Topics for MSc Theses, GIS Unit

March 2017

General Overview: Research in the GIS Unit

Our group develops and utilizes methods that seek structure in spatio-temporal data, thus turning raw data into geographic information, ultimately aiming at generating knowledge that leads to a better understanding of geographic patterns and processes. Our research focuses on the following application areas:

- Computational Movement Analysis and Simulation
- Language and Space
- Location Based Services (LBS) & Computational Cartography

Our methodological toolset draws from an interdisciplinary range of fields, including spatial analysis, spatial statistics, algorithms development, and computational techniques such as data mining and agent-based modeling.

Choosing a Topic

We recommend that you first take a look at the **list of ongoing and past MSc projects**, with **downloads** of MSc theses: http://www.geo.uzh.ch/en/units/gis/research/MSc-Theses0.html.

Think about what interests you most, and what you are good at. Do you want to program, are you good at it, or rather not? Do you like to work empirically, running experiments and analysing the results, or would you rather develop something new (in which case you would probably have to program)? Is real-world applicability important to you, or are you ready for blue skies research? Do you have your own topic, or a topic that you wanted to pursue with a third party (e.g. WSL, ETH)?

Finally, come talk to us. In the topic descriptions below, we have listed the contact persons in our group. Additionally, Robert Weibel can give an overview of the project topics in the GIS Unit.

Don’t forget that the MSc project is primarily a scientific project. Even if you might be more interested in applied work, the outcome must be more than what would typically be achieved in GIS projects undertaken by an engineering firm. Hence, what are the research questions you want to investigate? We are there to help you formulate suitable research questions and bring your research to fruition.

Computational Movement Analysis and Simulation

Trade-offs between precision and aggregation in computational analysis of human movement

Short description: Human movement is analysed with a wide range of differing methodologies but usually based on GPS and/or Accelerometer data. Almost always this is done way below the sampling rates that today's sensors could easily provide (such as 50Hz). This is mostly to save disk space and/or bandwidth. For some applications this aggregation is clearly sufficient. Other applications that have characteristic movements in the sub-second range would potentially benefit from the higher resolution. One such example would be transport mode detection, where long time series are important and therefore a high compression is desirable, but it seems plausible that small but characteristic movement patterns are present and it is unclear whether they can be captured fully by generic summary statistics.

The aim of this research would be to set up a system for collecting and labelling data of high granularity, conducting a data collection and labelling campaign and exploring the trade-offs between data compression and quality of the outcomes in e.g. transport mode detection. Assuming the trade-off is non-trivial (i.e. the added granularity indeed leads to an improvement of the classification), implications for future data collection efforts (classification at collection time, additional features to be collected…) should be thought about and ideally demonstrated.

Methods, requirements: This project requires a sound understanding of machine learning techniques (and at least one language that lets you use them, such as R, Matlab or Python) as well as the motivation to conduct a collection campaign.

Language: Thesis can be written in German or English.

Supervisor(s): Robert Weibel, Oliver Burkhard

Initial readings:
Laube, P., Purves, R. (2011): How fast is a cow? Cross-Scale Analysis of Movement Data. *Transactions in GIS*. 15(3): 401-418.
Prelipcean, A., Gidófalvi, G., Susilo, Y. (2016): Transportation mode detection – an in-depth review of applicability and reliabilty. *Transport Reviews*. http://dx.doi.org/10.1080/01441647.2016.1246489
Hemminki, S., Nurmi, P., Tarkoma S. (2013): Accelerometer-Based Transportation Mode Detection on Smartphones. Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems.

Cross-scale analysis and classification of movement

Short description: This topic is partly related to the previous topic ("Trade-offs …"). Movement tracking data is being generated at increasingly finer time intervals. Depending on the tracking technology used and the conditions of deployment, sampling rates in the sub-second range are not uncommon. For instance, video tracking typically works at 30 frames / second, that is, 30 Hz. Similarly, if a GPS tracker can be recharged daily and the data downloaded at frequent intervals, it is easy to set the sampling rate to 1 Hz or higher. That is, we find ourselves in a situation where the movement patterns that we are trying to detect are massively oversampled. As movement patterns (and the behaviors they represent) most often take place at different temporal scales, oversampling now offers the possibility to adjust the analysis scale to the adequate temporal scale, either by

resampling to coarser resolutions or by using inherently multi-scale methods (e.g. wavelets).

