LBS research agenda: one-paragraph proposals

1. Klemen Kozmus (Slovenia)

I believe indoor navigation, including outdoor navigation under adverse GNSS conditions, is the key issue for the future of LBS. I think more and more people require indoor wayfinding. Not just rescue personnel, but customers in shopping malls, museums etc. would like to know their positions and "get served" with information for that location.

2. Haosheng Huang (Switzerland)

<u>Side effects of Location-Based Services (Navigation systems)</u>

LBS are becoming more and more popular and have entered into general public's daily life. For some of LBS applications, such as mobile navigation systems, we can see many people are relying on them when travelling around. While these kinds of applications facilitate people's daily activities and decision-making, they potentially bring some detrimental effects. "Technologies change how we think, often by reducing our ability to reason effectively without the technology". Therefore, there is a strong need to understand the potential side effects of over-reliance on these technologies. There are several initial studies towards this direction, and they show that over-reliance on navigation systems actually harm our spatial ability and spatial knowledge acquisition (see Huang et al. 2012). However, until now, a systematic understanding of these issues is still missing, and very challenging, as it requires long-term longitudinal empirical research. Another more important question is "how can we design technologies that facilitate people's activities and decision-making without harming their spatial abilities". This still remains an unexplored field.

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<u>From Location-Based Services to Place-Based LBS</u>

Place is an important concept in Geography and Psychology, and is often distinguished from space. While space is abstract and objective views of the world, place relates the world with human existence, experiences and interaction. To provide meaningful services to users, it is important to transfer LBS from space-based services to place-based services. By place-based services, I mean services considering individuals' former (or even planned) experiences, interaction in the environment.

<u>Indoor behavior modeling</u>

Lots of progress has been made in outdoor behavior modeling. However, due to the challenges posed by the indoor tracking methods, we still have little insights regarding people's behaviors in indoor environments, such as shopping malls, university buildings, and hospitals, as well as in mixed outdoor/indoor environments.

<u>There is more to context than location.</u>

In order to ensure the usefulness (utility and usability), LBS should be adapted to their users, tasks, and the contexts maps are used. In other words, context-awareness should be introduced for LBS.

Context-aware adaptation has to consider following dimensions: Why (why do we need that a system adapts itself to the particular user/context), What (which features of the system can be adapted), To what (what aspects of the user/context working with the system can be taken into account when providing adaptation), When (timing and triggering of adaptation), How (which procedures are needed to adapt the adaptation objects according to the users/context), How well (how to evaluate the adaptation processes).

Another important question related to context-awareness in LBS is privacy. How can we provide context-aware LBS while accommodating users' privacy concerns remains unsolved.

<u>Advances in Interface Technologies and Devices</u>

Recent years have seen a range of new interface technologies and devices being introduced for LBS applications, such as smartphones, wearable devices like smart watch and Google Glass, haptic devices, and public displays. These kinds of devices often have their own characteristics, interaction modalities (e.g., voice, gesture, gaze based interaction), and technical constraints. To make use of these new technologies, conventional cartographic expertise (such as cartographic techniques, rules, and their relative priority), which was optimized for paper maps and maps on desktop computers, should be improved, updated, and even re-defined if needed. The rapid advances in interface technologies also bring challenges to usability studies, as new methodologies are often needed due to the different nature of interface technologies and devices.

3. Domokos Esztergár-Kiss (Hungary)

The connection of Location Based Services and travel behaviour analysis presents an outstanding opportunity to answer research questions of activity pattern analysis, new data collection methods and planning of activities with enhanced information. One subset of this huge field is the optimization of multimodal travel chains by introducing flexible demand points, where the aim of using LBS could help creating shorter activity chains and thus decreasing travel time for travelers.

4. Eko Sediyono (Indonesia)

A country has the sovereignty because of possessed of territory comprising terrestrial, the sea, and air. The power of a state declared in international convention (Vienna convention 1969). Next, in each country there existing territorial division, according to province, regency, and the smallest is a village. Each of the state regulates the region to prosper on the people living in the area. Unfortunately, developing countries, mostly of former regional a colony of a country, who obtained the independence or abandoned by colonialist, were unable to manage holistically terrestrial administration (Cadastral). As a result a lot of interest appears to conflict up to now. The development of developing countries obstructed mostly because of power dispute that was based on terrestrial areas. Methods and LBS technology expected to speed up the administrative cadastral. Researches toward mapping and administration ownership of terrestrial areas (terrestrial, the sea, and air) digitally is indispensable. If the studies can be achieved and can be in synergy with the political will of the government of the developing countries, it can be ascertained that the country will be developed faster.

5. Kai-Florian Richter (Sweden)

Human-in-the-loop Services (or Autonomy vs. Automation)

Using location-based services, human user and machine are usually co-located. And with these services human location-based requests mostly relate to the immediate surroundings, i.e., their current location. This significantly restricts spatial context, which tremendously helps the machine dealing with the requests. Still, there are usually many remaining ambiguities and open ends regarding context. Furthermore, human users tend to more and more rely on the machine for processing spatial information and making decisions, and, thus, lose their understanding of „the location". Therefore, it seems highly advantageous to involve users in the computational processes in a sensible way, i.e., to create human-in-the-loop services. This will allow for (a) resolving ambiguities and (potentially hidden) context dependencies by, for example, computing a set of plausible answers to a request and letting the user pick the one that best suits their needs, or by creating dialogic processes that see human and computer as partners; and (b) keeping users involved in the decision making, which will increase their (spatial) awareness and lessen their dependency on the device.

