NEXUS - Integrating Data and Services for Mobile Users of Location Based Applications

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Abstract. Within our society, the demands regarding individual mobility are increasing continuously. Thus, also the amount of traffic that is produced on highways and within cities is intensified. For this reason, it will be more and more important to manage and to guide the individual traffic so that the capacity of traffic networks can be exploited more efficiently and that traffic jams are reduced. For just-in-time traffic management, information and services have to be combined in a suitable way to support the mobile users.

An approach for this purpose can be delivered by the NEXUS project. It aims at the development of a generic and open platform that offers the possibility to access so-called location-based information and services. NEXUS is currently being carried out within a research group supported by the DFG (German Research Council) in cooperation between the Institute for Photogrammetry, the Institute of Parallel and Distributed High-Performance Systems and the Institute of Communication Networks and Computer Engineering of the University of Stuttgart. The central task of the project deals with data management aspects with respect to location awareness. Concerning traffic aspects, current data and navigation services can be combined within the NEXUS platform in order to improve the individual traffic management.

Within this paper, the architecture of the platform as well as the basic aspects of the Augmented World Model will be described in more detail. Within this context, also the integration of different data sources within the platform and the services provided by NEXUS will be presented. Furthermore positioning techniques within NEXUS will be discussed.

Key Words: Location-based Services, data management, positioning services

1 Introduction

Applications providing support for mobile users are becoming more and more important in a lot of different situations. People using little digital helpers are able to access information wherever they are, e.g. navigation information, information about the surrounding area or information about traffic, etc. . Mobile information services can be subdivided into two categories, depending on the way information access is controlled: Usual information services that access on information without regarding the users current location and so-called location-based services (LBS), which use the location information as one of the most important parameters [Fritsch 01]. Nowadays some proprietary LBS solutions exist as closed systems, concerning only one kind of service and preparing the necessary data depending on this special application. The disadvantage of this top down approach is that another solution is not able to use these proprietary data, but the same information must be prepared individually according to the needs of other applications. Thus another approach is to define and use an open platform comprising a scalable system architecture, which specifies basic services, open protocols and open data exchange formats needed for location-based services. NEXUS aims at the development of such a generic platform. The central feature of the platform consists of a model of the real world called the Augmented World Model (AWM). The AWM represents the real world digitally and augments it by virtual objects. Changes within the real world are directly reflected within the model. Using the AWM, information that is of importance for the mobile NEXUS user at his location can be provided. The only prerequisite is that the user knows his current position to be able to access the relevant information stored within the computer model. The positions of the mobile users can be detected by appropriate sensors. Beside GPS, GSM, etc., also hybrid methods exist which offer the possibility to use images for the positioning process.

2 Architecture and Data Model

2.1 Architecture

As shown in Figure 1, the NEXUS architecture is organized in three layers: The top layer contains the clients on which the applications run. The bottom layer consists of various servers that store the data provided by the NEXUS system. Compared to the WWW, the applications within the top layer play the role of web browsers and the servers within the bottom layer that of HTTP or FTP servers. Hence we call the top layer the Application Layer and the bottom layer the Service Layer. The middle layer federates the different data sources of the Service Layer to provide a unified view for the applications [Nicklas 01a].

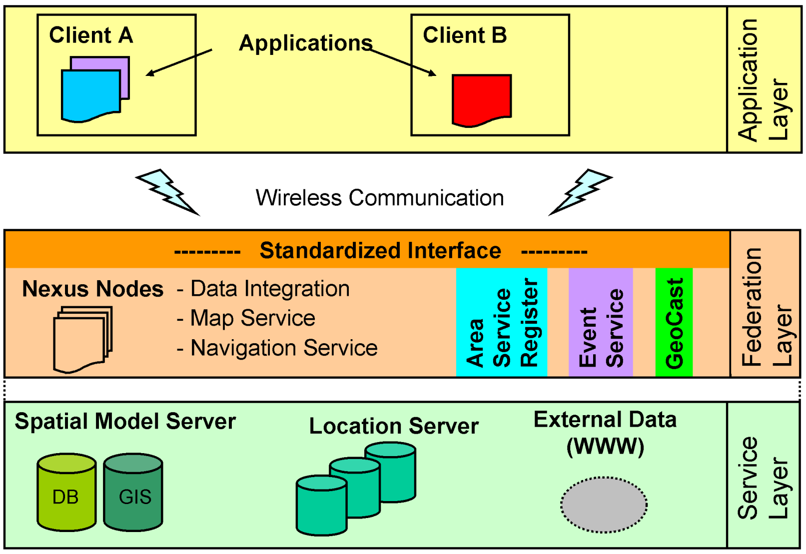

Fig. 1: The architecture of NEXUS is organized in three layers

Any application request is directed to *a NEXUS Node*. On each of the nodes, a federation component is running. The NEXUS nodes are responsible for developing a strategy to respond to application requests. They distribute the queries on the appropriate components of the Service Layer, namely the Spatial Model Servers and the Location Servers. A *Spatial Model Server* stores and manages the static spatial data (like buildings, streets, etc.) of one or more geographical areas. It also provides the necessary geoprocessing functionalities. Within NEXUS, spatial objects can also be linked to external information items like web sites, thereby creating a spatial context for this information. The *Location Servers* are dealing with the management of the user positions.

