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CARTOGRAPHIY AND ITS CONNECTING ROLE

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Abstract
Starting from a discussion on the evolution of maps from omnipotent documents of rare geographic knowledge to omnipresent location-based services as digital twins of the corresponding geoobjects in the reality, the author hails the unprecedented social visibility of cartography. At the same time, she points out that it would be misleading if the modern cartography is narrowed down to the scope of instant map design and use, thus minimizing user actions to simple mouse clicks on labels attached to the individual locations rather than exploring the vast information space between the locations. She appeals for the connection-oriented research and development of visual analytical open platforms for relational information in big data. In oder to shed some light on cartographers' contributions in geodata science and citizen science, she reviewed three doctoral theses dedicated to discovering events, behaviors, correlations and causal relations embedded in large datasets and social media.

1. FROM LOCATION-ORIENTATION TO CONNECTION ORIENTATION

Since its emergence as a profession, cartography has been steadily supporting the societal and scientific development and renewing its role. In ancient times, maps were almost omnipotent as they represented the rare and effortfully accumulated knowledge about the earth surface by a few elite scholars or adventure-loving explorers. With technical progresses century after century, the power of maps has dropped against the rising popularity of map services which are created in increasing numbers at decreasing costs. In today's digital era, maps have become omnipresent. The ubiquitously available geosensor network has largely accelerated the mass production of topographic maps and their updates. It remains a responsibility of national mapping agencies to provide seamlessly covered general map series in given scale ranges and to treat all locations equally from a geocentric perspective. At the same time, semantically rich data streams from social media are increasingly geotagged and provided as sharable open maps in the Internet. From ego-centric perspectives of different user groups for their different applications, locations are never equal because they bear different meanings. Some locations are a prior, or a posteriori important or they become important in any other ad-hoc ways. Therefore, in the citizen cartography, mapping activities are more concentrated on delivering "just-in-time" and "fit-for-purpose" information about hotspots and sharing with other people who are just some clicks away regardless of their physical locations. For time-critical applications, "quick-and-dirty" instant maps made by users for other users as decision support with bounded errors can efficiently fill some gaps left by unavailable or inaccessible standard maps.

The seamlessly covered general maps in combination with actual hotspot maps have kept us well-informed wherever and whenever we go online. What we pervasively encounter in our daily life are mainly news maps, weather maps and map-based navigation services. They show us what just happened or is happening or will soon happen at what places. Most of them, if judged by professional designers such as (Klanten et al 2011, Wiedermann et al. 2012), are elaborated visual stories or infographic masterpieces with an adapted look on diversified display devices. Often they are collaboratively designed by cartographers, media specialists, mobile phone vendors and automotive industry. Many design constraints need to be satisfied for the rendering of a map which may be valid only for a couple of seconds. The involved technical challenges range from incremental data processing, continuous positioning and map-matching, pre-fetching of data near the current locations of mobile users, dynamic computing of display scales depending on movement speeds and display size, changing user experiences etc. (Meng, 2015). They are automatically operated in a "black box" and presented at the user interface as a single mouse click. Indeed, the easy-to-use instant maps have been progressively penetrated into our daily life. We treat them as travel mates, tranquilizers or digital twins of the reality because map symbols are nearly synchronized with the corresponding objects or phenomena in the reality.

Taking a closer look at the aforementioned instant maps, we'll notice that they typically communicate to the public the known georeferenced information or turn-by-turn navigation guides. Little or no interaction is required. The design follows a location-oriented principle, drawing users' attention to individual locations as anchor points for descriptive information (e.g. in news maps), predictive information (e.g. in weather maps) and instructive information (e.g. in navigation maps). The continuous geospace is discretized into individual points with each representing a small proximity area. Depending on the context of applications, locations may take different geometric forms at different granularities.

Thanks to the omnipresence of instant map services, the cartographic know-how of translating complex geospatial scenarios to generalized pictures has reached an unprecedented visibility in the society. However, it would be misleading if the public begins to narrow the modern cartography down to the scope of design and use of instant map services. Being locked in the location-oriented view, users tend to identify the labels attached to the individual locations with the lexical information about “what”, “where” and “when”, “how much” rather than being prompted to explore the information space between the locations.

