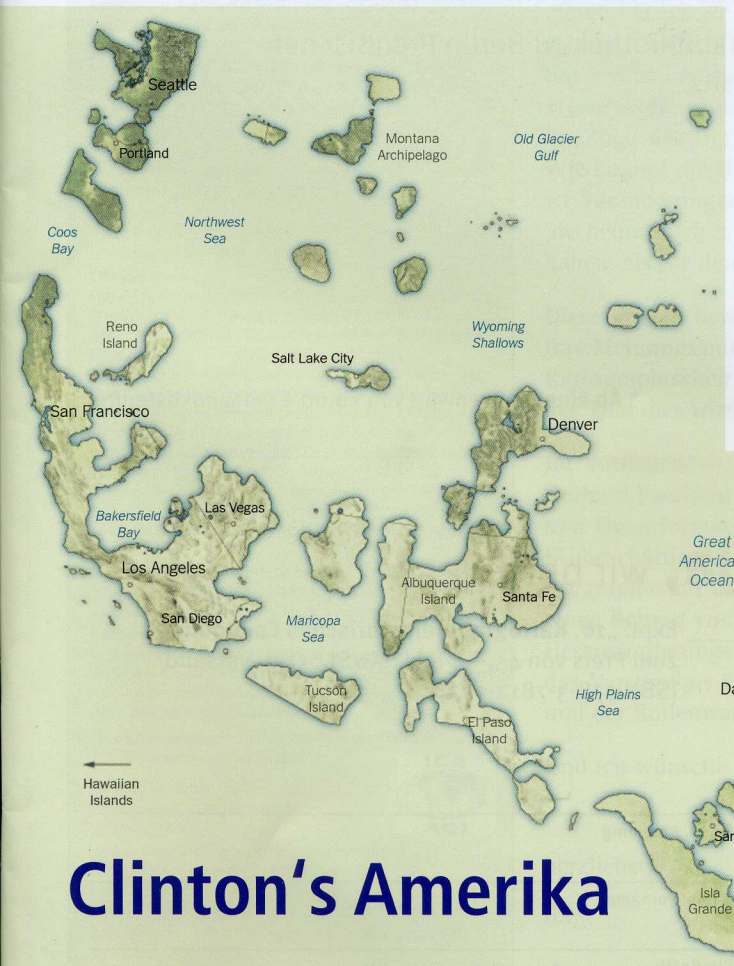
Trump's Amerika



Clinton's Amerika

Grafiken: By Tim Wallace/The New York Times

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Inhalt
Contents

Zum Titelbild:

Das Titelbild "Two Americas" zeigt die vom knappen Wahlergebnis zugunsten Donald Trumps "geteilten Staaten" nach der Präsidentschaftswahl 2016 in den USA. Tim Wallace, promovierter Geograph und Grafikdesigner bei der New York Times, teilte die USA anhand der jeweils gewonnenen Verwaltungseinheiten in Clintons und Trumps Amerika. "The Two Americas of 2016" wurde im Januar 2017 im DGfK-Blog "Die Bemerkenswerte Karte" besprochen: http://bk.dgfk.net/2017/01/10/die-zerteilten-staaten/

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A review of research works on VGI understanding and image map design

Ein Überblick über Forschungsaktivitäten zum Verständnis von Bildkartendesign

Liqiu Meng, Christian E. Murphy, Linfang Ding, Jian Yang, München

This paper reviews more than 10 recent doctoral theses and master's theses accomplished at the Chair of Cartography, Technical University of Munich (TUM). These research works address two persistent challenges involved in the digital mapmaking process: understanding complex input data and improving cartographic design to keep up with the changing roles and increasing demands of users on immediately usable maps. At first, a dedicated computational approach based on Conditional Random Fields (CRF) for data enhancement of Volunteered Geographic Information (VGI) is introduced and demonstrated with test data from trajectories of floating taxis and OpenStreetMap (OSM). It is followed by a summarized overview of visual analytical approaches for event and behaviour discovery and their implementations on various VGI data sources including trajectories of floating taxis, twitter messages and trajectories of football matches. Finally, a concept of image map with a multilayered visual hierarchy is proposed and demonstrated with a set of attention-guided design strategies.

