Mobility and Visuality of the Digital World

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ABSTRACT

In the recent years, the digital world has evolved from a mediator between uns and our living environment to an entertaining portal and marketing hub for the exchange of ideas and goods. With its ubiquitous accessbility, this digital world is nurturing the rapid growth of a mobile population on the one hand and fostering the upcoming ecosystem of self-regulating big data on the other hand. The everyday information overload, however, is increasingly depriving us of our attention and patience. Being exposed to the lasting perceptual stress, our eye-mind is getting less sensitive to external stimuli and more prone to ignoring important but visually inconspicuous messages. This paper is dedicated to visuality-driven information services with the aim to match the graphic design with users' limited perceptual capacity. Two interdisciplinary design approaches – visual storytelling and attention-guiding geovisualzation are introduced. Their synergetic effects are demonstrated in two case studies – image mapping and visual analytics of taxi driver's behavior.

1. INTRODUCTION

In the pre-digital era, travellers who had to navigate through an unfamiliar place usually relied on printed maps as tranquilizers. With the increasing digitization of the earth's surface, map services and other open-source information are now at our easy disposal at anytime and anywhere. A mobile device alone may fetch messages from all over the world around the clock. Meanwhile, we may take the liberty to share our feelings about "here and now", initiatives or feedbacks to any kind of information services with other people who are just some clicks away regardless of their physical locations. Since we generally believe that the informed life style may help us overcome the blind spots and raise the objectivity of decision-making, we suffer more than ever before from the fear of missing out. The more data we get, the "thirstier" we become. The addiction to the connected network makes the disconnection a painful endeavor.

The digitalization of the world was originally meant to bring the real world closer to us and to improve our understanding of land covers, footprints of living creatures and their relationships. With the steady progresses of globally networked geosensors, ubiquitous positioning systems, wireless telecommunication and cloud computing technologies, different types of geodata contributors ranging from public agencies, commercial enterprises to individual users of the omnipresent social media are competitively and cooperatively spreading data streams in structured, semi-structured or unstructured ways. Consequently, the digital world is being unfolded into numerous versions with different spatio-temporal and semantic resolutions.

In addition to the seamless coverage of the geographic reference data with systematically measured geometric and radiometric attributes, many hotspots of permanent or ad-hoc nature are intensively observed and registered as User Generated Contents (UGC) or Volunteered Geographic Information (VGI) for open access. The project OpenStreetMap (OSM) occurred in 2004 is one of the most popular UGC/VGI platforms. It allows its contributors 1) the immediate editing of maps and a frequent updating of the software functions, 2) the input of geodata from GPS-enabled devices, smartphones and other digital cartographic tools, 3) the access to the mapping activities, and 4) the collaboration with other OSM contributors through various communication channels. By the end of 2014, the OSM has already ca.1.85 million registered users and contributors (Arsanjani et al 2015, Mooney 2015).

Although geographic locations are still the epicenters of human and natural activities, the digital world is upgrading its role from a mediator of our living environment to a global entertaining portal and marketing hub for the exchange of ideas and goods. And there is a growing population engaged more with the virtual world than with the physical world.

2. IMPACTS OF THE DIGITAL SOCIETY ON CARTOGRAPHY

Mobility and visuality are two defining characteristics of the digital society. On the one hand, the constantly accelerated transmission speed and expanded volume of information flow, passenger flow and goods flow are changing the way the locations as well as their relationships are perceived. The distinctions between “near” and “far” and between “inside” and “outside” are getting increasingly blurred. More and more people are spending a substantial part of their working time on road, at home or in places other than offices. The workforce of this kind of “anywhere business” has been engineered to be always busy and therefore requires a 24/7 seamless web connection with its institution, project team and customers in order to remain updated and productive. On the other hand, the synchronized interaction with the digital world and the real world is cognitively stressful. Being exposed to the everyday overload of incrementally incoming data streams, our brain with its limited perception and memory capacity has become less sensitive and more selective. Due to the decreasing patience for the information reception, we have to chop the 24 hours into many tiny attention chunks, with each being dedicated to a specific task in the long to-do-list. It is well known that among all senso-motor organs, our eyes are the most powerful perception channel, and among various visual stimuli, graphic signs are more eye-catching than text-only messages. For this reason, innovative visuality-driven design strategies are required to satisfy the information need of impatient users.