In a recently completed PhD thesis (Soleymani 2016, Soleymani et al. 2017), several multi-scale methods for movement classification and for movement segmentation have been demonstrated to outperform existing single-scale methods. An MSc project could take two orientations. It could either take the new multi-scale methods and their implementations and apply these to different movement classification problems, further validating and potentially improving these techniques. Or it could develop these methods further. For instance, the segmentation method (Soleymani et al. 2017) has potential for further development; multi-scale classification could be linked to geographical context data; or further sensors (e.g. accelerometer) could be included.

Methods, requirements: This project requires a sound understanding of machine learning techniques (particularly if the second orientation is chosen), and at least one language that lets you use them, such as R, Matlab or Python.

Language: Thesis can be written in German or English.

Supervisor(s): Robert Weibel, Oliver Burkhard

Initial readings:
Soleymani, A. (2016): Cross-scale analysis in classification and segmentation of movement. PhD Thesis, Department of Geography, University of Zurich ➔ http://www.geo.uzh.ch/dam/jcr:6c19f44d-1c92-4a02-8345-0ebce51f4f6e/SoleymaniAli_PhDThesis_Final.pdf
Soleymani, A., Pennekamp, F., Dodge, S. & Weibel, R. (2017): Characterizing change points and continuous transitions in movement behaviors using wavelet decomposition. *Methods in Ecology and Evolution*. DOI: 10.1111/2041-210X.12755.

Mobility, Activity and Social Interaction Study of healthy older adults (MOASIS)

Short description: MOASIS collects individualized everyday-life health data in older adults. The project started in August 2015 as a collaboration between researchers from GIS and the Gerontopsychology Group at the Department of Psychology UZH. It ultimately aims to develop computational models to measure, analyse, and improve health behaviors and health outcomes in the everyday life of aging individuals. The study design of MOASIS includes baseline tests, self-reports, and an evening questionnaire, complemented by the ambulatory assessment of the physical (accelerometer), spatial (GPS) and social activity (audio) with the custom-built sensor uTrail.

Within the framework of MOASIS, potential research topics for MSc projects could be:

- Mapping places of social interaction. Approximately 4 times an hour, 30 second sound snippets of the participants' environment are captured. The audio data contains a lot of meaningful information and analysis of spoken content gives psychologists interesting insights into people's everyday activities. These analyses, however, are all based on manual transcriptions. The idea of this MSc topic would be to find ways to automatically derive information of these audio files (e.g., based on noise levels) that give indication on potential social interaction. In a second step the audio data can be linked to the simultaneously assessed GPS data and places of different types of social interaction could be derived thereof.
- Transportation mode / physical activity level / type detection based on uTrail data (GPS/ACC): In MOASIS, we have no ground truth data regarding modes of transport / types / intensity of physical activity. However, being able to reliably detect the participants' activities based on GPS and ACC data is of major interest. In the framework of a MSc project, data consisting of

a labeled set of different activities tracked with the uTrail could be gathered in a data collection campaign administered by the MSc student. Based on the GPS/ACC data assessed, different methods of activity detection could be applied and validated based on the ground truth labels. Note that this topic is related to the above topic "Trade-offs between precision and aggregation …", but takes a somewhat more pragmatic approach and is focused on the particular needs of the MOASIS project.

- In the health sciences, accelerometers have been used extensively to measure the level of physical activity (PA). In GIScience, on the other hand, accelerometry data has long gone largely unnoticed; unlike GPS data, it lacks the 'geographical' scale. However, in order to detect movement behaviors at the micro level, such as fine-grained PA types (e.g. different modes of locomotion, or activities of daily living), accelerometer data is indispensable. It also offers new dimensions for geographers, for instance by detecting PA types (possibly involving also GPS) and by relating these to geographical context (i.e. which PA types takes place in which environments? in which places? under which conditions?).
- More topics can be designed in coordination with the ongoing PhD projects of Hoda Allahbakhshi and Michelle Fillekes. Since MOASIS is a long-term project, lasting at least until the end of 2019, more topics and research problems are expected to evolve continuously

Methods, requirements: Depending on the focus, a combination of spatial statistics and empirical analysis in R or Matlab. Potentially machine learning methods for classification of either audio or movement and accelerometer data are included. A genuine interest in working in an interdisciplinary setting is a prerequisite. You are not afraid of statistics and getting your hands "dirty" with some programming. Some basic reading in the field of movement and potentially psychology will be necessary.