■ Keywords: Probabilistic Graphical Model, visual analytics, event and behaviour discovery, attention-guided design

Der vorliegende Beitrag gibt einen Überblick über die Forschungsinhalte von mehr als 10 aktuellen Dissertationen und Masterarbeiten, die am Lehrstuhl für Kartographie der Technischen Universität München durchgeführt wurden. Diese Arbeiten befassen sich mit zwei dauerhaften Herausforderungen in der digitalen Kartographie: Verstehen von komplexen Eingabedaten und Verbesserung der Gestaltungsverfahren, um mit den sich verändernden Rollen und den stetig wachsenden Anforderungen der Kartennutzer mitzuhalten. Zunächst wird ein auf Probabilistischen Graphischen Modellen (PGM) basierter Ansatz zur Datenanreicherung der VGI vorgestellt und anhand von Taxifahrtrouten und Straßennetz von OpenStreetMap (OSM) demonstriert. Es folgt eine Darstellung von visuellen analytischen Ansätzen sowie deren Umsetzung zur Entdeckung des Events und des Verhaltens von Personen in verschiedenen VGI-Datenquellen wie z. B. Trajektorien der Floating Taxis, Twitternachrichten und Trajektorien des Fußballspiels. Schließlich wird das Konzept der Bildkarte, die in der Regel aus Kartensymbolen im Vordergrund und einem Rasterbild im Hintergrund besteht, infrage gestellt. Eine Reihe von aufmerksamkeitsgetriebenen Gestaltungsstrategien zeigen, wie sich Bildkarten mit mehreren visuellen Ebenen generieren lassen.

■ *Schlüsselwörter: Probabilistische Graphische Modelle, Visuelle Analytik, Entdeckung des Events und Verhaltens, Aufmerksamkeitsbetriebene Gestaltung*

1 Introduction

A digital mapmaking process typically begins with the geo-referenced digital data on relevant themes of the Earth's surface and terminates with general, special or personalized maps, which may be viewed, queried and edited by their users. The results of user comprehension may be fed into the mapping system to create new maps. With the growing accessibility to remote sensing data and user-generated data or VGI, map designers have to allocate a substantial portion of their workload on the understanding and

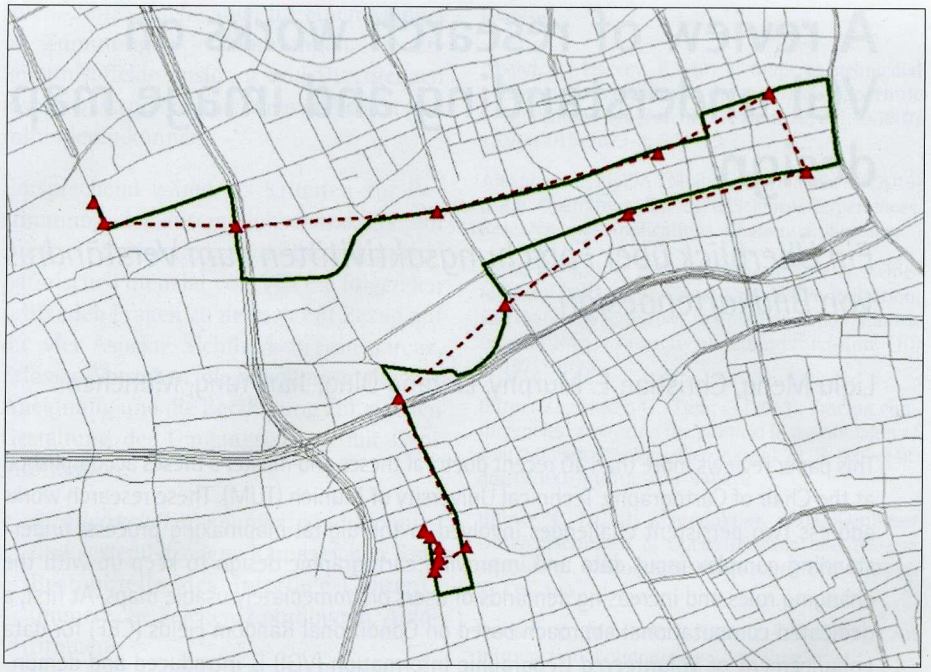

Fig. 1: An example for map matching between a GPS trajectory (dash line in red) and the road network of OSM (grey lines). The ground-truth driving route is marked in green (Yang 2016)

harmonization of the input data. In fact, cartographers in digital age face two persistent challenges at both ends of the mapmaking process. At one end, they always have to select from a large amount of fast evolving and heterogeneous geo-referenced data or data streams the relevant subsets, bring them together and assure the quality of integrated data for mapping purposes. At the other end, they must frequently renew and extend the cartographic design theories and methods to keep up with the changing roles of users and their increasing demands for immediately usable maps.

