LOC Postdoctoral Final Report

Human Wayfinding For Intelligent Building Design

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Leonhard
Obermeyer
Center

Technical University of Munich

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Human Wayfinding For Intelligent Building Design

by

Dr. sc. ETHZ Rohit K. Dubey

Supervisor:	Prof. Dr.-Ing. André Borrmann
Project Duration:	October, 2020 - August, 2022
Faculty:	TUM School of Engineering and Design

Preface

I thank Leonhard Obermeyer Center (LOC) and Prof. Borrmann for providing me with the prestigious LOC postdoctoral scholarship. I greatly appreciated the opportunities and freedom I received under the guidance of Prof. Borrmann, primarily the responsibility to take on the role of a Group Leader during the end of my fellowship. I am immensely thankful for the faith Prof. Borrmann has shown towards me and for always making me believe I can achieve and deliver. I've also gained valuable experience working in a cross-disciplinary team and writing scientific proposals at the Chair of Computational Modeling and Simulation.

Dr. sc. ETHZ Rohit K. Dubey
TUM, August 2022

Contents

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Research Projects

In this Chapter, I briefly describe the research I carried out and the publication that resulted during my postdoctoral fellowship at the Chair for Computational Modeling and Simulation.

1.1. Cognitively grounded floorplan optimization to nudge occupant route choices (To be submitted)

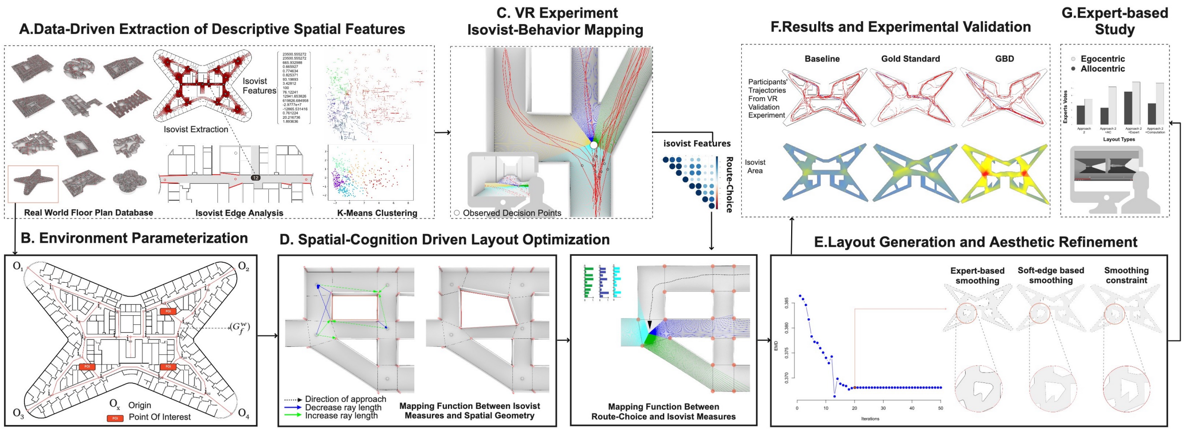

Figure 1.1: Framework Overview. The initial floor plan layout and the designers' specified entrances/exits and points of interest are sampled from a database (A) to parameterize the environment into architectural and navigational graph (A→B). A behavior experiment is conducted to empirically motivate the parameterization of the mapping function between human route choices and isovist measures (A→C). A low-dimensional, gradient-based optimization algorithm is proposed to approximate a required change in the spatial geometry of the floor plan, motivate a change in partial isovist measures, ensure the desired route-choice probability, and facilitate the desired circulation (s). Our algorithm quickly converges to a near-optimal solution, and the designer can select, modify, and repeat the process if desired. The optimized layout is then aesthetically refined (D→E) and employed for validation (F) using a VR experiment (C). Finally, an expert-based study is conducted to validate the proposed layout refinement operation (G). The modules highlighted in the dashed box are steps performed before and after optimization.

Abstract: Architectural layout planning is essential in an immersive simulated environment, virtual game design, and mid-scale commercial building design. Traditionally, the majority of the layout planning is designed for the eye of the beholder without considering its inhabitant. There has been little recognition provided to the role of human cognition in architectural design practice. This paper proposes a floor plan refinement framework by focusing on human wayfinding. Quantifying human perception of space during movement depends on multiple spatial attributes, such as the spatial arrangement of walls and the area of visible space. Existing approaches in computer-aided design have yet to leverage the role of architectural configuration to guide human route-choice behavior to support layout design. This paper presents a novel layout optimization framework grounded in spatial cognition to empower architectural designers to bridge the gap between computer-aided architectural design and spatial cognition research. To facilitate the proposed layout optimization, we introduce two mapping functions: (1)

Between isovist measures and route-choice probability, and (2) from isovist measures to the geometry. These mapping functions serve as gradients to optimize the environment's partial-isovist measures by manipulating its geometry during each optimization iteration. We conduct a Virtual Reality (VR) study to analyze the relationship between human route choices and also isovist measures at decision points. The experimental data is used to derive associations between human route choices, the isovist measures, and changes in floor plan geometry. A follow-up navigation experiment is conducted in VR to compare human wayfinding behavior across baseline, automatically optimized, and manually optimized layouts. Finally, a complementary study for the aesthetics evaluation of layouts is conducted with architectural experts. The results indicated that our method could simultaneously improve wayfinding performances, adhere to the aesthetics of architectural experts, and improve the total non-navigable space allocated for rooms or shops depending on the building type. Our studies provide strong evidence in favor of integrating human-centered criteria based on insights from spatial cognition research to inform floor plan optimization and enhance the quality of built environments.