6. Dirk Wenig (Germany)

Sustainable Location-Based Services

Current LBS, especially for mobile devices, are often designed to support the user on short notice to complete a task in a very specific situation at a very specific moment. They do not take into account if the user has to do the same task or a similar one at a later point in time. As a result, the users often need to be supported for the same task again and again. For example, navigation systems are built to guide people as fast as possible and ideally without any errors from one point to another. However, there are many situations where the user would clearly benefit from a more sustainable approach, which helps her/him to learn the route and the surrounding. For example, when a user visits a conference in an unfamiliar city. S/he needs to find the way from her/his hotel in the morning to the conference location, and the way back to the hotel in the evening several days in a row. Instead of just guiding the user on the first morning to the conference location as fast as possible, a sustainable navigation system could teach the user the route. As a result, the user would be able to find her/his way back to the hotel after a hard conference day in the evening without the support of a navigation system, and again to the conference location the next morning. Ideally, on the first day, a sustainable navigation system would have told the u! ser about nearby points of interest, which could be useful for the next days, such as restaurants or a grocery store. Similar, people moving to another city or tourists could benefit. Until now, most research has evaluated navigation systems regarding performance metrics (time and error), perceived usability and user experience. Only little research has investigated learning routes and spatial configurations. Because of that, I am convinced that not only navigation but also other LBS (e.g., searching POIs) could benefit from more sustainable approaches.

7. Martin Raubal, Christian Kray, Peter Kiefer, Max Pfeiffer, Ioannis Giannopoulos, Matthias Seuter, Champika Manel (Switzerland/Germany)

Evaluation of Location Based Services

Location based services (LBS) have become ubiquitous and now form an important part of many people's daily lives. While research has contributed to enabling LBS and keeps pushing the limits of LBS, the evaluation of such services regarding usability and usefulness is still not well understood. The lack of understanding in this particular area of LBS has a significant impact on the development of the field as a whole. For example, in order to ensure reliable progress (both in research and in practice), evaluation methods are required that facilitate comparison of different services and approaches. There is a strong need to systematically investigate test environments (Li & Longley, 2006) and evaluation methods for LBS: properties of existing environments and methods must be assessed, and new test environments and methods explored. In order to further improve the usefulness and acceptance of LBS it is essential to thoroughly evaluate them and to determine which method and environment to use when (Delikostidis et al. 2015). Due to the complex nature of LBS and their strong dependency on contextual factors, there is also a clear need to investigate how to best combine methods when evaluating different types of location based services.

One of the key challenges in this context relates to the fact that LBS are often used while people are on the move, and therefore dynamic aspects of mobile decision-making must be considered (Hirtle & Raubal, 2013). While usability is still one of the main concerns for the evaluation of mobile applications (Harrison, Flood, & Duce, 2013), we argue that a comprehensive framework for LBS evaluation must also account explicitly for the following characteristics: user interface, user properties and skills, cognition, device and service properties, environmental factors, and social aspects. In addition, the relation between the movement of the user (self-propelled or via a means of transportation) and the use of LBS needs to be explicitly considered. Overall, we believe that the evaluation of LBS is a critical area for future research in this field.

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Harrison, R., Flood, D., & Duce, D. (2013). Usability of mobile applications: literature review and rationale for a new usability model. Journal of Interaction Science, 1(1). doi:doi:10.1186/2194-0827-1-1

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8. Sebastian Feld, Martin Werner (Germany)

Multipurpose Usage of Digital Maps

There are numerous existing map representations all having their respective benefits and handicaps. Examples of such representations are simple bitmaps, shape files, 3D point clouds, navigation meshes and many more. Currently, the map representation to be used is chosen based on the one use case or requirement at hand, e.g. path planning, positioning, information extraction, or visualization. In order to enable a multipurpose usage of digital maps we envision the development of more versatile map representations, an intelligent fusion of the existing ones, and a seamless translation between them.

Improvement of Communication

Just as in the private context there is a huge risk of losing potential if the right people do not talk with each other. There is the chance that given problems in one domain are already solved in another one under different naming or that simple techniques of one domain can help to relax a tediously solved problem of another domain. Another aspect is the possibility to reduce the complexity of a problem by incorporating background information from another domain. We envision a sustainable and structured communication of researchers of cartography, geoinformatics, and algorithmics (both, computer science and mathematics). Depending on the proportion of fundamental research and applied research, researchers of human-machine interface and human-computer interaction are important dialog partners. In both cases general findings from the field of psychology can help to relax given problems or to make better assumptions. Tackling the heterogeneity LBS are getting increasingly complex on various levels. There are manifold data sources, the discrepancy of frequency and quality of measurements is huge, and also the format of the utilized sensor readings are getting more and more complex (GPS readings, high-definition pictures and videos, voice recording and more). The problem of tackling the resulting heterogeneity is in fact a fundamental research question in the field of big data and data science. We envision mechanisms to enable LBS to consistently collect, connect, and process the heterogeneous information. The envisioned systems should be able to perform self-organization, to discover their surrounding themselves, what can be summarized with the familiar term pervasive computing.