Both challenges have been well-reflected in the research agenda at the Chair of Cartography, Technical University of Munich (LfK-TUM) since nearly two decades. This paper gives an overview about some most recent research works at LfK-TUM. More than 10 doctoral theses and master's theses are selected to exemplify the research findings with regard to the enhancement and understanding of VGI on the one hand, and the attention-guided design of image maps on the other hand.

2 VGI-based geodata enhancement

VGI, such as crowdsourced GPS trajectories, road networks in OSM and unstructured space-related messages in various social media, has brought forth many opportunities to understand the dynamics of our living planet. Although a single source of VGI may be geometrically or semantically too uncertain to be useful alone, it potentially entails complementary and added values to other sources of VGI and to authoritative geodata from public agencies and private vendors. Fig. 1 demonstrates a trajectory of sporadically registered GPS points from a floating car and its corresponding ground-truth driving route in the OSM. With a sufficiently large number of such trajectories, various data enhancement tasks can be conducted, ranging from map matching, detection of transportation mode to inference of car status. In computer science, these tasks are formulated as labelling spatial trajectory, in which labels are discrete codes that indicate locations, transportation modes, car status accordingly. On the basis of Conditional Random Fields (CRF), which are a class of undirected Probabilistic Graphical Models (PGM), (Yang 2016) developed a dedicated approach of CRF for two labelling tasks: (1) map matching between GPS-trajectories and their routes in the OSM, and (2) inferring car status such as moving, parking, with passenger, without passenger.

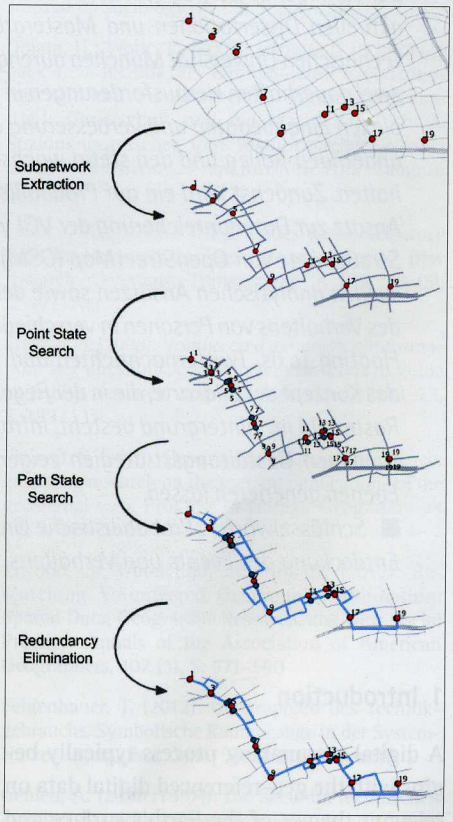

Fig. 2: The workflow of state generation – point observations (red dots), point states (green dots), path states (blue lines) (Yang 2016)

Building probabilistic models in this approach for labelling spatial trajectory involves four steps: design of a graph structure, feature induction and selection, estimation of model parameter, and model refinement. Firstly, a chain structure is employed to model the dependencies between the individual GPS points and their possible path states. These dependencies are formulated as conditional probabilities. Secondly, features are induced, depending on the geometric, topological, and semantic information that can be derived from the road networks. To resolve the dilemma between the computing efficiency and the risk of missing the truth, a workflow of generating hidden states for map matching is designed as shown in Fig. 2, where 35 alternative path states are found between the 5th and the 7th node after elimination of redundancy. Thirdly, inference and learning algorithms are selected to estimate the model parameter. Finally, L1 regularization is applied in model training to derive a sparse model which may achieve competitive performances.