Authors: Rohit K Dubey, Michal Gath Morad, Samuel S Sohn, David Xue, Tyler Thrash, Christoph Hölscher, André Borrmann, Mubbasir Kapadia

This paper was earlier rejected from IEEE Transactions on Visualization and Computer Graphics journal. My revise plan is to submit the above manuscript with minor revision to the Automation in Construction journal.

1.2. Occupant-Centric Midscale Floorplan Generation via Transformer Reinforcement Learning (Under development)

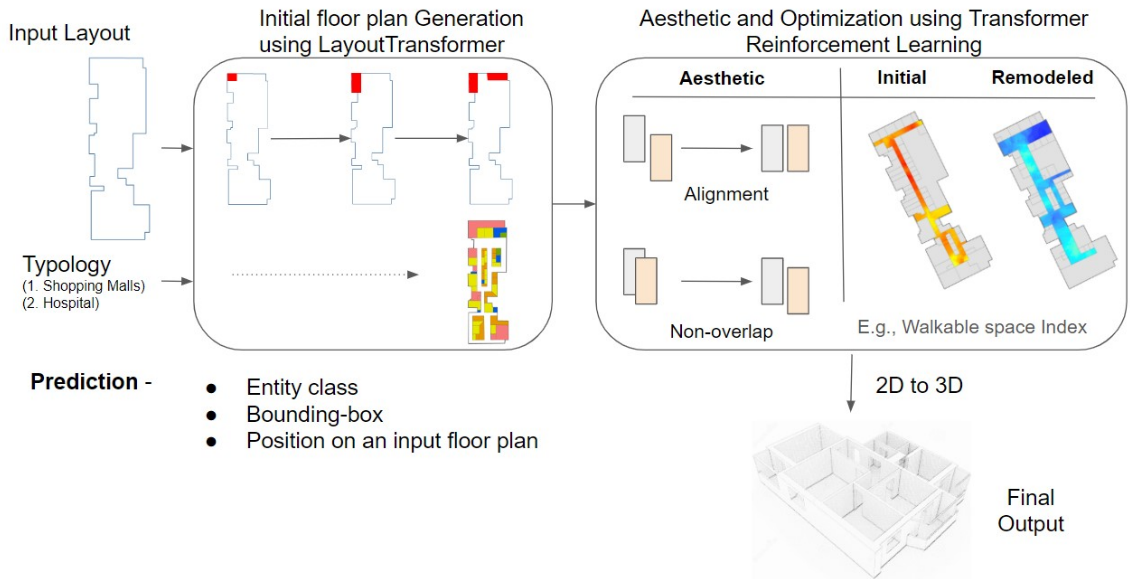

Figure 1.2: Overall working of Midscale floorplan generation using transformer reinforcement learning.

Goal: Automatic generation of midscale layout (e.g., shopping malls, hospitals, transit hubs, etc.) from an exterior wall boundary.

Challenge: Unlike residential floor plan datasets (e.g., RPLAN), midscale floor plan datasets (real or synthetic) do not exist for the research community.

Abstract: In the field of floor plan design, a strong and meaningful relationship exists between different building entities (rooms, stairs, entrances, toilets, etc). For example, staircases/lifts/escalators are at a central location for straightforward navigability, restrooms and utility rooms are tucked away inside a corridor, and entrances/exits are aligned with the city road network. Two factors contributing to the realism or plausibility of a generated floor plan are layout, i.e., the spatial relationship of different building

entities and their appearance (in terms of shape and size). Generating a realistic floor plan necessitates both factors to be plausible. Recently, Most building layouts can be represented as a meaningful arrangement of simpler compositional building primitives such as rooms, stairs, hallways, entrances, and atria. Generating a new floorplan or improving an existing floorplan requires understanding the relationships between these primitives. To do this, we employ LayoutTransformer, which leverages self-attention to learn contextual relationships between layout elements and generate novel floorplans. The proposed framework will allow to generate a new floorplan either from an empty set or from an initial seed set of primitives such as exterior wall boundary and location of exits/entrances. It can easily scale to support an arbitrary of primitives per layout. We believe that by using LayoutTransformer, the model can automatically capture the semantic properties of the building primitives. Furthermore, we employ reinforcement learning as a post-processing step and re-train the trained LayoutTransformer model to guide floor plan design further. To this end, we propose an occupant-centric metric: Cognitive Layout Index (CLI) (i.e., measures such as accessibility, cognitive load while circulation, and overall path-distance between sink points that are inspired by spatial cognition literature).

Authors: **Rohit K Dubey**, Samuel S Sohn, André Borrmann, Mubbasir Kapadia.

1.3. Cognitive Path Planning with Spatial Memory Distortion (Published)

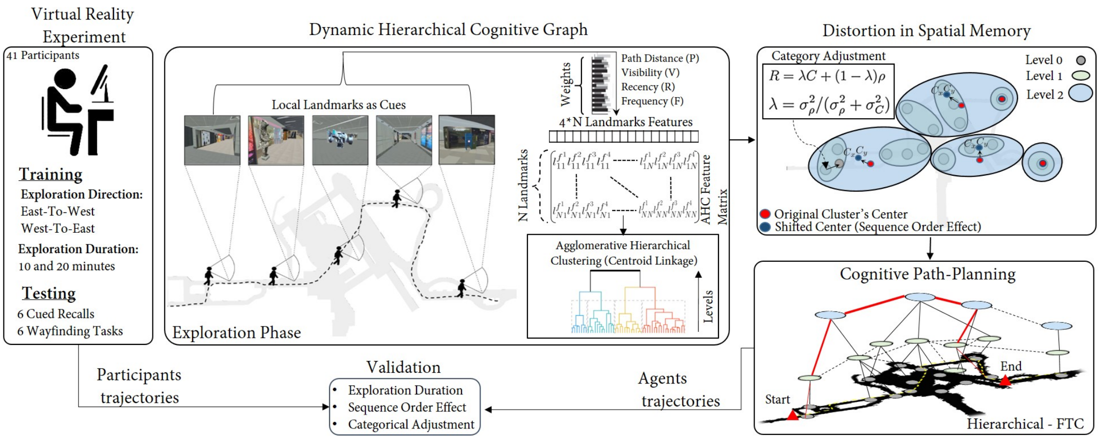

Figure 1.3: Framework Overview. We present a cognitive model of agent path-planning that simulates human-like learning of unfamiliar environments: (1) We propose a DHCG representation to encode the environment structure. (2) The influence of the landmarks sequence order and the systematic bias towards the center of the location's cluster is incorporated to model spatial recall errors due to memory decay. (3) The "Fine-To-Coarse" (FTC) path-planning heuristic commonly applied by humans during navigation is extended to incorporate spatial uncertainty during recall. (4) We conduct a VR experiment to validate the proposed path-planning model.

