DEEP MAP
Challenging IT research in the framework of a tourist information system

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Abstract

Deep Map is a research framework that aims at building the prototype of an intelligent next generation spatial information system. Deep Map realizes the vision of a future tourist guidance system that works as a mobile guide and as a web-based planning tool. This long term research project addresses several challenging research aspects covering intelligent integration of information from different data sources and services including geographical information systems, multi-media databases, and interactive internet data sources such as reservation systems. On the basis of this complex information system the European Media Laboratory plans to build user interfaces that allow intuitive and easy access to information. Such a user interface including visual and natural language processing will be included into a mobile device that navigates the user through a city. Also virtual tours in a 3D-reconstructed city will be possible. In this paper, we present the current system that already covers a number of these aspects and demonstrates how tourists may be guided in the future.

1. Introduction

Information technology (IT) is one of the driving forces in the information society. Current trends indicate that computers will soon be integrated into many devices and that there is virtually no limit of inter-networking all kinds of computers and services. These advances in computer science are basically quantitative and in many applications, a lack of qualitative improvements yields systems that are not better but even worse in terms of their usability. In spite of finding more information there is a tradeoff leading to spending more time searching for information. This effect also happens to many tourism applications of IT. The number of tourism-related services in the Web grows every day offering hotels, flights, tickets and information of all sorts. Since every service provider has a proprietary interface and a unique selection of services, it becomes hard for a tourist to effectively plan a trip to an unknown city and to collect the right information in advance. Moreover, when the tourist reached the destination, he or she will miss some information and be cut off from these information sources..

Even though, information as such can easily be carried around, it is still not really accessible for tourists for mobile use. A CD-ROM, for instance, may have all the useful information on a city such as a list of hotels, recommendations for restaurants, or knowledge on the architecture of a castle. But unless equipped with a laptop, it is quite useless when the user leaves the home PC. Therefore, most projects that aimed at bringing out tourists guides on CD-ROM more or less failed. The classical book is still a very powerful hardware that contains a lot of useful information, never runs into battery problems and is quite robust for rough conditions that occur in outdoor use.

A survey that was conducted by EML and the University of Heidelberg, recently showed that many tourists are very much reserved against IT assistance for their trip. Interestingly, however, the same amount of people would like to have some IT in form of a mobile computer. Thus, the question if people would like to use computers as a replacement of the traditional books and maps as tourist guides, splits the tourists into two groups: traditionalists who want to stick with classical paperwork and experimentalists who would like to try out new technologies. The question remains, why the second group still does not use mobile computers. The answer is simple, there are not yet the right IT systems available. PDAs are not powerful enough, Laptops not practical, networking is too slow, the systems do not know where they are and there are just not the services available that could compete with the information in a book.

In Deep Map, we aim at building information systems that overcome these problems. This imposes research challenges in a wide range of fields of IT research. In particular, the main research areas of Deep Map are geo-information systems, data bases, natural language processing, intelligent user interfaces, knowledge representation, 3D-modeling and visualization. The goal is to develop information technologies that can handle huge heterogeneous data collections, complex functionality and a variety of technologies, but are still accessible for untrained users.

2. Components and Design of Deep Map

In the long run, Deep Map will be a mobile system able to generate personal guided walks for tourists through the city of Heidelberg and to aid tourists in navigating through the city. Such a tour shall consider personal interests and needs, social and cultural backgrounds (age, education, gender) as well as other circumstances (from season, weather, traffic conditions to time and financial resources). Even though Deep Map is a long term research project, the current prototype already provides a good impression of the tourist guide for the future. In the following, we present an outline of the components of the current system and discuss how they are embedded in the whole Deep Map system.