The proposed probabilistic models and algorithms are implemented in MATLAB and evaluated using Shanghai taxi floating car data (FCD) from 2010 and the corresponding OSM data. For the task of map matching, a test dataset was generated from the routes of 70 taxis in downtown area covering a distance of 788 km. The raw data with the high sampling rate were manually matched to road segments, and then degraded to low-sampling-rate trajectories for model training and testing (on a 7:3 data split). The evaluations on error rate and overall confidence in comparison with the benchmark method from (Hunter et al. 2013) have re-

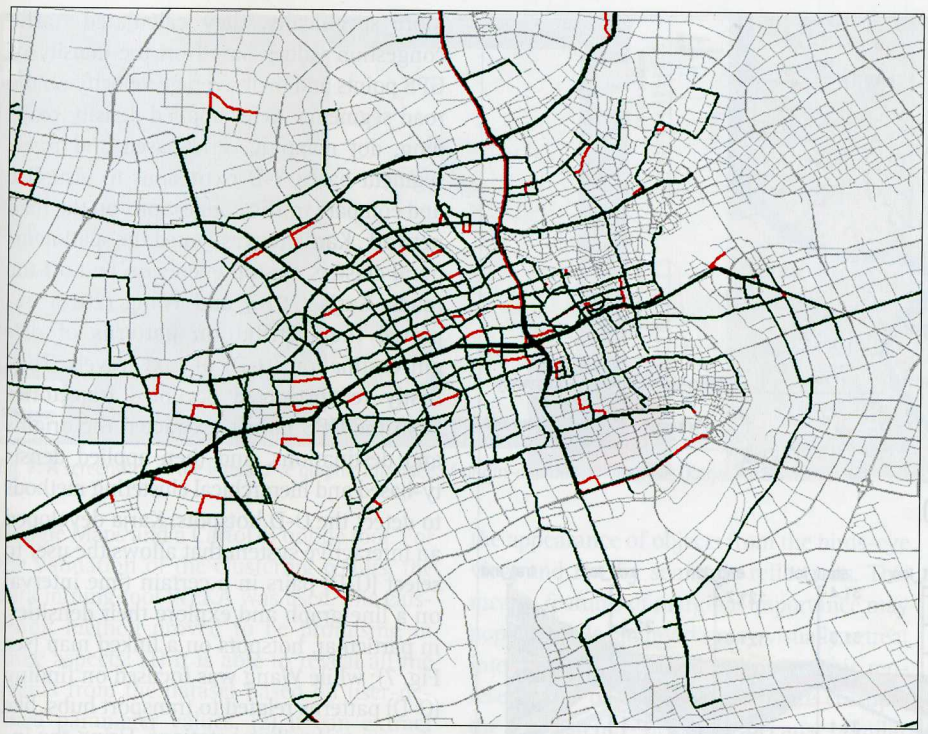

Fig. 3: Map matching results of CRF_L1 (red) overlaid by the ground truth (green) on the road networks of OSM (grey) (Yang 2016)

vealed that the CRF with L1 regularization achieves better matching accuracy and much higher reliability (see Fig. 3). For the task of inferring taxi status, the test dataset was prepared using one-day movements of 50 taxis. The evaluation on precision and recall has shown that the L1 regularized CRF model yields better results in spite of a much less model complexity than CRF with a common smoothing technique. Although this dedicated approach performs well on the test datasets, it may not be straightforward to apply it to larger scale trajectory labelling tasks which face the challenges of computing efficiency and require more workload for the preparation of training dataset.

Parallel to the research work by Yang (2016), Han (2015) proposed a fusion map matching algorithm, which incrementally matches the GPS data to road segments. This algorithm leverages both global and local matching strategies for label assignments, in which both forward and backward operations are allowed to handle data points with low labelling confidences. The experimental results on three test areas in Shanghai with varying road densities show that the fusion map matching achieves similar matching accuracies in comparision with the benchmark methods by Wei et al. (2012) and Newson and Krumm (2009). A significant spatial variance of uncertainty of map matching across test areas has been also observed.

3 Knowledge discovery from VGI

By integrating the analytical capabilities of the computer and the abilities of the human analyst, visual analytics allows novel discoveries and empowers users to take control of the analytical process (Thomas and Cook 2005; Keim et al. 2010). A wide spectrum of domains for decision making can benefit from visual analytical findings, for example, MacEachren et al. (2011) reported a case study on geotwitter analytics for crisis management, while the work from Andrienko et al. (2013) was dedicated to understanding the mobility patterns in movement data.