The dynamical changing human behavior in the digital society has profound impacts on the scientific, technological and artistic aspects of digital cartography. The standard map production and updating workflow is being shifted from coverage-orientation to feature-orientation, bringing more semantic meanings, events and trends rather than geometric seamlessness into view. Cartographic processes will increasingly go open-end. More and more decision-supporting map services will be likely derived from incomplete and evolving data streams. Meanwhile, the flourishing crowdsourcing with its remarkable social value but a low accountability forces cartographers to seek constructive ways of handling the semantic uncertainty embedded in UGC/VGI. For the mobile tasks such as localizing, way finding and turn-by-turn navigating, and time-critical applications, traditional general purpose maps are giving way to instant map services that should not only provide “just-in-time” and “fit-for-purpose” information, but also look good and feel good on diversified display devices. Most instant maps are jointly designed in collaboration with mobile phone vendors and automotive industry, and used either as hand-held supporting tool or as an element embedded in car navigation systems or more complex infotainment systems. Their technical and functional constraints include continuous positioning, map-matching, prefetching of data near the current location of the user, and computing of the adaptive display scale related to the movement speed and mobile tasks (Meng 2013).

3. VISUALITY-DRIVEN CARTOGRAPHIC DESIGN APPROACHES

If the proposition that at least 80% of all data have a spatial reference also holds for big data, then the big geodata constitute the main part of big data and should play a central role for shaping the big data ecosystem. Facing the general data overload in the digital era, graphic designers from different disciplines are heavily engaged in the efforts to convert the data flood into meaningful and controllable visualizations for entertainment, education and marketing purposes. Two approaches are worth mentioning with this regard.

3.1. Visual storytelling

(Klanten et al. 2011) published the first book on visual storytelling and introduced a rich collection of cutting-edge examples from leading companies. By combining infographics, illustration, photos and other media elements, these examples tell various stories about the leverage effect of graphics in terms of provoking business ideas and strengthening brand. (Bērziņa et al. 2012) introduced a large number of design examples contributed by international professionals who try to demonstrate the power of visual over the textual story in distilling human emotions, revealing hidden patterns about the world, conveying valuable news, surprising findings and individual interpretations for educational purpose. (Wiedemann et al. 2012) provided a tasteful showcase for visual narratives which are persuasive stories told in visually engaging form on a static, dynamic or interactive medium. Each visual narrative contains a point of view, a subject matter and an appeal for transformation in attitudes and behaviors. Although the visual storytelling is not necessarily geo-referenced, its design ideas are highly relevant for the design of instant maps which should communicate the geoinformation in eye-catching, informative and immediately comprehensible way.

3.2. Attention-guiding geovisualization

Based on findings in the field of neuropsychology for visual attention and visual information processing, Swienty (2008) proposed the concept of “attention-guiding geovisualization” according to which, cartographers face two constraints in the process of mapmaking. On the one hand, they have to preserve the ground truth of map features and their topological relationships to the extent that fits the map scale and purpose. On the other hand, they have to ensure the efficiency of map use by rendering a salience order of map symbols in accordance with the relevance order of the represented objects. By exposing a satellite image to different design alternatives with varying color hue, brightness, saturation as well as varying size of the overlaid symbols, Swienty recorded with an eye-tracking sensor the corresponding patterns of users’ eye-movements. A good match between the attention itinerary and the salience order was statistically verified. Further empirical studies on the relationship of thematic relevance and perceptual salience were reported in (Fabrikant et al. 2010). Zhu (2012) adapted the attention-guiding geovisualization approach to real-time routing tasks. She developed a salience model for the individual landmarks within the vision field of a moving passenger. The salience value is composed of a passive part determined by the characteristics of landmark itself and an active part determined by the relation between the landmark and the passenger. Given a location on the route, the movement mode and direction, the visible landmarks may be ranked in an ascending or descending order of salience and dynamically labeled. In the ideal case, the passenger will always perceive the right amount of routing-relevant information that matches his cognitive capacity. The feasibility of this salience model was approved in 2D and 3D routing map services.