In spite of the fact that the location-oriented instant maps have far-reaching impacts on our daily life, professional cartographers will position them at a corner rather than spreading them over the whole space in the map use cube defined by MacEachren and Kraak (1997). In other words, the modern cartography embraces a much broader typology than the omnipresent instant map services. Although geographic locations are the epicenters of human and natural activities, many things become meaningful only when they are related to other things. However, the discovery of higher-order knowledge such as hypotheses and solutions, also termed as diagnostic and prescriptive information, would be impossible if the analytical views describing the individual locations could not be broght into a holistic big picture.

2. CASE STUDIES OF CONNECTION-ORIENTED VIEW

Facing numerous high complex and ill-defined problems in the real world, cartographers are obliged to look more deeply into different temporal states of a location and to unveil the nested and latent connections among different locations. In this paper, the author appeals for a connection-oriented view of cartography. In the following sections, three doctoral theses accomplished at the Chair of Cartography, Technical University of Munich, are reviewed as case studies with the aim to promote the awareness among professional cartographers of the research need for the recognition and visualization of relational information in big data. These research works are respectively committed to acquisition and visualization of events, nowcasting of dynamic phenomena on the example of lightning data, knowledge exploration of big geodata on the example of Floating Car Data (FCD).

2.1 Acquisition and visualization of events

With the growing availability of data streams from low-end geo-sensors and volunteered contributors, there is an increasing awareness of the concept “event”. An event is a spatially and/or semantically perceivable change that happens within a time period. It usually incorporates both spatial and temporal relationships. The associated research questions include: How are events within a geospatial and temporal framework defined? What are the fundamental components of an event? How can events be collected, stored, analyzed, visualized, queried and interpreted?

Polous gave a try in her thesis work to find some of the answers to these questions by developing a platform “OpenEventMap” (OEM) which can be co-created by developers and users (Polous 2016). OEM is an extension of the OpenStreetMap (OSM) and is able to handle events as a type of higher-level geoinformation. Each event can be modeled with five attributes describing what happens, where it happens, when it happens, how it happens and which subject(s) and object(s) are involved. Two event examples are demonstrated in Fig.1-2. With OEM as a geo-collaborative interface, users have free access to the events, may compare the displayed events and explore the explicit and implicit connections.

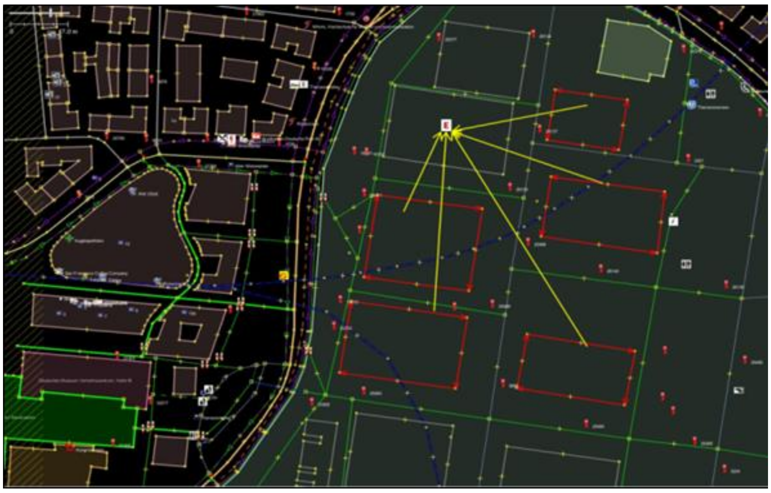


Figure 1. Five tents (red) are involved in a single event "draft beer service" at the October Festival in Munich (Polous 2016)