Abstract: Human path-planning operates differently from deterministic AI-based path-planning algorithms due to the decay and distortion in a human's spatial memory and the lack of complete scene knowledge. Here, we present a cognitive model of path-planning that simulates human-like learning of unfamiliar environments, supports systematic degradation in spatial memory, and distorts spatial recall during path-planning. We propose a Dynamic Hierarchical Cognitive Graph (DHCG) representation to encode the environment structure by incorporating two critical spatial memory biases during exploration: *categorical adjustment* and *sequence order effect*. We then extend the "Fine-To-Coarse" (FTC), the most prevalent path-planning heuristic, to incorporate spatial uncertainty during recall through the DHCG. We conducted a lab-based Virtual Reality (VR) experiment to validate the proposed cognitive path-planning model and made three observations: (1) a statistically significant impact of sequence order effect on participants' route-choices, (2) approximately three hierarchical levels in the DHCG according to participants' recall data, and (3) similar trajectories and significantly similar wayfinding performances between participants and simulated cognitive agents on identical path-

planning tasks. Furthermore, we performed two detailed simulation experiments with different FTC variants on a Manhattan-style grid. Experimental results demonstrate that the proposed cognitive path-planning model successfully produces human-like paths and can capture human wayfinding's complex and dynamic nature, which traditional AI-based path-planning algorithms cannot capture.

Publication: **R. K. Dubey**, S. S. Sohn, T. Thrash, C. Holscher, M. Kapadia and A. Borrmann, "Cognitive Path Planning with Spatial Memory Distortion," in IEEE Transactions on Visualization and Computer Graphics, doi: 10.1109/TVCG.2022.3163794.

1.4. Fire evacuation supported by centralized and decentralized visual guidance systems (Published)

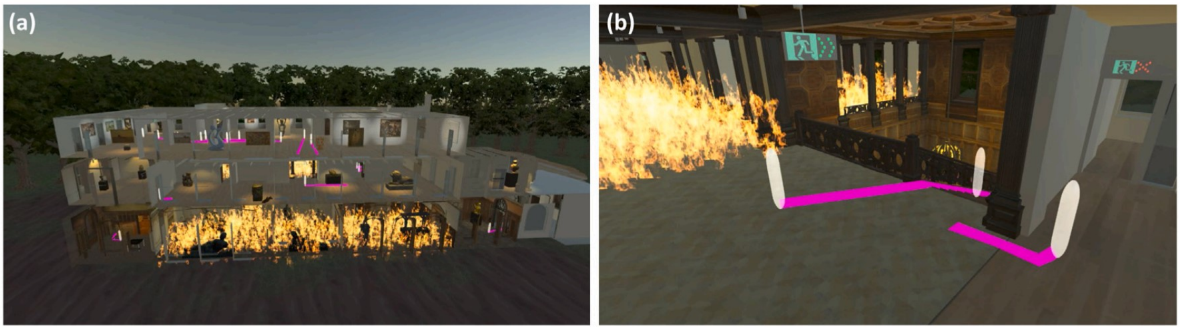

Figure 1.4: (a) Overview visualization of the agent simulation. Each agent is represented by a white cylinder. The pink lines represent the projected trajectories. (b) A closer view of the agent simulation on the second floor of the building. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Abstract: In the event of fires and other hazards, visual guidance systems that support evacuation are critical for the safety of individuals. Current visual guidances for evacuations are typically non-adaptive signs in that they always indicate the same exit route independently of the hazard's location. Adaptive signage systems can facilitate wayfinding during evacuations by optimizing the route towards the exit based on the current emergency situation. In this paper, we demonstrate that participants that evacuate a virtual museum using adaptive signs are quicker, use shorter routes, suffer less damage caused by the fire, and report less distress compared to participants using non-adaptive signs. Furthermore, we develop both centralized and decentralized computational frameworks that are capable of calculating the optimal route towards the exit by considering the locations of the fire and automatically adapting the directions indicated by signs. The decentralized system can easily recover from the event of a sign malfunction because the optimal evacuation route is computed locally and communicated by individual signs. Although this approach requires more time to compute than the centralized system, the results of the simulations show that both frameworks need less than two seconds to converge, which is substantially faster than the theoretical worst case. Finally, we use an agent-based model to validate various fire evacuation scenarios with and without adaptive signs by demonstrating a large difference in the survival rate of agents between the two conditions.

Publication: Zhao, Hantao, Amray Schwabe, Fabian Schläfli, Tyler Thrash, Leonel Aguilar, **Rohit K. Dubey**, Joonas Karjalainen, Christoph Hölscher, Dirk Helbing, and Victor R. Schinazi. "Fire evacuation supported by centralized and decentralized visual guidance systems." Safety science 145 (2022): 105451.