2.1. GIS and Databases

The core of Deep Map is a geographical information system (GIS). It can handle spatial and topological queries, allows navigation and route finding. Touristical information is location-dependent by nature. Each sight, building, hotel, restaurant, etc. does have a spatial location. Moreover, during mobile use, the tourist has a location and one important task is to relate the tourist's location to attractions in reach, the tour she wants to take and to the goal she wants to reach. This leads to a range of geography-related questions a tourist is likely to ask, such as:

- Where am I?
- How do I get from A to B?
- What attractions can I reach?
- Where can I find a hotel/restaurant/...?
- How do I get there in the fastest/cheapest/nicest manner?
- What was here before?

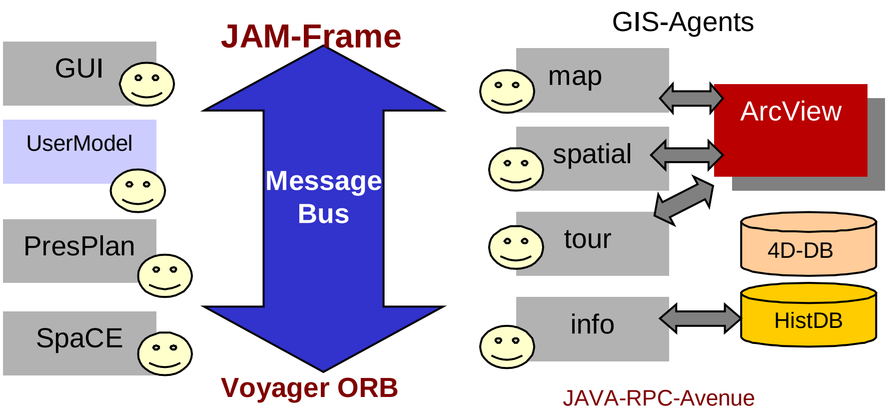

Fig. 1. Overview of the architecture of the GIS-agents. The four DB/GIS agents on the right realize access to the GIS and the DBs. They interact (also with the other agents on the left) via a message bus.

- Why does the area look like this?
- How did this part of the area evolve? (Why?)
- Which areas of the city are interesting for me or especially dangerous/ugly?

All of these questions need geographical knowledge that has to be managed by a GIS. Some questions take the position of the user into account and for their answer, we need to know the user's location. Some of the questions will also have to relate information from databases and other resources such as restaurant guides to the GIS. Of particular interest for tourist applications are questions that relate to historical and temporal changes. Here we also need temporal databases. And in many queries, the system has to handle fuzzy and user-specific measures such as "interesting", "ugly", or "in reach". In the following, the GIS and the databases of Deep Map are presented. Together, they form the core knowledge repository.

2.1.1. An Agent-Based GIS

Albeit Object-Orientation is a natural choice for development, object-orientation alone is too little for such an ambitious project such as Deep Map. Therefore we decided to take a step further and make use of the so-called agent-oriented software paradigm. Agents form a higher level of abstraction in software design. Moreover, the agent-based approach allows an easy re-use of components in different systems that may consist of a different set of agents and thus providing another range of services. This is especially important in our scenario where we have two quite different application platforms: a Web-based system for home-users (Zipf and Malaka 1999a) and the mobile system for a tourist on site (Zipf et al. 2000).

The GIS and databases are accessed through the following agents (Fig. 1):

- the *database agent* retrieves non-spatial information from the database,
- the *geo-spatial agent* retrieves spatial information from the GIS and performs a range of geo-spatial computations on that information,