Language: A good command of English is a prerequisite.

Supervisor(s): Robert Weibel, Hoda Allahbakhshi, and/or Michelle Fillekes (depending on the topic)

Assessment of older patients' real-life mobility by the general practitioner: Making use of modern technology

Short description: So far, the use of GPS-derived movement parameters to quantify physical performance has mainly been limited to team sports. In the health sciences, most applications have been confined to estimating activity spaces of individuals from GPS fixes, often linking these to active transport and body weight. There are only very few reports on applications of GPS-derived movement parameters in patient populations. So far, GPS-derived movement parameters have not been tested for validity and for how results compare to traditional measures of mobility function used in the health sciences.

While deriving speed and other movement parameters from consumer-level GPS (e.g. in smartphones or mid-range trackers) – due to its accuracy in the meter range – is feasible only over longer distances covered and at higher speeds, locomotion speed can be accurately extracted from accelerometer readings already over shorter distances. Since 3-axial accelerometers, like GPS, today are a standard component of contemporary smartphones, there is a potential for ACC measurements to be used to replace or complement traditional walking tests over short distances (4, 10, 20 m) used in the health sciences. Since accelerometers do not rely on an external referencing system – in contrast to GPS devices which require visibility of GPS satellites – they can be used both indoors and outdoors. On the other hand, GPS is the optimal method to determine locations over longer periods of time, and therefore the optimal method to assess life-space mobility.

Methods, requirements: This project would first implement a method to derive speed from ACC measurements and then experimentally assess the validity and reliability of the results compared to traditional walking tests. Furthermore, it would link these ACC-derived speeds to GPS measurements in order to develop a smartphone-based mobility assessment methodology that has the potential to replace existing traditional approaches, thus finding a more wide-spread deployment among general practitioners.

Language: Thesis should be written in English.

Supervisor(s): Robert Weibel, Timo Hinrichs (Department of Sport, Exercise and Health, University of Basel)

Initial readings:

Bertschi M et al. (2015). Accurate walking and running speed estimation using wrist inertial data. *3rd Annual IEEE Intl. Conference on Engineering in Medicine and Biology Society (EMBC)*, 8083-6.

Wilson AM et al. (2013). Locomotion dynamics of hunting in wild cheetahs. *Nature* **498**(7453): 185-9.

Do Taxi Drivers Take the Fastest Routes? – A Large-Scale Analysis Using GPS-based Floating Car Data in Vienna

Short description: Understanding the nature of taxi drivers' route choice behavior is essential for traffic modeling as well as the development of intelligent transportation systems. On the other hand, studying how taxi drivers make route decisions will also provide important insights to improve existing car navigation systems, which so far mostly provide shortest or fastest routes.

This project aims to analyze how taxi drivers make route choice decisions when they have passengers onboard, using a large-scale FCD (floating car data) dataset in Vienna (Austria). Particularly, the following research questions will be addressed: Do taxi drivers with passengers onboard take the fastest routes? How do the actually chosen routes differ from their corresponding fastest routes? What are the route characteristics preferred by taxi drivers with passengers onboard?

Methods, requirements: This project will focus on computational movement analysis, especially on big data analytics. Programming skills are required, at least in a scripting language.

Language: Thesis should be written in English.

Supervisor(s): Haosheng Huang, Robert Weibel

Modelling Urban Semantics and Mobility from Heterogeneous Crowdsensed Data

Short description: Thanks to the massive crowdsensed data collected in urban spaces, we can now understand human mobility patterns, urban dynamics, and spatial interactions from a new perspective. Existing research on this aspect has mainly focused on using a single type of data, particularly either on GPS data or social media data, but not both.

This research aims to integrate heterogeneous data sources to provide a more comprehensive picture of how people behave in the urban environment, particularly on urban semantics (e.g. how is the city used by its inhabitants, and does this relate to urban functional zones?) and urban mobility

(how do people move around the city?). The following types of crowdsensed data will be used and integrated: call detail record (CDR) data (i.e. mobile phone data), passenger flow data of public transportation (via smart IC cards), taxi GPS data (floating car data, FCD) and bus GPS data. A tentative study area will be the city of Shenzhen (China), which is one of the five largest cities in China, and is located immediately north to the Hong Kong SAR.