9. Pavel Andreevich Samsonov and Johannes Schöning (Belgium)

Connecting the Dots: LBS Beyond 'point-to-point' queries

Today, a large set of location-based services exists and are used by millions of people on a daily base. These services are capable of assisting with or fulfilling a variety of tasks, such as fetching points of interest or indicating friends nearby, performing web search requests which respect the context of the user, or navigating to a destination point. Even though they are very helpful tools, most LBS perform simply 'point-to-point' queries. We propose to address this shortcoming of current LBS and to "connect the dots" for future LBS. By doing so LBS can exploit the potential of 'point, line, polygon-to-point, line polygon' queries in contrast to of simple 'point-to-point' queries and extend their functionalities.

10. Jürgen Döllner (Germany)

Logic Maps Maps as generic, general-purpose approach to communicate spatial and geo-referenced information, are still driven and defined by geographic map projections. In contrast, our mind and our "mental maps" work differently: They transform, deform, and distort spatial information such that the more important becomes more prominent and the less relevant becomes removed. We still do not know too much about computational approaches that would be able to generate maps that follow these principles. These "logic maps", however, could be much more effective to uses as they would adapt to our perceptional and cognitive strengths.

11. Jochen Wendel (Germany)
Applications and research in LBS have a long history ranging from basic navigation applications to the analysis of LBS data such as social media and movement patterns to newer developments such as immersive LBS (AR and VR). While analytical capabilities of LBS have been demonstrated in many research projects and applications before, for many, especially in the area of immersive systems, it is often seen just as a tool for novel visualization. Further research on those immersive systems should focus more on the analytical aspect as well as the standardized integration of data and services. Moving away from immersive LBS (AR and VR) as a method for visualization to a medium for analysis. By doing so, many research questions and problems arise. For example, open-geo standards are lacking and will be needed specifically for larger amount of data on mobile devices (big-data paradigm, 3D data, and time series data) as well as linkage to other standards (e.g. OGC). Furthermore, standardized web-services are needed that are specifically tailored to LBS requirements for 2D and 3D (AR and VR).

12. Rui Li (USA)
One big problem that should be addressed to bring LBS into a higher level is to achieve spatial intelligence in both services and their users. LBS as one prominent example of geospatial technologies has greatly changed the way that humans acquiring spatial knowledge. For example, in the scenario of navigation, LBS has been increasingly fav! ored. Its efficiency is unquestionably acknowledged by users and market success. Following the turn-by-turn instructions, users are aware of the places that they just traveled. Researchers pointed out that the mechanism of existing navigation services degrades users' spatial awareness: the acquisition of spatial knowledge and cognitive mapping for orientation. In case of emergency, device failure, or spontaneous change to different locations, users using these navigation systems on LBS in an unfamiliar environment are unlikely to react or re-orient due to the lack of spatial awareness. Therefore, it is the goal of this research propose to suggest the design of LBS that not only support the efficiency of navigation but also the facilitation of spatial awareness. Being an interdisciplinary research question itself, this research proposal involves a wide scope of fields including spatial cognition, geographic information science, cartography, and computer science. Cognitive theory driven research is necessary to identify the important spatial information that contributes to a person's spatial awareness. Research from geographic information science would inform efficient extraction of spatial information from a data driven approach. Cartographic research contributes to this research by

suggesting effective map design that fits LBS in a mobile contexts. Last but not list, computer science plays an important role of the building of prototype for evaluation. In all, these interdisciplinary collaborations contribute to the goal of enriching the spatial intelligence in not only systems but also the humans who use them.

13. Huanfa Chen (China)

The vehicle routing problem generalises the well-known Travelling Salesman Problem, by seeking for the optimal set of routes for a fleet of vehicles to deliver to a given set of customers. Traditionally, the distribution of customers can be known in advance and is fixed. However, real-world applications often include dynamic demands. These dynamic demands remain unknown until it is revealed at the time, and they have to be dealt with within a time window. For example, in police patrolling, officers initially follow pre-determined routes, and they frequently respond to calls for service. As the calls happen dynamically in space and time, dynamic routing algorithms are needed to re-plan the routes. Another case is the takeout deliveries such as Deliveroo. Consumers can order a wider range of high-quality takeaway food and have it guaranteed on their doorstep within half an hour. The delivery vehicles bring food from restaurants to the customers. As orders arrive in real-time and the delivery vehicles are always out on the road, the delivery vehicles have to frequently change the routes to satisfy the dynamic demands . The dynamic vehicle routing problem introduces new challenges. Firstly, this problem often includes multiple objectives. It aims at minimising the response time to the demands. Moreover, the workloads of vehicles should remain balanced, to avoid work overload and to ensure the demands are satisfied as early as possible. Secondly, it requires quick decision making and route adjustment, which is often time-consuming. Developing parallel algorithms can reduce the time needed for optimisation and provide decision makers with highly reactive tools. Because of the above challenges, the traditional algorithms for vehicle routing problem are less effective for dynamic routing. On the other hand, there are limited algorithms for the dynamic vehicle routing problem. Therefore, it is necessary to develop new algorithms that consider dynamic demands for specific applications, such as police patrolling and meal delivery.