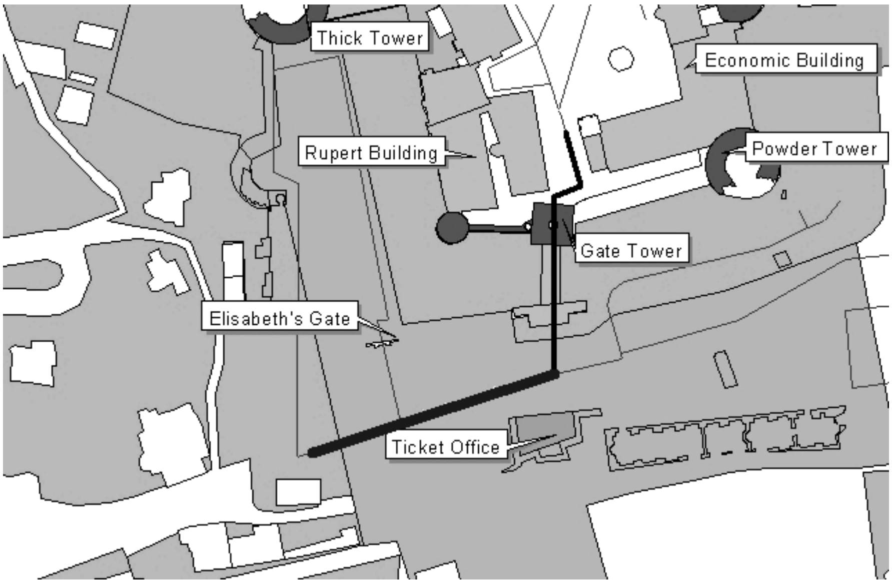

Fig. 2. Example of a map produced by the first version of the Map Agent with a tour and its active tour segment highlighted.

- the *route agent* computes and manages routes and their segments,
- the *map agent* generates and handles maps and their visualization.

First prototypes of these agents have been developed using the ArcView GIS as server platform. The agents themselves communicate via a message bus (Java Agent Management framework - JAMFrame (Chandrasekhara in prep.). Fig. 1 shows an overview of the System. The GIS-agents are implemented using Java wrappers that communicate with the ArcView GIS running on a specified server via RPC (Remote Procedure Call). Since on the one side, only string messages can be passed via RPC and on the other side, messages on the bus are represented as Java objects, these objects must be converted from/to text. For this reason an XML notation is used that allows the automatic conversion of Java objects from/to XML using the Java reflection API.

As an example we present one of these agents in more detail: The task of the Map-Agent is to render maps of specified areas. After receiving an appropriate request it figures out the suitable area and requests the geo-spatial data from one or more specified servers. Other options include the possibility to specify which data has to be shown explicitly and which have to be highlighted. In particular it is possible to visualize previously calculated tours as well as highlighting particular (actual) sections of these routes by specifying their identifier (Fig. 2).

A first version of the Map-Agent creates a map as a raster image on server side and returns this image to the requesting agent. The new Java based version gets the geometric data of the spatial features, that have to be displayed from a geo-server, and renders this vector data on client side. These two approaches will be evaluated against each other. Both belong to the three possibilities the OpenGIS Consortium identified in their recent Web Map Server Specification draft (OpenGIS 1999). The first one is the so-called picture case and the second the feature case. Similarly, the other agents allow flexible access to the data and can be parameterized in various ways in order to suit the user's needs.

2.1.2. The Tourist Database

Most of the knowledge and data about our tourist destination is stored within the GIS and a database we developed to capture all the information about the history, geography and cultural items o Heidelberg. We want to offer the most flexible ways to browse through the knowledge within our database on geographical and historical information on Heidelberg to the different users of Deep Map. Therefore we needed to develop a data model capable of integrating very different kinds of information in a very flexible way. This resulted in an "event" based data model for historical geo-referenced data. This relational data model consists of relations of different types between locations (several types of spatial objects and their respective subclasses) - persons (historic, real and legal persons) and (historic) events of different granularities. As it supports different media types from text images, video, sound to 3D and VR models, and all the links and relationships between these multimedia documents and literature, persons, places and events and as it is geo-referenced through the coupling of the locations in the database with the GIS, the data base has the power to act as a prototype of a digital library for Heidelberg. This is being realized within a conventional relational database, resulting in a quite complex data model with over 120 tables in spite of our struggle to keep it as simple as possible.