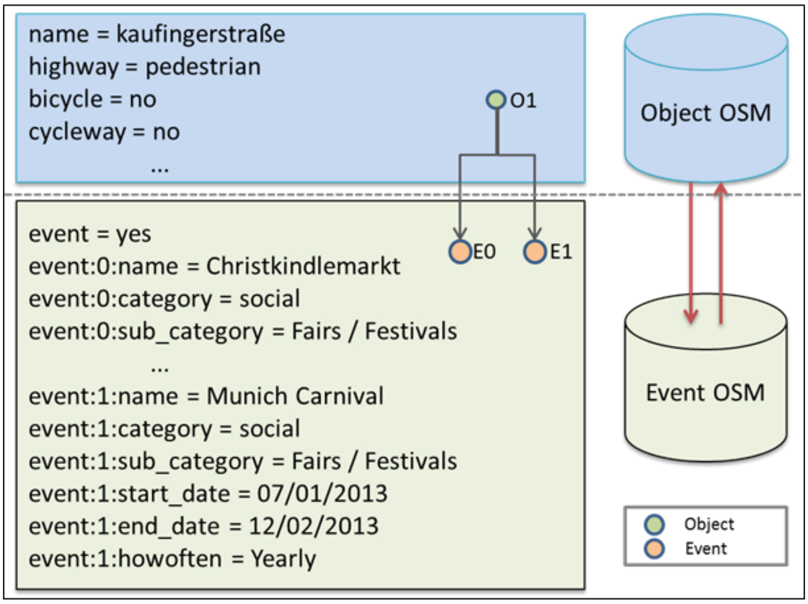


Figure 2. Two events happening at two different time points to the same street object (Polous 2016)

A number of event collection methods were introduced and implemented in the thesis. First, a plugin "Event Editor" was created for Internet users to input and edit events (see Fig.3). The collected events are stored in a querable event-OSM database and updated by means of an Event Calendar. This database can be visualized as "OpenEventMap" application and queried in terms of event name, category, start date, and end date. Following the same working principle, an Android application of "OpenEventMap" was then developed, which allows users to add, view, edit, search for events on an OSM server and meanwhile obtains some user information such as the current location. Finally, in order to enrich the OEM with event information from social media, Polous designed a web crawler for the automatic detection of event information from four social media - Twitter, Instagram, Flickr and Foursquare. The WebCrawler identifies at first the start and end tag of an event and then extracts from the text in-between the event information following crawling rules based on a rough-set matching approach. The event database can be converted to a queryable format by means of the calendar scheduler "Cron" and visualized in OSM for the users. To assist novice users with special technical constraints to operate on Web, she made use of open sources and developed a web-based application Graphical Event Visualization and Analysis Tool (GEVT) for the visualization and analysis of events. Events and their features can be either overlaid as markers, heat map or pie charts over the OSM or expressed as standalone graphs and charts.

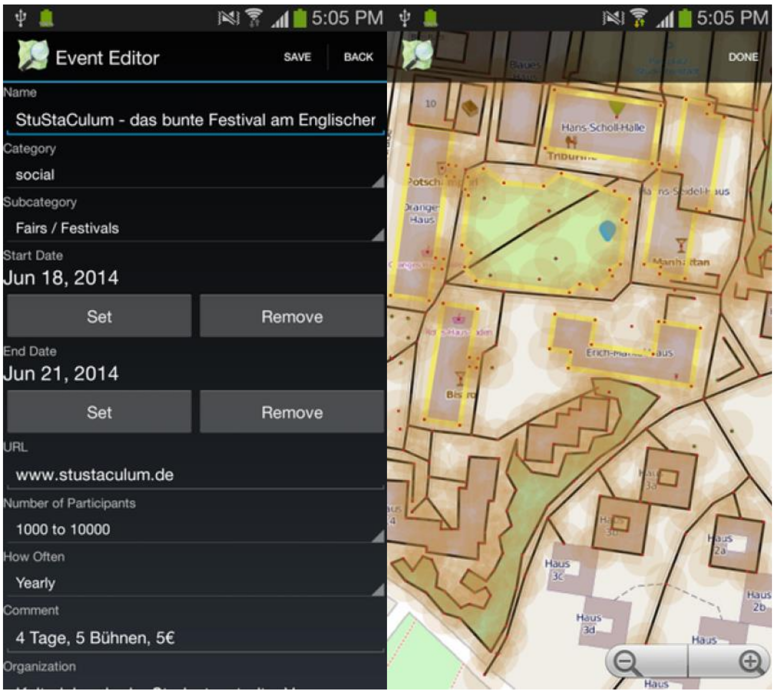


Figure 3. A screenshot of Even Editor showing the editable scope of a festival event in the English Garden