In order to create a strategy to answer application requests, a NEXUS node must identify which spatial data have to be used for query processing. For this purpose, the *Area Service Register* is established. It can be understood as a metadata repository or a spatial search engine, storing general information about spatial data sets (like spatial extent, level of detail, stored object classes etc.) and the addresses of the Spatial Model Servers where they are located. The Location Servers are providing efficient mechanisms to detect the current storage location of a mobile object on their own and for this reason the federation can address an arbitrary Location Server instance [Leonhardi 01].

After having queried the Spatial Model Servers and the Location Servers, the NEXUS nodes integrate the data that are returned from the Service Layer and provide additional services like navigation or map production. Eventually, the results are propagated to the application, taking into account its interface specifications.

There are additional components of the Federation Layer which offer further functionalities important for location-based services. The *Event Service* allows to notify the user about a predefined spatial situation. For example, a user might want to receive a message each time he is in the vicinity of a sports store. *Geocast* deals with techniques to send messages into geographical regions. With this functionality, useful services of the NEXUS system can be realized, like e.g. the 'virtual warning sign' scenario depicts. It assumes that in case of a car accident all other cars approaching the place of accident receive a warning information.

The interfaces of the NEXUS components have been defined in XML. Basically, the data exchange is realized using the SOAP protocol [W3org].

2.2 The Augmented World Model

The Augmented World Model is a common, object oriented data model that enables a federation of different data sources and allows a unified view on them. It comprises the standard class schema, a generic set of all object classes that might be of relevance for location aware applications. To achieve a reasonable semantic, each standard class contains an extensive set of attributes. However, most of the attributes are declared *optional*, i.e. a NEXUS service does not have to make the effort to provide all of the data, but if it wants to, the name and type of the attributes are defined. In case that an application still needs additional object classes that further specify the existing ones, they can be inherited from the classes of the standard schema, forming a so-called extended class schema [Nicklas 01b].

3 Positioning Methods for LBS

3.1 General Overview

Within the field of information services two main classes exist, as illustrated in the introduction. In case of location-based services the position information is one of the most important parameters. When LBS are described everybody has in mind small digital helpers that run different applications. As digital helpers are small, also positioning tools should be wearable, too. Of course it is not essential in case of a prototype, but the technology must offer the possibility to be minimised in future. In case of proprietary solutions often GPS technology or positioning techniques using the GSM infrastructure are recommended. In GSM Networks different approaches exist to compute position information depending on wave propagation between GSM device and receiver antennas. But not only the availability of position information is essential in case of LBS, in the same way also its accuracy is of interest. Some applications are only possible if position accuracy is high, e.g. if the mobile user want to access on object based information that depends on his current position.

The major functionality of positioning sensors can be divided into two categories: self-positioning and remote positioning. In self-positioning, the objects themselves determine where they are. Positioning receivers are able to make the appropriate signal measurements from geographically distributed transmitters and use these measurements to determine their own position. As an example, GPS is a self-positioning system. In remote positioning systems, receivers at one or more locations measure a signal originating from, or reflecting off, the object to be positioned. The use of GSM for determining the position can be classified as remote positioning.

As the principles and applications of popular positioning systems like GPS, etc. are discussed in many articles, this will be skipped here. In case of NEXUS, not only approved technology for positioning is of interest, but also new approaches are considered. One approach is the use of images and landmarks to provide positions of the mobile user or that of objects. It is of interest because this is also the way how people do their positioning. With the help of a small camera, a part of the environment the user is located at is captured. The idea is, that any captured image only can be provided from one special position or orientation, respectively. Using image analysis techniques, a 3D-model of the environment and spatial resection, the coordinates of the camera could be processed. Since users will move both outdoor and indoor, the advantage of this method is the usability for positioning in both areas. For indoor purposes, also some more special positioning techniques exist. Most of the indoor systems are so called tagging systems. The idea of that is to mark objects in a special manner, in order to be able to identify them precisely. Tagging systems do not locate persons or objects, they locate the tag which is fixed to the object. Self-positioning in indoor is feasible with devices permanently sending a unique ID, e.g. via infrared signals.