Methods, requirements: This project will focus on spatio-temporal data analysis and computational movement analysis, especially on big data analytics. Programming skills are required, at least in a scripting language.

Language: Thesis should be written in English.

Supervisor(s): Haosheng Huang, Robert Weibel

Behavioral classification of animal movement data

Short description: Tracking data recording the trajectories of animal movement are becoming increasingly available nowadays, together with data collected from other sensors (accelerometer, etc). In different domains of movement ecology, the interest is on the extraction of behaviors from such trajectories and possibly linking them to the environmental factors or to the patterns extracted from other sensors. Although the data might refer to different species, the aims of behavioral classification remain largely the same: developing methods that are capable of detecting relevant behaviors in trajectories of animal movement. This can be accomplished through segmentation of trajectories into different sections, analysis of movement parameters (speed, acceleration, turning angle, etc.), and the use of machine learning algorithms for the classification.

Potential projects: We are currently collaborating with several groups of animal ecologists, who have collected data and who are interested in getting help in spatio-temporal data analysis. Examples of past and ongoing MSc projects can be found at http://www.geo.uzh.ch/en/units/gis/research/MSc-Theses0.html. The precise topic of a new MSc project will be defined in collaboration with the external animal ecology group.

Methods, requirements: Computational movement analysis; machine learning (e.g. using RapidMiner, R, Matlab); statistical analysis (using R); programming in R and/or Matlab (or Python or Java)

Language: A good command of English is a prerequisite, as you will be collaborating with international groups.

Supervisor(s): Robert Weibel, and the corresponding (external) animal ecology expert

Additional remarks: A visit to the field site(s) of the species under study is an option.

Language and Space

"Language and Space" broadly describes the interdisciplinary field at the intersection between the spatial sciences and linguistics. MSc projects in "Language and Space" can either have a primary focus on the spatial sciences, with language being used as input information or, the focus lies on research questions deriving from linguistics and the goal of the MSc project is to fruitfully apply methods from the spatial sciences to linguistic data. The two types of projects are truly interdisciplinary in the sense that the master student will be supervised by researchers from different disciplines. This is ensured by the fact that our group participates in the University Research Priority Program "Language and Space" of UZH and currently also pursues two Swiss National Science Foundation projects jointly with research groups in linguistics. In the following, both types of projects will briefly be introduced and exemplified. Precise project definitions would be developed in discussion with the supervisors named below.

Spatial analysis and linguistic hypotheses

Linguistics is in the favorable situation that rich information on dialects and languages that has been collected in laborious field-work over the last century, has only recently been summarized and made available in large data bases. This information offers the opportunity to quantitatively test the wealth of linguistic hypotheses on how language evolved over space and time. In the following some hypotheses that might be tested in an MSc thesis are described:

- *Accessibility and linguistic complexity*: Remoteness, rough terrain or deep vegetation, in short: difficult accessibility, have often been argued to be key drivers of linguistic complexity. Languages in regions difficult to reach are said to have retained a richer morphology compared to languages in easily accessible regions. Potential case study regions for testing this hypothesis are South East Asia (incl. the Himalayas), South America or Italy (dialects).
- *Geography, a linguistic border*: The change from one dialect to another is often smooth and continuous. Also, adjacent languages tend to share many grammatical or lexical characteristics. At times, however, we observe sudden abrupt changes, be it in dialects or adjacent languages. Such abrupt language changes are often associated with geographical (e.g. mountain ranges, large rivers), administrative (states or cantons) or cultural (e.g. religion) borders. There is a wealth of linguistic data available that allows to test this hypothesis in different regions of the world (incl. Switzerland) and at different spatial scales.
- *Language Change and Mobility*: For a long time, language has been projected to space without further consideration of speakers. Newer theories, however, suggest that incorporating the speaker and his/her background might offer new insights into so far poorly understood patterns in the linguistic distribution. It is for instance assumed that local mobility behavior (such as excessive commuting, migration, etc.) has a strong impact on how — and in which direction — dialects or languages change. We have detailed linguistic information for the whole of German-speaking Europe that covers the last 100 years. Linking this data to local sociodemographic variables might prove to be a fruitful means for discovering new systematics in language change.
- *Sprachbünde*: There is a body of literature and theories on similarities of languages on a global scale (so-called Sprachbünde). However, most empirical work in linguistics exclusively focuses on single language families (hundreds of language families exist, sometimes counting up to 1000 languages). The aim of this strand of MSc projects would be to conduct quantitative studies on a global scale and thus test the hypothesis of larger Sprachbünde, for instance in Eurasia or the Transpacific Belt.
- *Language diffusion and contact in space and time*
  Understanding the diffusion and contact of languages is essential to understanding the diffusion of humanity. Human migration creates the potential for language contact and

