH are a product of this digital revolution (similarly e.g., Fridlund 2020 or Baum and Stäcker 2015, p. 4). A distinction has to be made what actually belongs (not) to the DH as also suggested by Sahle (2015, p. 55), who proposed that there must be specificity to the DH's tool of trade. Thus using an Online Public Access Catalogue (OPAC) for acquiring sources or literature would not constitute part of the DH. This question on what actually makes a 'digital humanist'–whether or not this is a conscious declaration–resonates in the distinction Fridlund (2020) made between "History 1.0" and "History 2.0." Characterizing "History 2.0" as a revolutionized digital or even computational history, Fridlund (2020, pp. 74–76) defined the former as certain naturalized digital elements that got "domesticated", "appropriated" or "augmented"– but which application and influence on the research process is not overly reflected or even "invisible" (ibid., p. 76), such as online searching, using data bases, or working in general with a computer. Not every historian is already a 'digital historian' even when using a wide range of computer-assisted indexes, literature portals, and word processing software (Guldi 2020, p. 328). The familiarity of working in a digitally mediated research framework culminated in the contention by Putnam (2016a, p. 380) that working with online repositories became "as revolutionary as oatmeal." This however falls short on the epistemological reflection needed on naturalized digital workflows. Underwood (2014, p. 64) called online searching, i.a. the "algorithmic mining of large electronic databases", a "deceptively modest name for a complex technology that has come to play an evidentiary role" in how information is accessed.

Following these assertions, only the reflective usage of methodologies or techniques can be considered part of the DH.

The development of a critical reflection on digital source criticism, digital hermeneutics, and digital and computational methodology and their applications for the humanities are certainly part of the merits of the DH.[31] These advances, however, remain to become integrated into the broader humanities. If digital "technology is always already with us" (Fridlund 2020) and if "computing and the use of digital sources and resources" are daily tasks of modern humanities academia (Romein et al. 2020, p. 1), then proper critical disseminations of the workflows using digital resources and computers are required. A digital hermeneutics (or an inclusive hermeneutics of the analogue and the digital) for every historians is inevitable. The resulting changes in the "epistemologies and ontologies that underlie a research program" that Berry (2011, p. 1) had postulated remain to be acknowledged.

Paradigmatic change on the periphery. Still, the DH, digital history and HNR can be considered paradigmatic changes in the humanities, historical studies, and network research respectively (following e.g., Rehbein 2020), and a fundamental media change (Hiltmann et al. 2021, p. 124). The digital format provided new kinds of data interesting for humanities' research, from eased-access retro digitals to born digital objects, social media data, and metadata, and as Sternfeld (2014) put this,"an extraordinary amount of visible and hidden information surrounding the text message [...] that conveys a history unto itself." Digitization and abundant availability of digital sources led to changes in the humanities' methodology in order to deal with this new kind of sources, whose amounts exceed the limits of human capacity (Nerbonne 2015, p. 36): from "distant

31. Partially, these overlap with developments in the broader sciences, such as new ideas on how to do science in the digital space like the Open Science/Open Access movement. Their discussions are neither unique nor solely focused on the DH, but consider all disciplines. The demand for publicly accessible research outputs (Open Access to both publications and datasets in editable formats), a systematically documented disclosure of the methodology (Open Methodology) and source-codes used in the scientific process (Open Source) are part of a different understanding of research in the digital era. This spearheads research practices that elevate intersubjective testing and comprehensible and wildly accessibly public dissemination and peer review in a "connected web of scientific knowledge", that focuses on the quality of research work and fostering the dispersion of knowledge. Challenges for these developments pose proprietary classifications, non-exclusive or commercial usage of datasets, and the heterogeneity of Open Source-codes provided that miss a standardization. Other examples would be the critical code studies, digital forensics, working with big data, or sociological concepts such as digital divide and participation gaps (Jenkins et al. 2006), or the differentiation between digital natives and digital immigrants (Prensky 2001).

reading" complementing a "close reading" of sources (and variations of "scalable reading"), to network approaches, statistical analysis, new geographical representation and analysis, and new ways to structure and represent these sources as e.g., in databases and digital repositories. These new approaches "follow[] a completely different logic than our established approaches to historical research," Hiltmann et al. (2021, p. 124) declared, "thereby alerting the framework of historical scholarship as a whole." Similarly, this can be said about the scope of humanities' research through digital and computational methodologies.

But the DH's methodological influence on the humanities still remains peripheral: Only slowly and sometimes the digital and computational methodologies and digital hermeneutics are integrated into the humanities' tools of trade. This development is juxtaposed by a growing community of DH scholars, and their processing professionalization. The way how, e.g., historical research is undertaken did not change profoundly, as more traditional research questions persevered, even when working with digital sources or digitally-accessible analogue sources. Dobson (2020) even argued that the humanities' methodologies remain virtually unchanged. Hohls (2018, A.1-10) remarked, that promises on the potentials of the digital turn grew "more realistic" as the epistemology in the humanities did "not [become] completely newly construed."

Instead, the methodological tool box of the humanities was extended on with new perspectives, approaches, and ways of thinking, while pertaining a specific humanities' perspective; their thorough integration though still pending, and remaining the exception not the rule. Porsdam (2013) and Rehbein (2020) noted that there is no common ground on "reaching new territory in research" in the opposition between technological ideologist and critical traditionalists. Reservations pertain about adopting computational or quantitative-based methodologies in fear of positivism and replacement of qualitative approaches (compare to section 6.3.2 on "Perceived Division on Methods"). Edelstein et al. (2017, p. 408) consternated that the humanities as a "field ha[ve] not been revolutionized as a result"; instead it developed more island studies and fields without greater "repercussions." "If we look back at what 'history and computing' has accomplished the results are slightly disappointing", Boonstra et al. ([2004] 2006, p. 9) wrote on the lasting effects of DH's predecessor, as "[...] 'history' failed to acknowledge many of the tools 'computing had come with." Nonetheless, the broader humanities have been fundamentally changed by the ever-present personal computing and the digital revolution, but more in the matter of a humanities"1.0" as remarked by Fridlund (2020, pp. 74–76) that had naturalized digital elements without greater reflection.[32]

In this regard, the DH serve already as an auxiliary science (e.g., Baum and Stäcker 2015, p. 5)[33], as a "technical support to the 'real' humanities" (Berry 2011, p. 3), where the "machine's efficiency [is used] as a servant" (McCarty 2009). Milic remarked in 1966,

32. Compare to section 6.2.3.

33. Piotrowski and Fafinski (2020, p. 6) argued, that the view of DH as a tool box would "undermine" its establishment as an independent discipline.

p. 4, "we have not yet begun to think in ways appropriate to the nature of this machine." The further integration of the new methodologies and as such the possibility of research otherwise unattainable before (Thaller) is one of the many challenges lying ahead.

Generating new domain-specific insights. The questions stands whether the promises on new insights due to the discovery of hidden patterns "that would have been difficult, if not impossible, to reach by analogue means" as e.g., proposed by Edelstein et al. (2017, p. 404), were fulfilled. *Was such domain-specific knowledge generated with computational and digital methodologies?*
The answer to this is manifold, and only some exemplary highlights will be brought forward here:

- network approaches and efforts to combine various collections of retrodigitals helped to cast a new understanding on the contacts, distribution, composition, and extent of the "Republic of Letters." In a broad series of studies new insights were generated from debunking the notion of Newton as a solitary working genius (Schaffer 2008), to an assessment of the actual role of English thought and influence on Voltaire's philosophy (Edelstein and Kassabova 2020), or reflections on the data itself as in the compendium by Hotson and Wallnig (2019).
- using a computational approach and analyzing a Protestant letter correspondence networks in Python, Ahnert and Ahnert (2015b) could shed light on the importance of prosecuted Protestants for their community during Mary I's reign in the 16th century, identifying "trends that only an expert in the field would have a sense of by reading all the letters, but would still find almost impossible to measure or quantify" (ibid., p. 30).
- debunking the notion that inefficacy led to Heinrich (VII.) removed from power by Friedrich II., but instead due to them supporting oppositional political factions identified with network mapping and community detection approaches (Gramsch 2013; Dahmen et al. 2017; Gramsch-Stehfest 2020).
- text mining approaches brought the identification of authorships, or even language characteristics for early signs of illness in a body of work, as in the study Identifying signs of onset dementia in the later work of author Agatha Christie (Lancashire and Hirst 2009), identifying e.g., gender dynamics and hierarchies in novels (Kraicer and Piper 2018), using quantitative methods to describe the "invisible editorial labor" of women abolitionists and the role of editing for community formation (Klein 2020, p. 27), or automatically annotating ambiguous concepts such as alchemical language (Lang 2020).
- an analysis of how much the Gestapo investigations knew about the Stauffenberg–conspiracy using network approaches (Keyserlingk-Rehbein 2018),

- new perspectives on helper's network organization during the NS-regime (Düring 2015),
- identifying the underlying pattern of inquiry in the "Great Inquisition" in the 13$^{\text{th}}$ century by Dominican monks against Cathar Heresy as "principally aimed at collecting evidence against village consulates" (Rehr 2019, p. 1).
- falsifying assumptions of the mainly qualitative scholarship on the penal practice during the Corporate State, as shown in our case study, or highlighting various levels of importance and interconnections of scholars in a global outlook on a big history of intellectuals.
- in the collection of case studies edited by Knowles et al. (2014a), mapping the spatio-temporal developments of the SS Concentration Camps in order to allow their comparative study (Knowles et al. 2014b), or the 3D reconstruction of Ausschwitz in order to study the "tension between the idealized plan and the actualized built environment, from the ideological goals to the physical realities of implementation" (Jaskot et al. 2014, p. 165).

