Information Management for Location Aware Applications

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ABSTRACT

Within the scope of the research project NEXUS that is being worked on at the University of Stuttgart 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, a generic platform supporting location aware applications with mobile users will be developed.
In order to facilitate the access to location-based information, distributed data sources and services have to cooperate within the NEXUS infrastructure. Therefore, a federated data management component has to be realized that allows an integrated view on data and services and that offers a standardized interface for applications. Besides that, mechanisms within the platform have to allow for an efficient retrieval of the relevant information.
In this paper, an overview about the information management strategies within NEXUS will be given. Furthermore, the approaches of existing client interfaces are presented briefly.

1. INTRODUCTION - GENERAL CHARACTERISTICS OF THE NEXUS PLATFORM

In times of increasing possibilities to access information of all kinds, it is often difficult to find efficiently what one is interested in. Thus, a growing demand for methods to structure information according to individual needs can be observed. Location aware applications offer an approach for this purpose: they are running on mobile computing devices, know the positions of their users and provide information and services that are of special importance at their current location. The goal of the NEXUS project is to develop a generic infrastructure that supports location aware applications. The most important properties of such an infrastructure are mentioned within this section.
Since the NEXUS platform is designed to contain huge amounts of data and various services which many users can access simultaneously, it is organized as a distributed system. Starting from a use case analysis, we have identified the necessary system components and designed an architecture for the infrastructure. Furthermore, we have specified the basic interface that the platform offers to the clients and applications respectively. In this context it has to be considered that different kinds of mobile devices like cellular phones, personal digital assistants or wearable computers being equipped with different sensors to capture the current contexts of the users are accessing the infrastructure. Therefore, an adequate interface to cover the demands of all possible combinations must preferably be realized. Also, the interfaces between the components of the infrastructure have been defined. Architecture and interfaces provide the basis for the information management within NEXUS.
In terms of an open system, anyone should be able to add new information sources to the platform in a straightforward manner, just like a new web server can be registered at the Domain Name Service. Therefore, we have developed an object oriented data model, the Augmented World Model, that allows to federate information from different providers into an integrated view for the applications (D. Nicklas & B. Mitschang, 2001). Within the NEXUS framework, especially the problems of interoperability of spatial data - as they have been addressed by R. Laurini (1998) - have to be taken into account. For this reason, homogenization mechanisms (V. Walter & D. Fritsch, 1999) have to be realized. Moreover, the spatial data must be offered in multiple representations in order to meet the individual needs of different applications. Hence, appropriate algorithms to deduce all the necessary levels of detail have to be implemented (K.-H. Anders & M. Sester, 1997).
The clients of the NEXUS system will apply different kinds of mobile communication technologies like wireless LANs (according to IEEE 802.11b) or WANs (e.g. GPRS). Therefore, a handover be-

tween these different networks has to be realized. Also, the adaptivity of the communication within NEXUS has to be guaranteed, so that, for example, bandwidth changes do not cause a breakdown of applications or the system itself.
Another vital aspect concerning the acceptance of NEXUS deals with the privacy of data and the protection against illegal data manipulation. Different approaches to avoid the abuse of personal data are being followed. They either try to reduce the accuracy of location information or aim at concealing the identity of the NEXUS users.
This paper focuses on the mechanisms that realize the information management within NEXUS. At first, the Augmented World Model is presented. Section 3 is dedicated to the architecture and the techniques and interfaces for data exchange. Within section 4, the concepts for efficiently providing information to the client are introduced. Eventually, the existing applications are described in section 5 before the article ends up with a conclusion.

2. A COMMON DATA MODEL – THE AUGMENTED WORLD MODEL

The applications must be able to perceive the combination of different spatial data sets as one big single model on which they can operate, i.e. the complexity of the distributed management of heterogeneous data has to be hidden from them. In order to allow this uniform view, an object oriented model has been developed (see Figure 1). 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 extenive 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. Anyone obeying the simple rules of our underlying data model can add information to the NEXUS platform. Since this data model should not only include real but also virtual objects, we have called it Augmented World Model (AWM).