Keeping this development trend in mind, Ding (2016) conducted an interdisciplinary study of thematic mapping in cartography and scientific visualization in informatics. Based on the synergetic effects of the two disciplines and their complementary methods, she proposed a visual analytical framework with three components – visual querying, interactive clustering and aggregation, and multivariate visualizations. The framework is implemented for knowledge discovery from the same floating car dataset as mentioned in the previous section. For visual analytical purposes the whole dataset containing GPS points collected from 2,000 floating taxis in Shanghai during May 10 and June 30, 2010 was considered. The knowledge embedded in the dataset ranges from simple events, driver behaviour to more complex causal relationships. Fig. 4a shows an example of multivariate visualization with pie radar glyph representing four events aggregated at different locations of city Shanghai: occupancy O (travel with passenger), non-occupancy N (travel without passenger), pickup P, and drop-off D. Fig. 4b demonstrates the method of parallel coordinates in which each trajectory is projected as a point feature with its multiple attributes corresponding to the parallel axes. The users may visually explore trajectory clusters and the multivariate correlations (e. g., starting location, duration, distance).

For an in-depth investigation of taxi driving behaviours, Ding (2016) inferred the daily income from the length of occupied trajectories and the kilometer price, and differentiate two income groups – "high" and "low". She found that the taxis of high-income group had a higher occupancy rate and wasted less idle time than the low-income

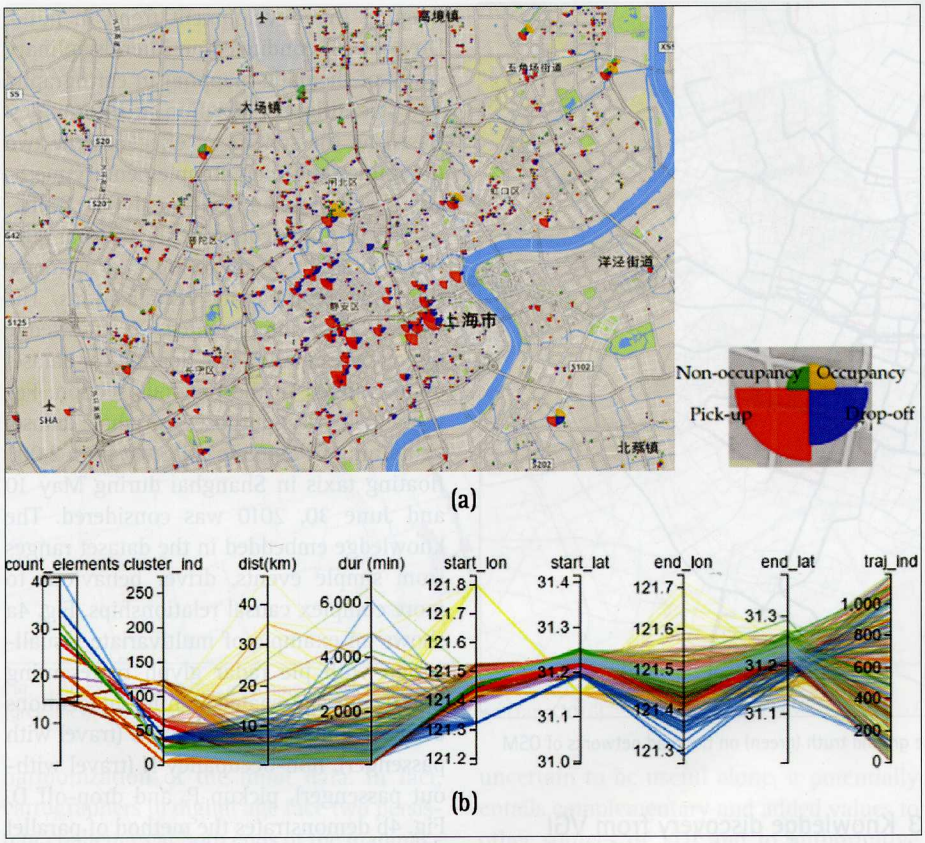

Fig. 4: (a) Spatial distributions of *(O, N, P, D)* point events at 3-4 h using the pie radar glyph; (b) The parallel coordinates showing significant trajectory clusters (Ding 2016)