Besides these achievements, the accusation remains that the DH (and digital history) did not contribute to domain specific knowledge *enough*, that the DH have not yet proven their worth for innovative discipline-based insights or revolutionary "revision[s] of lasting tropes in the discipline[s]" (Guldi 2020, p. 337), and that its contribution to research continue to be phrased in a "[p]erpetual future tense" (Blevins 2016). This is reiterated as well for network analysis in the humanities as an unfulfilled potential: There are still many open questions to be explored (Stegbauer and Häußling 2010a, p. 14), and the gain of historical network research can only by "cautiously addressed" as its possibilities are not yet fully utilized (Reitmayer and Marx 2010, p. 876), nor fully understood on how the formalized methodology should actually be applied. Instead an "eclectic" inspiration are taken from formalized methodological approaches that are enthusiastically adopted but too often little understood, that in the humanities' application often remain metaphorical (ibid., p. 869).

From a methodological point of view, this perceived lack results from a general lack of computational literacy and methodological understanding in the core humanities, and missing conceptual grasp on how to operationalize computation-based methods on historical research questions (Arguing with Digital History working group 2017). Coming from a qualitative, hermeneutical, i.a. interpretative analysis, the adoption (and comprehension) of computational methodology is hard.[34] There is no general curriculum in computational methodology, nor the various literacies canonized.[35] Only in the late 2010s, attempts have been made to establish a standardization of core DH methodologies, such as working with databases, computation-based spatial analysis, automated

34. Compare to section 6.3.5.
35. As will be discussed in section 6.3.1 on "Establishing literacy."

text mining, or network methodology[36]. In a similar vein, initiatives were founded to increase the visibility of argument-driven digital scholarship: such as the Journal *Current Research in Digital History* (inaugural issue in 2018) of the Roy Rosenzweig Center for History and New Media (RRCMN) was specifically designed to "encourage and publish scholarship in digital history that offers discipline-specific arguments and interpretations, rather than simply showcase digital projects."[37] Similarly, the "Models of Argument-Driven Digital History"-website of RRCMN (launched in August 2021) hosts a selection of (preprint and first version) articles, annotated by their authors with reflections on their underlying operationalizations, conceptualizations, and processing of their data, and subsequent analysis[38], in order "to highlight the use of digital methods to make historical arguments", and in a step to further the open discussion on the scientific process.[39]

But there still remains a general lack of understanding on how to use network methodology, or how the resulting graphs and figures should be interpreted.

Crymble (2021, p. 4) argued that indeed the DH and digital history did not contribute a lot to furthering the domain specific knowledge. Their focus have been on building the digital research infrastructure, and a methodological and source critical awareness first, and only then would turn to discipline based arguments and inferences using these tools of the trade.[40] As a result of these different goals, Crymble (2021, p. 33) argued it would be unfair to judge digital history by the amount of domain specific knowledge generated, as the focus lied on "working with the newly digital archive and understanding how or if it would facilitate new historical knowledge" (ibid., p. 43).

This circumstance also fits to explain the common accusation that "methods have won out over interpretations and argumentation" in DH as L. Mullen (2019a) noted, or that historical understanding had been drowned in the noise of historical big data. Rebutting this as a hypocrisy, L. Mullen (2019a) stressed that digitally working historians have to be more reflective, and more importantly, more transparent about their methodologies – including systematical approaches which data to include/exclude, their processing, and limitations – in contrast to more traditionally working historians, who tend to under-explain or "hide their methods" (similarly voiced also by Scheinfeldt 2012, or in regards

36. See for HNR the various "handbooks" edited by, e.g., Düring et al. 2016 or Stegbauer and Häußling 2010b and for the DH in general "*Digital Humanities: Eine Einführung*" edited by Jannidis et al. 2017. Other examples would be the various online tutorials in the "*Programming Historian*" (https://programminghistorian.org/) or the "*Computational Historical Thinking*"-Guidebook https://dh-r.lincolnmullen.com/index.html.

37. https://crdh.rrchnm.org/about/

38. Among those is also an annotated version of Ahnert and Ahnert (2015b) featuring insights on their underlying ideas for operationalization, data processing, and network analysis (compare to Ahnert and Ahnert 2015a).

39. https://model-articles.rrchnm.org

40. Not without irony, in multiple instances, Crymble (2021, pp. 33, 44) proceeds in making again promises of what is about to come, as it is always too early to tell: "We are just now starting to the see the fruits of their research as it comes to engage with the traditional historiography."

to transparency in how sources are researched (Crymble 2021, p. 33))

Furthermore, Crymble (2021, p. 43) noticed the differences in the domain specific discussions: the problems and questions encountered in DH "were not necessarily connected to the old ones," resulting in an incompatibility to the more traditional journals as "right venues for the new conversations." The transparent discussion and reflection on methodologies thus provide for an unaccustomed practice for the more traditional humanities' scholarship. This would then lead for one to the perception that DH focuses more on methodology instead of on interpretation, and for two to an opening for further criticism as a side effect of this transparency in methodology and data selection; a criticism that most 'analogous' working historians are not exposed to when their methodologies remain hidden.[41]

6.3 Challenges and implications

In the following, challenges and implications within the Digital Humanities and in the context of this thesis' case studies will be discussed, ranging from the problem of establishing literacy in the research process working with digital sources and data, (computational) methods and tools, arguing for a complementation instead of the classical divide between qualitative, qualitative, computational, and digital methods, reflecting on interdisciplinary research, outlining specific next steps in future research avenues in the context of the case studies, and finally giving an outlook.

6.3.1 Establishing literacy

In order to counteract the 'naive' belief in digital technology and in the 'black on white' number on paper (or, more accurately, on screen), an informed mature critical encounter with stats, figures, tools and data needs to be established. Computational multimodal literacy consists of the familiarity with a wide range of fields: methodological literacy, data literacy, tool and interface criticism, algorithmic and visual literacy. These competencies allow a reflection of the implications of the changes in the epistemological approach: How is new knowledge generated with the data used? How does the restrictions of the data influence inferences? On which assumption is a methodology based on? Does a user's ability to browse digital technologies and to produce results with the click of a button entail an intuitive assumption on whether these results are reasonable or correct?

A multimodal literacy is the foundation to understand that digital objects, tools, and methods are the products of decisions and processes which "are never neutral, and [which] historians will need to be equipped to evaluate" (Milligan 2019, p. 214). Knowing how to

41. Sternfeld (2014) gives for this the example on how sources are found: there is a 'tendency to brush aside a detailed explanation for how we [the historians] search for and discover archival materials, organize those findings, and then present them in a cogent argument" in traditional scholarship, that would have to be explicated as a changed work-flow in digital scholarship.

deal with the new-found normality of digital media(s) and computational competencies in navigating in the computerized world, the Directorate-General for Education, Youth, Sport and Culture (European Commission) (2019) declared digital literacy (also referred to as digital competence) as a necessity and part of "life-long learning goals." In the following, we will discuss these literacies that have yet to become a basic training in any humanities curriculum.

Data Literacy and source criticism

Data literacy involves knowing about the content, the structure and formalities of the data and metadata (including information on the format), the criteria of data selection, and the biases of the data used, following closely a source critical hermeneutical dissemination.

On sources as data. The digital turn brought an ontological transformation of sources to data in the humanities. In the commonly used definition by Kirn ([1947] 1968), sources are used to draw inferences on a field of research. In a source critical hermeneutical approach, sources need to be disseminated individually by the researcher, critically discussed and evaluated in their content, context, authenticity, and provenance. The classical definition thought of sources as ranging from text to imagery and multi-dimensional artifacts, but can easily be extended to integrate digital and digitized sources as well.

In contrast to sources, data[42] are formalized information made machine-processable, i.e. structured or coded.[43] Johanna Drucker (2011) rightly pointed out to the subjective nature of the seemingly objective data: unlike its etymological connotation, data is not something "given" (as its literal Latin translation purports), but consists of information that was extracted and constructed from something, i.a. a source. Drucker (2011) therefore proposed the more appropriate labeling of data as *"capta"* ("taken" in Latin) to stress its constructive and interpretive nature (similarly argued also H.E. Jensen in 1950, quoted in Becker 1952, p. 278; see also Kitchin 2014, p. 2). In this extraction process, sources (and their information) are interpreted, evaluated, weighted, and indexed, i.a. which information are recorded in which format and in which classification scheme (or index) from a source (compare to e.g., Kitchin 2014; Fickers 2020).