14. William Mackaness (UK)

Cognitive task artefact reminds us that technology is not neutral in terms of its impact on community power relationships & provides opportunity for fundamentally different ways of thinking and doing. VGI approaches to land registration are a case in point. In the context of off grid and marginalised communities, the socio technical implications are significant - in terms of 1) ease of use vs. functional complexity, 2) adoption/resistance to technology, 3) digital divide within and between different communities and its potential to adversely affect community dynamics (ie the role of the map in usurping traditional practice and ways of understanding the environment). Why: technology at risk of amplifying existing differences across a range of socio technical issues, not least the social/neo liberal construct of land ownership and its link to economic independence. More broadly the focus should perhaps be on the social fabric in which technologies are deployed and less of a focus on the technology itself.

15. M.R. Malek (Iran)
On the one hand new generation of GIS uses context-aware computing and information flow from sensor network to offer intelligent services and on the other hands big data produced by social networks especially location-based social networks (LBSN). I think a big step forward is taken if combine these two main issues. I intentionally prefer to use "big step forward" instead of "problem" here. In my view, intelligent tools such as smart phones can play an important role in LBSN and vice versa. In this viewpoint, smart equipment independently are members of LBSN, they share information, make recommendation for people or other devices and so on.

16. Catia Real Ehrlich and Jörg Blankenbach (Germany)
<u>Indoor Positioning</u>
For location based applications, the automatic determination of the user's position plays a key role. In outdoor environments, satellite based systems (Global Navigation Satellite Systems, GNSS) are mainly used for localization purposes. However, if the users are inside of buildings – people nowadays spend most of the day indoors (e.g. at supermarket, workplace or home) – with GNSS it is unfeasible to achieve a continuous and reliable positioning indoors due to propagation errors of satellite signals in buildings. Nevertheless, for the realization of location bases services inside of buildings (indoor location services) the indoor localization of people, machines or objects is crucial. Consequently, in the past years alternative infrastructure-based indoor positioning systems have been developed based on various signal technologies, for example radiofrequency identification (RFID), wireless local area network (WLAN), ultra-wideband (UWB), Bluetooth, infrared (IR), ultrasound or vision-based systems. However, the approaches are tailored for specific applications only. A universal "standard" solution such as GNSS for outdoor does not exist yet for built-up areas. The reasons for this are on the one hand the installation and maintenance of additional permanent infrastructure in buildings. This in turn can result in very considerable expenditure of time, costs and staff for large buildings. On the other hand, the signal can be strongly influenced by propagation errors (multipath effects, diffraction, etc.) and produce incorrect results. An alternative approach, which is independent from external infrastructure, is the inertial navigation utilizing built-in sensors from wearable devices. The use of inertial sensors (in particular triaxial acceleration and gyroscope), such as micro electro mechanical systems (MEMS) – sufficiently small and low-priced – seem to be optimal for pedestrian localization for mass-market indoor location services. According to the pedestrian dead-reckoning (PDR) navigation, it is possible to determine the travelled distance und moving direction. Starting from a known position, the sensor output signals are integrated over time to calculate the user's position successively. The drawback of this solution is the large error accumulations caused by offsets and drifts leading to tracking errors. Therefore, the exclusive use of inertial sensors is not sufficient.
For improving the quality of positioning services, different positioning technologies and techniques can be fused resulting in hybrid indoor positioning systems. Additionally, knowledge or heuristics (building models, user tracks etc.)

might be combined with the sensor data for improving the positioning quality. However, there are many unresolved issues towards an ideal solution so that the automatic indoor localization remains a big challenge. Today, many communication technologies (e.g. WWAN, WLAN, or Bluetooth) and also MEMS sensors (e.g. acceleration, temperature, gyroscope, light, magnetic field, pressure or proximity) are embedded in the very widespread smartphones. Thus, smartphones have become a promising platform for mass-market indoor location services utilizing the embedded technologies and sensors respectively. However, the indoor localization problem remains or is even getting bigger to achieve a sufficient accuracy, coverage and reliability in positioning using the low-cost smartphone sensors.

17. Bonan Wei, Jochen Schiewe (Germany)
Research of Visual Variables for Supporting Decision Making of Pedestrian Orientation in Combining Indoor and Outdoor Environments
Human beings depend both on the inside and outside. A locomotion in terms of the interchange between the inside and outside is an indispensable and inevitable part for each orientation task in an architectural environment, for instance, in clinics, shopping malls, or railway stations. Therefore, it is necessary using navigation and positioning techniques, connecting to the graphical user interface that the pedestrian navigation systems ensure the possibility of the orientation from the inside to outside or vice versa. Currently the GNSS signals in buildings usually cannot be received and many individual application possibilities for indoor navigation cannot be connected to the GNSS. If the navigation and positioning techniques are well advanced in the future, a completely new research area of cartography will be opened, and the map design will be focus on the following two key issues:

How can combining indoor and outdoor environments be site-specific visualized using visual variables?
And how to connect the cartographic representations of the inside with the representations of the outside graphically?