At last, the user can act as "sensor" by himself, e.g. if no positioning devices are available or if they fail. In some situations he/she can mark the current location within a provided map. Determining the position within the map, the application is able to provide it to further services. In Tab. 1, an overview about the quality of the described sensors is given. The positioning accuracy therefore is categorized in three levels: high (1-5m), middle (20-100m) and low accuracy (> 100m).

sensor type	mode of operation	accuracy
GPS (with SA)	self-positioning	low
real time DGPS	self-positioning	high
GSM	remote positioning	low
images / landmarks	self-positioning	High
tagging systems	remote positioning; self-positioning	high / middle
user (pointing to map)	self-positioning	high / middle

Tab. 1: Quality of position information

3.2 Hybrid Positioning Systems

As described before different methods for positioning exist. Hybrid location systems combine technology in a way that allows the strengths of one to compensate for the weakness of the other to provide a more reliable and robust location solution. In chapter 3.1 the use of digital camera systems was mentioned as a method for position estimation. Within the field of close range photogrammetry this technique is well known, whereas the idea is relatively new to use it as a hybrid system within the LBS sector. To delimit to close range photogrammetry the approach in context to LBS is called mobile photogrammetry. It combines conventional systems for navigation and a digital camera to improve positioning.

In addition to technical equipment the use of mobile photogrammtry also requires a model of the environment, to be able to compute position information. As a model, e.g. a highly detailed 3D city model or a more abstract one can be used, depending on the required accuracy of location information. In case of NEXUS, a 3D representation of the city of Stuttgart is available, containing highly detailed geometrical information about the buildings. The prototype sensory for mobile photogrammetry consists of several devices combined into one tool. In addition to images the device also collects the approximate orientation by means of a digital compass and the position using a differential GPS receiver. The hybrid operation illustrated in Fig. 2 allows to combine GPS measurements and further information. In case of mobile photogrammetry the image, the model and the compass measurements are combined within a spatial resection algorithm [Klinec 01].

DGPS	+	IMAGE	+	COMPASS	+	MODEL	=	HYBRID
High Accuray		Good Accuray		Middle Accuray		High Accuray		High Accuray
Good Yield		High Yield		Good Yield		High Yield		High Yield

Fig. 2: Hybrid operation

4 Applications for mobile user support

So far the prerequisites for location-based systems were discussed. Based on the prototype of the NEXUS platform two applications have been developed, which demonstrate the functionalities of the infrastructure. The CityNav application includes some features in order to offer an easier map handling and an automated access on object information [Klinger 2000]. Fig. 3 illustrates its user interface and displays the telepointing functionality, which offers the possibility to access information about objects by pointing at them. Since the mobile device is equipped with a differential GPS receiver and a digital compass the position and direction a user is looking in can be superimposed with map information. The line of sight can be drawn into the map. Due to inaccuracies of the digital compass and the GPS receiver a triangle has to be constructed that represents the tolerance, in which the line of sight can actually be. By intersecting the triangle with the geometry of other object classes represented within the map, an identification of the objects a user is looking at can be realised.