The afore-mentioned approaches of visual storytelling and attention-guiding geovisualization have been elaborated in a combined way in the following two case studies that respectively serve the purpose of communication and exploration.

Case study 1 - Image mapping

Since the mapping revolution with Google Earth, the creation of an image map mashup with the Keyhole Markup Language (KML) has become a matter of simple drags and drops. Layout elements such as legends and titles can be added to Google Earth. By defining the position of a virtual camera in relation to the map objects, the image map is then ready to publish as a downloadable KML-file for a standalone geo-browser or can be embedded in a website. Today, more and more Internet users are joining the process of creating their own image maps. They take the image as a canvas to pin down their individual geo-tags in form of icons, text, photos, audios, videos etc.

A traditional image map is two-tiered with an image background and discrete symbols incl. place names as figures. The image serves as a naturalistic reference to support the understanding of the map symbols. Various topographic objects on the earth's surface have different radiometric characteristics, therefore, their image looks inhomogeneous and may influence the overlaid map symbols in an uncontrolled way. At the same time, its varying appearance may become a noise that obstructs the figure-ground segregation and induces undesired optical illusions.

Some research works were focused on how to preserve the adequate figure-ground contrast, how to inhibit the optical illusions and how to make use of the complementarity of naturalism and abstraction (Bělka and Voženílek, 2013). By manipulating the graphic variables, the vector symbols and labels representing important features are made easily distinguishable and outstanding over the background image. At the same time, standard pixel-based operations such as binarization, resampling, antialiasing, color modification etc. are used to reduce the simultaneous contrast between neighboring pixels and make the overall image look more homogeneous. This may enhance the legibility of the overlaid map symbols and labels. Many raster image enhancing operations and symbol libraries are at easy disposal for an interactive graphic assembly.

Murphy (2014) pointed out two main drawbacks of the conventional image maps: (1) They largely ignore the changing behaviors and diverse demands of Internet users; (2) The immense design flexibility enabled by the media technologies remains unused. He redefined the image map as a crossover visualization of remote-sensing imagery and cartographic symbolization. His new definition allows a flexible composition of map symbols and imagery elements at the same or different visual levels. he then put forward an approach of so-called "concise image map design", which is essentially composed of a set of highlighting strategies for vector symbols and raster imagery, and a set of concepts showing how to embed map symbols at a right visual level and how to preserve a consistent appearance of re-occurring map symbols over the heterogeneous background. His preliminary experiments have proved the potential of innovative image mapping in many aspects: First, the irregular raster imagery can be treated as a special graphic variable for fine-tuning; Second, an image map has the capacity to accommodate more than just two visual levels of figure and ground; Third, vector symbols and raster image features can be interlaced to form a storage-saving mosaic. Finally, the vector symbols do not always have to stand out as figures on an imagery background, rather, they can be visually degraded to the same or even a lower level than some raster image features; Figure1-2 demonstrate some examples of concise image map design.