In the future, this research field will represent a major challenge in the context of location based services (LBS) with respect to map design. Several cartographers have already defined the problem of indoor and outdoor connection. They have utilized indoor infrastructures in an attempt to enhance the databases, thereby calculating and optimizing the route. However, the cartographic representations considering the visual perceptual process in the combining of indoor and outdoor environments has not yet been sufficiently taken into account. Because of changing the field of views during the locomotion, a wayfinding decision can only be taken in accordance with the environments perceived by individuals, for example, a passenger getting off a train at a railway station and stepping onto the platform. He must via a connecting underground pedestrian walkway access the concourse and on the railway station forecourt afterward. In this orientation process, the field of views are changed from panoramic view of the platform hall to a highly restricted view in the underground walkway and then to a large field of view in concourse and on the station forecourt. The egocentric map, in which the running direction is

consistent with the viewing direction, visualize and transmit the site-specific field of view and the associated anthropogenic landmarks perceived by individuals only to a certain extent. The scale and the visual variables are constant. However, the fields of views and the associated anthropogenic landmarks change invariably. This means that the environment depicted on the map is incongruent with the environment perceived by individuals. Therefore, in many cases the map users cannot understand the cartographic representations. That may lead to misinterpretation of the visual variables, so the risk of making a false decision in term of wayfinding will usually be increased.
Taking this issue as a starting point, options will be explored in empirical studies as to how geospatial information in the combining of indoor and outdoor environments can be structured utilizing visual variables, for instance, the congruence between differences in the height of geospatial objects and colour distance. The purpose of the research is the development of different parameters for the dynamic cartographical representations, thus would be making the congruence between the environment depicted in the map and the environment perceived by individuals possible whereby the pedestrian orientation is facilitated. Further research issues focused on usability, aspects of which will be evaluated in empirical studies and will be assessed based on indicia of implementations.

18. Liqiu Meng (Germany)
LBS sometimes misleads the public to believe that the modern cartography has been narrowed down to the design of location-based mobile map services for instant usage. Users tend to identify the labels attached to locations with the information about “what”, “where” and “when”, “how much” rather than being prompted to explore the big data between the locations. Although geographic locations are the epicenters of human and natural activities, many things become meaningful only when they are related to other things. The analytical views describing the individual locations should be brought into a holistic big picture. There should be some distinction between LBS in cartography and LBS driven by positioning sensors and locational accessibility. The former needs a closer collaboration with social sciences and ethics.

19. Min Lu (Japan)
Map is a fundamental component of LBS. The current LBS applications mainly apply general-purpose similar web and mobile mapping as the base map for their advantages in many aspects. However, the general map representation designed for multiple purposes is difficult to match the requirements of different scenarios, user context and cultural backgrounds. The following problems about the maps in LBS need to be concerned. 1. How to provide highly contextual and user-centered map representation with diversity for different application scenarios? 2. How to evolve the maps in LBS to take the advantages of new user interfaces, such as VR and AR, meanwhile absorb the fine traditions of Cartography? 3. How to make use of well-designed conventional maps in digital LBS applications for highly regional specified, differentiated and personalized services? 4. How to establish a platform to involve mapmakers, artists, engineers, volunteers and ordinary users to form an ecosystem of map contributors for evolving the maps in LBS?

20. H. Sebnem Duzgun (Turkey)
LBS deals with a large variety of data from different sensors, which have statio-temporal nature. However, not all the collected data can be used for spatio-temporal models like (triggering pattern identification, spatial regression models, co-location analyses, deep learning, etc.). There is a need for fast and efficient data processing algorithms specific to spatio-temporal modelling purposes by using LBS. Moreover, visualization of LBS data in model specific applications requires new visual analytical approaches so that appropriate models can be developed and results can be communicated in a user friendly manner. Therefore, the proposed big problem is how model specific data collection and processing can be performed for LBS and how such tasks can be supported with model specific visual analytical tools.