2.2 Nowcasting of dynamic phenomena on the example of lightning data

During the recent two decades, cartography has undergone a number of methodological extensions from 2D to 3D, from static to dynamic, and from geometric to semantic data handling. However, the exponentially growing data amount and complexity still outpace the expressiveness and analytical power of existing geovisualization tools. One of the most challenging issues deals with the visual exploration of dynamic object clusters whose behavior is difficult to predict due to fast changing spatial extension, shape and internal structure. Lightning which is a main cause of thunderstorm disaster represents a typical case of dynamic object clusters. The individual lightning cells may move, merge, split and disappear. Realtime visualization of relationships between the spatio-temporally neighboring cells is a prerequisite for the understanding of lightning behavior.

Peters addressed this challenge in his thesis and developed an interactive visual analytical system which involves three fundamental tasks - detecting the lightning clusters, tracking their trajectories and measuring their similarities (Peters, 2014). In addition to the extention of the popular static visualization techniques such as kernel density map, table lens, radar plot and parallel coordinate plot to display the temporal information, he also introduced the uncertainty presentation of nowcasting results in 2D view, 3D view or a spatio-temporal cube. Moreover, he defined a so-called Trajectory Complexity Gain (TCG) diagram to reveal movement diversity as well as unusual movement behaviors along a lightning trajectory.

The system was prototypically implemented for a 3D lightning dataset from the “Lightning Detection Network in Europe” with 5565 ground-cloud and 2919 intra-cloud lightning cells in the region between Munich and Prag on April 26. 2013 between 2pm and 7pm. As shown in Fig.4, the system provides synchronized spatio-temporal visualizations in different styles which allow users to make comparative exploration of lifespans of various lightning clusters incl. the cluster attributes. The analytical methods embedded in the system may support weather researchers to track lightning clusters based on cell densities and to conduct nowcasting based on the past and present state of a cluster. The visualization of nowcasted lightning clusters along with their uncertainty buffers as shown in Fig.5 may help decision makers at an airport to define safety corridors for flying and landing airplanes.