1.5. SNAP:Successor Entropy based Incremental Subgoal Discovery for Adaptive Navigation (Published)

Abstract: Reinforcement learning (RL) has demonstrated great success in solving navigation tasks but often fails when learning complex environmental structures. One open challenge is to incorporate low-level generalizable skills with human-like adaptive path-planning in an RL framework. Motivated by neural findings in animal navigation, we propose a **S**uccessor e**N**tropy-based **A**daptive **P**ath-planning (**SNAP**) that combines a low-level goal-conditioned policy with the flexibility of a classical high-level planner. **SNAP** decomposes distant goal-reaching tasks into multiple nearby goal-reaching sub-tasks using a topological graph. To construct this graph, we propose an incremental subgoal discovery method that leverages the highest-entropy states in the learned Successor Representation. The Successor Representation encodes the likelihood of being in a future state given the current state and capture the relational structure of states based on a policy. Our main contributions lie in discovering subgoal states that efficiently abstract the state-space and proposing a low-level goal-conditioned controller for local navigation. Since the basic low-level skill is learned independent of state representation, our model easily generalizes to novel environments without intensive relearning. We provide empirical evidence that the proposed method enables agents to perform long-horizon sparse reward tasks quickly, take detours during barrier tasks, and exploit shortcuts that did not exist during training. Our experiments further show that the proposed method outperforms the existing goal-conditioned RL algorithms in successfully reaching distant-goal tasks and policy learning. To evaluate human-like adaptive path-planning, we also compare our optimal agent with human data and found that, on average, the agent was able to find a shorter path than the human participants.

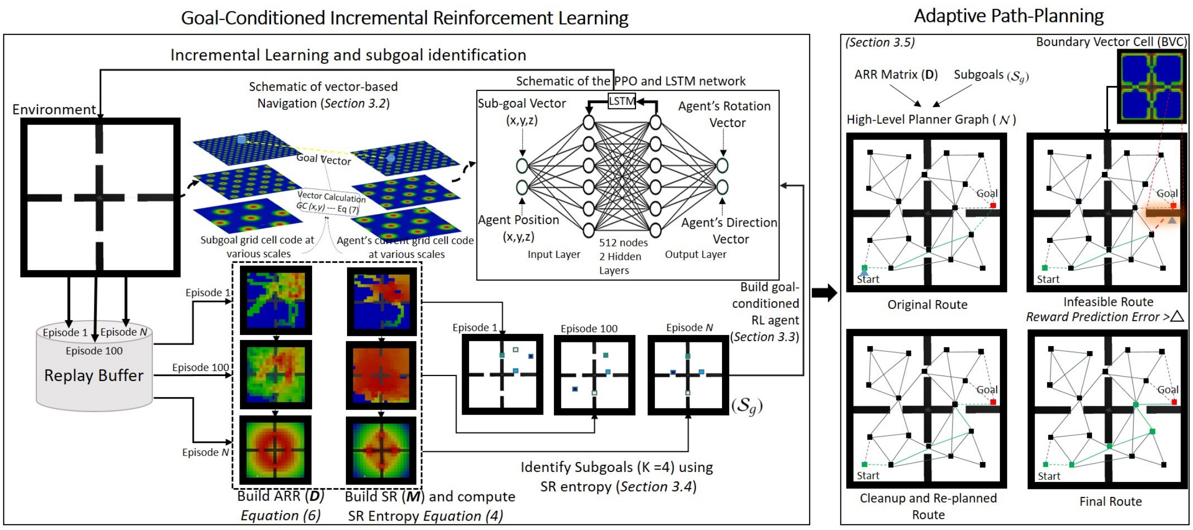

Figure 1.5: Overview of steps involved in **SNAP**.

Publication: **Dubey, Rohit K.**, Samuel S. Sohn, Jimmy Abualdenien, Tyler Thrash, Christoph Hoelscher, André Borrmann, and Mubbasir Kapadia. "SNAP: successor entropy based incremental subgoal discovery for adaptive navigation." In Motion, Interaction and Games, pp. 1-11. 2021.

1.6. Papers with PhD students as a group lead

Three conference papers resulted during my short span of supervising Ph.D. students in the Knowledge Representation and Reasoning group at the Chair for Computational Modeling and Simulation. I list them below:

- Ann-Kristin Dugstad, Rohit K. Dubey, Jimmy Abualdenien, Andre Borrmann. ”A BIM-based disaster response platform: Facilitating indoor path planning for first responders, UAVs, and UGVs” In EUROPEAN CONFERENCE ON PRODUCT AND PROCESS MODELING ECPPM 2022, 14TH - 16TH SEPTEMBER, 2022. TRONDHEIM, NORWAY.
- J. Clever, J. Abualdenien, R. K. Dubey A. Borrmann. ”Improving early phases of building design by predicting pedestrians’ evacuation times using deep learning methods” In EUROPEAN CONFERENCE ON PRODUCT AND PROCESS MODELING ECPPM 2022, 14TH - 16TH SEPTEMBER, 2022. TRONDHEIM, NORWAY.
- Jiabin Wu, Rohit K. Dubey, Jimmy Abualdenien, Andre Borrmann. ”Towards a framework for automatic adaption of non-compliant building designs” In EUROPEAN CONFERENCE ON PRODUCT AND PROCESS MODELING ECPPM 2022, 14TH - 16TH SEPTEMBER, 2022. TRONDHEIM, NORWAY.

1.7. Publications

Below I mention the publications that resulted during my postdoctoral fellowship.