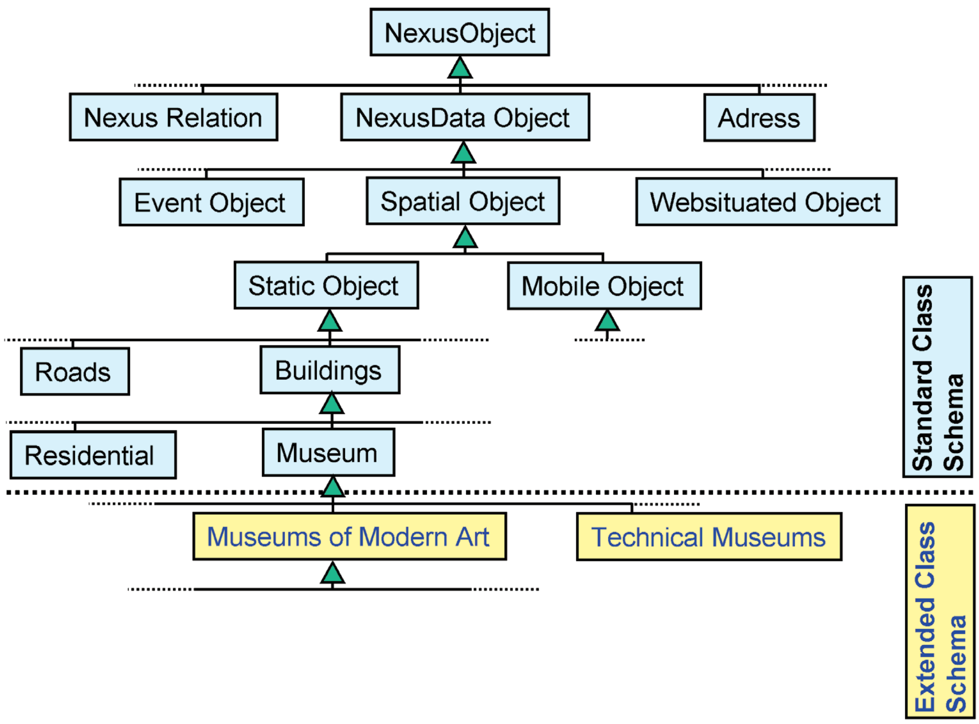

Figure 1: A clipping of the Augmented World Model, illustrating the idea of extensibility.

3. INFORMATION MANAGEMENT WITHIN NEXUS

The NEXUS platform has to be a generic infrastructure that supports all kinds of spatially aware applications. Therefore, appropriate components have been identified that provide the required services. They have been arranged to build up a federated architecture for the NEXUS system. Furthermore, transparent information exchange structures and the interfaces of the platform have been defined.

3.1. Architecture

As shown in Figure 2, the architecture is organized in three layers. Compared to the World Wide Web (WWW), the applications within the top layer can be seen as web browsers and the servers within the bottom layer as HTTP or FTP servers. The middle layer has no equivalence in the WWW architecture. It integrates all available NEXUS services into a single federated view, the Augmented World Model, which is then consistently presented to the applications.

3.1.1. Application Layer

Generally, NEXUS clients or applications are similar to web applications like browsers or applets. The difference is that they are mainly running on mobile devices which can determine the position of their users and which are able to communicate wirelessly. In order to use the distributed geographical data sources and services provided by the NEXUS platform, the applications have to access the infrastructure via the API of its standardized interface. This interface has to adapt to the different kinds of mobile devices, especially concerning different levels of computing power, different amounts of memory, different levels of network connection or different displays. For example, a PDA requires a completely different user interface than a wearable computer. The NEXUS system has to guarantee platform independent usage. That means that the different operating systems must also be considered by the application interface. A mobile device can run one or more NEXUS applications at the same time, each of which basically consists of three components: the user interface, the application logic and the unit that realizes the communication with the infrastructure.