facilitates the propagation of linguistic features. When we observe evidence for language diffusion and language contact, we observe evidence for human migration. Human migration is influenced by both the environment (e.g. topography, land cover) as well as cultural factors (e.g. population pressure, the emergence of empires). However, the role of geography for human migration is not always clear. The aim of this MSc topic is to test hypotheses of human migration in space and time using evidence from language diffusion and contact. Which spatial factors have facilitated or constrained human migration? For example, do linguistic features propagate along river networks, such as the Amazon?

This list of topics is not exhaustive and only gives a first overview of potential focus areas. All topics are motivated by a broad linguistic hypothesis, followed by a detailed and extensive spatial analysis. Examples of past MSc projects: http://www.geo.uzh.ch/en/units/gis/research/MSc-Theses0.html.

Methods, requirements: A basic interest in languages. A flair for spatial analysis and spatial statistics. Little to moderate programming skills. Experience in working with large data is helpful.

Supervisors: Curdin Derungs, Peter Ranacher or Robert Weibel, plus a co-supervisor from Dialectology or Linguistic Typology.

Language as a source of information

Language is the most commonly used tool for communication available to humans. Therefore, information gained from language use might represent how we make sense of the physical and social world. The usefulness of such information in numerous applications has long been recognized and is often associated with the label “data sciences”.
In the spatial sciences we are most interested in how the world — read space — is perceived and conceptualized in language and how such information can be automatically retrieved. MSc projects might focus on one of the following issues:

- How does the description and perception of landscapes change over time? Can such change be automatically studied, for instance from historical books? Books (nowadays in digital format) can have considerably long timelines and thus allow to look far beyond the temporal coverage of state of the art sensors in geography. The aim of this strand of MSc projects is to use historical, digitized text as a means for automatic spatio-temporal analysis of social (e.g. historical jurisdiction) or physical (e.g. historical alpine guide books) processes.
- What is the geographic meaning of word frequencies? Word frequencies are an established measure in the data sciences for gaining an insight into the meaning of text. However, studies on the relation between word frequencies and for instance characteristics of landscapes that are described in text have not gained much attention.
- Can the meaning of spatial relations, such as ‘near’, ‘north’ or ‘besides’, be investigated from large language data, such as web pages, digitized books or social media? Spatial relations are particularly prone to vary due to individual interpretation (What is ‘near’ and in what context?). However, understanding spatial relations is crucial for automatically retrieving spatial information from text. Additionally, text offers an under-investigated but very rich source of information on how people use spatial relations in different situations.
- How do people describe familiar places, such as public spaces in a city, and how do these descriptions reflect the characteristics and aspects of space perceived as being most crucial?

All of these examples are quite general and need further specification. If additional information is desired please don’t hesitate to contact the supervisors listed below.

Methods, requirements: Skills in programming. First experience in natural language processing is helpful but not a requirement.

Supervisors: Curdin Derungs, Ross Purves or Robert Weibel, plus a co-supervisor from Computational or Corpus Linguistics.

Location-based Services (LBS) & Computational Cartography

Indoor Route Planning

Short description: In daily life, people often encounter navigation problems when arriving at a new place, e.g. “What’s the way from the train station to the city hall?”. Outdoor navigation has been a research focus since the advent of the first location-based services (LBS). However, after arriving at a destination by using outdoor navigation services, people need to enter a building and start indoor navigation. Research has found that compared to outdoors, people tend to lose orientation a lot easier within buildings, especially complex ones, such as airport, hospitals, and university buildings. Indoor navigation systems are specifically designed to assist people’s wayfinding tasks in such indoor environments. However, current indoor navigation systems only provide users with shortest or fastest routes. Yet, humans rarely move around using only these criteria.