21. David Jonietz (Switzerland)
Location-based user profiling for personalization of LBS
Personalization is a key issue for Location-Based Services (LBS), with users increasingly expecting their devices and services to be tailored and adjusted to their specific needs and preferences (Aoidh et al. 2009). A prerequisite for such adaptation, however, is the generation of user profiles to store all relevant user-information, including preferences, rules or restrictions (ETSI 2005). This information, however, needs to be collected first, either by explicitly requesting it directly from the users, or implicitly by observing their behavior (Aoidh et al. 2009). In the context of LBS, naturally, the most prominent piece of information available about a user is his or her current location as well as the movement history. In today's systems, however, this knowledge is often merely used for providing personalized location-based information, e.g. local weather forecasts, and not for enriching the user profile itself with regards to other aspects, such as personal preferences, needs or restrictions. In fact, though, our spatio-temporal movement and activity patterns are not random, but the result of our individual planning and decision processes which, in turn, are determined by our personal needs and preferences. For instance, thus, one can imagine to be able to identify a person as a wheelchair driver just from examining his or her movement trajectories. Thus, it can be expected that observing the spatial behavior of users of LBS, e.g. via tracking their movements, and analyzing the recorded patterns in a way which incorporates their situational context and geographical setting would open up new possibilities for receiving richer, more detailed user profiles, which can then be used for enhanced personalization of LBS. Research is needed especially with regards to the development of spatial analysis methods, context models and learning systems.
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22. Dominik Bucher (Switzerland)
We use location based search (as part of Location-Based Services) to fulfill a diverse range of needs: From finding restaurants in our vicinity, over cinemas which still have free seats for our favorite movies to carpooling partners that

have the same schedule as ours. Furthermore, with more and more "intelligent devices" connected within a Web of Things, it gets important to make them find- and queryable (Where can I find a free parking spot? Which cafeteria is the least crowded right now? How many e-bikes are available at the local bikesharing station?). This finding of highly spatio-temporal and volatile information can be seen as a step further from plain Web search, which, after all, is arguably one of the most useful services within the Web sphere. Currently, many service providers build their own "silo", defining its own access points (e.g., an app, or an API) and data storage. There is a need for research that studies and develops models, methods and standards, which enable the interaction between different information providers, their linkability and the searchabiliy in a unified way. Failing to do so will require users to find and interact with all service providers for a certain domain individually (e.g., parking space providers), introducing an additional temporal and cognitive overhead, and preventing the interaction between different providers and different domains (Which restaurant has both free tables and free parking spots in its vicinity?). The relevance of such research is given by the wide application of location based search, which has even further increased in the last years, due to a wider spread of mobile devices and increased internet access with them. Research results will be directly applicable in new search engines and should make life easier for everyone looking for location based information, in short, anyone performing a "real-world search". In addition, efficiently finding things in the real world has the benefit of minimizing costs, be it time of involved persons, fuel used to transport goods, or high stress levels due to being stuck in traffic.

23. Stefano De Sabbata (UK)
LBS has been largely a technology-driven field, harvesting the possibilities opened up by the availability of new sensors and increasingly powerful devices. I think it is however crucial for LBS to engage with theoretical aspects of information science and geography, in order to develop an integral framework within which application can be developed. Pivotal within such framework will be a more theoretically grounded understanding of "context". The definition of such an important concept shouldn't be simply based on available data and sensors. Moreover, differences between the time and location in which a request of information is sent by the user and the time and location in which the information is received, or the difference between the world as perceived by the user and the representation of the world available to the system, can significantly impact the quality of service offered to the user, and thus need to be conceptualised and studied. I discuss some of these issues in a recent paper written with Prof Mizzaro and Dr Reichenbacher [1] A second important problem relates to the production and representativeness of social media, VGI, and other crowdsourced data. The use of these datasets (from Twitter, to OSM) is commonplace in LBS application, but their coverage and quality is largely unequal, varying significantly based on geography and socio-economic status. VGI quality is an active topic in GIScience [e.g., 2]. Recent work on information geographies I conducted with Prof Graham and Prof Zook takes a broader approach to investigate the issue of data production and representativeness [3]. I think that understanding the impact of such information inequalities on LBS

application should be among the priorities of the field, in order to conduct reliable studies and enable reliable services.

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[3] Graham, M., De Sabbata, S. and Zook, M.A., 2015. Towards a study of information geographies:(im) mutable augmentations and a mapping of the geographies of information. Geo: Geography and environment, 2(1), pp.88-105.

24. Andrei Popleteev (Luxembourg)

Wherever you are -- these three words describe one of the key challenges in LBS research. Current LBS heavily rely on satellite-based positioning systems and are therefore available only outdoors. (Which makes them surprisingly more suitable for people living in tents than for typical office workers.) In contrast, truly ubiquitous LBS will require a global indoor localization system with worldwide coverage. Unfortunately, existing systems are proprietary solutions, sparsely available in few specially instrumented buildings. The lack of a cheap and widely available indoor localization technology limits further development of location-based services. Our approach to this challenge is based on ambient radio signals, such as those broadcasted from FM and TV stations or cellular networks. In contrast to satellite systems, these signals have been specifically designed for indoor reception, are transmitted at high power and are globally available even in less populated areas. Early feasibility studies and in-depth experiments show promising results, so this infrastructure-free indoor localization approach might have a great potential to power future ubiquitous LBS -- wherever you are.