1. Rohit K Dubey et al. *Cognitively Grounded Floorplan Optimization to Nudge Occupant Route Choices*. In: Available at SSRN 4003119
2. Rohit K. Dubey et al. *Cognitive Path Planning with Spatial Memory Distortion*. In: IEEE Transactions on Visualization and Computer Graphics, 2022, pp. 1–1. DOI: `10.1109/TVCG.2022.3163794`
3. Hantao Zhao et al. *Fire evacuation supported by centralized and decentralized visual guidance systems*. In: Safety science 145, 2022, p. 105451
4. Rohit K Dubey et al. *SNAP: successor entropy based incremental subgoal discovery for adaptive navigation*. In: Motion, Interaction and Games. 2021, pp. 1–11
5. Ann-Kristin Dugstad et al. *A BIM-based disaster response platform: Facilitating indoor path planning for first responders, UAVs, and UGVs.* NLP-ECPPM 2022, 14TH - 16TH SEPTEMBER, 2022. TRONDHEIM, NORWAY
6. J. Clever et al. *Improving early phases of building design by predicting pedestrians' evacuation times using deep learning methods*. NLP-ECPPM 2022, 14TH - 16TH SEPTEMBER, 2022. TRONDHEIM, NORWAY
7. Jiabin Wu et al. *Towards a framework for automatic adaption of non-compliant building designs*. NLP-ECPPM 2022, 14TH - 16TH SEPTEMBER, 2022. TRONDHEIM, NORWAY

2

Grants & Proposals

The content of this Chapter is confidential and intended for the recipient specified in message only. It is strictly forbidden to share any part of this message with any third party, without a written consent of the sender.

I had the opportunity to write the following proposals as an individual PI (Section 2.1) and a collaborator in an international conglomerate comprised of (TU-Delft, ETH Zurich, EPFL, INRIA) (Section 2.2), and as a contractor with Cornell Univerisity (Section 2.3).

2.1. Deutsche Forschungsgemeinschaft (DFG)

Proposal ID:	BO 3575/13-1
Grant Amount:	$\sim$ 350K Euros
Project Title:	Cognitive modeling of information sources for human wayfinding
Status:	Under Review
Grant Type:	Individual (Temporary Positions for Principal Investigators)

Summary: Rapid urbanization and an unprecedented increase in the world's population have put tremendous pressure on existing infrastructures. Transportation hubs, office and educational buildings, stadiums, and malls serve increasing crowds daily. This issue is equally relevant when considering yet-to-be-built environments. Architects, designers, and planners must rely on their intuition and expertise when accounting for how people navigate when designing spaces, which becomes prohibitive when accounting for the myriad of contexts that spaces must accommodate. A critical challenge towards managing and designing built environments is understanding (from a cognitive perspective) how humans rely on various indicators when navigating these spaces. Human wayfinding involves the acquisition and processing of multiple sources of information to aid in route planning. Essential information sources include environmental landmarks, signage, spatial features, the presence and behavior of other people, and past recollection of a familiar environment. These information sources are filled with uncertainty, often contradict one another, and are a dominating factor for individuals getting lost in complex environments. The ability for people to find their way is a critical function of built space. It has far-reaching implications on the intended usage of a building, its inhabitants' quality of life, and security and disaster prevention.

Often public spaces are hastily redesigned (e.g., the changes made to the entrances and passageways of public spaces to modify pedestrian flow while minimizing contact among people) to reduce disease spread or accommodate an increased pedestrian flow. Unfortunately, the redesign of the public spaces is undertaken without thoroughly investigating the full effects of design choices, and sometimes they lead to unanticipated and detrimental effects. The existing simulation framework is often based on a simplified human decision-making model that does not reflect or accommodate human cognition during wayfinding in a realistic context. This project aims to fill the above gap and develop a scientific basis for performing pedestrian simulations, resulting in a real impact of the before-mentioned design

changes on the crowd flow. The overall goal of this project is to study human wayfinding (i.e., the way people decide to navigate in the presence of multiple information sources) and integrate the understandings into a cognitively motivated computational simulation of pedestrians through public spaces.

In this project, we seek to model how humans rely on sources of information in their surroundings (e.g., signage, spatial features, the presence and behavior of other people, and familiarity with the built environment) when navigating in complex indoor environments. The project aims to develop a cognitively grounded computational framework of human wayfinding which models the uncertainty and fusion of multiple potentially conflicting information sources and incorporates the knowledge acquired into a pedestrian simulator. We focus on investigating how humans learn to navigate so efficiently and generalize so robustly in varying environments of different complexity under multiple wayfinding information sources using lab-based VR experiments with human participants. The understanding learned from the above behavioral studies will then be leveraged to propose an information-theoretic framework that incorporates causal model-based decision-making for wayfinding. The proposed framework - **Cognitive Modeling of Information Sources for Human Wayfinding** - has four interlocking components. (1) Human subject experiments to investigate the impact of information sources on human wayfinding. (2) Information-theoretic multivariate fusion-based computation framework. (3) Cognitive agent model-based pedestrian simulations (4) Experimental evaluation and validation. Together, these four components will deliver a greater understanding of human wayfinding, translating into a better design and redesigning of public spaces. Compared to the conventional methods, our framework promises to provide a human-like and more accurate prediction of crowd flow in public spaces, which can then be used to efficiently design and redesign the built spaces.