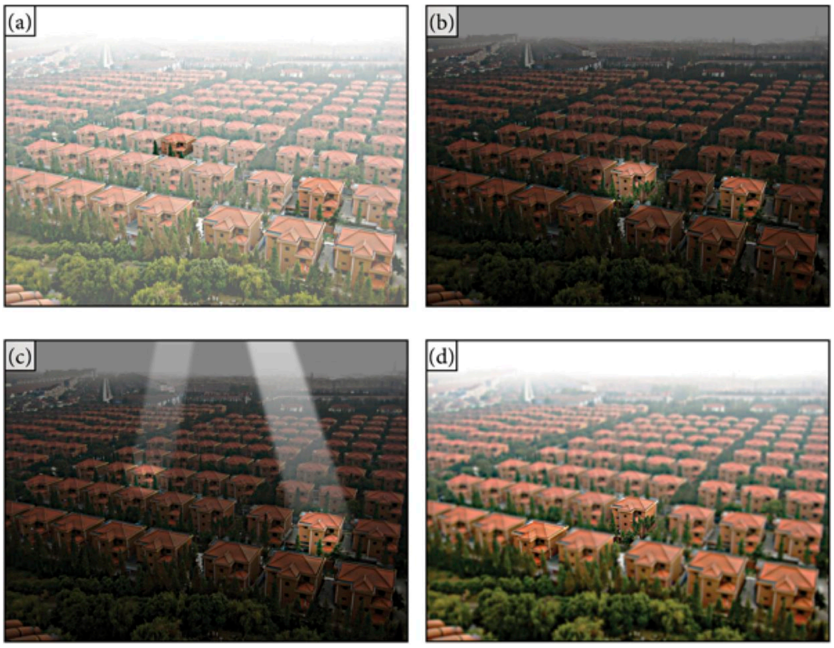


Figure 1: (a) Selective brightness; (b) Spotlight; (c) Light beam; and (d) Semantic focusing (Murphy 2014)

Figure 2: Road symbols and labels with a salience reduced to the same visual level as the image (Murphy 2014)

Case study 2 – Visual analytics of taxi driver's behavior

With help of a large sample containing GPS trajectories of 2000 taxis in Shanghai for the sampling rate of 10 seconds and the time period between May 10 and June 30, 2010, Ding et al. (2015a) conducted a number of visual analytical tasks with the aim to discover taxi driver's behavior embedded in GPS trajectories.

Each GPS point contains its geographic coordinates, time stamp and a number of attributes such as speed, occupancy state (with or without passenger), mobility state (moving or halting). The stationary duration of a taxi is the sum of its spent time in traffic jams, at street crossings or parking places. A compact visualization about the average stationary time of the taxis in Figure 3 reveals the pattern of sleeping hours, lunch breaks, rush hours during working days and the time shift at weekends or holidays.