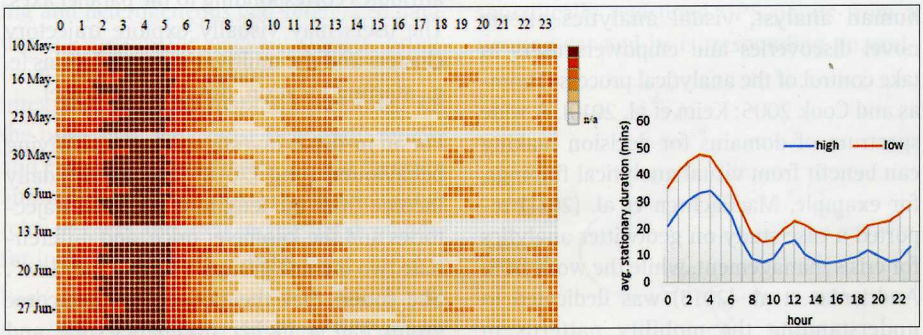

Fig. 5: Temporal patterns of stationary events (Ding, 2016): (a) the time matrix of the idle durations aggregated into 15-minute intervals, the darker the colour, the longer the idle time; (b) the average idle time in minutes within each hour at stationary spots

group. For non-occupied travels, she derived the stationary spots and idle travelling trips. The time matrix view (Fig. 5a) reveals the patterns of all taxis on all days their sleeping hours, lunch breaks, rush hours during working days and the time shift at weekends or holidays, while the line graphs (Fig. 5b) show that taxis of high-income group had shorter stationary time than the low-income group. For idle travelling trips, the average centers of the cruising points of the two income groups and their average daily deviations revealed that the high-income group left a more compact spatial scope of the idle trips than the low-income group did (Fig. 6).

In addition to behaviour discovery, Keler (2013) and Kartika (2015) derived traffic congestion values from the floating taxi data and integrated them using 2-D and 3-D symbols with the underlying road network. More specifically, they calculated traffic congestion values based on the density of GPS points and their average velocity on the road segments. Keler applied density mapping, dot mapping, grid-based and road-segment-based 3-D extrusions to visualize and compare traffic congestions on the road network. Kartika investigated the spatiotemporal clusters of stop events on and off the roads. Karja (2016) and Wang (2016) explored the distribution patterns of origin-destination (O-D) of taxi travels. They firstly reconstructed occupied trajectories from the GPS points, extracted the origins and destinations, and then applied density-based and hierarchical clustering methods to detect the O-D hotspots. Karja developed an interactive system that allows the user to select (O-D) pairs in a certain time interval on a line graph and explore their densities, in particular, hotspots on a linked map (see Fig. 7); while Wang was focused on finding (O-D) patterns related to transport hubs, like airports and railway stations. Using the interactive tools, users can also infer semantic meanings of the hotspot places.

Not only the floating car data, but also other open data sources of VGI have been increasingly used for knowledge discovery at LFK-TUM. To extract local hot topics circulating among the social media users, Singh (2015) developed a density-based spatial temporal clustering method with four parameters: ε (spatial searching radius), t (timestamp), MinDoc (the minimum number of documents of different users) and k (cosine similarity constant between text sentences). The local hot topics are defined as semantically similar topics that fall within a small radius of space and time and frequently occur in the documents of social media users. An experiment was conducted on geo-tagged tweets for a duration of 9 weeks from the Munich area. The detected local hot topics were visualized using 3D-scatter diagram, text visualization,

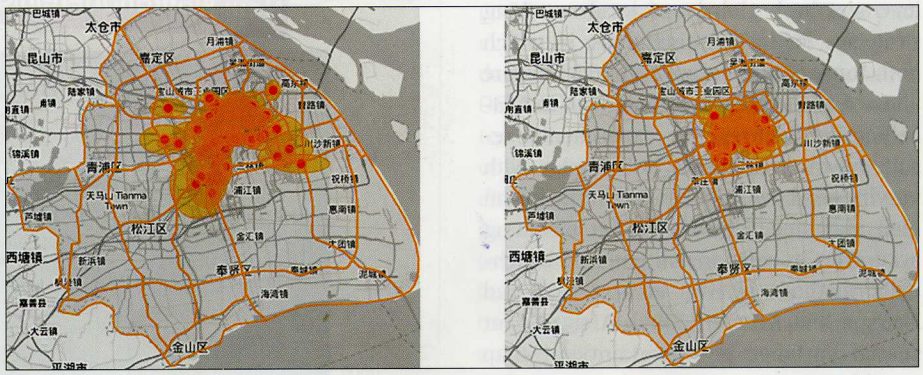

Fig. 6: Spatial distribution of idle taxi travels: low performance drivers (left) and (right) high performance drivers (Ding 2016)

Fig. 7: A screenshot of the interactive graphic interface of origin-destination analysis (Karja 2016)

Google Maps and a CartoDB online tool. For the validation of the clustering results, the data mining tool WEKA was used. The clustering method proved to be promising in three aspects: (1) It is able to reveal all the events from the dataset based on user-defined parameter values, (2) It can extract spatial, temporal and semantically separated clusters, and (3) it is suitable for any text-based social media data.