As a consequence, data literacy is overlapping to the humanities' hermeneutical source criticism–a "historical studies data criticism" (Fickers 2020) extended (or 'updated') from the analogue to the digital realm. This includes a critical evaluation of the data's authenticity, reliability, and objectivity of the content dependent on the purpose of the source. In contrast to the perception of authenticity in computer science as integrity, i.a. the intactness or semantical correctness of the data (as a copy), historical authenticity is concerned with the degree of reliability or factuality (and the provenance) of

42. Used in the following in plural following convention, which does not use the Latin plural of *"datum"*.
43. For a conceptualization of data compare to Kitchin (2014, pp. 1–26) and Borgman (2015, pp. 17–29).

the source.[44] A source critical approach entails, too, analyzing the context surrounding the data and the data provenance or historicity (origin, creation, storage and processing, possible migration), including its dating or periodization (either identified through context or available metadata) and to reflect on its *"Zeitgebundenheit"* (historicity) of the data used. In the words of Romein et al. (2020, p. 19), data literacy and a digital hermeneutics is "to do what historians have always done, [to] question the origin and authenticity of a historical source." This sets a "new standard" (Guldi 2020, p. 330), as "[h]ybridity is the new normal" when working with (digital and analogue) sources and data (Zaagsma 2013, p. 13; compare also to Fickers 2020). A critical perception of data brought new areas of expertise such as critical data studies as coined by Dalton and Thatcher (2014) as a "systematic approach to data criticism" and its societal implications (compare also to boyd and Crawford 2012; Kitchin 2014), as well as critical code studies and digital forensics or e-paleography, which critically examine the implications of the code itself and engage in the digital provenance, materiality, and origins of the digital object and its restoration (compare to Morris 1998; M. G. Kirschenbaum 2008; Baker 2019a, 2019b; for an overview on critical code studies see Marino 2020).

As a consequence of this processing, data can be considered models: they are a subjective representation of a reality (e.g., a source), which creation was guided by (underlying) assumptions that structured the selection (and indexing criteria) of the information recorded.[45] As a model, data are necessary a reduction (or: focus) on (supposedly) important factors striving to approximate reality (in this context: a source). The selection of data can too become a model in the definition by Stachowiak (1973) of a fundamental epistemic tools, which however remains a flawed approximation of the object of research. Therefore Flanders and Jannidis (2019a, p. 3) rightly pointed to the need to "understand the social, intellectual, and political contexts" in which data modeling took shape.

Similarly, research designs are models consisting of a set of assumptions, theories, and guide the selection of suitable data to be included for subsequent analysis dependent on the research focus. The problem here is representation: Is the parameter used in the model falsifiable and the right one for the problem? Is it a meaningful parameter? Meaningfulness can be justified with a corresponding theory that is guiding research as in a deductive approach. Theories themselves can be considered as models consisting of a set of assumptions. "A theory written in the form of a computer program is thus both a theory, and, when placed on a computer and run, a model to which the theory applies," wrote Weizenbaum ([1976] 1983, pp. 144–5) on the interchangeable nature of models and theories. Whereas there might be objective reasons to include certain data, the specific research design in the model is still subjective. As such the research process in selecting data and forming hypothesis need to be made clear as possible, especially when data is

44. Compare this to the discussion of authenticity and integrity in historical studies and computer science in (Föhr 2017, pp. 186–90).

45. Which implicit assumptions would have to be explicated in a 'good' model (compare to e.g., Flanders and Jannidis 2019a, p. 3).

fuzzy (Gius and Jacke 2020; compare to the following section on data biases). "Debates about methods are ultimately debates about our models," summarized this Flanders and Jannidis (2019a, p. 3)

Data Biases. Historical sources and the data extracted from them are in general burdened with problems in variety, ambiguity, vagueness, fuzziness, scarcity, and incompleteness (Rehbein 2020, p. 261)–Flanders and Jannidis (2019a, p. 5) called humanities data "strongly layered"–, which quantitative utilization are studied since the 1960s and 1970s (compare e.g., Boonstra et al. (2004) 2006, p. 35; compare also to section 2.2). To reflect on biases in analogue sources, a source-critical hermeneutics has been developed to ensure a source-based critical dissemination, assessing the content, context, authenticity and provenance of sources.[46] This hermeneutics need to be extended to the digital realm working with retrodigitals, born digitals, data, and metadata (compare e.g., to Föhr 2017; Cordell 2017). In the following, we reflect on biases in data based on digital and digitized sources, and their implications.

Systematic fragmentation. Already in the digital migration from analogue to digital, analogue sources systematically loose information in the digital reproduction (Kwastek 2015, p. 18). After digitization, retro digitals have to be considered a pre-selected source, that have become de-contextualized from the original artifact, and from their original collection context, alongside loosing their materiality and haptic information conveyed by examining the physical object, such as touch, weight, or smell (Arguing with Digital History working group 2017, p. 4). The digital artifact thus becomes more fragmented, if these information are not recorded in (meta)data.

Systematic and inherent subjectivity. At the same time, digitized sources can gain further information through extensive metadata documentation (e.g., information on the author, exact measurements, collection context), which enrich the available information conveyed by the artifact itself (e.g., the text in a letter). As such, digital collections synthesize and contextualizes sources, and influence their fundability and visibility heavily–but often fail to explain their choices for selection, description, and standardization (ibid., pp. 6–7) It is important to stress, that this enrichment of data–and the selection of which information to include in the data–is an act of interpretation, a translation accomplishment of an analogue source to a digital object. The digital collection itself thus becomes an argument, stressed the Arguing with Digital History working group (2017, p. 5). As a consequence, digitized sources are not the same as the analogue source; questions about the original do not become "obsolete" as remarked by Fickers

46. Differentiating between an "outer" (structural context based) and "inner" (content reliability based) source criticism, this allows to make inferences on the intention, motivation, and interpretation of the source. For an introduction to the hermeneutical methodology and source criticism in the historical studies compare to Droysen ([1882] 1977), and exemplarily, Beck and Henning (1994).

(2016). Instead, Cordell (2017, p. 189) warned that dependent on the quality of digitization, digitized sources have a bibliographical "lineage" of texts: "dirty OCR" can change the text itself as Cordell (2017) showed for Edgar Allen Poe's poem "*The Raven*" to what can be described as an (involuntary) edition, in which the OCR program acts as a "compositor" that "interprets" text based on best-guess approximations of the characters scanned (ibid., pp. 194–200). As such, a problematically digitized source becomes the result of the "priorities, infrastructure, and economics" and technical possibilities of digitization (ibid., p. 190). Digitized sources have to be considered "enriched (big) data" instead of simply "digital surrogates" (Romein et al. 2020, p. 3). From a source critical perspective, it is therefore relevant to cite the actual sources used. Blaney and Siefring (2017) pointed out that "historians still pretended to cite paper-based sources, while drawing heavily on new digitized archived, sticking their heads in the sand about any implications of using the digital surrogates." The Arguing with Digital History working group (2017, p. 1) summarize this digitized data as a "digital literacy."

Data are systematically not objective but constructed, characterized by systematic subjectivity (see e.g., Drucker 2011; Kitchin 2014). Data based on historical sources bear both such a systematic subjectivity and an inherent subjectivity. Historical sources inherently purport a certain perspective (or narrative) influenced by their origin (e.g., author, context of origin, time period), which have to be contextualized in order to deconstruct the narratives of their origin. The hermeneutical approaches applied on traditional sources are as applicable to digital sources, and consequently to data, too. Essentially, all data can be considered historical data.[47] "We need to unmask their [the data's] underlying assumptions in order to get down to the level of historical evidence. The role of the scholar thus becomes of finding meaning in the mass, which in the case of historical data is often also a mess," describes Edelstein et al. (2017, p. 419) the need to de-construct data. "'Raw data' is both an oxymoron and a bad idea", as Geoffrey Bowker put this (quoted in Gitelman and Jackson 2013, p. 1), while neither "[d]atasets seldom can be taken off the shelf and used blindly in an 'as is' form" (Batagelj et al. 2014, p. 388). This transparency and reflection on how data have been "always already 'cooked"' (Bowker quoted in Gitelman and Jackson 2013, p. 2), i.e. processed, are needed in order to converge closer to the historical 'truths' these data represent. This "data awareness" (Kwastek 2015, p. 17)–the understanding of data as models, surrounded by assumptions and context–extends on the commonly assumed data literacy.