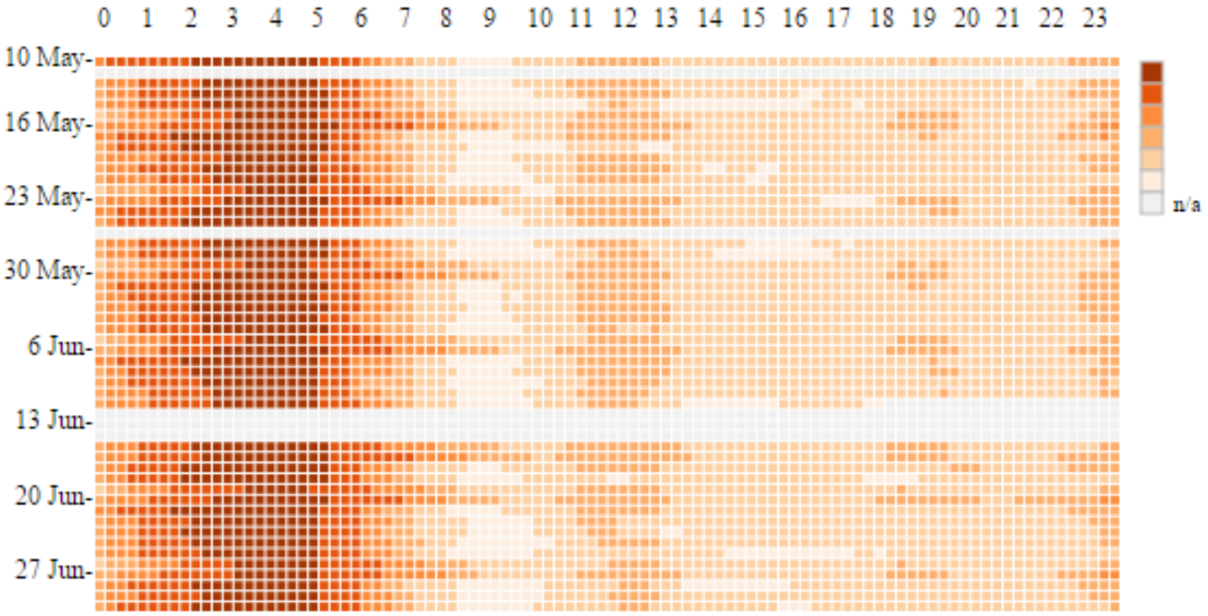


Figure 3: The average stationary duration of the taxis in six grades. The longer the stationary duration, the darker the color tone. Each grid corresponds to a quarter hour as aggregation unit. The days with missing data were left as blank rows (Ding et al. 2015a)

The trajectories of a certain taxi on a certain day are illustrated in Figure 4. The daily income of the taxi driver can be derived from his trips with passengers and the standard taxi fees. Figure 5 (left) shows the normal distribution of the average daily incomes of the 2000 taxi drivers, which are then divided into two groups "high" and "low". The high-income group had a higher occupancy rate and they wasted less idle time than the low-income group as revealed in Figure 5 (right).

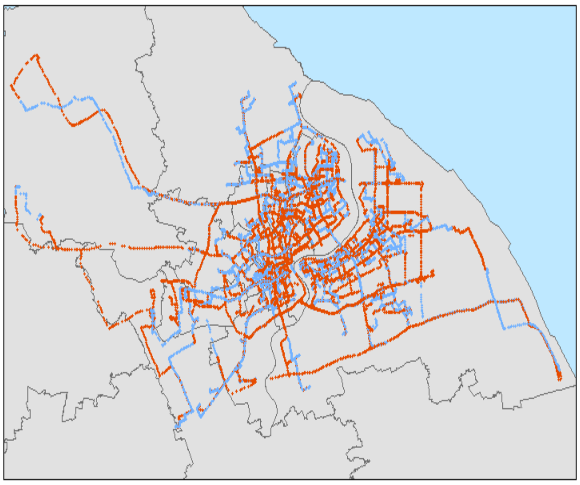


Figure 4: Trajectories of the taxi (ID = 10003) on May 12, 2010: with passengers (red), without passengers (blue) (Ding et al 2015a)

