# NEXUS – the mobile GIS-Environment

Dieter Fritsch, Steffen Volz

University of Stuttgart,
Institute for Photogrammetry
Geschwister-Scholl-Str. 24D, 70174 Stuttgart, Germany
(dieter.fritsch, steffen.volz)@ifp.uni-stuttgart.de

**Abstract**

*Individual mobility plays a crucial role in our everyday life. Since people spend a lot of time being mobile, making mobility more efficient is a demand of most of them. Due to the latest developments in the fields of computer technology and wireless communication, computer applications became possible to meet the needs of mobile individuals. Since also positioning techniques have reached an acceptable accuracy, the location of users can be exploited by mobile applications, too. Thus, location-based services (LBS) evolved. They are preparing information and services according to a user's position. The data and operations they provide very much coincide with those available in GIS. For this reason, LBS can be understood as mobile GIS applications.*

*At the University of Stuttgart, a research project called Nexus has been initiated to create an open and global environment for mobile GIS.*

*The paper briefly introduces the idea of Nexus and describes the architecture and the data model of the platform. Then, approaches for spatial data integration are outlined.*

## 1. Introduction

Mobile information services or mobile applications, respectively, can be subdivided into two categories depending on the way information access is controlled: usual information services that access information without regarding the user's current location and location-based services (LBS) or mobile GIS applications which use the location information as one of the most important parameters [3, 4].

Today, only isolated LBS like car navigation systems or mobile tourist guides are offered by different providers. They are restricted to certain data formats, certain mobile communication techniques and certain sensor technologies. In order to provide an open and generic environment on top of which various types of mobile GIS can be developed, Nexus aims at integrating all the different components.

One of the most crucial requirements for such a generic GIS platform is the availability of detailed and manifold spatial data. For this reason, heterogeneous data sources that have been acquired by different providers in different underlying data models and scales must be integrated into the Nexus platform. In order to achieve this goal, a generic data model called the Augmented World Model (AWM) has been developed that contains all object classes which are relevant for location-based applications. It is managed in a federated system architecture.

If data of overlapping geographical areas are supplied within the Augmented World Model, the problem of multiple digital representations of one and the same real world object occurs. Solving this problem is a major research task concerning the development of the Nexus system since GIS operators require the existence of *one* consistent and coherent data set.

The paper comprises an overview of the Nexus platform in section 2. In section 3, concepts for resolving problems with multiple representations are illustrated. Section 4 contains concluding remarks and an outlook on further research topics.

## 2. The Nexus Platform

The Nexus platform can be described as an open and distributed environment for location based applications. It consists of a federated architecture which manages services and information resources and provides a consistent view for the applications: the Augmented World Model.

### 2.1 Architecture of the Infrastructure

The components of the Nexus infrastructure are organized in three tiers (see Figure 1): applications, federation and services. Basically, the architecture of Nexus can be compared to the one of the World Wide Web. Just like Web servers, Nexus data servers can be provided by anyone and only have to be registered in a certain directory that stores the address and the properties of an information resource. Nexus applications are similar to Web applications like browsers or applets. However, the intermediate tier of the Nexus architecture, the federation, has no counterpart in the WWW. The federation organizes the response to client queries within the distributed Nexus architecture.

#### 2.1.1 Application Tier

Mobile GIS applications are typically running on small devices which are able to determine their position via appropriate sensors. When they are performing queries, they contact the Nexus nodes of the federation layer using wireless communication technologies like WLAN or UMTS.

Queries are formulated in the XML-based Augmented World Query Language (AWQL). AWQL contains spatial and attributive predicates required to perform tasks of mobile GIS. Clients receive the results of their queries in the Augmented World Modelling Language (AWML). AWML is also defined in XML and allows to serialize the objects of the AWM. Both AWQL and AWML have been specified by the Nexus project.