Inherent fragmentation and fuzziness. Furthermore, the sources might be inherently fragmented, something that is almost always true for historical data. Rehbein (2020, p. 260) noted that "digitization cannot change characteristics of historical research." An improved accessibility through digitization did not change problems of sources that entail

47. There pertain some differences in regards to the authorship; with exception to oral history, in historical studies the researcher is not the author of the source used as e.g., in interviews or survey data that are common in the social sciences

both known unknowns (such as vagueness or fragmentation that we known about/suspect) and unknown unknowns (missing elements that we don't know anything about), which need to be met with a traditional hermeneutical dissemination. Fragmentation and lack of sources naturally influence potential research angles and empirical analysis. As such the quantification of sources needs a way to reflect the "ambiguities, paradoxes and contingencies" of qualitative research (Edelstein et al. 2017, p. 419). The fuzziness of data has been commented on since the 1960s and 1970s (Boonstra et al. [2004] 2006, p. 35). Aydelotte (1966, pp. 805, 811, 820) warned on numerous occasions about "inherent frailties" and other restrictions that make a quantification (or: datafication, as in this context) difficult. These limitations to the data are ultimately permeable and not resolvable. All historical data is fuzzy, in that it is unclear how much information points are missing and how these missing information influence the outcome of any analysis.

There are several angles to tackle this fuzziness of data, which entail documentation, contextualization, robustness measures, further cross-referencing, and using large and varied datasets. A thorough documentation of the origin of the data and potential shortcomings helps to establish the validity of the data sources used, and their contextualization situates the data source in their creation and significance in time.[48] As such the data should be documented explicitly and data biases openly exposed similar to the "reading of a text in a scholarly edition" (Rehbein 2020, p. 265). Historical studies tackle limitations of sources by testing, counterposing, and critically disseminating a variety of sources from different perspectives and origins in order to infer to a historical "truth." Contextualization is key for historical work. Measures for robustness of data, such as certainty levels, can be implemented in computational methods, which help to again raise validity and reliability of the results. These can show varying degrees of the certainty of analysis, as e.g., the likelihood of the factuality or certainty of a date (ibid.), or forms of time-stamping of secured knowledge. Another approach would be to utilize large datasets following the law of big numbers, which can level out missing information due to the range of available data (Lemercier and Zalc 2019). However, problematic data cannot be compensated with a more sophisticated approach as Aydelotte (1966, p. 810) reminded his readers, and "boundaries of what it can accomplish" (and cannot accomplish) need to be accepted (ibid., p. 825). Furthermore, a cross-reference to other data sources such as cultural heritage resources or Linked Open Data could be used to validate an/or enrich the available data (Edelstein et al. 2017, p. 420).

This frustration with fuzzy data is ultimately not resolvable. It can only be combated with greater transparency on the data, their description, and reflection on possible shortcomings, and their significance for the outcome of research. Due to the fuzzy nature of sources, after all, research is always only to the best of our knowledge, and needs to be

48. A gross disregard of this principle was the recent analysis of the development of trustworthiness in portraits using machine learning by Safra et al. (2020), which received very strong criticism as "bad science" (Booch 2020; compare also to Fafinski 2020; Spanton 2020). This paper lacked a proper critical reflection on their sources, and ported among other things established bias on whiteness in their curated data set into their analysis of "trustworthiness" in 500 years of portraits.

refined in the light of newer (and more accurate) evidence at all times, as one of the core principles of science.

Selection and representation biases. Certain types of sources tend to be over-represented due to the incomplete digitization of sources[49] This bias in representation applies to sources especially that are more easily digitized such as typeset sources (especially of 19th and 20th century serial published newspapers) in contrast to handwritten manuscripts (that would require more sophisticated OCR, and manually trained HTR), or that have been digitized due to a project focusing on a specific source type (compare to Rehbein 2020, p. 259). Underlying to this is a selection bias which favors specific themes and types of sources (Edelstein et al. 2017, p. 414).

The availability of digitized sources then facilitates their increased referencing – alongside a hyper-focus on certain timeframes or periods these readily digitized sources originate from, and the specific perspectives these sources provide (Putnam 2016b). An illustrative example on this problem of over-representation gave Milligan (2013) on the digitization of two major Canadian newspapers–the Toronto Star and the Toronto Herald–, which in turn where used as main data sources in more research projects than ever before (ibid., p. 7). Milligan could show that they were cited much more due to their accessibility of digitization, but at the cost of neglecting other equally suited newspapers of the same period. As a consequence, the ready availability of data (and digital/digitized sources) guides research and veils what kind of (existant) sources are missing. Why look further, if the first result already fits? This asks the researcher to examine thoroughly and carefully what is included in the digitized collections, and what is literarily not there, but only available in physical sources. “And when we fish in digitized text, we are fishing in a very particular sea”, warned Putnam (2016b, p. 390) about the curated collections of digital access (Crymble 2021, p. 33).

Canonization and uniformity. The focus on an again small (but on trend always increasing) number of digital corpora of sources bears the danger of uniformity (in contrast to their variety), as it pushes the specific perspectives of these readily available sources. This threatens to render void one of the main advantages of mass digitization: to provide a complete picture on a field of research by offering–seemingly–all the sources, when instead the same sources are references again and again, and do not extend the “short tail” of canonized authors as known in literary studies (which has been the initial intention of Moretti 2005). As such the digitization of sources leads to a new form of canonization, from which nevertheless a “host of forgotten characters” emerge still (Edelstein et al. 2017, p. 414).

49. Which is constantly changing due to the “moving wall” of eligible sources for digitization.

In the context of this thesis, the same mechanisms of data biases are at play.[50] The analyses in the case study on political judiciary necessarily reflect the perspective (and information recorded) in the sources. The source basis are the court records of the provincial courts of Vienna I and II, which survived both the 'tooth of time'[51] and purges where there was only kept considered of 'value' as in the 1980s, and finally through the transmission into a database selected by the research project on political repression by Wenninger et al. (2017), in which process 1,836 cases were recorded. These are different forms of selection biases that dependent on transmission as well as on e.g., transcription noise. The records themselves are subjectively biased: they do offer a specific and non-objective view of the courts, the judiciaries, and the police on the supposed offenses of the defendants, and can be considered involuntary ego-documents (Schwerhoff 2011, p. 40). Any findings necessarily reflect the view of the courts, and can be considered only an approximation to historical reality.
Similarly, the analysis of network structures within the history of intellectuals corresponds to the information recorded in the datasource of YAGO, which obtained data from Wikipedia.[52] As such it reflects both current and popular knowledge on intellectuals in history and their influences, which were curated by a crowd-based review process. In this format only the 'most important' information were recored. Therefore, the case studies give an abstract view on the history of intellectuals similar to the broad strokes of a master narrative.

Methodological and algorithmic literacy

A methodological literacy has oftentimes been demanded (as e.g., by Rehbein 2020, p. 258; Mayer 2016; or in the white paper by the Arguing with Digital History working group 2017, pp. 11–13) as the foundation to use any method: a familiarity with the corresponding theories of the method, e.g., in network analysis with network and graph theories, and with certain statistical and quantitative foundations. Underlying questions guiding a methodological literacy entail: What is the method aiming at? Does the data foundation allow this kind of analysis?

Establishing method competencies and a critical reflection of results when working with computer-assisted tools is key. There are a myriad of introductory articles to help in the quest to learn *"How to Read Articles which Depend on Statistics"* (Thomson 1989), educate on how to identify manipulations with data[53], give guidance in adequate

50. For the following remarks, compare also to the sections on data description and limitations in Petz and Pfeffer (2021).

51. Resulting in their deliberate and random fragmentation through e.g., either removed or destroyed or simply fragmentarily transmitted record parts, such as e.g., proofs for periods of imprisonment, release dates, or imposed fees.

52. Compare to the discussion in Petz et al. (2021) and in section 5.2.2 on "A master narrative."

53. A humorous and high-circulation print example would be "*How to Lie with Statistics*" by Huff ([1954] 1993), or "*So lügt man mit Statistik*" by W. Krämer ([1991] 2001). Best (2005, p. 210) noted however, that statistics are socially constructed and less the product of lying than of "sincere, albeit

sampling sizes (Lemercier and Zalc 2019), or practical introductions to the methodological basics of network analysis (e.g., Graham et al. 2016, pp. 195–264; Stark 2016; L. Mullen 2019b; compare also to the tutorials of the "*Programming Historian*"[54]; and the general introductions to the principles of network analysis as e.g., by Wasserman and Faust 1994 or Jansen 2006).[55]

Methodological literacy is intricately interwoven with an algorithmic literacy: What does the algorithm/the function(s) do? What are the differences in the available methodologies and algorithms, e.g., for structuring or processing the data? What are strengths, advantages? If done thoroughly, algorithmic literacy means critical code review, as Guldi (2020, p. 335) stressed. Neither algorithms nor their underlying methodologies nor tools (which implement certain methods/algorithms) are neutral. This is rather well-established for search algorithms, which rank and select information à priori. This establishes hidden power relations in the background, which alter the obtainable results and have due to their easy use significantly changes the heuristics of searching (Bunz 2012; Fickers 2020).