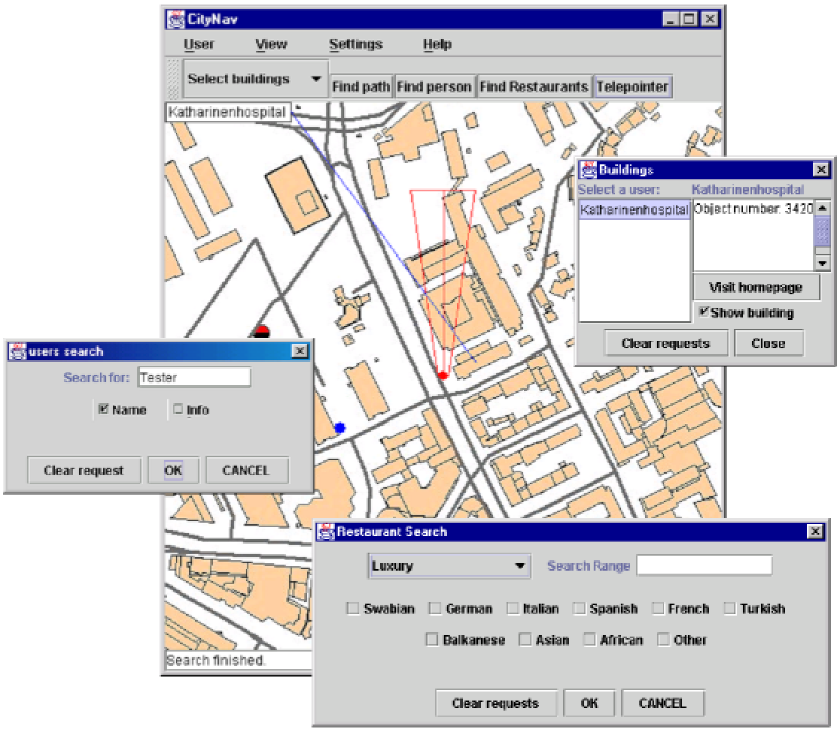

Fig. 3: Interface of the CityNav application

The second application uses virtual objects, so-called Virtual Information Towers (VITs), as metaphors to structure information spatially [Leonhardi 00]. The VITs are an electronic equivalent to real-world advertising columns. VITs have a certain geographical position and a given range of visibility attached to it. They host information and services that are relevant at the given location [Volz 00]. A mobile user has access to the information on all the VITs that are "visible" from his current position. Moving through an area, the application selects and displays those VITs. Fig. 4 shows a map containing VITs as seen by the user. The current position of the user is detected by a differential GPS receiver and indicated by the big (blue) dot. On the left there is a list of currently visible VITs. The application allows to browse through the hierarchical content of the available VITs. Via the VITs not only information stored within the NEXUS databases can be accessed, but also external resources like web pages or digital libraries are accessible so that, for instance, information stored in the WWW can be assigned to a geographical position or area, respectively.

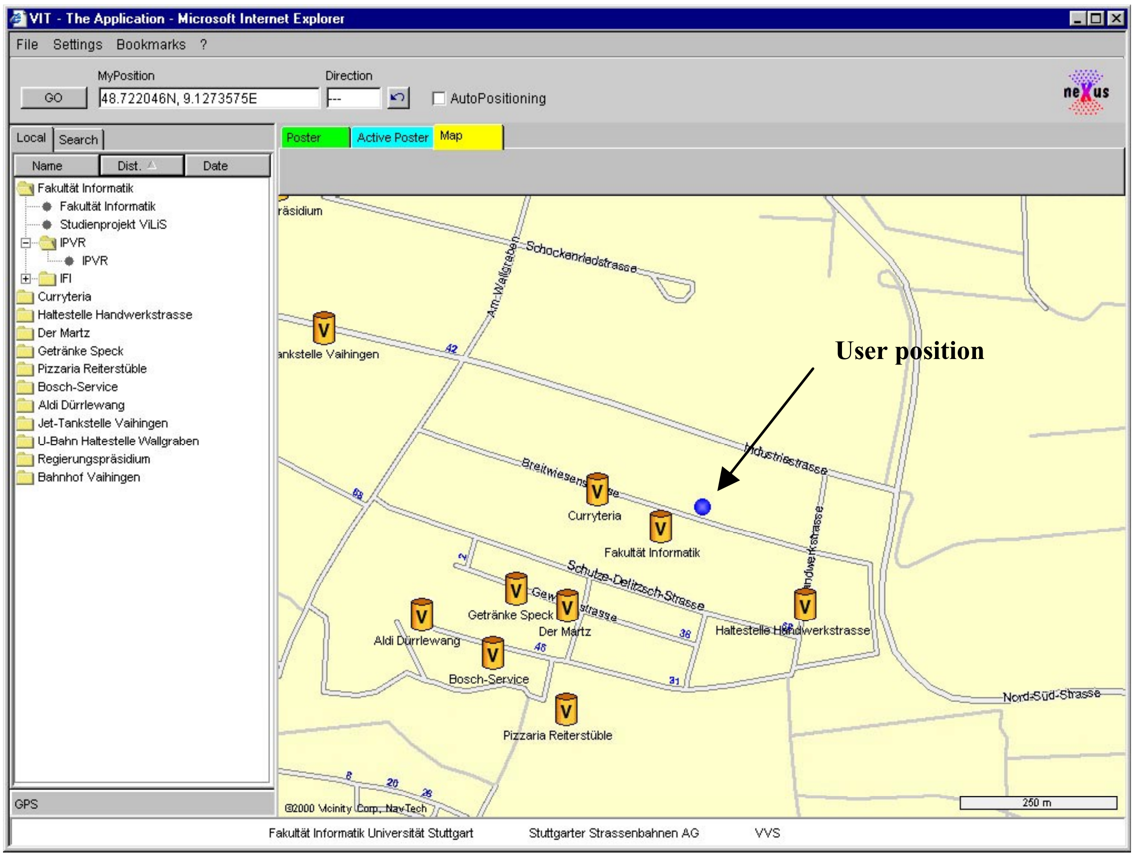

Fig. 4: Interface of the VIT application

5 Conclusion

The NEXUS concept focuses on the development of a global platform in order to support different kinds of location-based applications. It is intended to facilitate the access to required services and information by means of the infrastructure. Therefore, a common data model must be managed within a distributed system architecture. As a further prerequisite for the realization of location-based applications, the position of the users has to be known. For some applications a high accuracy of location information is required. It can be derived by hybrid positioning. So far, some prototypical implementations of NEXUS-based applications are available which are demonstrating basic features. Ongoing work is aimed at integrating further services of the platform like GeoCast or Spatial Events into the existing prototypes.

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