Vladic (2016) explored the large amount of trajectories left by a football match and developed a toolkit for mining the movement patterns of individual players and the teams, spatiotemporal relationships among the players, or between the players and the football during a match. Although the interpretation of the objectively recorded trajectories cannot replace the knowhow of experts, it provides a useful complementary information source for both professionals and the enthusiastic audience.

4 Attention-guided image map design

Image maps are a composition of remote sensing imagery and cartographic symbolization. While the remote sensing image is a seamless collage of depicted objects, a map needs a fair amount of empty space Kraak (2011). Combining both into an image map naturally contradicts most cartographic design rules concerned with simplicity, visual hierarchy, consistency and legibility. Map space that is not masked by cartographic symbols is covered by imagery depiction. This diminishes the simplicity principle. Depending on the theme, important map objects should visually stand out in front of less important ones. The established visual hierarchy concept Dent (1972) is not followed by a remote sensing image. Here, an unintentional visual hierarchy is driven by the appearance of objects from the birds-eye view and not by semantic reflections. This means, features of marginal importance may pop out while landmarks may visually retreat into the background. The photographic representation of objects furthermore corrupts the consistency principle because similar objects frequently look different because of their varying surface colours and textures in the image. And even the legibility is restricted as on the one hand it is challenging to design cartographic symbols that enable sufficient contrast in all parts of the image map, and on the other hand the imagery shows all sensed details that are not readable or not clearly distinguishable from each other at a given scale. These design challenges have motivated the research for an effective design of image maps that should facilitate the map-user communication.

When the naturalistic reflection of imagery should portray discrete objects, a few design constraints have to be satisfied. The position and extension of objects on the imagery has to stick to its footprint, while image objects can only be graphically modified to a degree that keeps them recognizable, otherwise the image would become illegible and highly confusing. This limits the design freedom of image objects and demands a completely different design approach from what is known in conventional cartographic symbolization.

A set of highlighting strategies for image objects were introduced by Murphy (2014), according to which image objects are ordered into visual levels by graphically mimicking natural light effects and monoscopic depth cues (Sherman and Craig 2003). Fig. 8a shows the 'Selective Brightening' strategy, in which objects of concern are made more salient by radiometric brightening while background objects are pushed down to lower visual levels by a simulated haze. 'Spotlight Highlighting' (Fig. 8b) creates a spotlight effect on objects of concern to guide the users' attention whereas 'Light Beam Guidance' (Fig. 8c) is an extension of the former strategy using cones of light. 'Semantic Focusing' uses the depth of focus as visual cue. Different grades of blur guide the viewer 's attention immediately onto sharply depicted objects (Fig. 8d). These highlighting strategies can incorporate the remote sensing imagery into map maker's intellectual plan (Murphy 2015). Furthermore, a series of user tests have proven the

