AGILE Workshop on
Adaptation in Spatial Communication

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AGILE workshop on

ADAPTATION IN SPATIAL COMMUNICATION

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Adaptation in Spatial Communication

Workshop organized in conjunction with AGILE 2009.

Human spatial communication is characterized by its specific pragmatic aim. To better communicate, people employ a variety of communication forms to aid their communication goals in assisting the recipient of the message. In this way, people *adapt* their communication in form and content to the situation and communication. Today's spatial assistance systems largely lack this ability. Consequently, such systems are experienced as awkward, cognitively inadequate or patronizing.

This workshop is the first of what may become a series of meetings of researchers active in the field of spatial communication. We aim to bring together leading researchers across disciplines to contribute to the informed design of spatial assistance systems through the exchange of research results and novel ideas. We hope to stimulate a lively discussion tackling open questions in adaptation of spatial communication and identifying principles that will allow for improved human-machine spatial communication, by drawing parallels between human-to-human and human-machine communication.

Six exciting contributions have been accepted at this first instance of the Adaptation workshop: three as fully reviewed papers and three as extended abstracts. The contributions of Tenbrink et al. and Gartner et al discuss adapting the content of spatial communication to the recipients. Tenbrink et al. approach this challenging task from a linguistic perspective in human dialogues, while Gartner et al. explore the consequences of communication adaptation for the design of systems. Kurata reviews the challenges in automatic adaptation to user preferences in the context of tour planning systems and the consequences on their usability. Wunderlich focuses on scenarios where such systems fail, and how users react when failure occurs. Finally, Delafontaine et al. and Bereuter et al. focus on the spatio-temporal aspects of adaptation in spatial communication in the context of sketches for moving object trajectories and identification of relevant references for users’ daily activities through filters, respectively.

No single workshop can address all facets and complexities of adaptation in spatial communication. We hope, however, that this summer a meeting in Hannover will help to stir ideas and point to promising research avenues ultimately leading to better spatial assistance systems.

Martin Tomko and Kai-Florian Richter

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FULL PAPERS

EXTENDED ABSTRACTS

Modelling Moving Objects in Geospatial Sketch Maps

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Abstract. Freehand sketching of spatial scenes is a natural way of everyday human communication, and an important representation used in many geospatial reasoning tasks. However, besides their spatial semantics, people tend to use sketch maps to explain things that happen in time as well. Until now, this temporal aspect has been neglected to a considerable extent. Motion – again a common aspect of human daily life – is one such issue where time enters the picture. This paper focuses on opportunities for representing moving point objects (a specific subcategory of motion) in geospatial sketch maps.

Keywords: sketch maps, moving point objects, geospatial lifelines

1 Introduction

For a long time, sketch maps have appeared to be a powerful tool for recovering information about spatial environments [2], attracting attention from numerous fields such as geography, planning and psychology. Nowadays, new technologies replace traditional pencil-and-paper-based methods, creating new opportunities for data collection, integration, and analysis [3]. Moreover, there is a need for computers to be able to deal with sketch maps as people do.

To date, some researchers have been studying sketch maps in a geospatial context [3-12], and a few systems have been developed [1, 13-15] (Fig. 2 and Fig. 4), allowing for basic reasoning and/or querying. These efforts share a primary focus on spatial information, and hence somehow overlook the capabilities to communicate temporal information by sketching as well. However, people tend to use sketch maps to make inferences which involve information far beyond purely static spatial scenes. Particularly, this applies to spatiotemporal phenomena, i.e. aspects that relate space to time or vice versa[1]. For example, consider the key role of temporal information in a soccer coach's sketch of an opponent attack or an eyewitness's sketch of a car crash.

Note that both examples focus on moving objects which relate to the spatiotemporal concept of motion. Over the past decade, the modelling of moving objects has been a hot topic in fields as GIScience, Artificial Intelligence and Information Systems [16]. Recent technological advancements have enabled the low-cost capture of motion data and thereby triggered the need for well-adapted analysis tools. In order to reflect this

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[1] Conversely, sketching would not make up a terribly good means to deal with abstract phenomena, i.e. aspects that exist only in time, such as thoughts, feelings, and business relations.

tendency, sketch-based information systems should be able to represent and reason about moving objects. In this paper, we aim to contribute to this development by examining the spatial and temporal properties of moving objects as represented in geospatial sketch maps. The restriction to geospatial sketch maps thereby briefly implies the following three assumptions:

- Elements are drawn from a top view perspective.
- Elements are drawn in a geographical space at an approximated spatial scale.
- Moving objects can be represented as moving point objects (MPOs) at the approximated scale of the geospatial sketch map.

The remainder of this paper is structured as follows. In section 2, we explicate and extend the concept of sketch maps and the related ontology of glyphs. In section 3, the concepts of moving point objects and geospatial lifelines are first introduced, and then utilised in order to determine the spatiotemporal characteristics of lifeline glyphs. Finally, section 4 mentions conclusions as well as avenues for future research.

2 Extended Sketch Maps

Sketch maps can be defined from several perspectives, and according to different research focuses. We will base on the alternative given by Forbus et al. [11], where sketch maps are considered to be "compact spatial representations that express the key spatial features of a situation for the task at hand, abstracting away the mass of details that would otherwise obscure the relevant aspects." They consider sketch maps to be composed of *glyphs* (entities) which on their turn consist of *ink* (drawing strokes) and *content* (the conceptual entity that the glyph represents).

Sketch maps are maps in the sense that they depict features in their spatial context. However, just as with cartography, where maps have evolved from paper to digital maps (1) and from static to dynamic representations (2), we believe that sketch maps can be extended in the same way. Although by definition, sketch maps are not precluded from being paper maps, we assume them, according to contemporary standards, to be digital representations managed by an information system. Furthermore, we assume that they are freehand drawn by means of a one-handed[2] input device (e.g. a mouse, a touch pad or a digital pen), with a standard click-and-drag line drawing tool in a two-dimensional space. Though these assumptions are definitely constraining, they offer the same facilities as common sketching with a pencil on a sheet of paper.

Concerning the evolution from static to dynamic representations, we basically agree with Forbus et al.'s definition except for the *spatial* keyword, which we propose to replace with *spatiotemporal*, in the sense that spatiotemporal features are features that exist both in space and time (cf. [1]). Temporality, in the sense of discourse sequentiality "controls an assortment of media, art forms, representations", quoting

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[2] According to HCI research, it is natural to assume that only one (preferred) hand is used to draw sensu stricto, while the other one performs complementary tasks such as leading and referencing [17].

Sternberg [18]. This certainly applies to sketching, which is as a kind of narrative or dialogue between the sketcher and its audience, although an audience is not always required, for instance in design [19]. The assumptions of one-handed input and line drawing mode inevitably impose an absolute chronological order of drawing. Consequently, sketch maps are not to be restricted to spatial knowledge, but should store temporal information as well. Hence follows the extended sketch map ontology, where time has entered the picture in several ways, as shown in Fig. 1.

First and foremost, there is temporal information involved with the ink concept. Like a human observer, but vis-à-vis a conventional sheet of paper, an information system is able to capture when a pen hits a tablet or when a mouse button is pressed or released. Each stroke thus can be associated with a certain interval of drawing time (Fig. 2 and Table 1). By consequence, ink can be considered as composed of spatial and temporal ink. On the other hand, temporal knowledge can be associated with the content part. For instance, this is the case when two or more separate glyphs model the consecutive states of one and the same object. Next to temporal information, content may be characterised by spatial and thematic, i.e. non-spatial and non-temporal, semantics.

While ink inherently constitutes what is sketched on a sketch map, content is usually provided using a secondary modality (e.g. speech) or directly interpreted by the listener in the case of a straight human-to-human communication. Consequently, in order to develop intelligent and natural sketch interpretation systems, systems require the ability to interpret glyphs as much automatically as possible, while avoiding significant error and/or information loss. Therefore, this paper will neglect the option of having additional content input. In addition, the remainder of this paper restricts to geospatial sketch maps, which are considered to be sketch maps that represent features in a geographical space at an approximated spatial scale from a top view perspective.

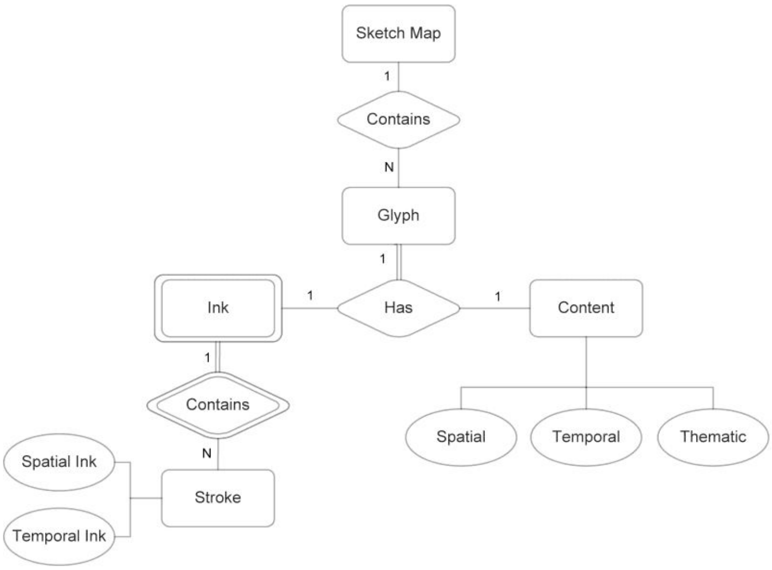

Fig. 1. ER diagram of the extended sketch map ontology.

3 Moving objects in geospatial sketch maps

3.1 Moving point objects and geospatial lifelines

From a geospatial background, a *moving point object* (MPO) is the most basic and commonly used representation of motion [20]. This container concept can be used to represent whatever individual object or subject moving in a geographical space, whether this is a vehicle, an animal, a human being, or an earthquake epicentre. The most basic conceptualisation of an MPO trajectory is the *geospatial lifeline*, or briefly lifeline [20] (Fig. 3). According to Mark [21] a lifeline is a continuous set of positions that an object occupies in space over a certain period of time. As a lifeline models a moving point, it is equivalent to a continuous spatial curve which maps to a continuous time range. However, in many, if not all cases, lifelines are approximated as a discrete set of space-time locations, or fixes [22]. A lifeline describes location as a function of time, and hence, each time instant corresponds to a unique spatial location, while the reverse is not true. In other words, for lifelines, time determines space.

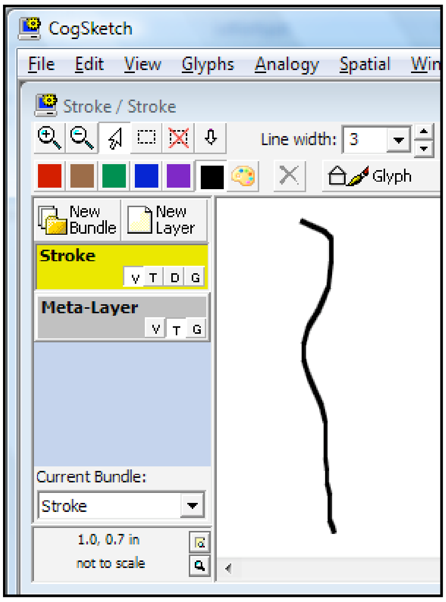

Fig. 2. Single-stroke glyph drawn in CogSketch [1].

Table 1. Export of spatial and temporal ink of the stroke in Fig. 2 as a set of timestamped polyline vertices.

Ink Point X	Ink Point Y	Ink Point Timestamp (s)
1,22	1,10	130,44
1,39	1,03	130,50
1,44	0,98	130,53
1,44	0,81	130,59
1,42	0,64	130,62
1,34	0,47	130,65
1,27	0,34	130,69
1,24	0,23	130,72
1,24	0,13	130,75
1,27	0,02	130,78
1,36	-0,20	130,84
1,40	-0,32	130,87
1,40	-0,57	130,94
1,41	-0,66	130,97
1,41	-0,75	131,00
1,43	-0,83	131,03
1,43	-1,01	131,13
1,45	-1,06	131,15
1,46	-1,10	131,19
1,46	-1,10	131,22

Note that the notion of geospatial lifelines drawn in top view (Fig. 3) differs substantially from approaches with other scientific backgrounds. In physics, for instance, a side view is predominant, and the motion of objects is dictated by external forces, instead of being predefined by a lifeline [14], as illustrated in Fig. 4.

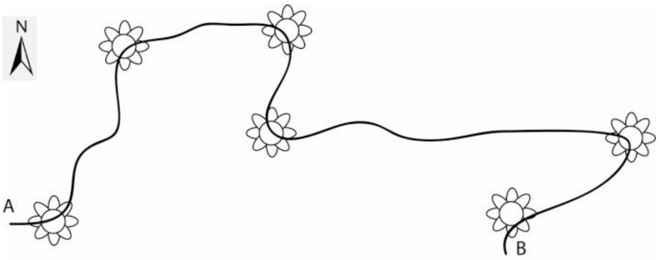

Fig. 3. Map of a geospatial lifeline of a butterfly moving from *A* to *B*, passing flowers on its way (own illustration after [20]).