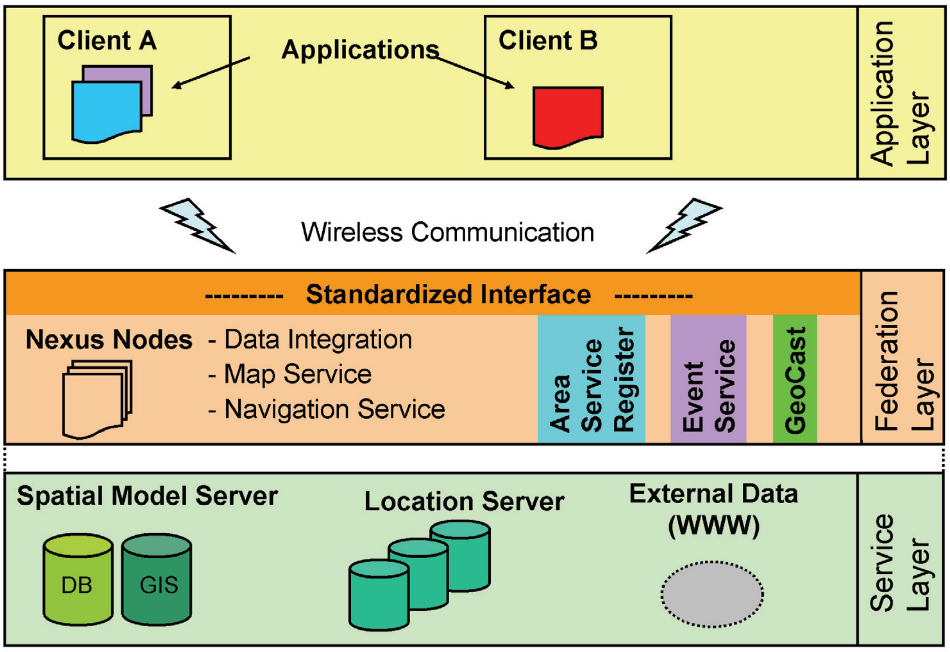

Figure 2: The architecture of NEXUS and its components.

3.1.2. Federation and Service Layer

Any application request is directed to a *NEXUS node* (usually the one closest to the user's location). 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. For this purpose, existing GIS or object relational databases with spatial extensions can be used. 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. Since huge amounts of location data is updated frequently, the properties of standard databases are inadequate. Thus, we have developed a main memory based solution for efficiently storing and retrieving the position data of mobile users (A. Leonhardi & K. Rothermel, 2001).

In order to create a strategy to answer application requests, a NEXUS node must identify, which spatial data has to be used for query processing. Therefore, the *Area Service Register* is utilized. It is a component that is directly associated to the federation. The Area Service Register 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 server instance.

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

Another component of the Federation Layer is the *Event Service*, which actively supports the participants of NEXUS. For example, a user might want to receive a message each time he is in the vicinity of a sports store. Thus, he registers for this event via the user interface of his spatially aware application. Thereupon, an appropriate event predicate, e.g. *[OnEnterArea(polygon, person_ID)]*, is instantiated at the Event Service and the action that must be carried when the event takes place is specified. The occurrence of the event is observed by the event observer component that is aware of the user's position and the sensitive areas around the sports stores as well. This information is to be drawn from the responsible Location and Spatial Model Servers. Then, if the event is thrown by the event observer, a so-called notification service informs the user by sending a message to the client device. Introducing events, the capability of the NEXUS users to perceive their surrounding according to their individual requirements can be extended.

Also assigned to the federation layer is the *Geocast* component that 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.

3.1.3. Communication Aspects

The components of NEXUS are interconnected by a communication unit. Generally, the communication infrastructure consists of fixed and mobile hosts. Fixed hosts are used within the Federation and Service Layer. They run one or more NEXUS services and are attached to the network by wire based interfaces. Mobile hosts, however, are usually carried around by the participants of the system and therefore rely on wireless interfaces. On mobile hosts, there will be more than one network interface since various network technologies might coexist at one place (e.g. a wireless LAN according to 802.11b and a wireless WAN like UMTS). The communication within NEXUS is based on the Internet Protocol (IP), enhanced by several mobility add-ons. The mobility support will be handled in the network layer and for this reason it is transparent for the applications. Furthermore, the communication API of NEXUS has to provide additional functions to the applications, e.g. in order to choose which network interface should be used for data transmission (possibly depending on billing tariffs or other circumstances).

3.2. Information Exchange

In order to guarantee a structured and transparent exchange of information between the NEXUS components on the one hand and the platform and its applications on the other hand, we have defined XML-based languages. For all of them, detailed Document Type Definitions (DTDs) have been specified as a preliminary solution. Since DTDs do not support data types and inheritance, the XML schema concept will have to be applied in future versions.

The Augmented World Modeling Language (AWML) describes all objects that NEXUS can deal with. Generally, it is intended to stick to standards as close as possible. For example, the AWML contains all definitions of the Geography Markup Language (GML), defined by the OpenGIS consortium (OpenGIS, 2000), as a complete subset. For the purpose of queries as well as insert, update and delete operations, the Augmented World Query Language (AWQL) has been defined. It is composed of boolean (and, or, not), comparative (equals, etc.) and geometrical (overlaps, includes, etc.) predicates and allows to select objects. The AWQL can be seen as a subset of SQL, specified to meet the requirements of NEXUS.