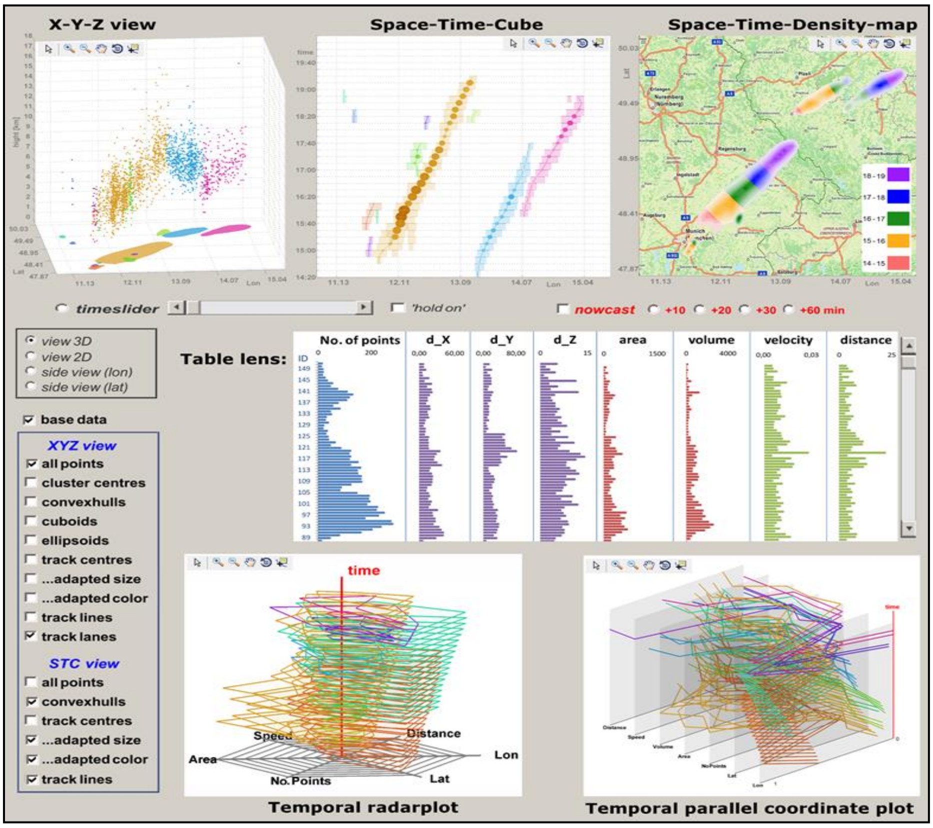


Figure 4. User interface of the visual analytical system for nowcasting of lightning behavior (Peters, 2014)

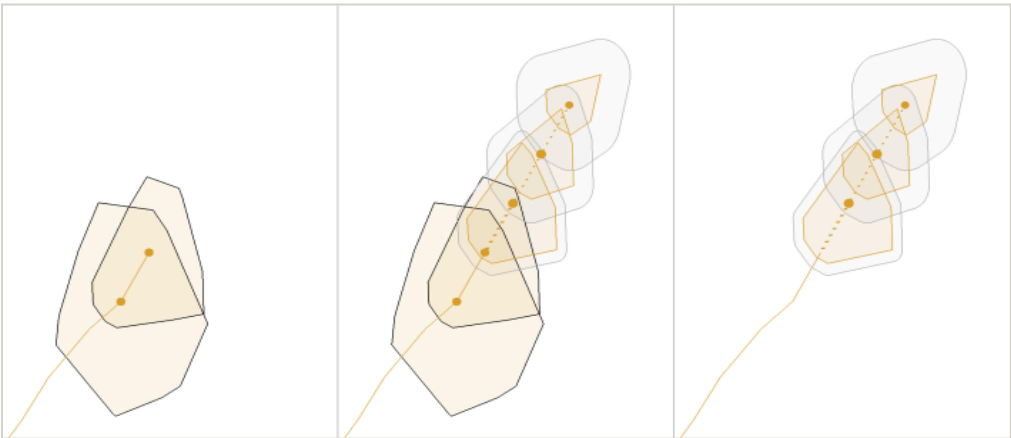


Figure 5. Buffered prediction uncertainty of nowcasting: last two lightning clusters (left), predicted clusters (right); past and predicted clusters (middle) (Peters, 2014)

2.3 Knowledge exploration of big geodata on the example of FCD

In the frame of her thesis project, Ding was engaged in knowledge exploration on a large sample of FCD with the 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. Based on an in-depth study on the synergetic effects of thematic maps and information visualization methods, she proposed a visual analytical framework consisting of three components - visual querying of the movement database, interactive clustering and aggregation, and visual representations (Ding 2016).

For a certain taxi on a certain day, she derived 1) the daily income from its trajectories with passengers and the standard taxi fare, and 2) the stationary duration as the sum of spent time in traffic jams, at street crossings or parking places. From daily incomes of all taxis on all days, two income groups - “high” and “low” were inferred. A compact display of stationary durations of all taxis on all days reveals the patterns of sleeping hours, lunch breaks, rush hours during working days and the time shift at weekends or holidays (Fig.6 left), while the analysis of the trajectories between the two income groups showed that the taxis of high-income group had a higher occupancy rate and wasted less idle time than the low-income group (Fig.6 right). Moreover, a kernel density estimation of the trajectories of the two income groups revealed that the high-income group left a more compact spatial scope of the idle trips than the low-income group did as shown in Fig.7.