Tool and interface criticism

Tool and interface criticism are concerned on one hand with the implementation of a methodology (or algorithm) in a tool, and on other hand with the presentation of tools and interfaces and their usability, in order to ensure a reflected and learned application and operation of a user. What does the tool do, what is the tool able to show? What are its underlying principles and applied methods? How is a specific method operationalized in the tool used? Connected to this: Are these methods appropriate for the research problem or data source? As a consequence, methodological and algorithmic literacy are requisites for tool criticism. The second part of tool and interface criticism is concerned with the presentation and usability of the tool or interface: How does this tool or interface influence potential research?

An ever increasing number of tools and interfaces–for text mining, distant reading, network analysis, character recognition, corpus exploration, and more–offer results seemingly with the click of a button (Wiedemann and Lemke 2016, p. 404; Rehbein 2020, p. 258). This followed demands to provide software and applications to be used easily by "masses of humanities scholars" (Boonstra et al. [2004] 2006, p. 19) with lower entry hurdles and for a multitude of research contexts similar to the revolution of accessible data analysis with SPSS since the mid-1980s (such as e.g., by Edelstein et al. 2017,

innumerate advocates [...] or [of] selectively highlighted" spotlights. For an overview on statistical literacy advocators and practical recommendations for statistical training compare to Johannssen et al. (2021).

54. https://programminghistorian.org/

55. For a discussion on the perceived divide and supposed hierarchy between quantitative and qualitative methods, and on a reflection on the interchangeability of methods, island solutions and standardization please compare to the following sections in 6.3.2.

p. 419; Rehbein 2020, pp. 258, 262).[56] The perception that these tools offer correct results clicking a button however is deceptive.

"All digital tools operate upon some form of modeled data, whether or not they fully expose that model to us, so if nothing else, we are creating information that corresponds to our tools way of modeling information," summarized Flanders and Jannidis (2019a, p. 11) this. As a consequence, its underlying model should be aligned with the researcher's own intentions (ibid., p. 12); the tool can control and restrain options of functionality for research, and thus shapes insights generated–it has to be considered an epistemic object of research.[57] In order to open this 'black box' of automation, both documentation from the side of the developer, but also a methodological and algorithmic literacy from the side of the user are requisites. The turn in recent years for open source software and tools is a step into the direction to establish peer-reviewed source codes. As a consequence, tools and interfaces need be re-contextualized as epistemic objects of study and have to be considered "interpretational machines" that do not necessarily provide the 'correct' answer (Romele et al. [2018] 2020). The computer–or any other tool– is both epistemically and "semantically blind" (Schwandt 2018, p. 108). Any meaning from the given results have to be brought forward by the respective researcher, and cannot be relied on the tool itself. Tools should therefore neither be blindly trusted nor discarded as "epistemologically incompatible" (Romein et al. 2020, p. 20). Tool and interface criticism/literacy is about evaluating the "full implications and possibilities" of the tool (Ayers 1999, p. 1) beyond a superficial usage (Nerbonne 2015, p. 39) in order to make informed choices.

This option for peer-review helped to bring notice to e.g., the "common sin" of producing spurious results when using the default metrics of the tool *Gephi* to analyze two-mode networks instead of one-mode ones for which the default applies (Graham et al. 2016, p. 262).

In the context of this thesis, for the case studies we decided to implement methods, approaches, and data processing in our own code utilizing the established open-source libraries of the statistical computing software *R*[58] (for network analysis: *R::Igraph*[59] and *R::Statnet*[60]) before switching completely to the programming language *Python*[61] due

56. "Now we do not have to be giants. We can be ordinary people, using statistical packages to play with data and examine hundreds of analytic possibilities," explained Wellman (1983, p. 74) the advantages of accessible statistical software.

57. The choice for specific tools can carry "cultural significance" as Flanders and Jannidis (2019a, p. 10) noted, such as the practicability and elegance of XML tree structures in contrast to the pre-XML data bases created in terms of speed and development, irregardible of their "extremely poor fit in modeling terms."

58. https://www.r-project.org/

59. https://igraph.org/r/

60. http://statnet.org/

61. Version 2.7, https://python.readthedocs.io/en/v2.7.2/contents.html

to it allowing to program object oriented[62] (for network analysis: *Python::NetworkX*[63] library; for statistical analysis: *Python::Numpy*[64] and *Python::Pandas*[65].

Interface criticism can be part of a digital hermeneutics, too, which involves the critical appraisal of the interface as a source–e.g., a website–and its perception as the result of a digital (re-)coding and possibly, a (re-)contextualisation as in e.g., how websites are archived. Fickers (2020) showed the changes websites go through when e.g., reconstructed by the “Wayback Machine” using time-stamped captures; their depiction however is only an approximation of the original at a certain time point with a certain browser. Consequently various forms of representation exists for a singular interface.

Visual literacy

Finally, visual literacy is essential to understand the visual output of research. What does a visualization of aggregated data or graphs mean? How to ‘read’ a chart or graph? This concerns both a critical reflection of the visual comprehensiveness–from accessible color schemes to labeling or an optimal distribution of nodes on the available surface or minimized line crossings (Tufte 1983; Mayer 2016; Pfeffer 2017)–, as well as the ability to understand visual manipulations, e.g. through axis shortening, distortion, and focus (for a popular overview on manipulation with visualizations see Huff (1954) 1993; and W. Krämer (1991) 2001, pp. 37–50) to the correct interpretation of topological location of a node within a network (Graham et al. 2016, pp. 159–194; Mayer 2016; Rehbein 2020, p. 258). A critical reflection of presentation and visual evidence tying in to visual literacy helps to uncover forms of appresentation of knowledge: where does this presentation lack, which are its advantages? Representation in visuals alone are not enough to provide explanations for “historical causality” (Sternfeld 2014).

Canonization of literacies

These literacies are iterated as digital competences in various contexts, as in e.g., Janssen et al. (2013, p. 478) as building blocks of core competences applicable in everyday life and support competences that reflect information and communication technology. Digital competence was officially recognized by the European Commission as part of the “Key Competences for Lifelong Learning” (Directorate-General for Education, Youth,

62. Initializing classes of “objects” (instances) within the code, that bear certain attributes or methods (compare to e.g., Lutz (1996) 2010, pp. 26–36). This allowed to process the raw database into e.g., the class *courtcase* with the attribute *defendant* recording when instantiated the case’s defendant’s unique ID. Object oriented programming as well offers the possibility to implement functions on the stored information of the class properties.
63. https://networkx.org/
64. https://numpy.org/
65. https://pandas.pydata.org/

Sport and Culture (European Commission) 2019), crossing over from a humanities specific competence to a universal one. It includes the "confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society" as well as various other literacies such as "information and data literacy, [...] media literacy[66], digital content creation (including programming), safety [...], intellectual property related questions, problem solving and critical thinking."

However, for the most part, these aforementioned skills are not implemented in the study curricula of the regular humanist scholar (compare to e.g., Rehbein 2020, p. 258); also Best (2005, p. 210) remarked, that "while critics agree on the desirability of increasing statistical literacy, it is unclear who might accept this responsibility." As such there is no canonization of these multimodal skills, as there is no mutual agreement among peers (following the paradigm of a scientific revolution as presented by T. S. Kuhn ([1962] 2012)) and remains a "niche" (Rehbein 2020, p. 259) that slowly was professionalized in an increasing number of professorial positions and degree programs. Online resources as the "*Programming Historian*"[67] or the "*Computational Historical Thinking*"-Guidebook[68] (L. A. Mullen 2019) offer accessible tutorials to introduce programming for historical research. It is no longer an option to engage as an historian with historical data criticism (or: data literacy) but a necessity, warned Fickers (2020) and pointed to what is at stake: the legitimacy of the field as a critical science.[69]

6.3.2 Towards a complementation of methodologies

The challenge remains to prove the "perpetual future tense" of the prospects of DH wrong.

Ideal of complementation of methods.

This can be achieved by successfully and fruitfully integrate qualitative, quantitative, digital, and computational approaches. Their combinations need a critical, reflected, and sensible application, combined with digital hermeneutics and various forms of digital competences and method literacies, as well as domain-specific knowledge and questions to further insights within the respective discipline, that we will discuss in the following.

Ideally, quantitative and computational-based approaches[70] would go hand-in-hand with qualitative methods of "close reading" and hermeneutical, critical dissemination of the sources used and their database be contextualized (as recommended e.g., by the

66. On the critical reflection, assessment and handling with media, awareness about technical manipulation and transformation.

67. https://programminghistorian.org/

68. https://dh-r.lincolnmullen.com/index.html

69. This reads in German as follows: *"Sich als Historiker mit den Chancen und Herausforderungen in der geschichtswissenschaftlichen Datenkritik zu beschäftigen ist night länger eine Option, sondern eine Notwendigkeit."*

70. For an overview see section 2.3.

Arguing with Digital History working group 2017, p. 14). Digital humanities project try to combine both methodologies as complementary, both having different advantages and perks that could harness the gains (Stegbauer and Häußling 2010a, p. 14), bridging "micro and macro" perspectives (Guldi 2020, p. 333). Indeed, Lindgren (2020, p. 14) argued that differences between both are not as grave: both approaches create "approximation of 'the truth' [...] [and are] by definition interpretive, no matter the chosen methodological strategy." However, the Arguing with Digital History working group (2017, p. 14) pointed to the limits of such an combination: a mixed methods approach is useful in the identification of structures and patterns, but is not discernible to give inferences on "causation and experience."[71] We stress that both types of methodologies actually complement each other, which we consider one of the core values of the digital humanities methodological tool kit, from which research profits greatly by allowing to make meaningful inferences on the topic research.