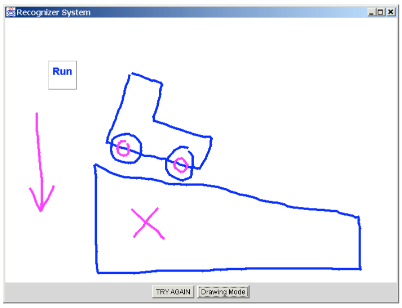

Fig. 4. A Shrewd Sketch Interpretation and Simulation Tool (ASSIST) [14].

3.2 Lifeline glyphs

This section addresses the research question of how lifelines can be represented through glyphs in geospatial sketch maps. To this end, a number of characterising binary distinctions will be considered according to the relationship between these representations and the lifeline of the underlying MPO they model. These distinctions can be regarded as dichotomies for a user to choose from when sketching about an MPO in a geospatial context. Of particular interest are the relationships which hold between the spatial and temporal properties of a lifeline and respectively the spatial and temporal ink that represents it.

Explicit vs. implicit. A major division can be made between implicit and explicit lifeline representations. Explicit representations are glyphs that embody (part of) a lifeline, i.e. true lifeline glyphs. Implicit representations are glyphs or groups of glyphs that do not directly represent a lifeline, but instead imply one, just as road signs imply the route you should follow in the case of a traffic diversion. Unless mentioned otherwise, the term lifeline glyph will refer to an explicit representation in what follows. Examples of explicit representations are illustrated in Fig. 5a-c; an implicit representations is shown in Fig. 5d.

Single-stroke vs. multi-stroke. The most basic and uncomplicated lifeline glyphs consist out of one single drawing stroke (Fig. 5a). Otherwise, lifelines may be composed out of multiple strokes, for some reasons (Fig. 5b-d). The temporal (and perhaps spatial) gaps in between two successive strokes may for instance model important breaks in the motion path of the underlying object, e.g. stops, events, turning or decision points, etc. (Fig. 5b). In addition, a single-stroke approach will be inappropriate whenever the lifeline becomes too complex, e.g. when the sketcher makes reflections about it while drawing. Also, glyphs with disconnected parts must be multi-stroke (Fig. 5c).

Continuous vs. discrete. Although lifelines are by definition continuous spatiotemporal entities (section 3.1), their representations may be either continuous or discrete. This distinction can be made both at the spatial and the temporal level, i.e. with respect to spatial and temporal ink respectively. Continuous spatial ink consists of one or more connected curves, whereas discrete spatial ink comprises at least two disconnected elements. Due to the restrictions of conventional sketching (assumptions of section 2), there is always a temporal gap in between two successive drawing strokes. Hence, for temporal ink, the continuous/discrete division is equivalent to single-stroke/multi-stroke division. In addition, since discrete spatial ink has to be multi-stroked, it cannot co-exist with continuous temporal ink. Thus, the following three configurations are realisable according to this dichotomy:

- Continuous spatial ink, continuous temporal ink, i.e. a simple single-stroke glyph (most basic glyph).
- Continuous spatial ink, discrete temporal ink, i.e. a spatially connected multi-stroke glyph.
- Discrete spatial ink, discrete temporal ink, i.e. a spatially disconnected multi-stroke glyph.

So far, one might ask for the difference between a discrete lifeline glyph (explicit representation) and a (discrete) implicit representation. The spatial ink of a discrete lifeline glyph is a discontinuous representation of a continuous curve, such as a dashed or dotted line (Fig. 5c). By definition, an implicit representation has no lifeline glyph(s) but other glyphs that imply a lifeline instead: the flower and arrow glyphs in Fig. 5d are autonomous entities, whereas a dash segment in Fig. 5c has no significance on its own.

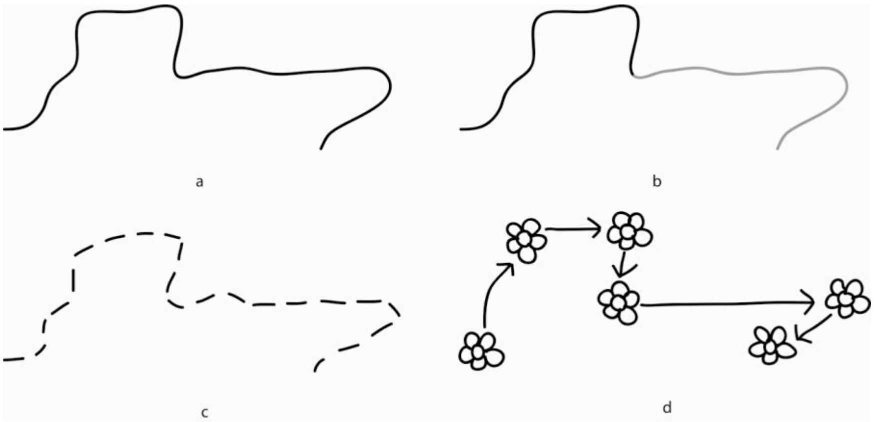

Fig. 5. Sketch map representations of the butterfly lifeline in Fig. 2: explicit single-stroke lifeline glyph (a), explicit multi-stroke lifeline glyph (b), explicit multi-stroke lifeline glyph (c), implicit representation by means of six flower glyphs and four arrow glyphs.

Aligned vs. non-aligned. Without doubt one of the most valuable derivatives of temporal ink is the chronological order of drawing. As is common in human communication, this communicative order often reflects the chronology of the underlying content [18]. We will term this the alignment relation: an element is aligned if its drawing chronology respects the order (*positive alignment*) or reverse order (*negative alignment*) of the chronology in the underlying content. Note that a negative alignment differs from the case of no alignment which applies when neither the right nor the reverse order matches the actual chronology. Three hierarchical levels of alignment can be distinguished within the context of sketch maps: inter-glyph, inter-stroke, and intra-stroke alignment. Note that although Huynh et al. [3, 5] already emphasized the significance of drawing sequences, they merely considered inter-glyph alignment.

The drawing evolution of aligned lifeline glyphs reflects the order of locations taken chronologically by the underlying MPO. For lifeline glyphs, the alignment relations imply an absolute ordering, i.e. a complete internal spatiotemporal chronology for properties such as motion azimuth or events such as performing a specific movement pattern. Thereby, they enable geospatial reasoning, allowing for making inferences like “the object took this bend before heading north”. Note that single-stroke lifeline glyphs are always aligned, be it positively or negatively.

Scaled vs. distorted. Alignment can be considered the key qualitative relationship between temporal ink and the temporal semantics of the underlying content. Next to alignment, numerous quantitative relationships may exist, which enable the extraction of high level information. However, it is highly probable that quantitative relations – despite their existence – will not be intended by the sketcher, and hence are meaningless. Nevertheless, the relationship of linear proportionality (fixed scale) merits our specific attention for two reasons. First, a linear proportionality is one of the simplest[3] relationships between two quantitative variables. Second, as elements in geospatial sketch maps are drawn at an approximated spatial scale, then why would it not be straightforward and natural for people to be able to draw them at an approximated time scale as well? Obviously, if intended so, perfect linear relationships are unrealistic, instead of approximate correlations.

As for the continuous/discrete dichotomy, the scaled/distorted division applies to both the level of spatial and temporal ink. In geospatial sketch maps, spatial ink is believed to have an approximate fixed scale. At the temporal level, alignment is a necessary condition for time-scaled glyphs. Time-scaled lifeline glyphs, allow for inferences about relative speed and travel time in statements such as “the object spent most of its time on this part of its trajectory”, or “the speed of the object in the bends is half of its speed in the straight parts”.

At an intermediate information level, in between aligned and time-scaled representations, temporal ink can be used to segment glyphs according to clearly distinguishable categories such as slow, moderate, and rapid drawing speed. For lifeline glyphs, these categories, when meaningful, reflect the actual speed of the modelled MPO.

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[3] The simplest one would be the equality relation, which does not make sense, except for the trivial case where the MPO of interest is the pointer of the input device at hand.

3.3 Typology of lifeline representations

On the basis of the distinctions made in section 3.2, a typology of lifeline representations in geospatial sketch maps can be deduced, as shown in Fig. 6. A lifeline is modelled through one or more glyphs (dashed relationship in Fig. 6). These glyphs will be either explicit, or implicit representations. Within both subtypes, aligned representations can be distinguished from others (non-aligned). Explicit aligned glyphs can be further subdivided in continuous and discrete types. Finally, continuous cases may be scaled or distorted.

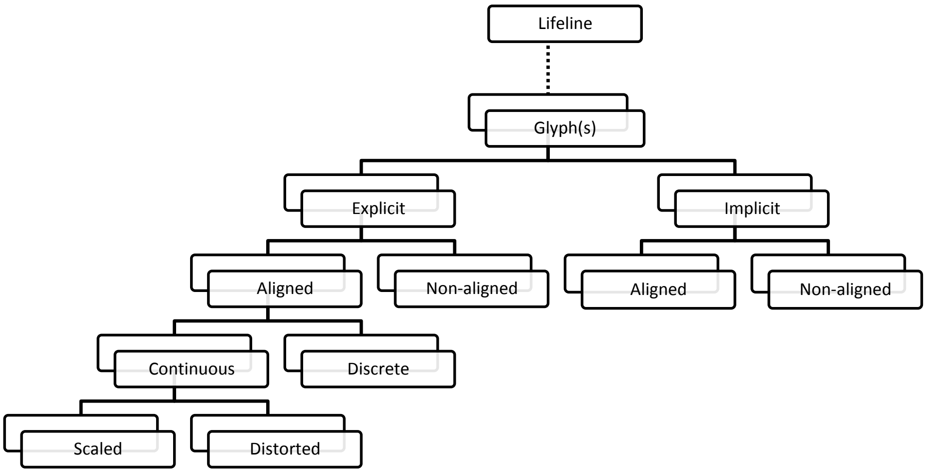

Fig. 6. Typology of lifeline representations in geospatial sketch maps.

3.4 Multiple lifelines

So far, we considered the characterisation of individual lifeline glyphs. However, reasoning about interactions between moving objects, requires relating multiple lifelines to each other. These inter-lifeline relations have to be temporal, as time determines space for lifelines, and not vice versa (section 3.1). In section 3.2 we have shown that alignment properties can be used to describe temporal relations within and among glyphs. However, lifeline representations are not always aligned. More than that, the assumptions of one-handed input and line drawing tool preclude a sketcher from drawing two separate elements simultaneously. Hence, temporal inter-glyph relations cannot be expressed by means of alignment, apart from the exceptional cases restricted to before and after relations. Conversely, interactions between multiple MPOs will be especially relevant for lifelines that happen simultaneously or at least have a temporal overlap. Therefore, these relationships need to be imposed by means of additional content such as found in annotations, meta-layers, or specialised interfaces, which is out of the scope of this paper as stated earlier.

4 Conclusions and outlooks

In this paper, we extended the static concept of sketch maps, and the related ontology of glyphs carrying ink and content, to a dynamic framework. Temporal information – next to spatial information – takes a key role in this renewed model, where it can be found in both ink and content associations. In order to focus on the representation of MPOs in geospatial sketch maps, we relied on the well-known notion of geospatial lifelines. The extended model has then been utilised to elaborate a set of characteristic binary distinctions about lifeline representations. They can be regarded as dichotomies for a sketcher to choose from when sketching about MPOs in a geospatial context. Throughout the paper, there is a focus on the interrelations between the spatial and temporal properties of lifelines and the respective spatial and temporal ink representing it. We believe that such interrelations are important for information systems in order to improve the automatic interpretation of the content of lifeline glyphs by their ink, thereby making extensive use of its temporal ink, next to its spatial component.

Above all, this paper can be considered a basis for further research. Its content has been underpinned by theoretical concepts, literature and common sense arguments. Nonetheless, the authors are well aware of the fact that empirical research is a necessary next step in order to elucidate and assess how people do represent and reason about moving objects through sketches. Therefore, we are planning to set up appropriate test cases and build a tool to acquire and analyse the according sketch map data. This will enable to answer questions such as to what extent do human sketchers respect alignment relations, or do humans have the ability to reproduce time-scaled representations in sketch maps.