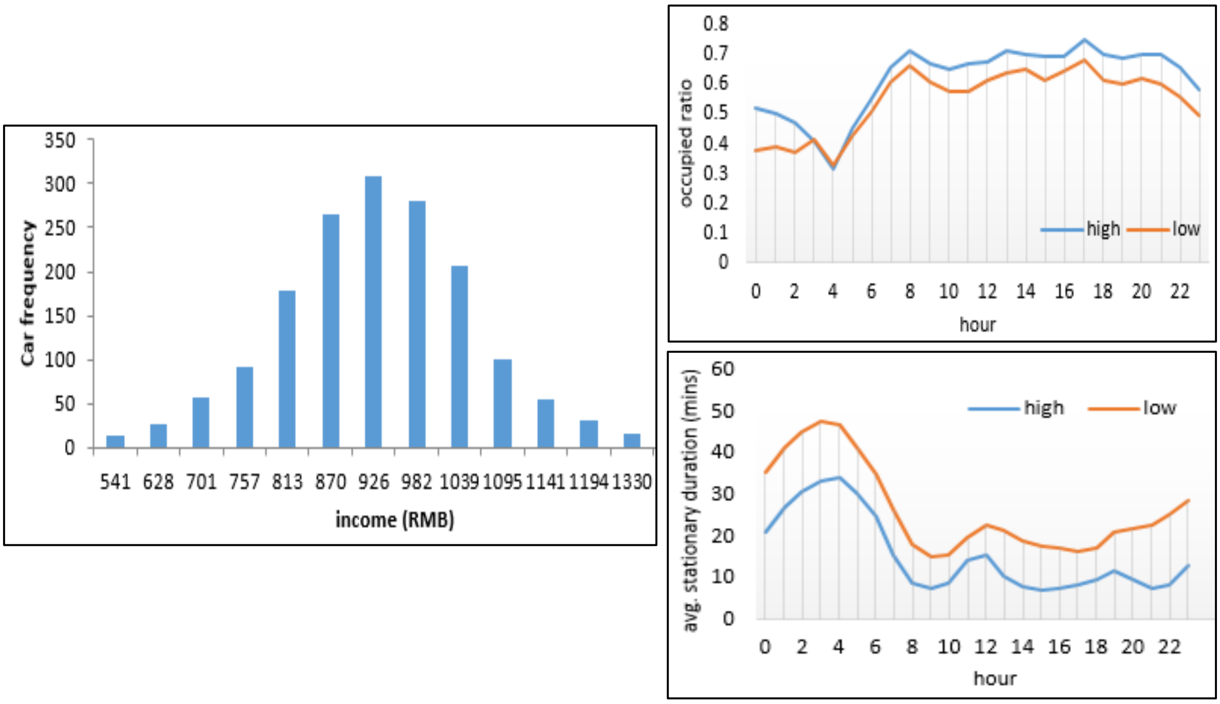
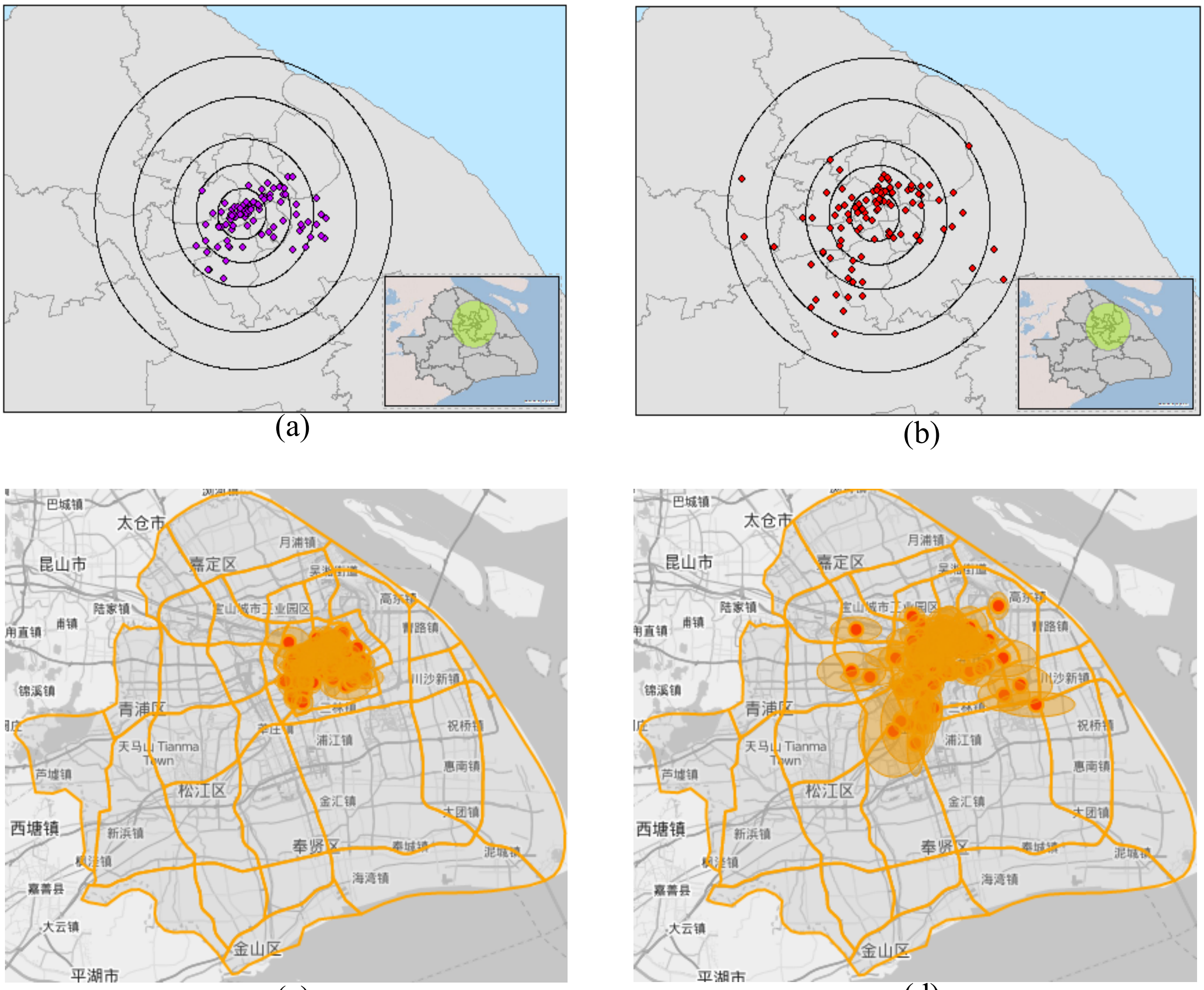