25. Thomas Liebig (Germany)

In the last decades the spatial awareness of services and information systems grew rapidly. Besides the generation of open interfaces and standards for spatio-temporal data, open platforms and libraries for data storage and analysis, also affordable devices for spatio-temporal data monitoring, tracking, sensing and self quantification were created in a close collaboration of industry, research, and the public sector. These developments allow real-time spatio-temporal data analysis to pervade into many existing information systems and combine them with location based services. In this process, spatio-temporal data analysis faces same challenges as big data analysis. The volume, speed, variety and veracity of the data streams are the most urgent challenges for data storage, filtering and analysis and prediction. This motivates the future research challenges for location-based services: * real-time data handling (storage, analysis and prediction) * data fusion from multiple sensor streams (e.g. based on semantics and ontologies) * distributed and high performance computing for spatio-temporal applications * ensuring data integrity and privacy in massive spatio-temporal data streams.

These challenges arise also in other fields of big data analysis. Thus, it is important to address them multidisciplinary among all disciplines of data science in close collaboration with domain experts.

26. Peng Jia (China)

I conduct health geography research, which is a disciplinary area by geo-science and public health. One big problem we are concerning about is how individuals are exposed to their surrounding food environment, which means how individuals actually interact with different types of food outlets/venues (e.g., supermarket, fast-food restaurant, full-service restaurant, etc.) The conclusions from current studies are like "if more supermarkets are located in a zip code, the people there are more likely to eat healthy and have less likelihood to get obese". However, 1) it is not necessary for everyone to always visit the supermarkets in his/her own zip code, and 2) it is not necessary to buy healthy food at the supermarkets just because they provide healthy food. The food purchasing behaviors directly affect what they actually eat. However, such data are severely lacking. Location-based service (LBS) techniques can be used to create this dataset. LBS, at least, can be used to capture which food outlet/venue each individual actually visits, and at a higher level, LBS can also be used to record which food they buy during each visit to a certain store, with some promotion available via partnering with business.

27. Johannes Scholz (Austria)

Location-based Services for Indoor Environments

Due to the recent "move" of Geographical Information Science and Systems from outdoor to indoor environments, there is a high potential for research in LBSs in this area too. Besides the research in indoor positioning systems - which already deliverd a number of commercial solutions - there are a number of fundamental questions that are of interest in an indoor environment: - How to people perceive an indoor environment? Are there differences in cognitive reasoning between indoor and outdoor? - How do concepts like cognitive maps and spatial qualitative reasoning work in indoor environments? - How do humans "translate" (meant as coginitve process) between indoor objects and maps of the indoor environment and vice versa. Answering these research questions could contribute toweards generating better LBSs that help people to better orient themselves and to fully understand the indoor environment they are in. An additional set of research questions arises with respect to indoor navigation and routing. With the help of a semantic description of indoor spaces with ontologies indoor navigation and routing could be enhanced by using affordances. By using affordances, any navigation task could be tailored to the needs, restrictions and preferences of both the indoor environment and the moving object. The moving object could be a human being or any other physical entity (like a production asset). Scholz & Schabus (2014) have presented some preliminary work for the application area of indoor production environments. A closer look into the issues raised in this paper as well as a generalization of these findings could contribute to LBSs in indoor environments.

Scholz, J. and Schabus, S. (2014): An Indoor Navigation Ontology for Production Assets in a Production Environment. In: Stewart, K., Pebesma, E., Navratil, G., Fogliaroni, P., Duckham, M. (Eds.): Geographic Information Science

2014, Lecture Notes in Computer Science, LNCS 8728, pp. 204–220, Springer.

28. Nina Polous (Germany)

Objects or locations on earth can hold infinite different states with different characteristics (semantic information) at different times. Alterations from one state to another are the result of ongoing dynamic processes that are triggered by different kind of events like social, natural or political. Mapping the events causing these infinite states interconnected to processes offers a broad range of possibilities to develop novel location based services tailored to the need of different target group users. For instance, our future navigation systems should not only provide route options that are fastest or shortest; one will be able to choose from a variety of option routes such as routes with minimum crime or maximum number of historical events, routes that are emotionally happier or wealthier, or routes in them a specific event is (not) happening at that time. "From location-based services to connection-based services" is an initiative to develop and allocate services in a dynamic geo-connected system. For this, we propose a generic event-oriented perspective which implicitly represents causal relationships among different components of a Spatio-Temporal Geographic Information System. In this way, the objects in space and time are considered merely as information elements of events, which are connected to other event elements through internal or external processes. In this new perspective, providing services goes beyond the concept of developing services for spatial objects with distinct spatial, temporal and attributive identities. Indeed, instead of focusing only on spatial parameters, we are dealing with an event based connected network composed of different states for its involving objects and processes in which each component has its spatial, temporal and semantic properties. This event-based model can handle real world dynamisms and connectivity of the reality through relationships amongst involving objects with each other, objects with events, events with events and the involving processes.

29. Guenther Retscher (Austria)

A large number of LBS application fields reveal the significance of indoor positioning to our society. Contrary to outdoor environments where GNSS-based navigation is dominating there is no overall solution based on a single technology for indoor navigation. Indoor positioning is very challenging due to many reasons caused by the complexity of the environments, such as low probability for line-of-sight signal availability, blockage of signals and severe multipath, etc. The current suitable positioning methods have unique advantages and disadvantages. A stringent requirement is that high performance has to be achieved using low-cost technologies and sensors. Thus, smart hybrid positioning where different absolute and relative location technologies are integrated is a major research topic. In this context, main challenges are the development and improvement of existing and emerging positioning technologies and their sensor fusion where more than one type of algorithm at the same time has to be employed. Furthermore, many applications also require not only the positioning of an individual but also an integrated cooperative positioning of a whole user group. New approaches have to be developed for addressing these type of applications. Thus, for the geospatial communities the extension of common technologies and new discoveries is a big challenging issue.