For easy data maintenance, an user interface for data input has been developed, that supports sophisticated access and maintenance for different kinds of users (Häußler 1999). All information in the database can be given a time period for which it is valid. This period can be specified with different granularity and also supports the specification of the accuracy of the data entry to allow fuzzy time specifications, what is often necessary for historic data. Even though, the data collection is only done for the city of Heidelberg, the database is developed in a general way such that it could easily be used for any other city.

2.1.3. From 2D to 3D Information Systems

Normal maps just contain 2D information. For many aspects in our application, however, 3D information is needed. For instance, the natural language interface described below, needs 3D information in order to direct a person to a city. The reason for this is that we attempt to generate route instructions that do not sound as

go 205.4 meters straight, turn 30 degrees to the right and go 67.9 meters straight,

but rather like

follow the street and turn right after the big red building and head towards the church.

In order to do so, we need knowledge on the visibility of objects from each location and we need the 3D information for the selection of good landmarks that are both prominent and visible. 3D-information can also be used for resolving queries such as "What is under the Karlstor?" that impose three-dimensional topological questions. Such questions may also occur when tourists ask for architectural details of complex tourists sights such as the famous Heidelberg castle. A third aspect is of course the usage of 3D as a means for visualization. The use of 3D-models is always a very attractive means for visualizing virtual sights of a city.

In the current version of Deep Map, we have extended 3D knowledge for the area of the old town of Heidelberg. Here we have 3D reconstructions of buildings with textures from photographs. For the rest of the city we only have the surface information and can generate simple block-based 3D models.

2.1.4. From 3D to 4D Information Systems

Many types of data are not only spatial but also temporal, e.g., environmental, climate, or city development data (Meusburger and Zipf 1998). In the domain of Deep Map, the need to handle 4D data comes naturally facing questions of tourists standing in front of a historical place like a ruin of a castle asking *how did that look like when it was not destroyed?* In this case we would like to turn back the time and allow a virtual time travel displaying a reconstruction of that place as a VR model. At the moment, we included a 3D reconstruction of the Heidelberg castle into Deep Map, where destroyed parts can be re-built on the user's mouse click.

We also aim at reconstructing less spectacular buildings in order to be able to allow the virtual view back into history at other locations. For this purpose, a collection of architectural elements (windows, roofs, doors etc.) that have been used during the centuries is being initiated. This database serves as a repertoire of building blocks for reconstructing buildings at different locations and epochs (Weinmann et al. 2000) where old maps and images (photos, paintings, engravings) are used for identifying shape and type.

2.2. Personalized and Integrated Services

The vision of Deep Map wants to allow the user to get personalized and easy access to a variety of information. We already described how geographical information, a tourist database and even 3D and 4D information is integrated within the databases of Deep Map. We now want to outline aspects on how these data can be used for personalized services and how a user can access multiple data sources without complex queries.

2.2.1. Proposing personalized tours to tourists

For Deep Map, we develop a tour planning system that is capable of generating individual tour proposals through a city based on the personal preferences and interests of a tourist. In order to achieve this, several problems have to be solved. These include recognizing of the individual interests. For building such user models, we plan to integrate user model components that are built together with colleagues from GMD[1].

If the user interests are known, there are several possibilities how to include them into a tour planning or tour proposing algorithm. First of all the range of possible attributes that may influence the choice for a particular section of a route have to be identified and modeled. Appropriate variables have to be included into the database and attached to the street network within the GIS. Such attributes include both „hard“ restrictions, or physically given attributes (like height, steepness, turn rules, legal rules, etc.) as

[1] German National Research Center for Information Technology, Bonn.

Fig. 3. Calculated tours for passenger with high preferences against noise and smoke versus high preferences for attractive areas.

well as a range of more dynamic and „soft“ parameters, which importance can vary extremely from person to person or time to time. Such parameters could include esthetic aspects, the social milieu of the area, dislike of motorized traffic or preferences for areas with high degree of architectural interesting buildings or just a high rate of nice viewpoints.