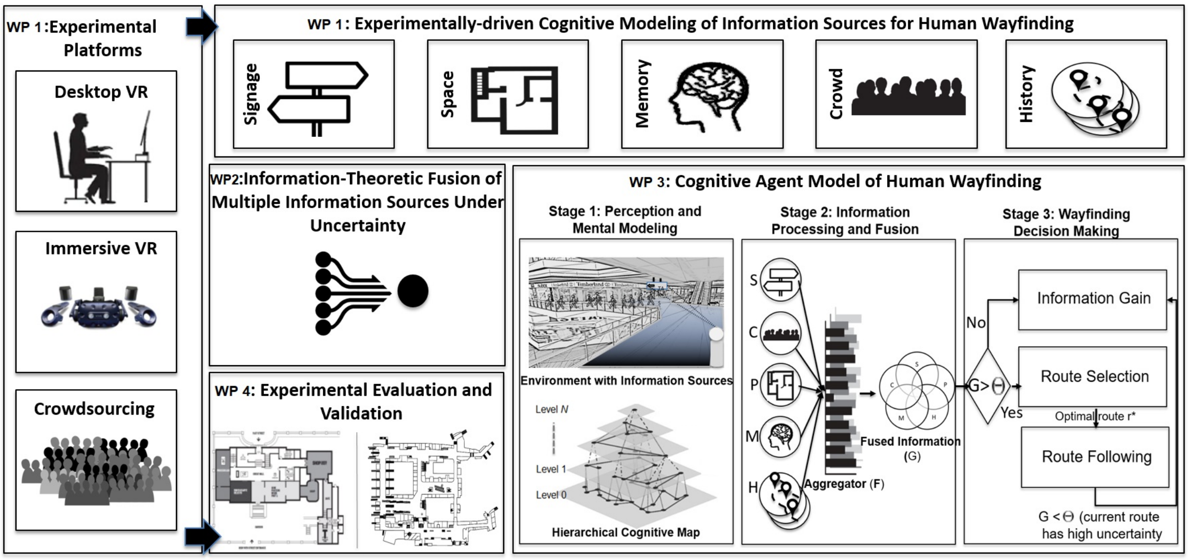

Figure 2.1: Proposed Research Activities.

2.2. HORIZON-MSCA-2021-DN-01 (MSCA Doctoral Networks 2021)

Proposal ID:	101073442
Grant Amount:	$\sim$ 2.75 million Euros
Project Title:	Walk2Resilience
Status:	Rejected. Total score: 67.80 (Threshold: 70/100.00)
Grant Type:	HORIZON-MSCA-2021-DN-01-01

Title: Developing techniques, theories and applications to revolutionize the design and management of pedestrian spaces in the resilient, sustainable, smart city of the future.

Summary: In accordance with the sustainable development goals, countries are searching for ways to create resilient sustainable cities. Walking and public transit are essential parts of the sustainable transport of tomorrow. Yet, to ensure people adopt more sustainable mobility patterns, the friction of sustainable modes needs to be eliminated and the resilience of pedestrian infrastructure improved - it needs to improve sustainability and benefit the pedestrian experience. Even though knowledge and expertise pertaining to the design of pedestrian infrastructures and open spaces in the urban built environment (e.g., streets, squares) have been developing, we do not have all the insights and tools to shape this transition. The objective of this network is to shape the next generation of pedestrian researchers and engineers, who can research, design, and manage pedestrian infrastructures with the newest digital tools and a holistic, multi-disciplinary vantage point, thus allowing them to unravel pedestrian behaviours that cannot be studied right now and shape a completely new integrated way of designing built environments. The scientific aim of this doctoral network is to develop theories, methods, and tools to support the design, operation, and management of resilient pedestrian infrastructures and urban built environments while at the same time training a network of young researchers for a career in the design of resilient pedestrian infrastructures for the smart cities of tomorrow. In particular, theories and tools are developed around three themes, namely sustainability (how to entice people to take up sustainable transportation patterns), health (what are the benefits and risks of walking), and safety (how to ensure the safety of pedestrians under normal and adverse conditions). This proposal brings together multi-disciplinary, experienced research teams from across Europe in a way never seen before in the field of pedestrian research.

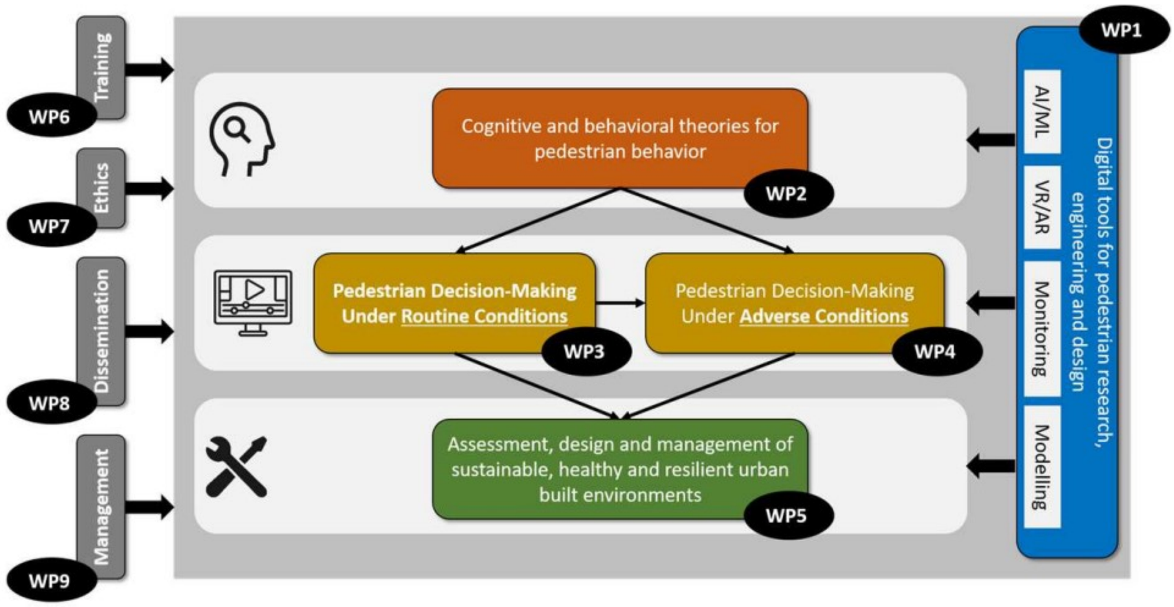

Figure 2.2: Relationships between the Walk2Resilience workpackages

2.3. National Science Foundation (NSF) USA

Grant Amount:	$\sim$ 500K USD
Status:	Under Review.
Grant Type:	Small Grants for Exploratory Research (SGER)
Role:	Contractor (Responsible for the development of Cognitive Agent.)