30. Konstantinos Papangelis (China)

Through mobile phones and social media we can be physically present at a particular place, but still be digitally connected to a different one. This has caused the boundary between the physical, virtual, offline and online world to become blurred and come together. This is especially true with the rise of the newest generation of smartphones and social media services that allows users to tag the information they share with geo-located content at any time in any place. Among the most popular geo-tagging services are Facebook, Foursquare, Twitter, Google Latitude and Flickr. These services allow us to combine real-time location reporting with traditional social network functionality. A possible use scenario for these type of services would be, "find X store from the my current position that provides Y service and has at least Z number of good reviews and several of my social-media friends have visited it". Based on research we have conducted in the field (Two studies have been conducted and the first series of research papers is underway) we have identified that the main issues around location based social services is an interplay of UX elements (appropriate technology and interactions) combined with appropriate evaluation studies, and privacy issues. It is our opinion that these need to be addressed as a whole and not individually as it is our belief that one significantly affects the other. Please see number list bellow for few thoughts that we compiled during our studies.

1) The choice for a particular technology or interaction method (such as only allowing in-situ access) might exclude potential users or usage of the application.
2) Providing an alternative method to access the user generated content (such as a desktop application or website) can order a more complete experience of the application.
3) Introducing game-like elements to regular interactions can provoke playful and creative use of the application.
4) Laboraty research or controlled experiments can be useful for testing a locative media application during the early stages of development.
5) Field research about the everyday practices of users in the area of locative media services seems to be neglected in existing literature. It is our belief that we need to focus more in this area and understand how people use locative media, what kind of information is shared and what interactions among users stem from the usage of locative media.
6) Evaluation methods have been an ongoing issue during our work. The (rather small) literature has focused in qualitative feedback. This aligns with our findings and as such we believe that suggested evaluation methods for locative (social) media services should include: observations, unstructured interviews, regular feedback meetings, focus groups and user diaries. However, these may not be appropriate when conducting long term studies. As such it is our believe that interim feedback sessions, diaries and interviews in which the the user created content can be discussed during feedback sessions can provide meaningful results.
7) Locational privacy is one of the biggest issues that designers of location aware applications have to deal with. During our work with locative social media we found that the users should be well informed about the implications of disclosing

locational information. Furthermore, users should be able to control several privacy aspects, such as the accuracy of their published physical location.

31. Jukka Krisp (Germany)

Location Based services are a dynamic field and I see the concept as an umbrella topic. Recent more specific issues that require research are "*cartography* and LBS" (meaning e.g. "better" maps as a service), "*location based games*" (e.g. PokemonGo, what is the hype about it?), and "*privacy issues* & data privacy issues (on a global scale)". These privacy issues seem to be of increasing concern. Related to the privacy issue is the *personalization of LBS,* which is still a very pressing issue. That includes for example personalized routing (e.g. driver beginners routing, as described by Krisp & Keler, 2015) and personalized maps (e.g considering cultural background).
Additionally there had been thoughts about the development of LBS previously. Krisp and Meng (2013) state that, "LBS can be unfolded into the following mainstreams: Acquisition of a meaningful digital world. [...]. Openness of location-based data and services. [...]. Participatory location-based services and analysis. [...]. A pressing research issue is the concept of an i*ncremental LBS*. A near-real-time LBS should grow and shrink with the *data streams* and show always the current state of the objects and their relations."
Gartner (2013) points out that "especially the rapidly increasing use of geospatial information during this time leads to a growing recognition amongst both governments and the private sector that an understanding of location and place is a vital component of effective decision making." Miller (2013) states, "Location-based data and information will be widely available at higher volumes, fidelities, and velocities. One solution to collective action problem is cooperative behavior […] LBS can mitigate the daunting collective action failures associated with human mobility and related activities in our increasingly crowded and connected world. There are also deeper reasons to believe that LBS can facilitate cooperative behavior. Technological advances and the convergence of LBS and social media can provide capabilities to facilitate more cooperation and self-organization over time and space, avoiding or mitigating the bad collective outcomes from mobility. […] However, there are challenges to create tools that go beyond sharing to support more complex types of cooperative behavior such as collective actions."

Gartner, G. (2013). Location Matters: LBS 2030. Progress in Location-Based Services. J. M. Krisp. Berlin, Springer: 15-29.

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Krisp, J. M. and A. Keler (2015). "Car navigation – computing routes that avoid complicated crossings." International Journal of Geographical Information Science 29(11): 1988-2000.

Miller, H. J. (2013). Location-Based Services in 2030: From Sharing to Collective Action. Progress in Location-Based Services. J. M. Krisp. Berlin, Springer: 29-35.
The LBS2013 book delineates a issues concerning LBS in 2030.