In addition, traffic hubs such as airports and railway stations could be detected based on the relative densities of drop-offs and pick-ups. In Fig.8 an interesting pattern was illustrated using a space-cube view according to which there are far more taxi travels without passengers from the airport than to the airport. The drop-off locations other than the traffic hubs were further aggregated using "Gaussian mixture models" and assigned the label with the dominating function of surrounding buildings collected as POIs in OSM, such as public building, commercial building, residential building or industrial building.

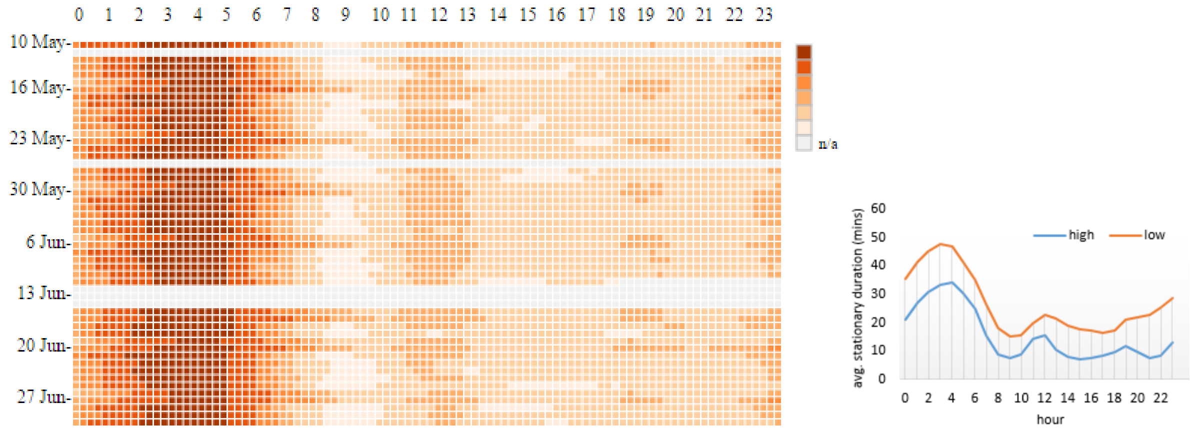


Figure 6. Temporal patterns: (Left) The time graph of the stationary durations aggregated into 15-minute intervals (the stand-by duration is proportional to the darkness of color), (Right) the average hourly duration at the stationary spots for high and low performing drivers