Perceived Division and Hierarchy of Methods.

Despite these assertions, the quantitative (computational) methods are practically not commonly paired with qualitative methodologies. There is a perceived divide in the humanities between quantitative (computational) methodologies and qualitative approaches.

The common accusation of qualitative methodologists against quantitative methods is that these focus on empiricism: on what can be accurately measured (Bode 2020). On the one side, this leads to the problematic association of quantitative-based approaches with positivism (Graham et al. 2016, p. 23; Edelstein et al. 2017, p. 408; Jannidis 2019, p. 67; Piotrowski and Fafinski 2020, p. 4). Critics warn that with a positivist approach only things measurable are recognized; what cannot be empirically measured cannot be targeted with empirical methodology. As a consequence, non-empirical information–such as mentalities, feelings, or subtext–would be lost for humanities' research. Qualitative approaches in contrast would be able to capture these hidden information, and thus would be superior to positivist approaches.

On the other side lies the claim that quantitative-based methods would be regarded superior to qualitative-based methods–, a "positivist, cliometric vision of computational supremacy"[72]–, that mirrors a hierarchy between them. This reproach has been refuted ever since by the DH community, as e.g., by Russian computing historian Ivan Koval'Chenko in 1964, pointing to that "quantitative methods are not a key to absolute truth that is going to render qualitative research meaningless" (quoted in ibid., p. 175).

This fear about a super method mirrors a supposed hierarchy between the 'hard science' approaches vs those of 'soft' science: the humanities would be"natural scientified"

71. This is in contrast to the field of cliodynamics that seeks to find universalizing rules in history and causal theories to predict historical events in a macro perspective (Turchin 2008).

72. Which Edelstein et al. (2017, p. 408) pointed out is not the point of introducing computer-based methodologies into the humanities.

through quantification. The incorporation of digital methods and general digitalization of research would as a side-effect somehow elevated the humanities to a "proper" science on par with the "hard sciences"[73], suggesting the inferiority of the "soft science" of humanities' methodology[74]. Subsequently, traditional analogue research would be in danger of marginalization (Fridlund 2020, pp. 69–70; Guldi 2020, p. 330; Aydelotte 1966, p. 804). In 2011, Hitchcock lauded that the humanities had "hitherto resisted the siren call of analytical positivism" in the context of code-breaking culturomics.[75]

How deeply ingrained this perception of a hierarchy of approaches are showed again Lindgren (2020, p. 7) argument for an "anarchistic approach" to combine both methodological strategies.

This perceived opposition of methods is refuted strongly in the DH, arguing for the complementation of methods and sounding sensible ways how to combine both quantitative- and qualitative driven approaches. It is saying a lot, that still in 2020 Guldi (p. 330) in her essay on the establishment of good scientific conduct in digital/computational research workflows in digital history felt the need to refute the "contention that digital history is itself imperial and *universalising* in nature, threatening to draw all history practitioners into a single method" addressing the fear that (analogue) historical work might become obsolete in the age of computers. This iterates concerns from the 1960s: Aydelotte (1966, p. 804) defended that there was no "single methodology in history" having addressed fears of the orthodox historical scholarship, that the quantitative method might replace the qualitative one. Jannidis (2019, pp. 67–8) stressed that neither methodology should exist alone in the DH research framework: quantitative methods should not replace the act of hermeneutical interpretation and contextualization, and quantitative method should not replace the qualitative analysis, nor that computers should do the analysis independently.

Reservations about a positivist stance in computational methodology can be tackled with a thorough hermeneutical approach that includes heterogeneous sources and an explication of implicit biases. Any quantitative or computational analysis should be accompanied by a qualitative-based contextualization to make meaningful inferences

73. In another strand, the assimilation of the humanities as a new "hard science" is consolidated in the active re-framing of the humanities' research experience: notes become lab diaries, the historian an experimenter, the archive an laboratory, and passive learning an act of active creating, or the ideal research process of "thinkering", a portmanteau of thinking and tinkering as e.g. promoted by Fickers (2017) and Fickers and Heijden (2020) of new DH research techniques. Instead, the incorporation of interdisciplinary methodologies and approach is an ongoing process that is further blurring the disciplinary boundaries since their establishment between humanities and natural sciences by Wilhelm Dilthey (1883) (Nerbonne 2015, p. 33; Baum and Stäcker 2015, p. 7).

74. In a controversial editorial in Nature, *"Poetry in Motion" (2011)* suggested that through the DH, the humanities would become actual sciences using scientific methodology, as if not before: "It seems just a matter of time before the humanities like the social sciences before them, wholeheartedly embrace scientific methodology. And that should be reason to rejoice, not remonstrate" (compare also to Piotrowski and Fafinski 2020, p. 330).

75. Compare to section 6.3.2.

on the topic researched. As part of this thesis, we contextualized a quantitative and network-based analysis of court records with the insights from a qualitative scholarship in order to understand what and why things are happening in the Corporate State's Viennese courts in 1935. This allowed us to falsify certain assumptions of qualitative scholarship about the judicial practice during the time. We operationalized the harshness of sentences based on upper and lower bounds of penalty limits, and identified certain configurations for malevolent court decisions towards political partisanship. In the case study on intellectual history, we conceptualized various approaches on how to approach their analysis on a big data scale, in order to assess the importance of scholars in various contexts.

A bouquet of methods.

Instead of a perceived hierarchy of methods, any digital method, or its combination with traditional method is only part of a big bouquet of methodologies available to humanities' scholarship. E.g., quantitative evidence of frequencies are only "one more component in a complex landscape of evidence" (Hitchcock 2011). The computational method is "one method among many," remarked also the Arguing with Digital History working group 2017, p. 14. However, the Arguing with Digital History working group (2017, p. 18) warned, that computational methods within history alone "rarely provide[] the complexity of explanation that historians seek", and therefore should be "woven with non-computational methods of history into a coherent argument" (ibid., p. 19). "[D]ifferent scholarly agendas are best met by different technologies, we do not think it possible or even desirable to dictate a unique methodological approach for all experiments in digital history," Edelstein et al. (2017, p. 422) stressed on this matter. Each and every new approach unlocks new research questions and answers previously unavailable before; therefore, Romein et al. (2020, p. 20) formulated the hope (or goal) that the methodologies of the DH become mainstream, even if DH does not.

One step in the direction to educate on the different insights possible with different approaches is the study on text re-use in citing the Bible in the accounts on the Conquest of Jerusalem in 1099 by Hiltmann et al. (2021), highlighting the "differences between the analogue and the digital approach" and their gains (ibid., p. 122).

On the interchangeability of methods. Despite these assertions of a bouquet of methods available, there is no ad lib interchangeability of methods and approaches, no free pick of methods (L. Mullen 2019b) and no one approach "fits it all" to the very heterogenous research questions and sources.

Big data in historical studies is simply not the same size as social big data, but "filled with hidden multipliers" (Edelstein et al. 2017, p. 411), insecurities and fuzziness in the data.[76] The humanities are missing the real-time live-streamed data common in the

76. Compare to the section 6.3.1 on data biases.

social sciences; consequently many statistical methods favored by data scientists are not applicable (ibid., pp. 418–9). "[F]ormal statistical presentations are appropriate only for a limited range of historical problems," warned already Aydelotte (quoted in Piotrowski and Fafinski 2020, p. 5). Small data of the humanities might be too problematic to be properly statistically represented: Data biases, "[i]nherent frailties" and ambiguities make research and quantification difficult dependent on the kind of sources (Aydelotte 1966, pp. 805, 811, 813, 820). If the data is incomplete or suspect, not even an "impressionistic, subjective approach" such as qualitative analysis would be superior to a quantitative approach (ibid., p. 816). Such problematic data would not be compensatable with a more sophisticated approach (ibid., p. 810). Aydelotte (1966, p. 825) stressed that "boundaries of what it [the method] can accomplish" need to be accepted. These boundaries have to entail an open critical discussion of the limitations of data, and the perspectives these represent. As such, any analysis is highly dependent on the nature and quality of the data (Baum and Stäcker 2015, p. 9), and the applicability of a methodology might be contained due to the aforementioned restrictions in data scope, breath, validity, and fuzziness.