Title: Using Mobile Brain-Body Imaging to Develop an Evidence-based Cognitive Agent Framework

(EBCAF) for Computational Spatial Navigation Simulation

Summary: This research project is focused on developing improved, evidence-based simulation techniques to help architectural designers optimize the built environment for better human navigation. In recent years computational simulation has become increasingly adopted by designers to improve their work in areas such as occupant behavior prediction, building energy simulation, building evacuation, and wayfinding. One of the common challenges for this approach is that the models are limited to the available quantitative data, which in many areas is insufficient to support robust simulation. A recent survey of 274 building simulation practitioners in 36 countries reported that human-occupant-related assumptions in simulation models are generally very simplistic, and that there is a strong need to improve the models by collecting more empirical data about diverse human behaviors. For example, in wayfinding and evacuation simulations, the software tools that are used to model human behaviors and macro-scale crowd movement patterns are generally limited to direct-routing algorithms (such as the A* path-search algorithm) that simulate obstacle-avoidance along a shortest path between origin and destination points. This type of simulation assumes idealized rational behavior that is vastly inaccurate in relation to the actual behavior of human agents who are seeking to find their way through unfamiliar environments in urgent conditions. In the proposed work, the PI aims to bring a more evidence-based approach to computational modeling in design by developing a framework for quantifying human behavioral and cognitive responses to architectural features and integrating the resulting behavioral metrics into wayfinding simulation tool. Rather than relying on rational/idealized pathfinding algorithms, these simulations will be based on actual data from human participants who take part in wayfinding scenario studies. The goal is to empirically test perception, memory, attention, and decision-making in natural settings and incorporate this information into the current computational models in wayfinding simulations. The aims of the work are part of a growing intellectual shift toward evidence-based design approaches grounded in the robust study of human behavioral patterns in relation to design variables.

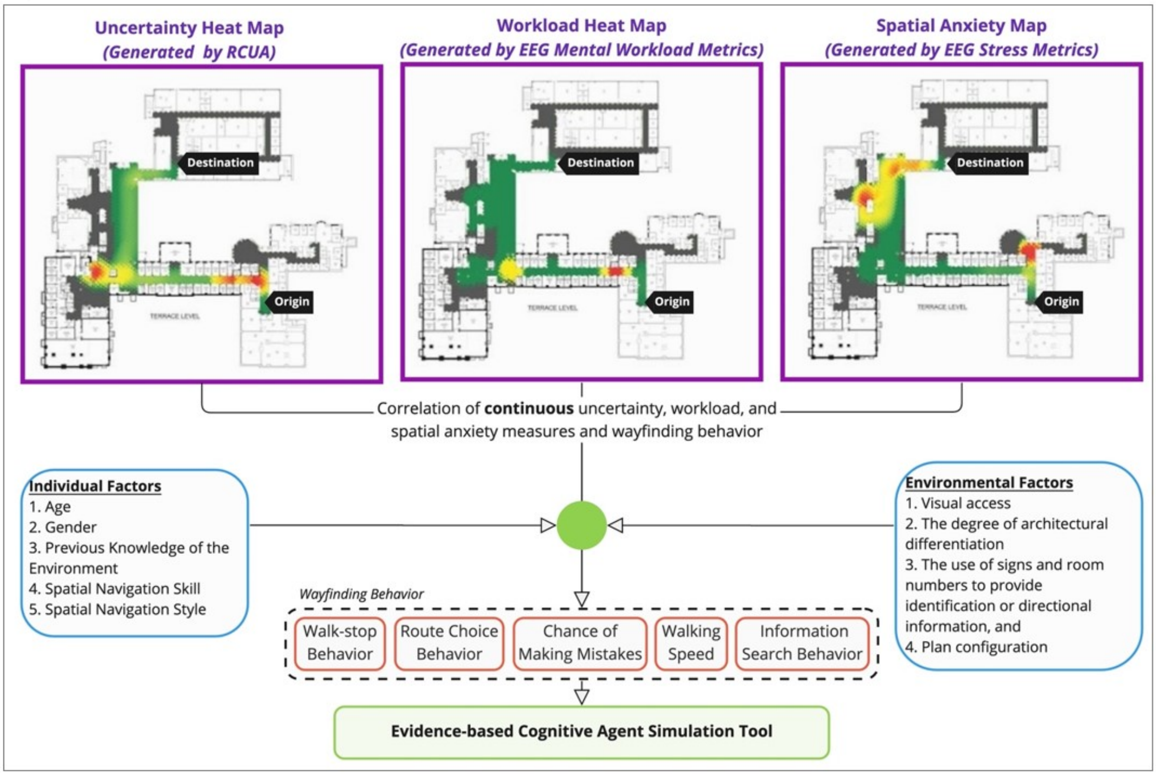

Figure 2.3: Overview of the Evidence-based Cognitive Agent Framework (EBCAF). Robust empirical studies of human responses to environmental features (at left) lead to findings that are integrated into simulation tools to help designers better predict the outcomes of their work.

3

Teaching

I am thankful to Prof. Borrmann for providing me with an opportunity to teach two courses during my stay at the chair for Computational Modeling and Simulation. My rewarding experience as a lecturer has reinforced my desire to continue my career in academics. Please find below information on the courses I was involved in during my postdoctoral fellowship.

Course Name: Professional Software Development (4 Credits)
Course Level: Masters (TUM School of Engineering and Design)
Link: `https://www.cms.bgu.tum.de/de/lehrveranstaltungen/master/professional-software-development`
Supervisor: Dr. Rohit K. Dubey
Tutor: Rohan Fernandez (Msc, Informatics)
Date: Summer semesters, 2021, 2022

Course Name: Engineering Databases (3 Credits)
Course Level: Masters (TUM School of Engineering and Design)
Link: `https://www.cms.bgu.tum.de/de/lehrveranstaltungen/master/engineering-databases`
Supervisors: Jimmy Abualdenien, Dr. Rohit K. Dubey
Date: Winter semester, 2021

4
Student Supervision

I co-supervised an Interdisciplinary Project (IDP) and Software Lab projects during my postdoctoral fellowship.