Figure 5: The distribution of the average daily incomes of the 2000 taxis (left); The occupancy rates of both income groups (upper right); The stationary duration of both income groups (lower right) (Ding et al 2015a)

The spatial distribution of trips without passengers is shown in Figure 6, where the individual dots in Figure 6a,b correspond to the geometric middle points of the trips, and their kernel densities are demonstrated in Figure 6c,d. Obviously, the high-income group left a more compact spatial scope of the idle trips than the low-income group did.

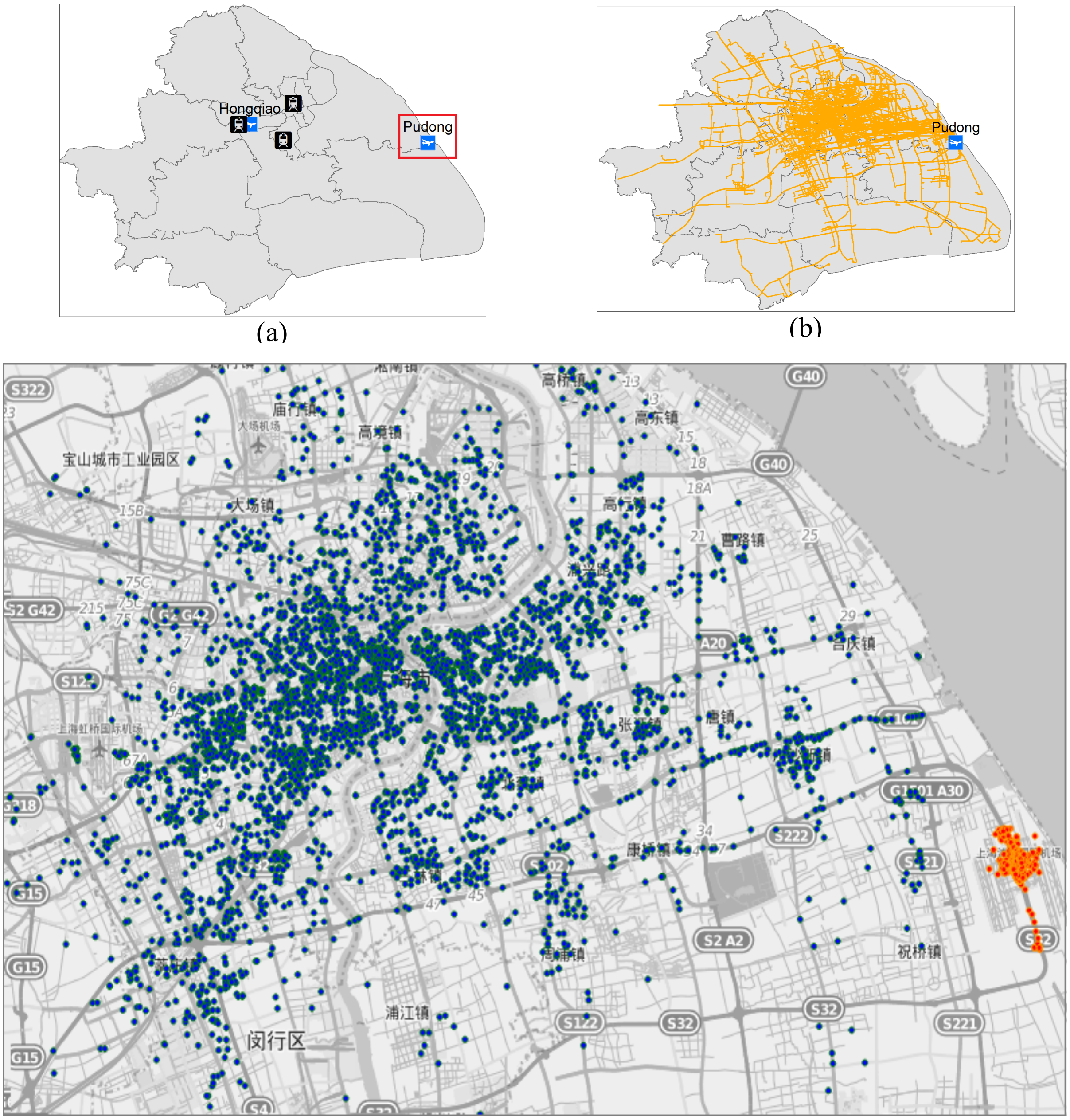


(a) (b)

(c) (d)

Figure 6: Spatial distribution of the trips without passengers for the high-income group (a,c) und the low-income group (b,d) (Ding et al. 2015a)

It is also possible to interpret the taxi trajectories starting from traffic hubs such as airports and railway stations. In Figure 7 the trajectories of taxi trips with passengers from Shanghai Pudong Airport to diverse destinations in City Shanghai as well as the drop-off locations are visualized. The drop-off locations can be further aggregated using "Gaussian mixture models" and assigned the label with the dominating function of surrounding buildings, such as public building, commercial building, residential building or industrial building. The buildings were mostly collected as points of interest (POIs) in the Open Street Maps. Deviations may occur if the POIs are not sufficiently representative.



(a)

(b)

(c)

Figure 7: (a) The location of Shanghai Pudong International Airport; (b) Trajectories of taxi trips with passengers from the airport; (c) Pick-up locations (orange) and drop-off locations (blue) (Ding et al. 2015b)