Indeed, also the presumptions of a methodology might not apply to the research problem and source base at hand. In the context of this thesis, an analysis of significant factors for convictions using Exponential Random Graph models (ERGMs) had to be abandoned. ERGMs model the probability of observing a set of relationships within a graph on a fixed set of nodes without assuming any independence between them.[77] The network is considered the dependent variable. ERGMs allow to test whether the empirical network's structures occurred by chance (Valente 2010, p. 156) and to describe the strength of "local selection forces that shape the global structure of a network" using hypothesis testing variables (Hunter et al. 2008). ERGMs estimate statistically the conditional probabilities (log-likelihoods or log-odds) of the "effects of covariates on the ties in a network" in order to describe the "form of dependence that could exist" there (Cranmer and Desmarais 2011, p. 67). Suitable data for ERGM analysis is considered to be based on random choices for tie forming[78] and cross-sectional data which did originate

77. ERGM similar a random selection of possible networks via a (now default) Marcov Chain Monte Carlo procedure, a 'forgetful' random walk through a fixed set of nodes, which generates a multivariate probability distribution of networks. The empirical network is regarded as the most likely of many possible realizations of networks (Cranmer and Desmarais 2011, p. 70), which is compared to the simulated networks. ERGM gives p-values to estimate the significance of the hypothesis-testing covariate's influence on the empirical network based on a logit-regression analysis with a binary outcome variable. In order to make this feasible, it is required that in theory each tie could exist in the network. The ERGM procedure thus allows to model complex dependencies without having to prove the independence between the covariates and nodes first. For an overview on the functionality and use of ERGMs compare to Hunter et al. 2008; Valente 2010; Cranmer and Desmarais 2011; Lusher et al. 2012; Heidler 2015; Block et al. 2019.

78. The networks' "actors [have to have] consider[ed] the costs and rewards of each tie separately [...] without a mutual comparison" of existing ties when the network was formed, therefore assuring that

at the same point in time (Valente 2010, p. 156).[79] While in the case study on political judiciary, the court trials can be considered to have been tried very close in time, some of the requisites of ERGM analysis did not apply to the specificities of the data source: Court cases are not randomly assigned to judges, but based on an underlying allocation mechanism regulated by the yearly *"Geschäftsverteilung"* (executive organization chart), which is not available for 1935. As such, questions of systematic prejudice, or professionalization in the sense that certain types of cases would be allocated to certain judges, could not been tackled.

As a result of the problems with data in the humanities, methodologies of the DH cannot be considered formalized, as the problems encountered are usually not standard-problems. Sahle (2015, p. 53) noted the *"unausrottbare Startannahme"* (ineradicable initial assumption) that a research problem within the DH can easily be solved with a technical standard-problem. Instead, Lindgren (2020, p. 5) stressed that methods need to be "transformed and adapted" to the requirements of the research questions and the data base in question. Rehbein (2020, p. 262) warned that a profound (historical) understanding is central for a source reading which cannot easily be delegated to an algorithm. This as a backside tends to lead to a constant "re-imagination of the wheel" (Sahle 2015, p. 52) for solutions for fuzzy problems, and to the establishment of "island solutions" (Baum and Stäcker 2015, p. 9), which also provide an option to coin one of those[80], and bear the danger of arbitrariness. Nerbonne (2015, p. 39) noted that methodological approaches as a result develop "opportunistically" and often "naive" (as in historiographical uncertainty).
Reasons for this lie in the lack of a consensual unification of best practices. In recent years, suggestions for standardization/formalization and best-practice recommendations have been made in a vast range of handbooks (as e.g. in the "*Handbuch Historische Netzwerkforschung*" by Düring et al. 2016). These represent an attempt to both legitimize the methods used and to increase the validity of the results (Sternfeld 2014). This wish of many DH authors stems from the feeling of being neglected by traditional humanities research and therefore to justify the methods used (see e.g., Cordell 2016; compare also to the Arguing with Digital History working group 2017, pp. 1–2 white paper's recommendation to publish digital methods in traditional history journals in order to combat missing acknowledgment by traditional historians and to become part of the "historiographical conversation").

there is no dependencies among the variables (Block et al. 2019, pp. 233, 69).

79. For an overview on the functionality and use of ERGMs compare to Hunter et al. 2008; Valente 2010; Cranmer and Desmarais 2011; Lusher et al. 2012; Heidler 2015; Block et al. 2019

80. As e.g., in the attempt to coin "quantum age" for a new development within the DH (Sternfeld 2014), or in Fernándes Riva (2019, p. 40) on the transmission of Medieval manuscript, the spatial metaphors of continent, archipelagos and islands were used to describe the network structures of core, periphery, and isolates.

6.3.3 Interdisciplinary research cooperation

Both the humanities and computer sciences and maths can benefit from this mutual enterprise. The humanities offer rich, extremely diverse–and problematically fuzzy–data sources and real-world applicable research questions, onto which computational methods can be applied. Guldi (2020, p. 341) called this the "biggest draw" of the humanities. These provide both new fields of application, optimization problems training grounds for new methodologies in real-world application contexts. In return, computer science and maths offer novel and unique perspectives on what can be done with the humanities' data, and can help to further the domain-specific knowledge on a research topic in the respective fields. The goal in here is to develop innovative methodologies[81] and domain-specific insights.

Reclaiming the field for humanities' arguments

In establishing a mutual literacy, voices can be appeased that warn about the humanities experiencing a "hostile acquisition" by the technically affluent computer sciences (as noted by e.g., Nerbonne 2015), resulting in what Fickers (2017) at the dhnord2017 conference called for history a "*historia nuda*", a history devoid of interpretation and argument in contrast to the desired "*historia ornata*."[82] Le Roy Ladurie brought this already in 1973 to an escalation that the scholar will come to an end with the increased usage of the computer: "*L'historien de demain sera programmeur ou il ne sera plus.*"[83] This quote has been picked up as a positive stance for the humanities' scholarship having to adapt to the new technologies.

Hammer, nails, and code-breaking

Questions on the applicability of a method aside, the methodology should not be the goal of inquiry in itself. A technologically-based method offers no road to / promise of salvation ("*Heilsversprechen*") nor "magically" fixes problems.[84] When technology and methods become a cause for themselves, this would lead to a "technical solutionism" (ibid.) devoid of practical applicability and sincere historical (or other humanities') interpretation, finding "nails" for Maslow's "hammer" of methodology.[85]

81. Something that has been bemoaned by e.g. Stegbauer and Häußling 2010a or White 1992 that methodologies have only been refined but not innovated anymore since the 1980s.

82. This assessment might also be the result of the different focus on developing a digital hermeneutics and methodological literacy instead of on (historical) argument, as described in section 6.2.3 on "Keeping promises."

83. Translated from French by the author: "The historian of the future will be a programmer, or he will no more."

84. E.g., of claims of "big data evangelists" such as Anderson (2008), "the data does not speak for themselves" (Lindgren 2020, p. 13). Lindgren (2020, p. 13) called this "mythological beliefs" that "a higher form of truth [...] can be computationally distilled rather than interpretively achieved."

85. Referred to the law of the instrument introduced by Kaplan ([1964] 2017), Maslow (1966) described in 1966 the cognitive bias to overly rely on the familiarity of a tool, or in this case, a methodology, even

The underlying problem of such "technical solutionism" is that any method will give some result at any time. The question remains however how valid these results are, and how robust. Are the findings actually meaningful? Does the applied method help gather new knowledge on the object of research? Baum and Stäcker (2015, p. 5) warned about that not everything technically feasible is also worthwhile for scientific insights.[86]

From a normative perspective, DH-projects need to be funded in a research direction based on humanities' approaches: domain knowledge from the humanities are key to be able to interpret the findings of the interdisciplinary (digital/computational) method.

This should help avoid attempts to "code breaking [...] human society" (Hitchcock 2011). A *Science* article on *"Quantitative analysis of culture using millions of digitized books"* by Michel et al. (2011b) became a "caricature for over-exuberance" (Crymble 2021, p. 39) that dit not "critically discuss [...] why it was interesting, or even whether it actually represented what it purported to show" (ibid., p. 38), or how a certain term was used in the past (Hitchcock 2011). Recently, another such article was published in *Nature Communications* on the development of trustworthiness in portraits using machine learning (Safra et al. 2020), which received similar backlash.[87]

On the other hand, the amount of work needed for data preparation and analysis sparks what (Baum and Stäcker 2015, p. 5) called "digital discomfort" ("*digitals Unbehagen*"): will this much work actually gain useful insights?

The use of programs for digital humanities was nevertheless until recently for the most part of programmatic nature and rarely put into practice, due to constraints of individual prowess, recognition of the importance of actually understanding the technology/methodology, and willingness to go beyond familiar techniques. The decision for a specific tool might not be based on the best fit, but often is the result of the unfamiliarity of the researcher with other tools, as Flanders and Jannidis (2019a, p. 10) has warned. This also repeats in the observation by Piotrowski (2020, p. 11) on the persistence of using e.g., spreadsheets instead of more potent statistical programs such as R (Callaway et al. 2020, p. 11).