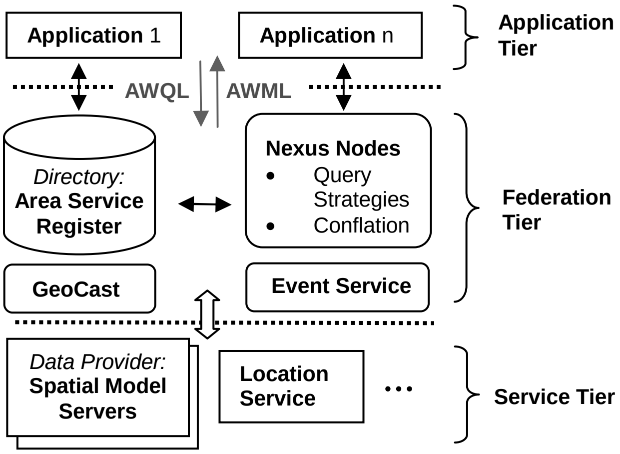


Figure 1: Architecture of the Nexus platform.

### 2.1.2 Federation and Service Tiers

Any application request is directed to a *Nexus node*. On each node, 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 Tier, namely the Spatial Model Servers and the Location Service. A *Spatial Model Server* stores and manages the static spatial data (like buildings, streets, etc.) of one or more geographical areas. It also provides geoprocessing functionalities. Usually, Spatial Model Servers are regular DBMS. For this reason, AWQL has to be transformed into SQL.

The *Location Service* deals with the management of the user positions. Since huge amounts of location data is updated frequently, the properties of standard databases are inadequate. Thus, a main memory based solution for efficiently storing and retrieving the position data of mobile users has been developed [6].

In order to create a strategy to answer application requests, a Nexus node must first identify, which spatial data have to be used for query processing. Therefore, it addresses the *Area Service Register* which can be understood as a metadata repository 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. After having queried the appropriate Spatial Model Servers and the Location Service, the Nexus nodes integrate the data that is returned from the Service Layer to one consistent and coherent result set by conflating multiple object representations (see section 3). Then, typical GIS services like navigation or map production can be performed on these data. Eventually, the results are propagated to the application (see Figure 2).

Concerning navigation, a Nexus-specific approach to store network topology in the Augmented World Model has been presented in [9]. All those GIS-functionalities of the federation component which are defined within the simple feature specification of the OpenGIS Consortium [8] are implemented in adherence to the standard.

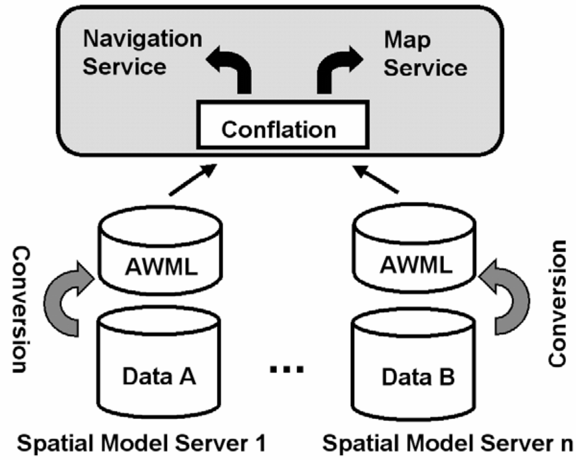


Figure 2: Conflation as an important service of the Nexus federation component.

Another component of the Federation Tier is the *Event Service* [1], which actively supports the participants of Nexus. It notifies users each time they are in a predefined spatial context. For example, if someone wants to receive a message whenever he's in the vicinity of a shoe store, he has to register at the Event Service. The service then observes the user and if the situation occurs, it notifies him. 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* [2] 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.

## 2.2 The Augmented World Model

The Augmented World Model (AWM) is an object-oriented information model for location-based applications [7]. It allows a unified view for the applications and enables the federation of spatial data from different providers. The object classes of the AWM are defined in the Augmented World Schema (AWS). The AWS comprises the standard class schema, a generic set of all object classes that might be of relevance for location-based 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 already 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 (see Figure 3).

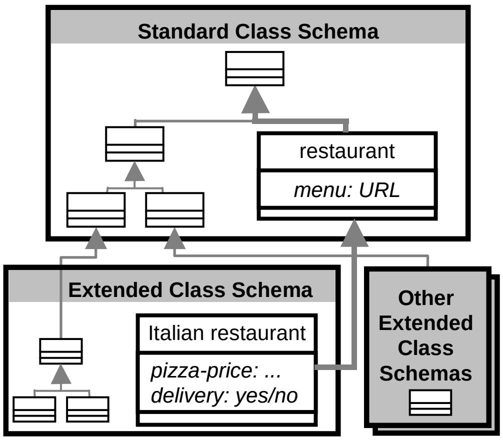


Figure 3: The AWS standard class schema can be extended according to the needs of applications.