This research will explore methods to provide routes with other characteristics (e.g., simplicity, fewest-turns and floor-first, and main-corridor-first), based on existing indoor data models (e.g., IndoorGML). The Irchel Campus of UZH (or other similar public places) will be used as a test area.

Methods, requirements: Starting from analysis of existing indoor data models, this research will computationally formulate route choice criteria, and develop route-planning algorithms to provide routes other than the shortest route.

Language: Thesis should be written in English.

Supervisor(s): Haosheng Huang, Robert Weibel.

Initial readings:
Golledge, R. G. (1995). Path selection and route preference in human navigation: A progress report. In A. Frank & W. Kuhn (Eds.), *Spatial Information Theory A Theoretical Basis for GIS* (Vol. 988, pp. 207-222). Heidelberg: Springer.

How do People Communicate Indoor Route Instructions?

Short description: Currently, semantics-enriched navigation systems become more and more popular. Instead of providing metric-based route instructions such as "walk straight in 100 meters", semantics-based navigation systems provide users with semantically enriched instructions, such as "walk straight, pass the theatre, and walk to the crossing" or simply "cross the park". This kind of guidance is more natural to users, and can improve users' navigation performance.

This research aims at empirically answering some fundamental questions of indoor semantic wayfinding, such as “What are the direction and motion concepts used by humans to communicate route instructions in indoor environments?” and “What are indoor landmarks?”. Specifically, user studies will be implemented to collect participants’ route instructions in-situ. These collected instructions will then be used to derive fundamental linguistic elements: motion concepts (verb, e.g., walk, cross, turn, pass), direction concepts (prepositions/adverbs, e.g., straight, along, through), and landmark concepts (nouns, e.g., WC, lobby, printer). The instructions will be also analyzed to see how these different kinds of concepts can be meaningfully combined for indoor route guidance.

Methods, requirements: This project will focus on user experiments. Methodology and approaches from a previous research project SemWay (mainly focusing on outdoors; refer to the papers below for more details) will be reused for the indoor environment.

Language: Thesis should be written in English.

Supervisor(s): Haosheng Huang, Sara I. Fabrikant

Initial readings:
Karl Rehrl, Sven Leitinger, Georg Gartner, Felix Ortag (2009): An analysis of direction and motion concepts in verbal descriptions of route choices. In: K. Stewart Hornsby et al. (Eds.): *COSIT 2009*, LNCS 5756, pp. 471-488, Springer-Verlag, Berlin-Heidelberg.
Gartner, G., Huang, H., Millonig, A., Schmidt, M. & Ortag, F. (2011): Human-centred mobile pedestrian navigation system. *Mitteilungen der Österreichischen Geographischen Gesellschaft (Communications of Austrian Geographical Society)*, 153.

Mobile Maps for Supporting Mixed Indoor/Outdoor Navigation

Short description: Mobile navigation systems are designed to facilitate users' wayfinding tasks in unfamiliar environments. Current navigation systems either deal exclusively with indoor or outdoor navigation. An integration of both versions into one single system has hardly been considered. However, daily wayfinding often involves mixed outdoor/indoor environments. Obviously, both types of environments often have different presentation forms. The scale of an indoor map is naturally larger than the scale of an outdoor map, and therefore a seamless switch between an indoor route map and outdoor route map is a challenging task. It is still unclear how this switch could be realized without an abrupt visual switch that potentially leaves the user disoriented. This research will also explore techniques to support a seamless visual transition between outdoor and indoor navigation. The proposed technique will be then evaluated in a user experiment.

Methods, requirements: This project will involve mobile map design as well as user experiments. You should therefore have an interest in empirical cognitive studies as well as the methods of user testing.

Language: Thesis should be written in English.

Supervisor(s): Haosheng Huang, Sara I. Fabrikant

Characterizing the Service Interface of Indoor Positioning Methods

Short description: Location-based services have become more and more popular not only in citywide outdoor environments, but also in shopping malls, museums, and many other indoor environments. Compared to outdoor LBS, which often employ GPS to obtain users' current location, indoor LBS need to rely on other technologies, such as WiFi, Bluetooth and radio-frequency identification (RFID). Currently, different indoor positioning solutions have been proposed, while a universal solution such as GPS is still missing. This effectively hinders the current development of indoor LBS, as users will always need to switch the indoor positioning methods when entering a new indoor environment. If we can "standardize" the service interface of different indoor positioning solutions (such as GPS for outdoor environments, or OGC's WMS, WFS, WCS and WPS, which

standardize the input/output of geospatial data and processing services), then an indoor LBS application would work smoothly across different indoor environments with different positioning solutions.