Sketching is often seen as a multi-modal, multi-domain and multi-disciplinary issue. Consequently, in further stages, this work can be extended in numerous ways. To begin with, special cases of lifelines have been overlooked. Examples are periodic displacements, e.g. cycles and to-and-fro movements, and lifelines (partially) shared by multiple objects such as for a herd of animals. In addition, several interpretative aspects are still to be assessed, such as the abilities to inter- and extrapolate lifelines, or the integration of multiple lifelines and their underlying interaction patterns. Furthermore, the restriction to MPOs and two-dimensional top view can be abandoned, and replaced with other motion concepts and perspectives from different backgrounds. In time geography for instance, the predominating perspective is that of a three-dimensional (two spatial and one temporal dimensions) space-time cube [23], and, to our knowledge, the ability of people to draw sketch maps in such setting has not been examined yet. In other future work, this work could be extended beyond motion, to other concepts and applications which relate space and time such as change assessment and physical planning. Finally, the applied data acquisition restrictions may be adjusted. We have applied the constraints of conventional pencil-and-paper sketching. Instead, different assumptions could be employed in order to reflect for instance the opportunities offered by the latest or planned technological developments with respect to multi-modal sketching interfaces.

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References

1. Forbus, K., Usher, J.E., Lovett, A., Lockwood, K., Wetzel, J.: CogSketch: Open-domain sketch understanding for cognitive science research and for education. In: Alvarado, C., Cani, M.-P. (eds.): EUROGRAPHICS Workshop on Sketch-Based Interfaces and Modeling (2008)
2. Golledge, R.G., Stimson, R.J.: Spatial Behavior: A Geographic Perspective. The Guilford Press, New York (1997)
3. Huynh, N.T., Doherty, S.T.: Digital Sketch-Map Drawing as an Instrument to Collect Data about Spatial Cognition. Cartographica: The International Journal for Geographic Information and Geovisualization **42** (2007) 285-296
4. Blaser, A.D.: A study of people's sketching habits in GIS. Spatial Cognition and Computation **2** (2000) 393-419
5. Huynh, N.T., Hall, G.B., Doherty, S.T., Smith, W.W.: Interpreting urban space through cognitive map sketching and sequence analysis. Canadian Geographer / Le Géographe canadien **52** (2008) 222-240
6. Schlaisich, I., Egenhofer, M.J.: Multimodal Spatial Querying: What People Sketch and Talk About. In: Stephanidis, C. (ed.): 1st International Conference on Universal Access in Human-Computer Interaction, New Orleans, LA (2001) 732-736
7. Sezgin, T.M., Stahovich, T., Davis, R.: Sketch based interfaces: early processing for sketch understanding. ACM SIGGRAPH 2006 Courses. ACM, Boston, Massachusetts (2006)
8. Egenhofer, M.J.: Multi-modal spatial querying. In: Kraak, M.J.M.M.F.E.M. (ed.): 7th International Symposium on Spatial Data Handling (SDH 96). Taylor & Francis Ltd, Delft, Netherlands (1997) 785-799
9. Egenhofer, M.J.: Query Processing in Spatial-Query-by-Sketch. Journal of Visual Languages & Computing **8** (1997) 403-424
10. Davis, R.: Magic Paper: Sketch-Understanding Research. Computer **40** (2007) 34-41
11. Forbus, K.D., Usher, J.E., Chapman, V.: Qualitative spatial reasoning about sketch maps. 15th Innovative Applications of Artificial Intelligence Conference (IAAI-03). Amer Assoc Artificial Intell, Acapulco, MEXICO (2003) 61-72
12. Okamoto, K., Okunuki, K., Takai, T.: Sketch map analysis using GIS buffer operation. In: Freksa, C., Knauff, M., Krieg-Bruckner, B., Nebel, B., Barkowsky, T. (eds.): Spatial Cognition IV. Reasoning, Action, Interaction. International Conference Spatial Cognition 2004. Revised Selected Papers. Springer-Verlag, Frauenchiemsee, Germany (2004) 227-244
13. Haarslev, V., Wessel, M.: VISCO-querying GIS with spatial sketches. Proceedings of Formalizing Reasoning with Visual and Diagrammatic Representations. AAAI Press, Orlando, FL, USA (1998) 103-104
14. Davis, R.: Sketch Understanding in Design: Overview of Work at the MIT. AAAI Spring Symposium. AAAI (2002)
15. Hammond, T., Davis, R.: LADDER, a sketching language for user interface developers. Comput. Graph.-UK **29** (2005) 518-532
16. Bitterlich, W., Sack, J.R., Sester, M., Weibel, R.: 0851 Abstracts Collection - Representation, Analysis and Visualization of Moving Objects. In: Bitterlich, W., Sack, J.R., Sester, M., Weibel, R. (eds.): Representation, Analysis and Visualization

of Moving Objects, Vol. 08451. Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, Germany, Dagstuhl, Germany (2008)
17. MacKenzie, S.: Motor Behaviour Models for Human-Computer Interaction. In: Carroll, J.M. (ed.): HCI Models, Theories, and Frameworks (2003)
18. Sternberg, M.: Telling in time (I) Chronology and narrative theory. In: Bal, M. (ed.): Narrative Theory. Critical concepts in literary and cultural studies., Vol. 2 (2004) 93-137
19. Cross, N.: Natural intelligence in design. Design Studies **20** (1999) 25-39
20. Laube, P.: Analysing Point Motion - Spatio-Temporal Data Mining of Geospatial Lifelines. Universität Zürich, Vol. Doctoral (Erlangung der naturwissenschaftlichen Doktorwürde - Dr. sc. nat.), Zürich (2005) 135
21. Mark, D.M.: Geospatial lifelines. Integrating Spatial and Temporal Databases, Vol. 98471. Dagstuhl Seminars (1998)
22. Laube, P., Dennis, T., Forer, P., Walker, M.: Movement beyond the snapshot - Dynamic analysis of geospatial lifelines. Computers, Environment and Urban Systems **31** (2007) 481-501
23. Kraak, M.J.: The space-time cube revisited from a geovisualization perspective. Proceedings of the 21st International Cartographic Conference (ICC), Durban, South Africa (2003) 1988-1996

Challenges in User-Adaptive Tour Planning Systems

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Abstract. User-adaptive tour planning systems are tourist information systems that can make tour plans customized for individual users. Several systems have been already proposed, but such usability issues as frustrating preference/personality registration process and lack of sense of participation still remain. In this paper, we review these usability issues and discuss the following challenges for more practical user-adaptive tour planning systems: collaborative tour planning, smart detection of user's preferences, more realistic settings of tour optimization problems, and mobile-oriented service.

Keywords: tour planning, user's preference, selective travelling salesman problem, candidate/critique model, trajectory-based preference detection

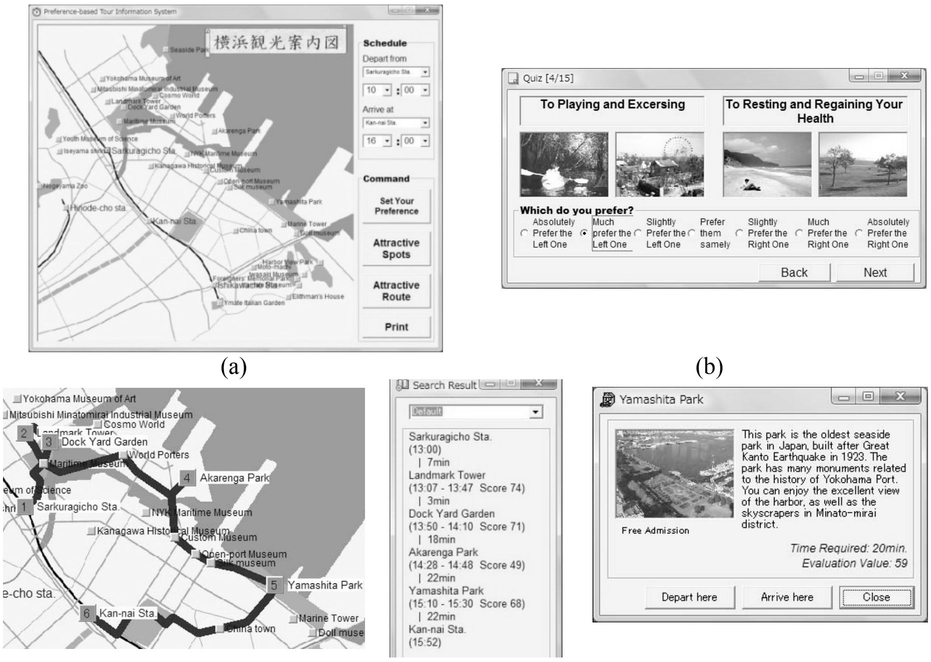
1. Introduction

Tourism is a spatial activity that depends highly on the preferences of individual tourists. Naturally, tourist information systems are desired to provide information adapted to individual users, especially when the users' destination is a tourist city where many types of *points of interest* (*POIs*) exist densely and tourists have to decide which POIs to visit without sufficient prior knowledge. Indeed, a number of user-adaptive tourist information systems have been proposed before. For instance, some systems sort or filter POIs based on the user's preference (e.g., [1-3]). However, even if the user is informed about which POIs will be interesting for him/her, designing an efficient tour plan remains a hard task. Thus, several tourist information systems, including ours [4, 5], were equipped an ability to design tour plans customized for individual users [4-8]. These tour planning systems still have several usability problems, such as frustrating process of preference registration and lack of sense that the user participates in the planning. In this paper, we review these problems and discuss some challenges to achieve more practical user-adaptive tour planning systems.

The remainder of this paper is structured as follows: Section 2 reviews the previous user-adaptive tour planning systems. Section 3 discusses the problems and challenges in user-adaptive tour planning systems. Finally, Section 4 concludes the discussion.

2. Tour Planning Systems

Most tour planning systems have similar three-step structures: preference setting, evaluation of POIs, and route optimization. As an example, screenshots of our system [4, 5] are shown in Figs. 1a-e. In this system, the user specifies his/her interest through a questionnaire (Fig. 1b), from which the system judges the user's preference. Based on this preference, the system calculates the expected value of each POI. Finally, the system computes a tour plan that maximizes the total values of POIs to be visited (Figs. 2c-d). The system can also show the information about POIs (Fig. 2e).



(a)

Quiz [4/15]

To Playing and Excersing

To Resting and Regaining Your Health

Which do you prefer?

○ Absolutely Prefer the Left One ● Much prefer the Left One ○ Slightly Prefer the Left One ○ Prefer them samely ○ Slightly Prefer the Right One ○ Much Prefer the Right One ○ Absolutely Prefer the Right One

(b)

(c)

Search Result

Default

Sarkuragicho Sta.
(13:00)
| 7min
Landmark Tower
(13:07 - 13:47 Score 74)
| 3min
Dock Yard Garden
(13:50 - 14:10 Score 71)
| 18min
Akarenga Park
(14:28 - 14:48 Score 49)
| 22min
Yamashita Park
(15:10 - 15:30 Score 68)
| 22min
Kan-nai Sta.
(15:52)

(d)

Yamashita Park

This park is the oldest seaside park in Japan, built after Great Kanto Earthquake in 1923. The park has many monuments related to the history of Yokohama Port. You can enjoy the excellent view of the harbor, as well as the skyscrapers in Minato-mirai district.

Free Admission

Time Required: 20min.
Evaluation Value: 59

(e)

Fig. 1. Screen shots of our tour planning system [4, 5]: (a) its main screen, (b) a question asking users' preference over two tour purposes, (c-d) a customized tour plan shown on a map and by text, and (e) information about a POI

Setting of the user's preference is a problematic process. Traditional decision-support systems ask the user to specify his/her preference on several criteria manually, for instance by sliders [9]. This approach frustrates the users because they are forced to evaluate their own preference on obscure scales. Thus, our system took an alternative approach based on *AHP* (*Analytical Hierarchical Process*) [10], in which the user is given fifteen questions that ask which tour purpose is preferable (Fig. 1b) and from his/her answers the system calculates the user's weights on ten tour purposes (Fig. 2). We considered that the weights on these ten tour purposes represent the user's tour preference. This comparison-based process is easier than the slider-based approach, but the questionnaire takes a lot of time. To realize more quick setting of user's preference, some systems ask the user to input age, gender, occupation, and so on, assuming that the tourists with demographically similar properties have similar tour interests [1, 8]. This approach, however, also frustrates the users, making them feel that their privacy is offended or that the system has a stereotypical view of their preferences.

Once the user's preference is modeled, the system evaluates all POIs in the target area based on this model. The value of each POI may be evaluated from the user's weights on several criteria and the POI's scores in these criteria [4, 5] or based on the evaluation by other tourists with similar preferences/properties [1, 8]. In our previous system, each POI is rated in ten criteria, which corresponds to the ten tour purposes (Fig. 2). Thus, by weighting the ten criteria with the weights on the ten tour purposes, the score (value) of each POI is calculated.