4.1. Interdisciplinary Project Report

Title: Analysis of Human Trajectory Prediction methods and Future use cases.

Abstract: Human Trajectory Prediction (HTP) has become an important research area when it comes to motion planning and decision making for autonomous systems. Coming up with a safe way to predict human trajectories has been challenging because of the complex interactions between agents and their environment. We must take into account the egocentric point of view of each agent as well as the system as a whole. The agents past states and its influence on future states, how agents interact and influence each other, and how to remove environment bias when training on a dataset are all essential information to inform our predictions. We have analyzed the three best performing models on the ETH/UCY dataset, which is used as a benchmark dataset for trajectory prediction, and deduced which aspects we could combine to form a better HTP model in the future.

Student Name:	Teute Drini (03742835)
Supervisosr:	Prof. Dr.-Ing. André Borrmann, Dr. Rohit. K. Dubey, Jimmy Abualdenien
Submitted On:	27. April 2022
Faculty:	Chair of Computational Modelling and Simulation

4.2. Software Lab

Title: MuBLayout3D - Generating 3D Layout of Mixed-use Building from 2D Floorplan Images.

Student Name:	Lip Kun Tee, MSc. Computational Mechanics Nikita Kurkin, MSc. Civil Engineering
Supervisors:	Prof. Dr.-Ing. André Borrmann, Dr. Rohit. K. Dubey, Andrea Carrara
Submission due:	November, 2022
Faculty:	Chair of Computational Modelling and Simulation

Abstract: The task of transforming 2D architectural building layouts into 3D representation has been intensively researched in computer vision and pattern recognition. However, most research in the past has focussed on the residential-scale floorplan ignoring the Mixed-use building (MUB) layouts (e.g., transit hubs, educational buildings, shopping malls, museums, hospitals). A mixed-use building seeks to combine multiple building functionalities into one structure and enables large crowds of occupants to meet and move about, which are relatively less studied. This project will investigate data-driven (ML), and heuristic-based design alternatives studied in the past in converting the 2D floorplan into a 3D model and propose a framework MUBLayout3D. MUBLayout3D provides an end-to-end model that take an input architectural floorplan consisting of various structural and auxiliary information objects, such as walls, doors, windows, rooms, atria, sink locations (lifts, staircases, entrances, exits) and outputs a vector-graphics floorplan and a 3D model of the same.

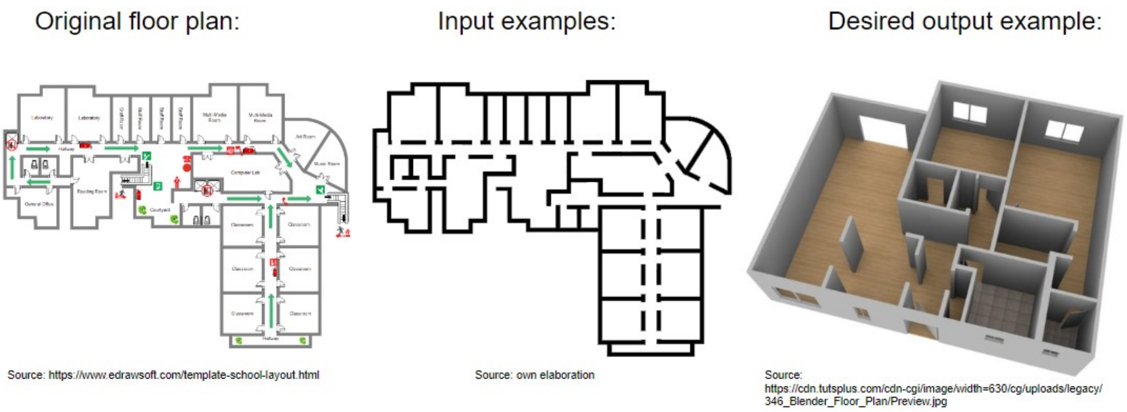

Figure 4.1: Brief overview of MuBLayout3D framework.

References

[1] J. Clever et al. *Improving early phases of building design by predicting pedestrians' evacuation times using deep learning methods*. NLP-ECPPM 2022, 14TH - 16TH SEPTEMBER, 2022. TRONDHEIM, NORWAY.

[2] Rohit K Dubey et al. *Cognitively Grounded Floorplan Optimization to Nudge Occupant Route Choices*. In: Available at SSRN 4003119.

[3] Rohit K Dubey et al. *SNAP: successor entropy based incremental subgoal discovery for adaptive navigation*. In: Motion, Interaction and Games. 2021, pp. 1–11.

[4] Rohit K. Dubey et al. *Cognitive Path Planning with Spatial Memory Distortion*. In: IEEE Transactions on Visualization and Computer Graphics, 2022, pp. 1–1. DOI: 10.1109/TVCG.2022.3163794.

[5] Ann-Kristin Dugstad et al. *A BIM-based disaster response platform: Facilitating indoor path planning for first responders, UAVs, and UGVs.* NLP-ECPPM 2022, 14TH - 16TH SEPTEMBER, 2022. TRONDHEIM, NORWAY.

[6] Jiabin Wu et al. *Towards a framework for automatic adaption of non-compliant building designs*. NLP-ECPPM 2022, 14TH - 16TH SEPTEMBER, 2022. TRONDHEIM, NORWAY.

[7] Hantao Zhao et al. *Fire evacuation supported by centralized and decentralized visual guidance systems*. In: Safety science 145, 2022, p. 105451.