Despite all technical advances, key to research are still "explicitly formulated hypotheses" (Clubb and Allen 1967, p. 605) and to do more pronounced inferences "beyond mined correlations followed by post hoc interpretations" (Piotrowski and Fafinski 2020, p. 6). The goal is a *historia ornata* of accurate historical interpretation and analysis in contrast to the *historia nuda* of dates, people and events (Fickers 2017). All those technical new tools aside, in its core digital history is still a very hands-on profession: The big databases are created by hand in archives, where the historian spends years of their life to accumulate entries about original sources (Graham et al. 2016).

though it might not be fitting for the task ahead.

86. This reads in German: *"Nicht alles, was Technische [...] machbar erscheint, ist für den wissenschaftlichen Erkenntnisgewinn much sinnvoll."*

87. Compare to section 6.3.1.

Sustainability of research

Another aspect of interdisciplinary research is that of sustainability. This entails for one that the developed methodologies and models can be adapted to fit more than one project only. Guldi (2020, p. 328) painted a future of inter-fruitful research in which "the topic models used here to analyze German humanist discourse" gets recycled "elsewhere to [e.g.,] study the history of British parliamentary debates about infrastructure and 20^{th}-century American newspaper coverage of cities"; and its training retained for more uses. This ignores but that each model has to be trained again on the particular dataset.

For two, another requisite of sustainable research would be the expansion and combination of available data repositories as Linked Open Data in the context of Open Science. Edelstein et al. (2017, pp. 417, 423–4) identified as the current challenges in this data pooling and harmonization in standards in a LOD cyber-infrastructure. Despite the successes in digitization processes in the last three decades, concerns remain in this context how memory and heritage institutions can be enabled to "share [...] metadata without relinquishing full control of it" (Hotson 2019, p. 451).

Interoperability of data still remains a challenge and promise unfulfilled (Bauman 2011; D. Schmidt 2014), as it would need a shared understanding and shared conceptualizing of data (Rehbein 2020, p. 263). Current developments such as the NFDI however are pointing into such a direction.

6.3.4 Next steps in future research avenues

Next steps in regards to the specific case studies of this thesis involve the integration of further court records from earlier and latter years of the Corporate State to further evaluate the sentence practice, and to compare their results to those of qualitative scholarship. In a further development of this study, text mining approaches can be applied on the court records made machine-processable in text format in order to track how these differences in sentence practices regarding to political partisanship were semantically constructed.

In regard to the history of intellectuals, we would like to extend our analysis on a different source basis. The analyses made in the series of case studies iterated the abstract and 'broad stroke' representation of the history of intellectuals as recorded in YAGO and its data providers. Ideally, we would like to extend the database for a representative and global outlook, and to apply the established methods and conceptualization of the YAGO network on a more 'fine-grained' influence network that takes more than the 'most important' influences of the 'most important' intellectuals into account derived from e.g., primary sources or compendia on the history of intellectuals. This could be used for a further evaluation of the dynamics of intellectual influences, and to compare those tho the YAGO3 dataset. Furthermore, a more fluid or extended interpretation of the disciplines of each intellectual (considering different or multiple disciplines) would serve for a robustness evaluation of the formation of the computationally detected communities. Further progress would entail an in-depth analysis of the interrelations of core groups (which remain unchained) and their floating members (which 'switch' communities throughout the periods) with other communities.

6.3.5 A long way towards digital competences coming of age

Better, faster, bigger – harder

The long history of integrating technology in humanities' scholarship shows that almost everything can be bigger, better, and faster: The assessment of what is to be considered big and feasible research changed continuously. While research (and work) became easier through an eased and extended access to sources and bibliography, at the same time, research also grew harder (similarly noted e.g., by Romein et al. 2020, p. 20) as the requirements of domain-specific and methodological knowledge are constantly expanded, and reached "sheer overwhelming scale[s]" (Guldi 2020, p. 331). Fickers (2020) also spoke about a "methodological and epistemological double taxation." This constant "task of keeping up" (Guldi 2020, p. 331) also provides a great deal of stress on all those involved. In order to counteract those notions, the idea of "slow scholarship in the Digital Age" was introduced in Leeds in 2014, and published in a series of papers (Karkov 2019).

The very focus of computational methodology and quantitative analysis actually is considered "repellant to many historians" (Decker 2020), and constitutes a hinderance on the way to become included to the "general toolkit of humanistic inquiry" (Rehbein 2020, p. 258). Another aspect to why not many humanities embark on this course: it is hard and needs effort. Using computer-based methods and approaches requires a vast range of literacies from data to methods to tools and presentation, and are filled with snares and pitfalls despite their appearance of easy results with a simple click of a button.[88]

Towards better research

Finally, the success and goal of the DH ultimately lies in to provide better and more reflected research.

This entails the sometimes not so obvious: to make research more inclusive. Some strands in the DH embrace a greater diversity in research from the side of the researchers–highlighting and/or including the work of BIPoC and LGBTQ+ researchers–as well as a content-based focus on the histories of marginalized people in a post-colonial discourse (see e.g., "*Disrupting the Digital Humanities*" edited by Kim and Stommel 2018; Risam 2016; Ruberg et al. 2018; or the new volume on "*Exploring Digital Humanities in India*" intended to "decolonialising the humanities in India and adapting emerging digital cultures developing in India to wider uses" by Dodd 2020).

88. Compare to section 6.3.1.

This also entails to make ethical research: Any analysis has an ethical dimension in the terms of the political implications and social dimensions; as we have established, machine-based analysis and digital processing are not free of assumptions or biases (Baum and Stäcker 2015, p. 5; compare also to Bunz 2012).[89] While this is more problematic when using social media data, also humanities data features problem areas such as access, consent, copyright, privacy, security, and public consideration when displaying data online, and questions of provenance, provenience, and custody (compare e.g., Kitchin 2014), as well as safeguards for manipulations, censorship, or various forms information control.[90] Better research means to reflect on inherent biases and possible discrimination that would otherwise implicitly or explicitly guide the subsequent analysis, and to cater to the ethical dimensions of the datas provenance (Arguing with Digital History working group 2017, p. 10).
We agree here with the assertion by Fridlund (2020, p. 70): Better research and generating greater understanding should be the fundamental goal in any research project regardless of applying analogue or digital methodologies. However, when working with digital objects–which is hardly unavoidable–a certain critical literacy is requisite (Mayer 2016; Düring and Kerschbaumer 2016). Guldi (2020, p. 332) contrasted the competences needed as a new normal. The mentioned literacies–computational, digital, data, methodological, visual–are important both for the researcher applying these techniques and for the reader on the receiving end of the research, as the production and dissemination of knowledge are deeply interconnected Establishing these literacies means to loose the "naivety in the handling of the digital" as Romein et al. (2020, p. 3) put this and to "open up the black box of digital analysis" (Guldi 2020, p. 333). A critical thinking about the motives and limits of particular kinds of research, the constraints of the research process, and the influences of the research design, e.g., which keywords, tools, or algorithms that were used and how these choices influence the results (see e.g., Romein et al. 2020, p. 20), are fit to "highlight the distance between *interpretive* work and *computational* work in each research process" and to make "the process of curation, critical inquiry, secondary reading and interpretation [that] remain at the heart of scholarly inquiry" transparent, as Guldi (2020, p. 343) demands. The approach taken needs to be made as explicit as possible to allow for a proper review: Does the model suffice? Which biases are at play?

This thesis identifies the complementation of methodologies as the core of the fruitful integration of computational methodologies, tools, and digital hermeneutics of the digital humanities. These approaches provide a magnifying glass or prism for historical research

89. Another aspect of this is that of information control. As Tiffert (2019) has shown information does not remain untampered after digitization, i.e. censorship or information control as in the removal of access to certain documents in the knowledge platform JSTOR in China.

90. In this context, the study by Tiffert (2019) raised awareness about the silent commission of certain articles for a Chinese audience by respected online providers such as the knowledge platform *JSTOR*, the collections of Cambridge University Press online edition of *The China Quarterly*, or *Springer Nature*.

in order to fulfill the prospects of DH.[91] A pronounced method (tool) criticism needs to be paired with a digital source criticism and digital hermeneutics in order to evaluate the quality of analysis, relationship between the digital reproduction and the analogue 'original' (including a commitment to the full disclosure of the actual sources consulted (Blaney and Siefring 2017) following the ontological and source critical implications) and its consequences for the production and processing of data.[92] Any analysis can only be as good as the available source material; this follows the familiar aphorism in computer science of 'garbage in, [means] garbage out'. Gramsch (2016, p. 89) warned that the available source materials have to guide the potential analysis. Ultimately, diligent and reflected research generates better understanding and extends our knowledge with (possibly new or) deeper insights.

The spread of computational and digital literacy in the humanities and in the DH need to derive to a certain digital maturity, a digital coming of age: the responsible and reflective digital "*Mündigkeit*" of a digital hermeneutical approach in critical reflected research combining computational, quantitative, qualitative and digital methodologies and bridging all disciplinary borders.

91. Refer to section 6.2 "Impact of the DH."
92. Compare to section 6.3.1.

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