Finally, the system computes an optimal tour plan. Normally, this problem is a variation of the *Selective Traveling Salesman Problem* (*STSP*) [11] and defined, for example, as follows:

> *Given a complete graph* (V, E)*, the utility (value) of each node* u_i*, the time spent at each node* ${t^{visit}}_i$*, the travel time between two nodes* ${t^{travel}}_{ij}$*, origin* $v_{ori} \in V$*, destination* $v_{goal} \in V$*, and time constraint* T*, find a series of nodes to be visited* $v_{a_1}, \dots, v_{a_k} (v_{a_i} \in V)$ *that maximize the some of utilities under a time constraint* T*.*

$$\begin{aligned} \text{maximize} \quad & \textstyle\sum_{i=1}^{k} u_{a_i} \\ \text{s.t.} \quad & \textstyle\sum_{i=1}^{k} {t^{visit}}_{a_i} + \sum_{i=0}^{k+1} {t^{travel}}_{a_i a_{i+1}} \le T \\ & v_{a_0} = v_{ori},\ v_{a_{k+1}} = v_{goal} \end{aligned} \tag{1}$$

Since this problem is NP-hard, we developed a heuristic algorithm for approximate solutions, in which we gradually increased the time constraint up to *T* while revising the tour plan repeatedly [4]. Alternatively, P-Tour [6] adopted a genetic algorithm for approximate solutions. We, however, believe that strict solutions may be derived in a practical time by dynamic programming, since the scale of the problem is usually small (for instance, a tourist rarely visits more than ten POIs in one day).

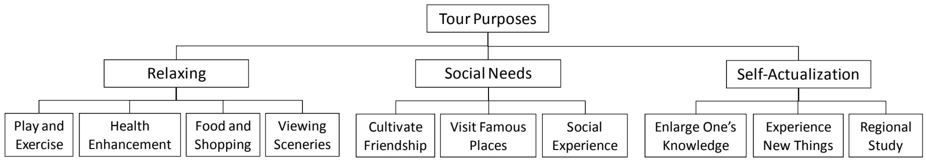


Fig. 2. Hypothesized structure of ten tour purposes used in [4, 5]

3. Problems and Challenges

We asked 25 human subjects to test our prototype system [4]. Almost all users agreed that the customized tour plans matched their preferences, even though they could not tell whether the recommended plans looked the *best* for them. Some users complained about the inability to modify the recommended plans—for instance, removing the POIs that they had visited before. Some users complained about the questionnaire, as it took long time and seemed not directly linked to the planning process.

Actually other tour planning systems have similar problems, as they also impose certain frustrating preference/personality registration processes and do not allow manual modification of recommended plans. Exceptionally, P-Tour [6] avoids the preference/personality registration process, leaving the evaluation of POIs entirely to users. Thus, the user has much freedom to express what he/she does and does not want to visit. As a drawback, the user is forced to estimate the value of POIs that he/she has never been. We, therefore, consider that the desirable approach is a *hybrid* one; that is, the system coordinates the tour planning while the user is allowed to modify the plan and participate in the planning. The system also learns the user's preference from his/her involvement and makes use of this information to revise tour plans. We are going to explain this idea more explicitly.

3.1. Collaborative Design of Tour Plans

How can we encourage the participation of the users, without increasing their obligations? One possible solution is the use of the *candidate/critique model* [12]. Imagine that you are shown several plans: one fits the *tentative* model of your preference, while others follow different interests. Then, you are asked to compare the plans and specify which you prefer. If you choose one of the alternatives, then the system infers what criteria you emphasize, revises the model of your preference, and recomputed tour plans. This process is repeated until you agree with the recommended plan. This approach is preferable for the user, since he/she can learn available choices and clarify his/her needs through the comparison of actual plans. Even though this approach may be time-consuming, the user probably gets high satisfaction in the final plan. Fig. 3 shows the interface design of an envisioned tour planning system that will enable such collaborative tour planning. For simplification, it shows only two plans on a screen, but the user can see various alternative plans with different characteristics by clicking the buttons in the right-bottom.

For more flexible tour planning, it is also desirable that the system allows the user to express which POIs he/she wants to visit or avoid. Even if the user does not want to estimate the value of all POIs, he/she may want to specify his/her request about certain POIs. For instance, a tourist, who usually likes art museums but not historical monuments, may request to visit Palace of Versailles because it is world-famous, while he may also request not to visit Musée d'Orsay because he has been there several times. The tour planning system should be able to accept such case-by-case requests, just like a human tour coordinator can do. The interface design in Fig. 3 also considers the support of such requests. Addition/removal of a POI can be realized by dragging its name tag to the three icons labeled "*add to tour*", "*not attractive*", and "*visited before*". We distinguished "*not attractive*" and "*visited before*" because dragging to the former icon may be used to revise the user's preference model, while dragging to the later icon does not.

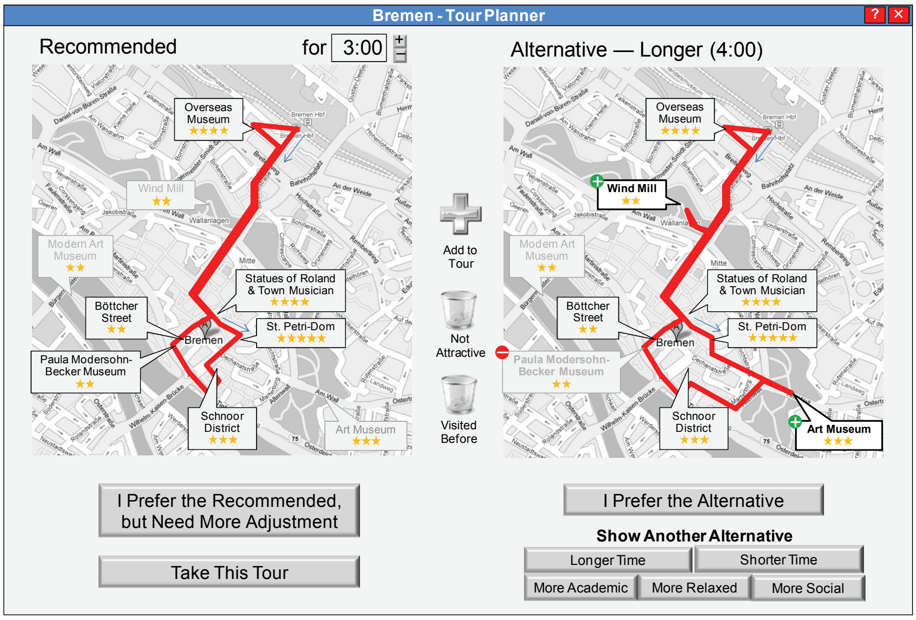


Fig. 3. An image of a new tour planning system that realizes collaborative tour planning

In Fig. 3, the value of each POI is shown by 1- to 5-stars, as the stars are more intuitive than quantitative scores (e.g., Fig. 1e). On the other hand, the total values of the recommended plan and alternative plan are not displayed, because the total values, calculated from an incomplete model of the user's preference, may confuse the user's choice of two plans.

3.2. Smart Detection of Users' Preference

How can we avoid the preference/personality registration process? One potential solution is, as introduced in the previous section, that the system seeks the user's preference from the choice of alternative plans through iterative interactions. The second potential solution, which is effective in mobile use, is to ask the user to evaluate each POI after a visit and to revise the model of the user's preference according to the user's response. Of course, the evaluation of POIs easily becomes an annoying process during an actual tour. Thus, we should carefully design the interaction process, such that the evaluation is easy (e.g., selection from one-star to five-star) and its frequency is minimized.

Another potential solution in mobile scenarios is to learn the user's preference from his/her trajectory. Where the user visits and how much time he/she spends there *may* tell something about his/her preference, especially when it is compared with the data of ordinary people. Schmidt-Belz *et al.* [2], however, questions this trajectory-based approach, saying that the visit to a church may be not because of the tourist's interest in churches, but because of a concert in the church, an exceptional view from its tower, or even a little café in the aisle. Yet, we believe that the trajectory-based preference detection is still useful, especially if we can tell from the micro-level trajectory whether he is actively involved in sightseeing or, say, taking a rest in a POI. Kiefer and Schlieder [13] discusses the method to infer the user's intentions by parsing his/her trajectory. Such *mobile intention recognition* techniques are useful for inferring the user's touring behaviors from his/her trajectories.

3.3. More Realistic Settings of Tour Optimization Problems

Although it is not apparent in our user test, one weak point of our previous system is its too simple setting of the tour optimization problem. To make the problem more realistic, we can think about the following extensions:

1. To assign values not only POIs, but also links
2. To allow the temporal/seasonal fluctuation of POIs' values;
3. To regard the travel time between POIs as a fuzzy value;
4. To adapt the estimated time spent at each POI to each user;
5. To take weather conditions into account; and
6. To give lower scores to 'monotonous' tours.

By Extension 1, the attractiveness of routes between POIs is incorporated into tour planning. This extended problem is a sort of *EPTP* (*Enhanced Profitable Tour Problem*), whose approximate solution algorithm is already proposed in [14]. Of course, how to evaluate the attractiveness of routes remains as a research question.

Extension 2 is critical for practical tour planning. For instance, museums have zero value when they are closed. Some overlooks have more values at sunset, while losing their values when the sunlight comes from the front. Botanical gardens are attractive in summer, but not in winter. In this way, POIs' values vary from time to time and such temporal fluctuation is not ignorable. Matsuda *et al.* [15] already tackled Extensions 2 and 3. They formulated *FORPS* (Fuzzy Optimal Routing Problem for Sightseeing) and proposed a heuristic algorithm for its approximate solutions. Extension 3 is also important for supporting the variation of travel time due to traffic jams or infrequent service of public transportation.

For Extension 4, we have to develop a model for estimating the time spent at a POI from the tourist's preference and the POI's characteristics. For this, we have to analyze the statistical data of tourist behaviors.

Extension 5 is also essential for practical tour planning. For instance, if the weather forecast predicts rain in the afternoon, it is better to plan a tour such that outdoor attractions are visited in the morning while museums are left for the afternoon. Even after the tour has started, the plan should be modified flexibly in case of a sudden rail. These problems can be handled by the techniques used for Extension 2.

As for Extension 6, current systems evaluate POIs individually, but not as a combination. As a result, for instance, if the user likes museums, the systems tend to recommend a plan that visits museums for all day—which may be boring even for this user. Thus, it is desirable that the systems can evaluate the monotony of visited POIs and utilize it for tour planning.

3.4. Mobile-Oriented Service

In the big trend to mobile computing, tour planning systems will be used more often in mobile context. A key question is how to provide the service tailored to mobile devices. For instance, the mobile version of P-Tour [16] monitors the user's location by GPS and warns the user if he/she is out of the route or behind schedule [16]. The capability of such schedule monitoring and real-time tour re-planning is a potential strength of tour planning systems in mobile use. Trajectory-based preference detection (Section 3.1) is another possibility of mobile-oriented tour planning systems. Furthermore, the potential of tour planning systems is more expanded if it is combined with other intelligent mobile technologies, such as smart route navigation (e.g., *route-specific route instructions* [17]) and location-based querying (e.g., *iPointer®* [18]), to form a comprehensive tour support system.

4. Conclusions

Tourist information systems should meet a large variety of user's needs. At the same time, the systems should not provide too much information to the users, as overwhelming amount of information makes their decision more difficult. We already have several user-adaptive tour planning systems, but, they still have room for improvement. We discussed several challenges for the future tour planning systems; they are (i) collaborative tour planning, (ii) smart detection of user's preference, (ii) more realistic setting of tour optimization problems, and (iv) mobile-oriented tour planning service. In addition, the validity of the tourist preference model in the previous tourist information systems (e.g., that in Fig. 2) should be examined carefully for the improvement of the tourist information system.

Smart detection of user's preference/needs/personality is a key technology for all kinds of user-adaptive information systems. Among these systems, mobile information systems can make use of the user's locational information for profiling the users. The idea of trajectory-based preference detection is applicable to other user-adaptive spatial information systems. For instance, bike navigation systems may learn from the trajectory what kind of routes that the user prefers. The information about where and how long the user spend time during shopping may be useful for adapting advertisements to the users. We, therefore, believe that the research on trajectory-based preference detection will expands the capability of spatial assistance systems.