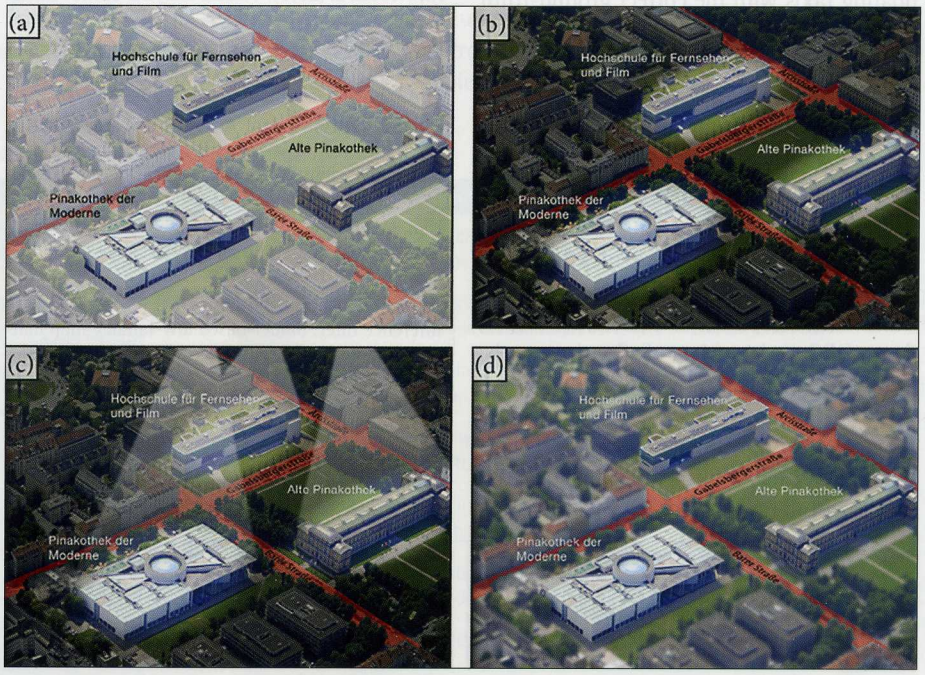

Fig. 8: Highlighting Strategies (Murphy 2014): (a) Selective Brightening, (b) Spotlight Highlighting, (c) Light Beam Guidance, and (d) Semantic Focusing

feasibility of this new design concept in terms of creating a clear figure-ground segregation and a multi-layered visual hierarchy.

In addition to the findings on image object highlighting, Kolev (2015) investigated the label design styles and developed an algorithm to allow an automatic labelling contrasting the local radiometric properties of the image details. The process chain of the algorithm ensures labels to be legible on any kind of image background. One possible solution features a halo designed in a colour tone blending into the image background with an incorporated transparency gradient for a visually seamless transition between label and imagery (see Fig. 9).

5 Conclusion

This paper addresses two persistent challenges involved in the digital mapmaking process: understanding a large amount of fast evolving and heterogeneous geo-referenced data streams, and improving cartographic design theories and methods to keep up with the changing roles and the increasing demands of users for immediately usable maps. An overview about the related research works at LFK-TUM is given.

At first, a computational approach based on CRF with L1-regularization is reported, which can be applied to enhance VGI data in terms of improving geometric and semantic precisions. With a carefully designed graph structure and task-relevant features, the approach proves efficient to match GPS trajectories of floating taxis with the correct ground-truth routes and inferring car status such as moving, parking, with passenger, without passenger. However, for larger scale labelling tasks, more efforts are required to develop algorithms for scalable model training.

A number of advanced and interactive visual analytical methods and tools are then introduced for the purpose of knowledge discovery. They are successfully implemented on various VGI data sources ranging from GPS trajectories of floating taxis, twitter messages and trajectories of football matches. The discovered knowledge includes movement patterns, spatiotemporal clusters, hot topics of social events, human behaviour and performance indicators.

Finally, the concept of image map is revisited in order to exploit the whole design potential in multimedia cartography. The conventional two-tired structure with image as background and cartographic symbols as foreground is extended to accommodate a visual hierarchy of more than two layers. In such a multilayered hierarchy, image objects are treated as additional design variables. Depending on user demands, they can be visually accentuated or inhibited so that they can either appear more outstanding than cartographic symbols or retreat behind the background imagery. A set of attention-guided highlighting strategies for image objects and texts are developed and implemented.

The doctoral theses and master's theses summarized in this paper are multidisciplinary endeavors and mainly inspired by the most recent methods from computer science, cognitive science, data science and digital media services. In the coming years the computational and visual data-mining approaches will be continued and elaborated to understand and discover knowledge from further structured or semi-structured VGI sources. Meanwhile, extensive usability tests will be carried out in combination with open portals for the acquisition of user experiences.

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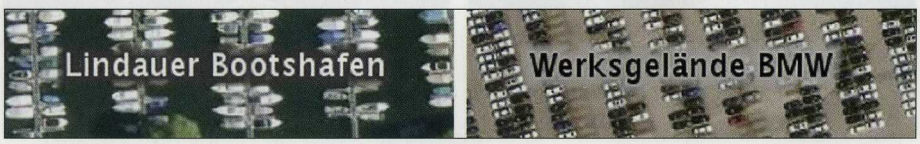

Fig. 9: Label design for image maps (Kolev 2015). A transparency gradient combined with an image-related halo tone for blending into the image background (right and left)

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