Right now we have developed two planning algorithms that take into account a range of hard and soft parameters for each street section. They are implemented using the Network Analyst extension for ArcView GIS. One is based on interpolating so called service areas on the street network, the second is based on buffering the street network algorithms (Roether 1999, Roether and Zipf 2000). The maps shown in Fig.3 the results of the first algorithm when varying the degree of importance for particular soft parameters are displayed. The first is the result, when there is a high dislike of smoke and noise and the second shows the route with a preference for attractive areas in general. Thematic interests such as interest in particular architectural epochs or for particular persons are not taken into account within this examples. Right now the tourist can choose between several modes of transportation (car, foot, bike and wheelchair).

2.2.2. Information Integration

Apart from the core databases, additional data sources are necessary for online data that has to be updated frequently, e.g., hotel reservation services. The user, however, should not be bothered with a variety of different interfaces for these systems. Moreover, the user should have seamless access to those systems without even realizing that not only one database but a whole set of integrated databases and services are connected within Deep Map. Therefore, the system must provide standardized means for the integration of these additional sources that are independent of the core system. This is also essential for continuous automated database maintenance.

There are several possibilities for technical solutions for that problem that have to be combined on multiple levels of abstraction. In our framework, we employ an agent-based approach (Fig. 1 and 4) where agents communication complies with the FIPA standard (FIPA 1997, 1999). The underlying communication system of the agent platform for sending and receiving messages uses the middleware technologies CORBA or RMI. This allows a flexible distribution of the components on a network and also the integration of service agents that reside on remote servers.

The message content is modeled using an object-oriented ontology that is represented in a class hierarchy. This allows an agent communication where agents can communicate on a higher semantically level. Moreover, this ontological approach allows a unified representation and translation of concepts for all sub-systems.

2.3. Human-Computer Interaction

Usability is one of the most important aspect for the future success of tourist information systems such as Deep Map. The tourist as a user who wants to use the system for entertainment and on vacation won't bother with an extended tutorial or with complex interface languages. The system needs to be intuitively usable and it should be comfortable to carry and to use it. Fig. 4 shows the architecture of Deep Map in a view that shows how the layout of the system provide means of easy access.

The interface layer provides multiple modalities for input and output. For mobile use, natural language is one important modality that allows hands-free operation which is important for a user that moves as a pedestrian or car driver. Here, visual information is not adequate. In other situations, a visual/graphical user interface (GUI) can be useful when complex information has to be visualized, e.g., in maps. An additional 3D interface allows interaction with 3D VRML models. Note that not each modality is used at every time. In particular, the 3D interface is currently only used for the stationary PC version due to computational performance restrictions on the mobile device.

The cognitive layer aims at translating human concepts into system queries and system responses back into human-adequate presentations. The query and answer translator (QUATRA) and the presentation planner are doing this for either direction.

On the knowledge layer, the GIS and databases presented above, external services and other systems provide the knowledge on the contents and on how to solve problems like tour planning.

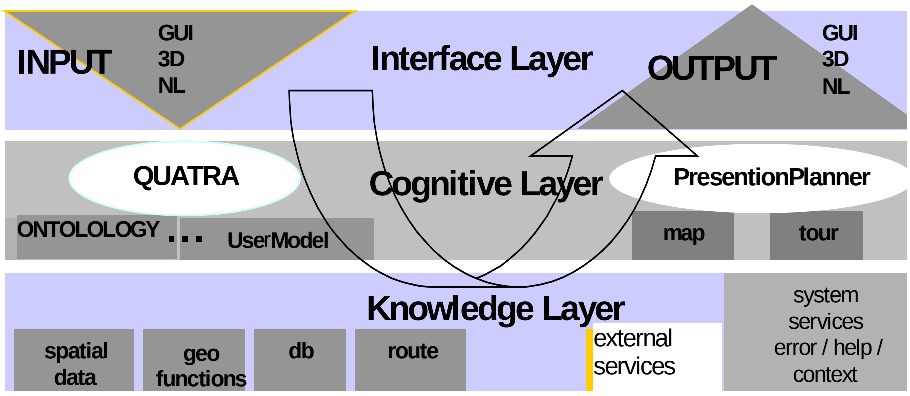

Fig. 4. Deep Map Architecture.