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References

1. Ricci, F., Arslan, B., Mirzadeh, N., Venturini, A.: ITR: A Case-Based Travel Advisory System. In: Craw, S., Preece, A. (eds.): ECCBR 2002, Lecture Notes in Computer Science, vol. 2416, pp. 613-627. Springer, Berlin/Heidelberg, Germany (2002)
2. Schmidt-Belz, B., Nick, A., Poslad, S., Zipf, A.: Personalized and Location-Based Mobile Tourism Services. In: Workshop on Mobile Tourism Support Systems, pp. 18-20 (2002)
3. Ardissono, L., Goy, A., Petrone, G., Segnan, M., Torasso, P.: Intrigue: Personalized Recommendation of Tourist Attractions for Desktop and Handset Devices. Applied Artificial Intelligence: Special Issue on Artificial Intelligence for Cultural Heritage and Digital Libraries 17(8-9), 687-714 (2003)
4. Kurata, Y.: Development of a Preference-Based Tour Planning System. Bachelor's Thesis (in Japanese). Department of Urban Engineering, University of Tokyo, Tokyo, Japan (2000)
5. Kurata, Y., Okunuki, K., Sadahiro, Y.: Development of a Preference-Based Tour Planning System. In: Papers and Proceedings of the Geographic Information Systems Association (in Japanese), vol. 9, pp. 199-202 (2000)
6. Maruyama, A., Shibata, N., Murata, Y., Yasumoto, K., Ito, M.: A Personal Tourism Navigation System to Support Traveling Multiple Destinations with Time Restrictions. In: 18th IEEE International Conference on Advanced Information Networking and Applications, pp. 18-22 (2004)
7. Goy, A., Magro, D.: STAR: A Smart Tourist Agenda Recommender. In: Configuration Workshop at ECAI 2004, pp. 8/1-8/7 (2005)
8. Lee, J., Kang, E., Park, G.: Design and Implementation of a Tour Planning System for Telematics Users. In: Gervasi, O., Gavrilova, M. (eds.): ICCSA 2007, Lecture Notes in Computer Science, vol. 4767, pp. 179-189. Springer, Berlin/Heidelberg, Germany (2007)
9. Hochmair, H., Rinner, C.: Investigating the Need for Eliminatory Constraints in the User Interface of Bicycle Route Planners. In: Cohn, A., Mark, D. (eds.): COSIT'05, Lecture Notes in Computer Science vol. 3693, pp. 49-66. Springer, Berlin/Heidelberg, Germany (2005)
10. Saaty, T.: The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill, New York, USA (1980)
11. Laporte, G.: Tour Location Problems. European Journal for Operations Research 106, 2-3 (1996)
12. Linden, G., Hanks, S., Lesh, N.: Interactive Assessment of User Preference Models: The Automated Travel Assistant. In: Jameson, A., Paris, C., Tasso, C. (eds.): Sixth International Conference on User Modeling, pp. 67-78. Springer (1997)
13. Kiefer, P., Schlieder, C.: Exploring Context-Sensitivity in Spatial Intention Recognition. In: Gottfried, B. (ed.): Intl. Workshop on Behavioral Monitoring and Interpretation, TZI-Bericht, vol. 42, pp. 102-116. Technogie-Zentrum Informatik, Universität Bremen (2007)
14. Joset, M., Stille, W.: A User-Aware Tour Proposal Framework Using a Hybrid Optimization Approach. In: Volsard, A., Chen, S. (eds.): 10th ACM International Symposium on Advances in Geographic Information Systems, pp. 81-87. ACM Press (2002)
15. Matsuda, Y., Nakamura, M., Kang, D., Miyagi, H.: An Optimal Routing Problem for Sightseeing with Fuzzy Time-Varying Weights. In: IEEE International Conference on Systems, Man and Cybernetics, vol. 4, pp. 3665-3669 (2004)
16. Shiraishi, T., Nagata, M., Shibata, N., Murata, Y., Yasumoto, K., Ito, M.: A Personal Navigation System with Functions to Compose Tour Schedules Based on Multiple Conflicting Criteria. IPSJ Digital Courier 1, 528-536 (2005)
17. Richter, K.-F., Klippel, A., Freksa, C.: Shortest, Fastest, – but What Next? A Different Approach to Route Directions. In: Münsteraner GI-Tagen 2004, pp. 205-217. IFGI prints, Münster, Germany (2004)
18. Frank, C.: An Egocentric Spatial Data Model. Department of Spatial Information Science and Engineering, Master's Thesis. University of Maine, Orono, Maine, USA (2003)

Spatial Granularity and Perspective in Route Descriptions for Humans and Dialogue Systems

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Abstract. When conveying information about spatial situations and goals, speakers adapt flexibly to their addressee. Our aim is to equip our dialogue system with the communicative abilities required for such a natural, adaptive dialogue. In this paper we investigate how humans react to other humans and to a dialogue system when giving route descriptions with a map. We focus on two aspects of spatial language known to be crucial for navigation: perspective choice and references to places across levels of granularity. The results of two studies involving human-human and human-system interaction show that humans adapt to their interaction partner systematically with respect to both.

Introduction

How do people communicate with dialogue systems about navigation issues? Today's GPS-equipped navigation systems are well suited to conveying route information both visually and verbally – with many configured to react dynamically to a predefined range of user requests. However, flexible natural language-based dialogue with such a system is still impossible at present, and open questions remain as to what kinds of phenomena such a dialogue system would have to cover. A range of possible application scenarios are conceivable, encompassing not only user-centric outdoor route navigation but also various indoor settings in which either a human or a system instructed by a human, such as a mobile autonomous service robot for home usage, needs route information. In this paper, we address a restricted scenario in which the user tells a robot – in this case a robotic wheelchair – to move to a particular location. The environment, as well as the wheelchair, is depicted schematically on a screen in order to provide a shared basis for spatial communication. We investigate two types of linguistic aspects known to be crucial for spatial interaction, perspective choice and references to places across levels of granularity. Although both of these phenomena have been addressed from diverse angles in the literature, very little is known so far about users' intuitive linguistic behavior in this regard when confronted with a dialogue system equipped to deal with spatial settings. In order to gain insights about the impact of the interaction partner, we use the same scenario twice – comparing the linguistic choices made by humans interacting with other humans, with those made by humans interacting with a dialogue system.

In general terms, dialogic spatial interaction is a major area of importance for spatially-aware systems particularly in navigation scenarios; yet it remains under-represented in the literature thus far. Specifically, it is an open question how speakers' choices of conceptual reference systems and their linguistic representations are influenced by the discourse history and by the interlocutor's feedback. It is well-known that speakers react intensively to the requirements of their artificial interaction partner, both with respect to linguistic choices (Amalberti et al., 1993) and high-level decisions (Hinds et al., 2004). Even small changes in the experimental setting, including the robot's reactions, may be crucial in this regard (Moratz & Tenbrink, 2006), along with users' preconceived mental models and expectations that are equally decisive for users' conceptualization of the dialogue and their ensuing linguistic reactions (Clark, 1999). Existing evaluations that have been carried out in human-robot interaction (HRI) without restricting in advance the language that may be adopted by users have shown that systems can do very badly, simply because the actual language used lies outside of that supported (Thrun 2004). It is therefore essential for HRI to be based on realistic assessments of what language users will produce, and how they will react to the system’s output. To handle such known problems we combine established psycholinguistic experimentation with qualitative empirical discourse analysis of 'freely' produced dialogic contributions, using both human-human baseline-establishing experiments and genuine HRI and human-system interactions. For the latter, the dialogue system is progressively augmented with automatic adaptation according to user models as the empirical results are transferred.

Perspective and granularity

Consider a situation in which you need to communicate information about a spatial goal to an interaction partner, and you are required to do that via a computer interface such as the one depicted in Figure 1. Here, a two-dimensional map is shown on the screen together with a chat interface to be used for communication with the agent – in this case a wheelchair. In our scenario, we used two versions of this task: in one case (cf. Study 1, HHI, described below), the wheelchair was assumed to be occupied by a human user, who used the chat interface to interact with the route instructor. In the other case (cf. Study 2, HCI, described below), the chat interface was coupled to a dialogue enabled agent capable of travelling along a described route; such a scenario may be used, for example, in order to demonstrate a service robot's future path or to visualize a route in reaction to a request made by a human. In both cases, the simulated wheelchair moving around in the scene could be observed by both interlocutors – but only instruction givers could see the location of the next destination (marked in the map).

In such a situation, as in all spatial communication tasks, a number of strategies are available to the interlocutors (cf. Tenbrink, Fischer, & Moratz, 2002). Here we will focus on two distinctions crucial for navigation: *granularity* and *perspective*. With respect to granularity, route instructions may be achieved either by referring directly to the goal location by using destination descriptions as described by Tomko (2007), or by incrementally guiding the traveler to the goal by using turn-by-turn directions (Richter, Tomko, & Winter, 2008). While this may appear to be a binary distinction, in actual fact speakers combine and vary their descriptions flexibly along these lines (Tenbrink & Winter, 2009). In the present scenario, a purely destination-based description is complicated since none of the pre-defined goals has a label (as only very few locations in the map are labeled at all). Previous research has additionally shown that goal-based spatial reference is conceived of as particularly difficult for robots (Fischer & Moratz, 2001). This leads us to expect that *incremental* directions will be the norm in both variants of the task, but perhaps more so in the HCI case. Discrepancies between human expectations and strategies with respect to the preferred choices of granularity in instruction settings could lead to communication failure, especially if the system is not equipped to deal with the level of granularity chosen by the user, or lacks the information necessary to infer the relevant spatial relationships (Tenbrink & Shi, 2007). The investigation of natural HHI interaction provides a gold standard for the joint negotiation of spatial goals in this regard.

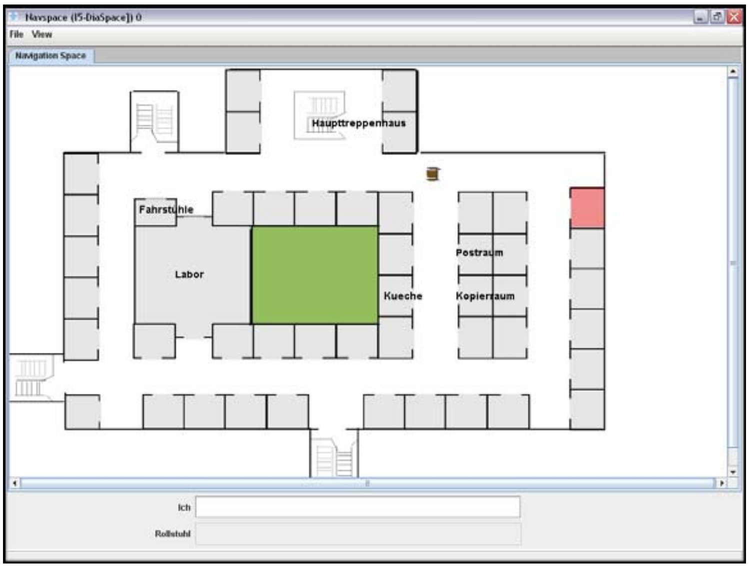

Figure 1. Our map instruction scenario. The robot wheelchair is indicated on the top hallway, facing towards the left side of the picture. The goal location is marked for the instruction giver only; the location labels are always visible. In the HHI case, joystick movements by the instruction receiver make the wheelchair move on the screen; in the HCI case, the wheelchair movements are handled by the system.

With respect to perspective choice, in this scenario, there are two main kinds of perspective available (Garrod & Anderson, 1987; Taylor & Tversky, 1996): survey (looking at the map from "outside" the scene) versus route perspective (as seen by the route-travelling agent). Previous research has established that speakers' perspective choices are flexibly adapted to various kinds of contextual influences (Tversky, 1999); crucially, interlocutors react subtly and systematically to their interlocutors' situation and ability (Schober 1998, 2009). In a recent series of studies directly related to our endeavors reported here, Andonova and Coventry (2008) used a restricted experimental setting focusing on single direction changes (rather than complex route descriptions). In that setting, route perspective dominated overall while survey descriptions averaged only about a third of cases. The naïve speakers' choices of spatial perspective were influenced systematically by the perspective the confederate used on the preceding trials. This result further motivates our parallel investigation of HHI and HCI studies, as reported next. Study 1 (HHI) was previously reported and analyzed with respect to perspective (but not granularity) in Goschler et al. (2008). Study 2 (HCI) was reported with respect to system evaluation (but not perspective or granularity) in Ross (2008). Here we focus on the direct comparison of the two studies concerning the two conceptual aspects motivated in this section.

Study 1: Human-human interaction

The HHI study involved a schematic map as shown in Figure 1, and two naïve participants who were seated at two computer terminals in separate rooms and who both looked at the schematic map showing the simulated wheelchair's position. One of these participants was asked to imagine sitting in the wheelchair and to give instructions (using the chat line) to navigate towards a goal pre-defined by colour marking on their screen (but not on their partner's). The other participant was asked to: (a) imagine that their partner was sitting in the wheelchair; (b) steer the wheelchair with a joystick towards the goal according to their partner's instructions; and (c) ask clarification questions using the chat line when necessary. Given this setting, the participants were allowed to use their own linguistic strategies. Accordingly, the heterogeneity in the data is considerable. Here we focus on issues of granularity and perspective as described above. 11 dyads (same-sex pairs) were tested in this scenario. Each of them were given 11 tasks to solve, yielding a corpus of 121 dialogues containing 1,301 utterances in total (873 of which were produced by the instructor). 1,121 of the utterances were task-related (on average: 9.26 task-related utterances per dialogue; 101.91 per dyad). Here is one typical example of a HHI dialogue from our corpus:

Instructor:	*2 räume weiter*	[2 rooms further]
Instructee:	*rechts oder links*	[right or left]
Instructor:	*nach rechts*	[to the right]
Instructor:	*rechts 2 räume weiter*	[right 2 rooms further]
Instructee:	*wohin*	[where to]
Instructee:	*in den raum bei dem flur rechts* [to the room at the hallway on the right]	
Instructor:	*gleich in den ersten raum wo wir schon mal waren* [directly in the first room where we have been before]	
Instructee:	*das sagt mir nichts*	[that doesn't tell me anything]
Instructor:	*2 räume über raum b*	[2 rooms above room b]

Perspective

The analysis of perspective is described in detail in Goschler et al. (2008), who identified 552 utterances indicating a spatial perspective (49.24% of the task-related utterances). A range of linguistic markers of perspective typical of this setting could be identified in the data, such as *vom Rollstuhl / Fahrer aus* [from the wheelchair / driver], *wieder (links / rechts)* [again (left / right)], *hinter* [behind], *vor* [in front of], *vorwärts* [forwards], *rückwärts* [backwards] as indicators of the route perspective, as opposed to *von dir / mir aus gesehen* [from my / your point of view]*, auf der Karte* [on the map]*, oben* [top]*, unten* [bottom]*, hoch* [up]*, runter* [down] as indicators of the survey perspective. Such unambiguous allocations are essential for the development of dialogue systems, since they can be used to support the identification of underlying perspectives in an interaction situation. For the analysis of linguistic data, it is additionally necessary to consider the current spatial situation in order to interpret potentially ambiguous expressions correctly.