As a step further towards this 'standardization', the research aims to study what *metadata* are needed to characterize and specify the service interface of different indoor positioning solutions. Existing standards on geospatial metadata will be adapted and extended.

Methods, requirements: This research will involve analysis of diverse indoor LBS applications and indoor positioning methods, as well as adaptation of existing geospatial metadata standards.

Language: Thesis should be written in English.

Supervisor(s): Haosheng Huang

Initial readings:
Geospatial metadata, https://en.wikipedia.org/wiki/Geospatial_metadata

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MSc Projects in Collaboration with Parkbob

Short description: Parkbob (http://www.parkbob.com/) is a fast growing LBS company, focusing on providing context-aware on-street parking services. Based on crowdsensing approaches, Parkbob permanently collects parking activity data from smartphone sensors of its 250,000 monthly active users. Together with other data sources, these sensors are then used to derive parking events and parking regulations/rules of particular spots, and finally provide real-time parking services.

Methods, requirements: Depending on the topic, different methods will be used and different skills required. Mostly, the topics will be related to crowdsensing, mobile sensor data fusion and analysis (e.g., detection of parking events and parking regulations/rules), and context-aware prediction of real-time parking availability.

Language: Thesis should be written in English.

Supervisor(s): Haosheng Huang and Robert Weibel, with support from the corresponding contact persons at Parkbob.

User Testing of Algorithms for Real-time Generalization in Mobile Mapping

Short description: A PhD project has recently been completed in our group by Pia Bereuter, which resulted in a number of novel algorithms for real-time generalization of point data, such as the point data that are frequently used as foreground in map mashups of Google Maps, OSM and other online map services. In order to achieve real-time performance, some simplifying assumptions were made in comparison to traditional cartographic generalization, and alternative approaches, such as space deformation (focus+context methods, Bereuter and Weibel 2017), or content zooming (Bereuter et al. 2014), have been introduced.

The questions is now, how effective are these methods in providing information to the mobile user and supporting his/her information seeking process? How effectively is the user supported in particular tasks such as wayfinding? How accurately can the user estimate distances, directions and quantities? In this project, user experiments will be employed to establish evidence about these or similar questions.

Methods, requirements: This project will focus on user experiments. You should therefore have an interest in empirical cognitive studies as well as the methods of user testing. Preferably, you have taken GEO 878 (Geovis) and GEO 884 (LBS).

Language: Thesis can be written in German or English.

Supervisor(s): Robert Weibel and Sara Fabrikant

Initial readings:
Bereuter, P. & **Weibel, R.** (2013). Real-time generalization of point data in mobile and web mapping using quadtrees. *Cartography and Geographic Information Science*, **40**(4): 271-281.
Bereuter, P., Weibel, R. & Burghardt, D. (2014). Content zooming and information exploration for mobile maps. International Journal of Geomatics and Spatial Analysis / Revue internationale de géomatique. 23(3-4).
Bereuter, P. & Weibel, R. (2017). Variable-scale maps in real-time generalisation using a quadtree data structure and space deforming algorithms. *International Journal of Cartography*, 3(1).

MSc Projects in Collaboration with swisstopo (swisstopoEDU)

Short description: The Swiss national mapping agency swisstopo has a program for collaboration in the framework of Masters projects, called swisstopoEDU. In 2013, two MSc students from the GIS Unit at GIUZ have won a swisstopoEDU award with their respective projects. It would be great to repeat that experience with new projects.

Methods, requirements: Depending on the topic, different methods will be used and different skills required. For projects linked to the GIS Unit, the focus will mainly be on topics of digital cartography (automated generalization and symbolization of TLM data, mobile cartography, geodata in education).

Language: Thesis can be written in German or English.

Supervisor(s): Robert Weibel, with support from the corresponding contact person at swisstopo. Or other staff member from GIS, GIVA or Gecomputation, depending on the topic chosen.

Additional remarks:
Information about the swisstopoEDU program, as well as a description of currently available topics, can be found at http://www.swisstopo.admin.ch/internet/swisstopo/de/home/topics/stedu.html

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