Besides these fundamental structures, further languages have been developed, mainly defining the parameters of services. For instance, the Augmented Area Description Language (AADL) specifies which meta information (like spatial extent, contained object classes, etc.) is available for spatial data sets. As a second example, the Map Predicate Language provides the features to describe how a map should look like (format, resolution, etc.).

3.3. Interfaces

Since we have defined XML-based exchange and query structures, functional interfaces of the NEXUS components could be reduced to a minimum. All the query functionality, for example, is encapsulated in AWQL, and so we do not have to specify each possible query as a function, but we can rather use AWQL statements as parameters for a generic query function. Thus, an easy extensibility of the interfaces can be achieved. For each component, four functions are basically sufficient: insert, update, delete and query. For data manipulation procedures (insert, update and delete), change reports are returned so that it is possible to control the success/failure of operations.

4. EFFICIENT INFORMATION RETRIEVAL

In order to improve the efficiency of the access to information and the communication between client and platform, the NEXUS system needs to provide adequate services (D. Nicklas, 2000). These services should facilitate a straightforward user interaction.

Besides an intelligent caching mechanism, a hoarding (or prefetching) component is part of the infrastructure. This component is able to predict, which data will be of interest for the user in the near future and downloads this information in advance (U. Kubach & K. Rothermel, 2001). Thus, the data is already stored at the user's mobile device and can directly be accessed when it is actually required. The prediction is mainly based on statistical analyses: information units are assigned to cells covering the geographical region a user is located in. Depending on the global request for information units, each cell receives an average value, reflecting the probability that a user wants to access the information available within this cell. The attractiveness of information can be very dynamical, i.e. the value of cells might change frequently. Therefore a high rate of updates is necessary.

Directly related to the hoarding service is the idea of info-fueling. It implies that within a geographical region there are so-called hot spots or info stations (typically wireless LANs, see Figure 3) which offer a much higher bandwidth. Thus, if data should be hoarded or if users want to transfer information, the system takes into account that it should preferably be up- or downloaded within a hot spot region.

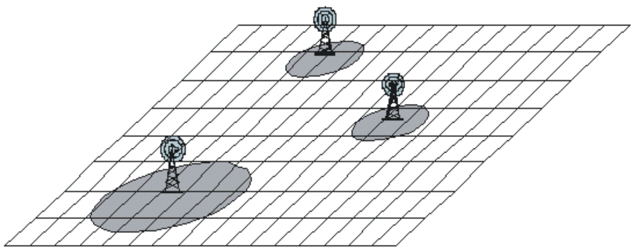

Figure 3: Grey-shaded circles represent hot spots, white rectangles cells of a wireless WAN

As another means of realizing an optimal support for user interaction, it is planned to enable the participants of NEXUS to define their individual user profiles. Thus, by specifying priorities, a selection of information and services a user is interested in within a geographical region will be possible.

5. EXISTING USER INTERFACES

Based on a centralized prototype of the platform, some applications have been developed that are using NEXUS services. The CityNav User Interface which is illustrated in Figure 4 provides some features in order to offer an easier handling for the user (R. Klinger, 2000). Since the mobile device on which the application is running is equipped with a digital compass, the map can always be oriented so that it coincides with the direction a user is looking in. The line of sight can also be drawn into the map. There might be inaccuracies due to the GPS receiver and the compass, and so a triangle has to be constructed that represents the tolerance, in which the line of sight can actually be. Furthermore, by intersecting the line of sight wih the geometry of other objects classes within the map, an identification of objects is possible. This functionality can be used for a service we called Telepointing, which allows to identify objects by adjusting the mobile device in the direction of the objects' location.

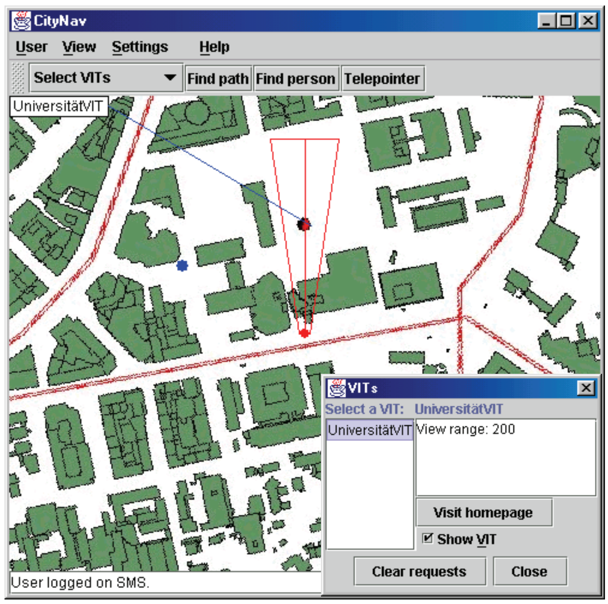

Figure 4: GUI of the CityNav application, illustrating the Telepointing functionality