The analysis revealed that 314 (56.88% of the perspective-based utterances) clearly used route perspective, while 148 (26.81%) clearly used survey perspective. The close examination of perspective choices within dyads highlighted a considerable amount of variation, and no clear dominance of one of the two perspectives. Perspective shifts could apparently be triggered by misunderstandings and mistakes; in that case, the instructor may feel a need to re-represent the spatial description in a different way. Such a behaviour could also be initiated by the instructee, in which case there is a parallel to findings from a different dialogic scenario examined in our research (Tenbrink, Andonova, and Coventry, 2008): In the negotiation of object locations, addressees were found to contribute to the formulation of a spatial description by making suggestions of their own, sometimes using different conceptual perspectives. Thus, it appears that perspective shifts in route scenarios can be helpful to disambiguate a potentially problematic description.

Granularity

The utterances produced by both interlocutors vary considerably with respect to granularity. Besides movement descriptions presupposing an underlying perspective as just analyzed, some utterances describe minor (incremental) actions such as *go on* or *stop*. Here we take a closer look at utterances on a somewhat coarser level of granularity, namely references to locations as in *go out of the room*, which are based on the environment depicted in the map. Such location descriptions may refer to start locations, subgoals, or the destination itself. Destination descriptions as such, however, do not necessarily contain locations; these may also remain implicit as in *jetzt der vorletzte links* [now the second last on the left]. Since both of these interrelated aspects relate to the issue of granularity, our analysis addresses both in turn: first we investigate speakers' use of spatial noun phrases (references to locations) along with their linguistic context to identify more closely what they are used for; then we address destination descriptions (independent of noun usage).

Noun usage. 315 (28.10% of all task-related) utterances contained at least one noun referring to a spatial entity, such as *hallway, room, intersection* and the like. Of these, 265 (84.13%) were produced by the instructor (rather than the instructee). 68 (6.07% of all task-related) utterances contained a location name (one of the labels provided in the schematic map). The preposition *zu* [to] occurred altogether 46 times in the whole corpus, but only twice together with a location name (*hoch zum Treppenhaus* [up to the staircase] and *fahr erst mal zum Labor* [first just drive to the lab]). Thus, simple directions to a labelled subgoal were rare in this corpus. The remaining utterances with location names were typically either complex destination descriptions (see next paragraph), or clarifying descriptions formulated by the addressee (*bin jetzt vor dem Labor* [I'm now in front of the lab]), or they used the locations as landmarks during the wayfinding process, as in *hinter der Treppe rechts* [to the right behind the staircase]. Thus, speakers used location names typically as part of a more complex spatial description process.

Destination descriptions. Altogether, 158 utterances by instructors (19.68% of all of the 803 instructors' task-related utterances) could be interpreted as destination descriptions (four of these without noun usage). Many of these were linguistically complex, such as *wir müssen ganz nach oben ins Haupttreppenhaus in den obersten raum rechts* [we have to go all the way up into the main staircase into the uppermost room on the right]. Most destination descriptions occurred after directing the instructee incrementally towards the goal, as in:

Instructor:	*links*	[left]
Instructor:	*jetzt rechts*	[now right]
Instructee:	*ok*	[ok]
Instructor:	*dann den Gang runter und das 2. Zimmer* [then down the hall and the second room]	

This dialogue represents an uncharacteristically short example; most trials were much longer even if they did include a destination description at some point (up to 112 utterances within one single task dialogue until the goal was reached). However, there were some notable exceptions, namely those that already started out with a destination description. Of the 121 *first* instructions in the collected dialogues, 44 were destination descriptions. Remarkably, although some dyads apparently used this method as a strategy (two of the dyads used it for each single task, accounting for 50% of these initial destination descriptions), altogether 8 of the 11 dyads used it at least once. Such dialogues did not require much negotiation; often there was no further exchange once the destination was determined by the first utterance. The two dyads that relied entirely on this strategy used only 23 and 27 task-related utterances respectively (through the 22 dialogues they produced). To compare, the average of utterances per dyad was 101.91 as mentioned above.

Study 2: Human-computer interaction

The dialogue system used for the HCI study was rudimentarily equipped with the capacity to interpret simple spatial movement instructions, indications of non-understanding such as *Tut mir leid. Ich habe nicht verstanden* [I'm sorry. I didn't understand], and agreement (*OK*). This was intended in order to establish a baseline for simple spatial communication with a system. The study was carried out for two reasons. On the one hand, we wished to evaluate the current status of the dialogue system by investigating how easy it would be for users unfamiliar with the system to navigate the virtual wheelchair to a predefined destination. This aspect is discussed in Ross (2008); following some system improvements, the success rate was actually quite high (86% of started tasks were completed within the time-out window of four minutes). On the other hand, we aimed to compare the linguistic data collected in this study with the HHI data as just described. This is our current purpose. 13 naïve participants (7 of them before the said improvements) were familiarized with the system before they were asked to instruct the schematized wheelchair to move to an indicated location as in the HHI study, while imagining they were seated in the wheelchair. Not all of the dialogues could be completed, as described in Ross (2008), and the linguistic data of one user were lost. Altogether, we collected 104 dialogues with 1,727 utterances in total. 1,380 of these utterances were produced by the users; all of these could be classified as task-related (average: 13.27 per dialogue; 115 per user).

Already at first sight, the contents of the users' descriptions differ considerably from those of the humans in the HHI situation. While the HHI situation contained many complex utterances such as those exemplified above, the user utterances in HCI were overwhelmingly sparse, containing repetitions of simple movement instructions such as *links* [left], *rechts* [right], *geradeaus* [straight ahead], *stop* [stop] and the like. Here is one typical example of a HCI dialogue from our corpus:

User: *geradeaus* [straight on]
User: *halt* [stop]
User: *nachlinks* [totheleft]
System: *Tut mir leid. Ich habe nicht verstanden.* [I'm sorry. I didn't understand.]
User: *nach links* [to the left]
User: *geradeaus* [straight on]
User: *nach rechts* [to the right]
User: *geradeaus* [straight on]
User: *nach rechts* [to the right]
User: *nach rechts* [to the right]
User: *zum Haupttreppenhaus* [to the main staircase]

Perspective

Of the 1,380 utterances produced by human users, 926 indicated a perspective, only one of which could be clearly identified as survey based. Specifically, of the linguistic markers identified by Goschler et al. (2008) as indicating survey perspective, there was only one occurrence of *hoch* (up) used in a discourse context in which the frustrated user apparently tried out a number of possibilities. Generally, the instructions by the human users relied consistently on an underlying route perspective.

Granularity

Noun usage. 166 (12.03% of all 1,380) human instructions contained at least one noun referring to a spatial entity; 83 (6.01% of all) contained a location name. The preposition *zu* [to] occurred altogether 40 times in the whole corpus, 34 times together with a location name (e.g., *zum Labor* [to the lab]). Thus, simple directions towards a labelled subgoal were fairly regular. The remaining utterances with location names were sometimes destination descriptions (see next paragraph), but more typically either sparse utterances containing only the location name, indications of direction as in *Richtung Postraum* [direction of mail room], or instructions to leave a labelled area (*aus dem Postraum* [out of the mail room]). Thus, speakers used location names typically to label subgoals in a simplistic fashion.

Destination descriptions. 21 instructions could be interpreted as destination descriptions (all of which included a noun). Two of these occurred in the first instruction of a trial (but could not be interpreted by the system). More typically, users finalized an incremental instruction by an utterance like *nächste Tür links* [next door left].

Table 1. Main features of the human-human and human-computer interaction data

	HHI		HCI	
	%	No. of cases	%	No. of cases
Survey perspective (clear cases of all perspective-based utterances by humans)	26.81	148 of 552	0.11	1 of 926
Utterances containing nouns (of all task-related utterances by humans)	28.10	315 of 1,121	12.03	166 of 1,380
"zu" (*to*) & location name (e.g., *to the lab*) (of all task-related utterances by humans)	0.18	2 of 1,121	2.46	34 of 1,380
Destination descriptions (of all task-related utterances by human instructors)	19.68	158 of 803	1.52	21 of 1,380
Initial destination descriptions (of all initial instructions by humans)	36.36	44 of 121	1.92	2 of 104

Discussion

In order to investigate speakers' choices of perspective and granularity levels when interacting with dialogue systems and with other humans, we carried out two studies involving map-based linguistic interaction. Table 1 gives an overview of the main results of the analysis, comparing a subset of linguistic features related in each case to the relevant subset of utterances. Route perspective (imagining being inside the scene and moving through the hallways with the wheelchair) was generally preferred throughout. However, in the HHI study the speakers freely and frequently switched and negotiated perspective choices, for example in the case of problems, similar to earlier studies in spatial communication (e.g., Garrod & Anderson, 1987; Healey & Mills, 2006). Although there was no lack of problems in the HCI case, the human users never used a switch of perspective as a clarification strategy. Similarly, the two data sets differed considerably in the area of granularity, not only with respect to the frequency of references to locations, but also with respect to the particular role these references played in the spatial description process. Human interlocutors frequently employed references to labeled places embedded in more complex spatial references, often as part of direct destination descriptions which made communication very easy. Thus, the HHI dialogues provide examples of joint negotiation of granularity levels, corresponding to earlier findings from monologic settings (Tenbrink & Winter, 2009) but switching flexibly in response to features of the interaction development. In the HCI situation, in contrast, references to locations were restricted to simple references to subgoals as "stepping stones" in order to reach the goal incrementally; the small number of destination descriptions usually referred to a near goal location approached via step-by-step instructions. This indicates a constantly low level of granularity, similar to earlier findings on user strategies for spatial communication with robots (e.g., Fischer & Moratz, 2001).

Thus, speakers adapted to the automatic dialogue system as interaction partner on several levels. They consistently employed simple syntax with reduced spatial content from the start, along with differentiated spatial strategies when referring to locations, and a reluctance to switch perspectives. Apparently, current users of such systems are not prepared to employ complex spatial descriptions resembling those used regularly in human-human interaction. As such, this result is not surprising given earlier results on humans' adaptation to systems as interaction partners (e.g., Amalberti et al., 1993; Hinds et al., 2004) – however, the specific impact on the crucial spatial issues of perspective and granularity had not been identified in this way before. While humans are known to be particularly flexible in these areas (e.g., Tversky, 1999; Tenbrink & Winter, 2009), the present study has identified the existence of simple default options that are apparently quite unanimously felt to be suitable for automatic dialogue systems. Such low-level strategies are in fact useful as they exclude misunderstandings due to perspective switches, or to clashes with respect to the chosen level of granularity. Speakers appear to use such simple linguistic problem avoidance strategies intuitively, even if they lack earlier experience with the system as in the present study. However, humans' natural interaction strategies in spatial settings allow for far more flexible communication, including strategies for clarification and adaptation that ultimately lead to enhanced efficiency (such as switches to direct destination descriptions). Such flexibility also corresponds more closely to human mental hierarchical structuring of environments (see for example Taylor & Tversky, 1996).

Conclusion

We presented the results of two studies investigating route directions with a map, first with human dyads interacting via a chat interface (HHI), second with individual human users interacting with a dialogue system (HCI). Results showed systematic differences between these two cases concerning both choice of perspective and level of granularity. We conclude that, when confronted with an automatic system equipped with limited capabilities, speakers restrict their linguistic choices to a fairly limited subset of the options generally available to them. This affects not only the surface of language (such as syntactic and semantic range) but also the spatial and conceptual aspects of the navigational setting, leading, for instance, to a re-interpretation of landmarks to subgoals (in HCI) rather than orientation aids (in HHI). As an outcome, human-computer interaction remains artificial, awkward and unflexible. For natural interaction to run efficiently, the employment of suitable clarification strategies and feedback by the system should encourage users to widen the scope of their linguistic strategies, gradually moving towards more flexible interaction. We are currently developing suitable dialogue models precisely for this purpose (Shi, Ross, Tenbrink, & Bateman, subm.). Further work concerns the controlled investigation of alignment and misalignment, particularly with respect to speakers' repair strategies in cases of communication failure based on mismatches of perspective and granularity levels (cf. Tenbrink & Shi, 2007).