Figure 8 shows a screenshot of the visual analytical user interface with three linked graphic components – a map field, a circular histogram (lower right) and a clock diagram (upper right). An overwhelming part of the taxi passengers were dropped off at places surrounded by public or commercial buildings. Moreover, there is a more intensive taxi traffic between the airport and the central train station than elsewhere as shown by the overlapping green lines between the two traffic hubs. The central train station is highlighted with a red polygon in a white frame. The corresponding drop-off frequency at the central train station is represented by a white stab in the circular histogram in the lower right corner of the screen shot. In the upper right corner, the 24 hours are projected onto 8 time blocks of the clock diagram. The user may arbitrarily select a time slot and observe the corresponding temporal pattern in the map field and the histogram in a synchronized way.

Figure 8: User interface showing the drop-off clusters and their functions: - public building (blue), commercial buildings (yellow), residential building (green) and industrial building (magenta); Trajectories between Pudong airport and destinations (green lines of varying density) (Ding et al. 2015b)

4. CONCLUSIONS

Attending to eye-catching messages and finding meanings or anomalies in a large dataset belong to our survival instinct that can protect us from being overstressed by the digital world. The visuality-driven design approaches for map services may remedy our decreasing patience and sensitivity to external stimuli, and enhance the efficiency of information perception, exploration and understanding.

5. ACKNOWLEDGEMENTS

I sincerely thank my team members at the Chair for Cartography of Technische Universität München for their implementation of case studies and Prof. Chun LIU from Tongji University, Shanghai, for sharing with us the test data of floating taxis.

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