Another application uses virtual objects, so-called Virtual Information Towers (VITs), as metaphors to structure the availability of location-based information (A. Leonhardi & M. Bauer, 2000). Each of the VITs has a certain area of visibility attached to it, reflecting where the information available at a VIT is most important. Moving through an area, the application only displays those Virtual Information Towers whose areas of visibility contain the location of the user. Thus, irrelevant VITs are faded out automatically. 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 available so that, for instance, information stored in the WWW can be assigned to a geographical position or area, respectively (see Figure 5).

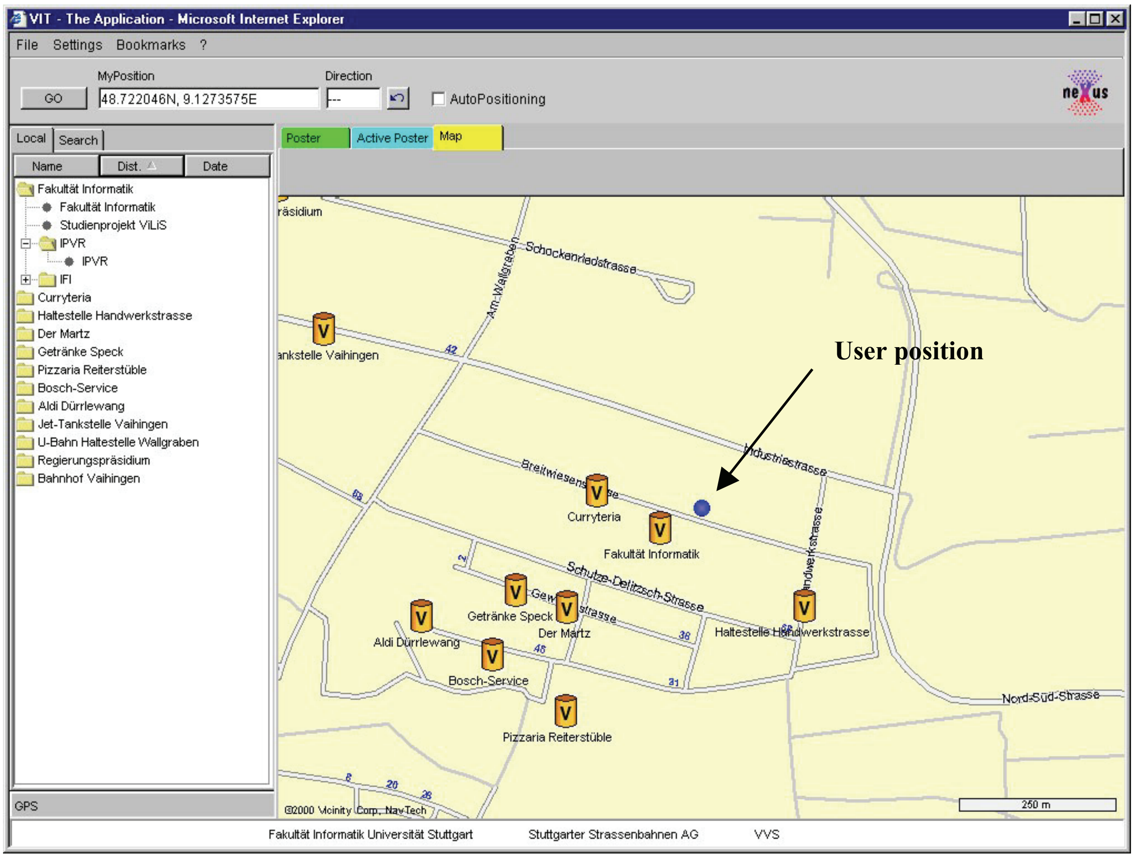

Figure 5: The interface of the VIT application. Different VITs are visible for the user via which he can query for information about his immediate environment.

6. CONCLUSION

The NEXUS infrastructure focuses on a system-level support for spatially aware applications. It is intended to facilitate the access to required services and location-based information and to support user interaction as extensively as possible by appropriate mechanisms within the platform.
Up to now, the emphasis has been put on the development of the information management within a federated architecture. A first prototype of the NEXUS infrastructure providing basic functionalities will be available next year.

7. REFERENCES

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