References

Amalberti, R., N. Carbonell, and P. Falzon. 1993. User Representations of Computer Systems in Human-Computer speech interaction. *Int. Journal of Man-Machine Studies*, 38:547-566.

Andonova, E. and K. Coventry. 2008. Perspective Priming in Spatial Descriptions. *14th Annual Conference on Architectures and Mechanisms for Language Processing*, Cambridge, UK.

Clark, H. H. 1999. How do real people communicate with virtual partners? In *Proc. of AAAI-99 Fall Symposium,* November 5-7th, North Falmouth, MA. Menlo Park, Calif.: AAAI Press.

Fischer, K. and R. Moratz. 2001. From Communicative Strategies to Cognitive Modelling. *Proceedings of the First International Workshop on Epigenetic Robotics: Modeling Cognitive Development in Robotic Systems*. Lund University Cognitive Studies, Vol. 85.

Garrod, S. and A. Anderson. 1987. Saying what you mean in dialogue: A study in conceptual and semantic coordination. *Cognition* 27: 181-218.

Goschler, J., E. Andonova, and R. Ross. 2008. Perspective Use and Perspective Shift in Spatial Dialogue. In C.Freksa, N. Newcombe, P. Gärdenfors, and S. Wölfl (eds.), *Spatial Cognition VI: Learning, Reasoning, and Talking about Space*. Berlin: Springer, pp. 250-265.

Healey, P.G.T., and G.J. Mills. 2006. Participation, Precedence and Co-ordination in Dialogue. In R. Sun and N. Miyake, eds., *Proc. of the 28th CogSci Conference*, pp. 1470–1475.

Hinds, P.J., T.L. Roberts, and H. Jones. 2004. Whose Job is it Anyway? A Study of Human-Robot Interaction in a Collaborative Task. *Human-Computer Interaction, 19*:1/2, 151-181.

Moratz, R. and T. Tenbrink. 2006. Spatial reference in linguistic human-robot interaction: Iterative, empirically supported development of a model of projective relations. *Spatial Cognition and Computation 6*:1, pp. 63-106.

Richter, K.-F., M. Tomko, and S. Winter. 2008. A Dialog-Driven Process of Generating Route Directions. *Computers, Environment and Urban Systems, 32* (3), 233–245.

Ross, R.J. 2008. Tiered models of spatial language interpretation. In C. Freksa, N. Newcombe, P. Gärdenfors, and S. Wölfl (eds.), *Spatial Cognition VI: Learning, Reasoning, and Talking about Space.* Berlin: Springer, pp. 233-239.

Ross, R.J., H. Shi, T. Vierhuff, B. Krieg-Brückner, and J. Bateman. 2005. Towards Dialogue Based Shared Control of Navigating Robots. In Freksa, C., M. Knauff, B. Krieg-Brückner, B. Nebel, and T. Barkowsky (eds.), *Spatial Cognition IV: Reasoning, Action, Interaction.* Berlin, Heidelberg: Springer, pp. 479-500.

Schober, M.F. 1998. How addressees affect spatial perspective choice in dialogue. In P.L. Olivier and K.-P. Gapp (eds.), *Representation and processing of spatial expressions* (pp. 231-245). Mahwah, NJ: Lawrence Erlbaum.

Schober, M.F. 2009. Spatial Dialogue between Partners with Mismatched Abilities. In K. Coventry, T. Tenbrink, and J. Bateman (eds.), *Spatial Language and Dialogue* (pp. 23-39). Oxford: Oxford University Press.

Shi, H., R.J. Ross, T. Tenbrink, and J. Bateman (subm.) Illocutionary Structure Modelling and the Analysis of Task-Oriented Dialogues.

Taylor, Holly A. and Barbara Tversky. 1996. Perspective in spatial descriptions. *Journal of Memory and Language, 35*, 371-391.

Tenbrink, T., E. Andonova, and K. Coventry. 2008. Negotiating spatial relationships in dialogue: The role of the addressee. In J. Ginzburg, P. Healey, and Y. Sato (eds.), *LONDIAL – The 12th SEMDIAL workshop*, June 2nd - 4th, King's College, London, UK, pp. 201-208.

Tenbrink, T., K.. Fischer, and R. Moratz. 2002. Spatial Strategies in Human-Robot Communication. In C. Freksa (ed.), *KI 4/02 Themenheft Spatial Cognition*, 19-23.

Tenbrink, T. and H. Shi. 2007. Negotiating spatial goals with a wheelchair. In Keizer, S., Bunt, H. & Paek, T. (eds.): *Proc. of the 8th SIGdial Workshop.* Antwerp, Belgium, pp. 103–110.

Tenbrink, T. and S. Winter. 2009. Variable Granularity in Route Directions. *Spatial Cognition and Computation* 9, 64 – 93.

Thrun, S. 2004. Toward a Framework for Human-Robot Interaction. *Human-Computer Interaction 19*:1/2, pp. 9-24.

Tomko, M. 2007. *Destination Descriptions in Urban Environments*. PhD Thesis, Melbourne.

Tversky, B. 1999. Spatial Perspective in Descriptions. In P. Bloom, M.A. Peterson, L. Nadel, and M.F. Garrett (eds.), *Language and Space* (pp. 109-169). Cambridge, MA: MIT Press.

EXTENDED ABSTRACTS

The Use of Filters for Adaptive Mobile Mapping Scenarios

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Abstract. Location based services should communicate information that is relevant to the user and personalized to his/her interests and needs. Existing LBS exploit ancillary information such as the user's position, user profile, or time of day to personalize information delivery. However, there are a variety of information sources that remain largely untapped in current LBS. These include data from other applications on the mobile device, Web 2.0 sources, or special sensors. They have the inherent ability to define relevant places, events, activities for the particular user; they also allow to derive spatio-temporal behavior patterns that adapt to context. Using appropriate filters, user-specific information can be mined from these additional ancillary data sources, hence allowing to minimize user interaction, better personalize content, and generate more meaningful real-time map displays. This extended abstract hence proposes the use of different filters to further enable adaptation of mobile map applications to the user and his/her context.

Key words: mobile computing, adaptive filters, context-awareness, mashup

1 Introduction and Motivation

Despite the rapid evolution of techniques and capabilities available for spatial communication; adaptation to context, given tasks and dynamic user profiles are not exploited completely. Hence adaptation in spatial communication remains a major research topic in the area of mobile computing and location based services (LBS).

Most mobile applications/services do not fully exploit the inherent data available and the possibility to improve user interaction to adapt to certain situations. By 'inherent data', we mean sensor data (e.g. GPS, accelerometer, microphone, camera) and user information that is inherent to the mobile device such as address book, calendar, pictures, or music. These provide substantial information for better adaptation to immediate and extended context. Furthermore this inherent data, along with additional services from the Web (e.g. Web 2.0 services), allows retrieving personalized content such as user interests, hobbies, reading lists, music styles.

The retrieved data contains highly user-specific information that is not easily derivable from mobile device usage alone. The data in this case is not completely structured semantically but keywords and key-value pairs can be derived from it (For example: *interest*, as they key with *science, culture and art*, as the respective values).

An example of such a mobile application is a map representation showing information that is within the time-budget of a tourist and according to the tourist's interests. Someone who is interested in science may visit the musea rather than all the sourrounding shopping malls. The time-budget relevant information is generated with the help of information from the device calendar within the device, web2.0 travel profiles and public transport systems. Whereas, information on the tourist's interest could be collected from internal profile data or web2.0 social networking applications such as Facebook. In the later section discussing the use case a similair example is shown.

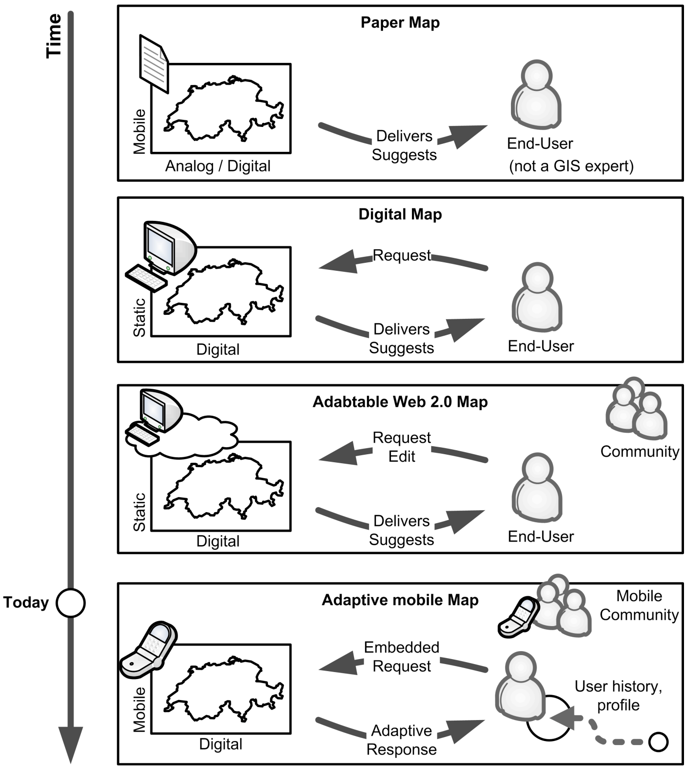


Fig. 1. Timeline for maps from an end-users perspective.

2 Change of Map Usage

Map usage has changed rapidly over the last decades (Fig. 1). As a consequence, the end-user is presented with an increasing variety of map products and options. From paper maps to digital maps (GIS systems included); from general-purpose digital maps to adaptable Web 2.0 maps (e.g. mash-ups with volunteered content); and recently from adaptable maps to adaptive maps (in the mobile context). The usage of mobile mapping services in a highly dynamic environment requires adaptation of content to different changing contexts. Small screen size and limited processing power are further limitations of mobile devices. Furthermore, changes of display scale and content need to be sufficiently fast on the mobile display, thus requiring powerful algorithms for on-the-fly generalization [1]. User interaction needs to be minimized and services adapted to become context sensitive and personalized [2–4]. Other limitations that need to be considered by the dynamic use of various mobile services are transparency, privacy and obfuscation [5].

3 Proposed Filtering Methods

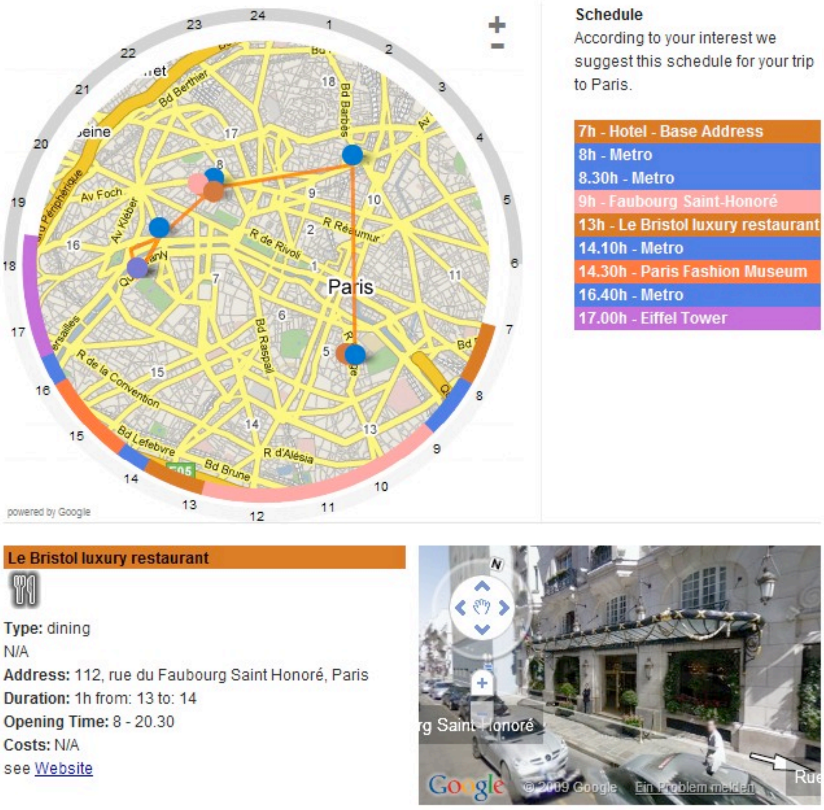
In order to filter and organize information for on-the-fly personalization and generalization of data, we have looked at different possibilities of filtering spatial, temporal, network, hierarchical, profile and device data. These filters and their combination allow reducing and ranking the data according to immediate and future context.