2.3.1. Natural Language Processing

A natural language interface for a system like Deep Map that is not a command-word driven interface but that allows free speech and real dialogs, is a quite ambitious research project. The focus of research at the EML lies in building components for NLP systems that allow a deeper understanding of utterances beyond their word-by-word meaning. Another focus is the multi-modal integration of NLP with gestures on the input and graphics on the output side.

Currently, the system uses a recognizer and parser for English provided by the Interactive Systems Labs (Woszczyna 1997). For language understanding, we also employ modules of DFKI that deal with spatial relations (Kray and Blocher 1999). A special focus in language generation lies on natural route instructions that are similar to those used by humans (Porzel et al. 2000). Next to the English version, a German and a Japanese version are in preparation. The scientifically most challenging question is the translation of queries like: ”How do I get from here to the castle?”, ”Is there a bakery?”, ”What is this?”, ”What was here before?” Such sentences have to be disambiguated and translated into database queries. The user’s context and previous experience may help the system and if necessary, the system has to ask qualifying questions like ”Did you mean the big red building on your left?” Language understanding also requires an intermediate representation (knowledge representation, formal ontology) that represents the concepts within the Deep Map database.

2.3.2. Virtual City

Next to NLP, graphical interface techniques are of high importance. Graphical information is very useful when complex spatial data has to be given to the user. Maps as a two-dimensional representation are widely used for this purposes (Fig. 2). We also use the 3D modeling and 3D reconstruction in various ways. If, for instance, a tour has to be visualized, we can display the tour in a 2D map, but we can also give a 3D relief picture that can help the user to identify landmarks and thus make it easier to grab the spatial information. Advanced techniques could also visualize a tour in a video sequence where the user is taken on a virtual flight through the 3D model of Heidelberg (Zipf and Malaka 1999a, b). Moreover, the three-dimensional Virtual Heidelberg al-

Fig. 5. Tourist with Mobile Deep Map System based on a wearable computer.

lows users to take virtual walks through today's and yesterday's Heidelberg. In a prototype of our Web-based system, the tourist will have the possibility to go on a virtual tour through Heidelberg.

2.4. Mobile System

Deep Map appears as a system with different faces. One version is be a Web-based planning and exploring tool for virtual visits and pre-trip planning. The mobile version uses a wearable computer that allows hands-free usage. The current prototype is based on a wearable computer (Xybernaut MA IV) with a handheld color LCD display and a light weight headset with microphone and earphones (Fig. 5). For instant access to services in the net and for server access, the system is equipped with wireless LAN that allows data communication with stationary computers. The current mobile version is realized as a prototype that can be used for a limited area around Heidelberg castle.

3. Current State and Future Directions

Deep Map is not a product but rather a framework that poses a long term challenge to our research. Nevertheless, a first prototype already demonstrates the concepts of Deep Map in a real world scenario. This first prototype includes natural language processing, GIS, databases, VR simulations, combined multimedia presentations on tourist sights, all available on a mobile "wearable" computer. Thus this proof of concept demonstrates the new possibilities for IT-based tourism guidance.

Next to the mobile system, a Web-based interfaces allows to use Deep Map components from a home PC. This scenario employing two faces of one system makes a perfect tourist assistant that can help the user at home and on her visit. In the next stages, we plan to extend the system such that we can work on usability studies. Meanwhile, further research is done on all areas of Deep Map: GIS, databases, agent systems, VR modeling, user interfaces. In particular for the mobile use of Deep Map, performance issues concerning the quality of service, location awareness and networking are of importance.