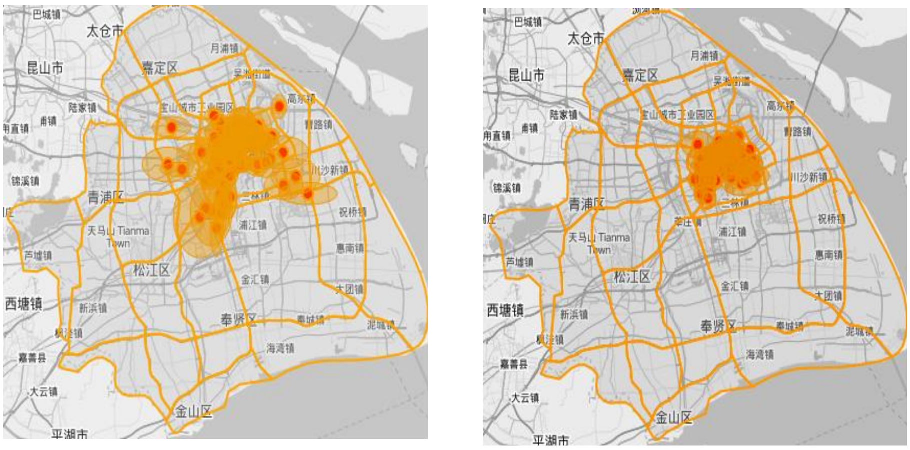
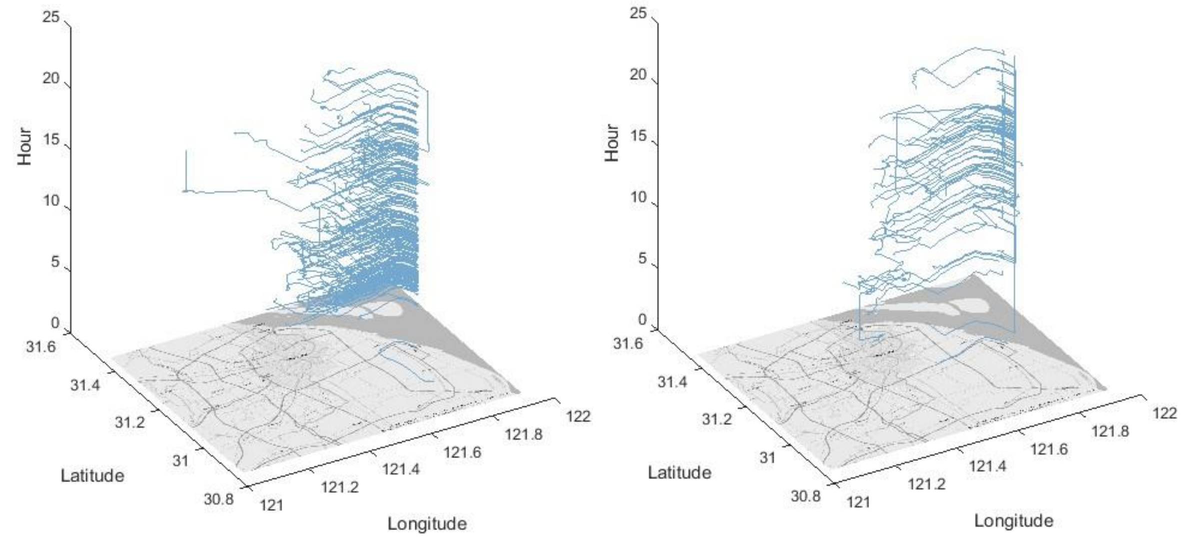


Figure 7. Spatial distribution of idle taxi travels: low performance drivers (left), high performance drivers (right)



(a) cruising from Pudong airport *(b) cruising to Pudong airport*

Figure 8. The non-occupied travels from vs. to Pudong airport on 31 May 2010

3. CONCLUDING REMARKS

With the exponentially growing high-end and low-end sensor networks and ever-expanding social media, more and more Internet users have become part of active data producers and meanwhile they are more eager to participate in the value-adding processes of the data streams which should unveil "what", "how" and "why" is happening at various locations and between them. For this reason, the cartographic capability of bringing many analytical views into a holistic and easily understandable big picture has become a highly sought after skill in geodata science and citizen science.

In an era of globalization and interdependence where everything can be spatially, temporally and/or semantically precisely located and related to everything else, cartographers are confronted with two essential challenges and great opportunities as well: keeping pace with the social demand on more location-oriented instant map services on the one hand, and getting more committed to developming connection-oriented visual analytical sysems on the other hand.

By reviewing some recent doctoral theses as case studies towards the connection-oriented research, the author attempts to shed some light on cartographers' contributions in discovering events, behaviors, correlations and causal relations embedded in the digital world and using the potential power of these high-level information to support decision making in front of ill-defined or wicked problems in the reality.

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BIOGRAPHY

Liqiu Meng is a Professor of Cartography at the Technical University of Munich. Following studies of geodetic engineering in China, she completed her doctorate at Leibniz University of Hannover in Germany before moving to Sweden to teach and to work as a GIS consultant at SWECO while finishing her qualification for professorship in the field of geodesy and geoinformatics at KTH, Stockholm. Her research interests are geodata integration, mobile map services, multimodal navigation algorithms, and geovisual analytics. She is a member of "German National Academy of Sciences" and “Bavaria Academy of Sciences”. She served as the Senior Vice-President for International Alliances and Alumni of TUM from 2008-2014 and as Senator of Helmholtz Association from 2009-2012. She is currently serving the Senate of German Aerospace Center DLR, the Board of Trustees at German Research Centre of Geosciences GFZ, and the International Advisory Board of Alexander von Humboldt Foundation.