The filters take input parameters such as spatial or temporal distribution to filter for different parameters or constraints according to the type of filter. The output then is a subset of the input data enriched with the filter parameters and the filter rank. Depending on the input data structure filters can be chained or the output can be used as parameters for a further type of filter. The different filters personalize the data and help to simplify generalization tasks. Learning algorithms, along with filters and training data such as user and movement data, help discover emerging patterns in the form of associations or rule sets [6, 7]. A possible set of filter categories is presented below:

- Spatial filters analyze spatial characteristics like proximity or visibility [8].
- Temporal filters derive patterns from timelines of movements, availability and events [9].
- Network filters analyze personal relations and other graph like structures [10].
- Profile filters look for instance at similarities between users to derive local interest groups using Web2.0 and social networking applications.
- Hierarchy filters order the dataset by hierarchies inherent in the data, e.g. considering administrative units [11].
- Semantic filters analyze and order the datasets according to semantics [4].
- Pattern filters search for movement patterns [12, 13].
- Device filters handle device settings and constraints.

4 Use Case

The use case proposes a mashup application (Fig. 2) to predict important places to visit during a trip to Paris. The use case applies some of the above proposed filters using profile or personal information, which is extracted from online social networking profiles like Facebook [14] and travel profiles like Dopplr [15]. The information helps in determining a pattern in tourism habits and more importantly determining what the user may want to see. Depending on the user's hobbies, interests and activities or travel portfolio, places of visit in the city are predicted. The goal is to point out important places for different users after looking at their profile, their travel intent, and also after learning from places they have already been too.



Schedule
According to your interest we suggest this schedule for your trip to Paris.

- 7h - Hotel - Base Address
- 8h - Metro
- 8.30h - Metro
- 9h - Faubourg Saint-Honoré
- 13h - Le Bristol luxury restaurant
- 14.10h - Metro
- 14.30h - Paris Fashion Museum
- 16.40h - Metro
- 17.00h - Eiffel Tower

Le Bristol luxury restaurant

Type: dining
N/A
Address: 112, rue du Faubourg Saint Honoré, Paris
Duration: 1h from: 13 to: 14
Opening Time: 8 - 20.30
Costs: N/A
see Website

Fig. 2. Example application for spatial filtering and profiling together with a mashup of geographic data.

5 Discussion

Above, we have proposed a set of filters that collectively are more comprehensive than what current systems usually offer. Thus, we hope to tap into new information sources and utilize more complete information that can be used to personalize LBS to the user and his/her context. We propose filters as a possibility to enable mobile mapping services to better adapt to user needs for spatial communication and user-defined mash-ups, combining information mined from unstructured web resources with well-structured static information.

As a first step towards implementation, we have looked into functions of deriving patterns and rule sets from user history, profile and activity logs. In a further stage of the work more filters are planned to be included and applied to different types of use cases. Furthermore, the linkage to on-the-fly generalization will be studied.

6 Conclusion and Outlook

The project has only recently started and hence this paper focuses on the conceptual level and on providing initial results to indicate the direction of our future research. The next steps consist in analyzing the requirements for ad hoc data integration on the server-side and formalizing different filters of the types described above, as well as their interaction with on-the-fly generalization procedures.

References

1. Weibel, R., Burghardt, D.: On-the-fly Generalization. In: Encyclopedia of GIS. Springer (2008) 339–344
2. Raper, J., Gartner, G., Karimi, H., Rizos, C.: A critical evaluation of location based services and their potential. Journal of Location Based Services **1**(1) (2007) 5–45
3. Raubal, M., Panov, I. Lecture Notes in Geoinformation and Cartography. In: A Formal Model for Mobile Map Adaptation. Springer (October 2008) 11 – 34
4. Reichenbacher, T.: Mobile Cartography-Adaptive Visualisation of Geographic Information on Mobile Devices. Verlag Dr. Hut, München (2004)
5. Duckham, M., Kulik, L., Birtley, A.: A Spatiotemporal Model of Strategies and Counter Strategies for Location Privacy Protection. Lecture Notes in Computer Science **4197** (2006) 47–64
6. Ashbrook, D., Starner, T.: Using gps to learn significant locations and predict movement across multiple users. Personal and Ubiquitous Computing **7**(5) (2003) 275–286
7. Kohonen, T.: The self-organizing map. Neurocomputing **21**(1-3) (1998) 1–6
8. Mountain, D., MacFarlane, A.: Geographic information retrieval in a mobile environment: evaluating the needs of mobile individuals. Journal of Information Science **33**(5) (10 2007) 515
9. Zhao, J., Forer, P., S., H.A.: Activities, ringmaps and geovisualization of large human movement fields. Information Visualization (July 2008) 198 – 209

10. Strogatz, S.H.: Exploring complex networks. Nature **410**(6825) (2001) 268–276
11. Burghardt, D., Purves, R., Edwardes, A.: Techniques for on the-fly generalisation of thematic point data using hierarchical data structures. Proceedings of the GIS Research UK 12 thAnnual Conference (2004)
12. Laube, P., Dennis, T., Forer, P., Walker, M.: Movement beyond the snapshot - dynamic analysis of geospatial lifelines. Computers, Environment and Urban Systems **31**(5) (2007) 481–501
13. Brimicombe, A., Li, Y.: Mobile Space-Time Envelopes for Location-Based Services. Transactions in GIS **10**(1) (2006) 5–23
14. Facebook API: retrieved march 23, 2009. http://developers.facebook.com/ (March)
15. Dopplr API: retrieved march 23, 2009. from http://dopplr.pbworks.com/

Strategies of Context-based and semantic Adaptive Route Communication

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In recent years, technological progress and an increasing amount of ubiquitously available information set the stage for the development of mobile navigation tools for pedestrians. However, the vast quantity of accessible navigational and environmental information aggravates effective information extraction. In order to facilitate the provision of customised information and to avoid redundant information, we currently determine three steps to overcome the shortcuts of existing approaches: building typologies of pedestrian behaviour, deriving context models out of activities of pedestrians and deriving semantic descriptions of routes. Based on this strategy we propose, that a more efficient and adaptive communication of routes for pedestrian wayfinding can be achieved.

The aimed pedestrian typology is derived by using a multi-method approach considering motion behaviour as well as underlying preferences and individual attitudes. We developed a methodological set-up including qualitative-interpretative and quantitative-statistical data, which leads to the determination of a typology of lifestyle-based pedestrian mobility styles. In the first of two consecutive empirical phases performed in an indoor and an outdoor shopping environment we collected datasets of over 100 trajectories observed by shadowing techniques. We compiled speed histograms which have been classified using clustering algorithms. Furthermore we collected and analysed data from 130 interviews. In the currently ongoing second empirical phase we analyse and classify over 100 datasets collected by localisation technologies (GPS, Bluetooth), as well as more than 200 semi- standardised interviews. Initial results show that observations produce a set of homogeneous behaviour clusters which can be used for tailoring wayfinding instructions and additional location based information to individual needs.

Based on fundamental models, like the pedestrian behaviour typology, one of the most important aspects of ubiquitous computing - context-awareness can be derived. In this paper, we adopt an interactional perspective on context: something is context because it is used for adapting the interaction between human and the current system; activity is central to context; context differs in each occasion of the activity. Based on this understanding, we propose an Activity Theory based method which attempts to answer the following questions: how to analyze activity for context- awareness, and how to identify relevant context parameters. This method includes two steps: by using Activity Theory's hierarchical structure of activity, an activity is decomposed into actions, which we take as units for identifying context parameters; by making an extension to the Activity Theory's framework we identify relevant context parameters for each action. Finally, an outlook how this method can be used in designing context-aware pedestrian wayfinding services is given.

Context-models based on activity theory and behaviour modelling has to feed forms to communicate resulting routes. The aim of semantic route descriptions is to learn from humans and to adapt their way of describing the world and routes to use them in navigation systems. In order to do that in an automated manner a formal model of navigation language is needed. We have chosen to develop our model from empirical experimental data: Test persons were asked to describe surroundings and route choices in situ. This resulted in several thousand statements, which then were processed and classified using methods proposed by literature. From this we plan to derive a formal model that is not limited to our test routes. In a second step it is planned to use this model to implement semantically enriched route instructions in a prototype navigation device. By doing this we can not only provide a model useable in real-world applications but also test the semantic navigation in comparison to traditional navigation.

In summary we propose various ways as a strategy to improve pedestrian navigation services by especially addressing issues of activity-theory, context-modelling and semantic wayfinding.

Individual Preferences on Spatial Control in Map Usability Research

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Abstract. Using a navigation device is a proper and safe way to find a destination in an unknown environment - at least as long as the navigation device keeps working. But a failure of such a device, while being in an unknown environment, might result in a high stress level for the user, as users of navigation devices usually follow given instructions and dont take into consideration the surrounding environment. An empirical evaluation, run by the author, will create validate data about this phenomena. The results of this test describe the strength of such an effect as well as individual parameters on this effect. Also their possible influences on usability research of navigation devices will be investigated.

Using a navigation device in order to find a destination means that the user is transferring work processes to the navigation device. In the case of navigation, these processes are referring to spatial tasks. But not only spatial work processes are transferred to the navigation device, also control on spatial behaviour is transferred to the navigation device. The reason is that the actual route is no longer determined by the user but by the device. In order to reach the destination in an effective and efficient way, the user has to follow the navigation instruction as precisely as possible. Current usability research tries to investigate how map display or user interface can improve the users ability to follow the navigation instructions precisely (e.g. [6], [2]). Schmid et al. [5] introduced a new sight on usability of navigation devices, as they postulate that the map display should enable the user to self-correct routing errors and that the map display should introduce the unknown environment to the user. Furthermore this transfer of spatial control might help to reach the destination but the transfer of spatial control can also result in stress, as control is an important part in cognitive psychological models of stress. [1] Therefore in line with [5] it can be presumed, that transfer of navigation work processes to specialised devices might improve the efficiency and effectiveness of the navigation task, resulting in a higher usability of navigation devices compared to traditional methods of navigation, e.g. route maps. But it can also be presumed, that the transfer of spatial control might result in a higher stress level and a higher uncertainness regarding the unknown environment.

These are the first two questions of the mentioned empirical evaluation. The third question is the identification of individual characteristics, which might describe the extent to which a user is feeling a spatial uncertainness by the transfer of spatial control. The fourth question is the identification of environmental conditions, which might have an effect on the spatial uncertainness, aroused by the transfer of spatial control. Two empirical methods will be used in the evaluation. On one hand an online survey will get information about the individual characteristics of the study participants, which are students from the department of Geography. It will also give information on the spatial uncertainness of the participants while using a navigation device. On the other hand an experiment will be prepared, containing a navigation task in a virtual environment. This virtual environment shows a computer-simulated model of the town of Heidelberg from the project www.gdi-3d.de [7], presented on the XNavigator 3D-Viewer [4]. The model of the town of Heidelberg will substitute a real environment. For challenging issues using virtual environments see e.g. Gyselinck et al., (2006) or [3]. The test is still running; the results of this empirical evaluation will be presented at the AGILE workshop Adaptation in Spatial Communication.

References

1. Hellbrück, J., Fischer, M.: Umweltpsychologie. Hogrefe. Göttingen, Bern, Toronto, Seattle (1999)
2. Kiechle, G., Göll, N., Rehrl, K.: TourGuide A navigation System for Ski Tourers on GPS-enabled Smartphones. In: Proceedings of the 4th International Symposium on LBS & TeleCartography, Hong Kong (2007)
3. Peters, D., Richter K.-F.: Enhancing Wayfinding Abilities in a Large-Scale Virtual City by Schematization. In: Probst, F., Keßler, C. (eds.): GI-Days 2007 - Young Researchers Forum (Proceedings of the 5th Geographic Information Days), Vol. 30, IfGI prints. Institut fr Geoinformatik, Münster (2007) 257-260
4. Schilling, A., Basanow, J., Zipf, A.: Vector based mapping of polygons on irregular terrain meshes for web 3D map services. In: 3rd Int. Conference on Web Information Systems and Technologies (WEBIST). Barcelona, Spain (2007)
5. Schmid, F., Peters, D., Richter, K.-F.: You Are Not Lost - You Are Somewhere Here. In: Klippel, A., Hirtle, S. (eds.): You-Are-Here-Maps: Creating a Sense of Place through Map-like Representations. Workshop at Spatial Cognition (2008)
6. Wunderlich, M., Auer, M.: Perspective Maps in Mobile Devices Just Style or Proper Function? In: 5th International Symposium on LBS & TeleCartography. Salzburg. Austria (2008)
7. Zipf, A., Basanow, J., Neis, P., Neubauer, S., Schilling, A.: Towards 3D Spatial Data Infrastructures (3D-SDI) based on Open Standards - experiences, results and future issues. In: "3D GeoInfo07". ISPRS WG IV/8 International Workshop on 3D Geo-Information: Requirements, Acquisition, Modelling, Analysis, Visualisation. Delft, Netherlands (2007)