3. Conclusions

Tourism and IT are two areas that fit well together. On the one hand, IT has continuously influenced tourism and the use of advanced IT products in Tourism is still growing. On the other hand, tourism makes a perfect application domain for IT research on new interactive user systems that allow easy access to complex information systems. Both aspects are covered by Deep Map. It represents a vision for future tourism assistance systems and it incorporates challenging IT research. Even though a product with Deep Map technology will need another five years of development, some of the demonstrated features could soon be integrated in simpler but still useful systems.

There are a number of lessons that can be learned from Deep Map. Each single field of research brought further insight into new and challenging aspects of IT research. On the level of the whole system, the main message from this project is that real progress in building ambitious new IT applications for the future, require a whole set of intelligent technologies rather than just one new idea. The integration of various techniques such as databases, artificial intelligence, natural language understanding and more is a very hard task but it sets the stage for those new and easy-to-use systems we will take for granted once they are available. Deep Map already outlines how such a system can be used in the tourism domain.

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References:

Chandrasekhara, V. (in prep.): *Jam Frame. The Deep Map Java agent management framework*.

Foundation for Physical Agents (FIPA) (1997) *Agent Communication Language ACL / Agent management (Specification version 2.0)*, http://www.fipa.org

Foundation for Physical Agents (FIPA) (1998) *Specification version 1.0*, http://www.fipa.org/spec/fipa98.html

Häußler, J. (1999) *Prototyp eines GIS-gestützten historisch-geographischen Städtführers für das WWW*, Diplomarbeit, Geogr. Institut der Universtät Heidelberg.

Kray, C. and Blocher, A. (1999) *Modeling the Basic Meanings of Path Relations*, Proc. of the 16th IJCAI, Morgan Kaufmann: San Francisco, CA, 1999

Meusburger, P. und Zipf, A (1998) *Auf dem Weg zu einem 4D-Geoinformationssystem - das Projekt Deep Map*, HGG-Journal, Heft 12.

Open GIS Consortium (OpenGIS) (1999) *The Web Map Server specification* (draft), http://www.opengis.org.

Porzel, R. Klabunde, R. and Jansche, M. (2000) *Generating spatial descriptions from a cognitive point of view*. In: Olivier, Spatial Language, Kluwer, Dortecht, to appear.

Roether, S. (1999) *GIS-basierte Routenfindung mit individuellen Streckenpräferenzen*, Diplomarbeit, Geographisches Institut der Universtät Heidelberg.

Weinmann, R., Häußler, J. Zipf, A., Malaka, R. (2000) *Die Besucher Heidelbergs informieren: Die multimediale Deep Map Datenbank*, In: HGG-Journal 1/2000, to appear.

Woszczyna, M. (1997) *Fast speaker independent large vocabulary continuous speek recognition*, Ph.D. Thesis, University of Karlsruhe.

Zipf, A. und Malaka, R. (1999a) *3D und 4D - Deep Map - das historische Touristeninformationssystem für Heidelberg*, In: GeoBit 07/99.

Zipf, A. und Malaka, R. (1999b) *Web-basierte Planung und animierte Visualisierung von 3D Besichtigungstouren im Rahmen des Touristeninformationssystems Deep Map*, In: AGIT 99. Salzburg.

Zipf, A., Chandrasekhara, V., Häußler, J. and Malaka, R. (2000) *GIS hilft Touristen bei der Navigation – ein erster Prototyp des mobilen Deep Map Systems für das Heidelberger Schloß*, In: HGG-Journal. 1/2000, to appear.

Zipf, A and Roether, S. (2000) *Tourenvorschläge für Stadttouristen mit dem ArcView Network Analyst*, In: Liebig: ArcView Arbeitsbuch, Huethig Verlag, to appear.