## 3. Multiple representations - problems and solutions

Since the Nexus platform is aimed at providing a generic environment for different kinds of mobile GIS applications ranging from city information and guidance systems, via information systems of department stores or airports, up to information systems for exhibitions, data sources from all possible application fields must be integrated in the AWM. Therefore, existing data models have to be mapped onto the Augmented World Schema. This allows on the one hand a further use of already available data. On the other hand, data from multiple sources can be federated since they are available in a common data format. The process of mapping data from different sources onto the AWS is described in [10] with the example of road objects of GDF (Geographic Data File) and ATKIS (Authoritative Topographic Cartographic Information System of Germany).

However, besides creating a common data format, spatial data integration also has to deal with the development of methods allowing an identification of multiple representations in order to enable the conflation (fusion) of adjoining and overlapping spatial data sets. Thus, one single, consistent and coherent data set can be generated on which typical GIS operators can be applied .

Generally, a conflation process is the more successful, the less discrepancies between two spatial representations in terms of scale and data model exist. In Nexus not only data with a high degree of similarity must be matched, but also correspondences between heavily differing objects must be detected. The following sections introduce the problem of multiple representations and describe the concepts for conflating spatial data within the Nexus platform.

### 3.1 Problems with multiple representations

Each time a client query that requires the usage of overlapping spatial data is directed to a Nexus node, the problem of multiple representations occurs. Basically, multiple representations can have different properties in terms of geometry and attributes (feature-based properties). Moreover, relational aspects like e.g. the topology of features can vary. Thus, when identifying corresponding representations of one real world object, different conflicts arise depending on the diversity of spatial data sets. For example, if objects are described by lines in one data set and polygons in another data set, it is not possible to conduct the matching without preprocessing. Therefore, in order to work on common geometrical elements, polygons would have to be reduced to lines by a skeleton algorithm accepting some loss of information.

Another problem is the different levels of detail in which objects are stored in data sets. Geometries can be either very detailed or rather abstract and may consist of multiple parts or only one single instance. Considering this fact, the cardinality of corresponding objects is not limited to one to one, even many to many relations are possible, considerably increasing the complexity of the matching process. But even when multiple representations are stored in similar scales, an identification of correspondences is not trivial (see Figure 4).

In addition to geometrical differences, semantic deviations can occur. In the case of Nexus, these problems are already resolved during the schema integration that allows a mapping of original data models onto the AWM.

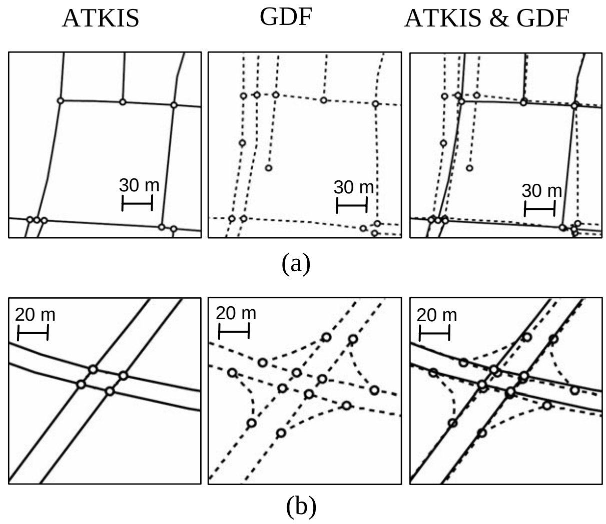


Figure 4: Conflict situations while matching road data from different origin (after [11]).

### 3.2 Conflating multiple representations

The first step for conflating multiple representations concerns the identification of corresponding instances. This is done by a matching process, where a set of objects A is mapped onto a set of objects B by an appropriate function. Up to now some approaches for road data have been developed.

In [11], a relational matching algorithm has been proposed. At first, it generates a list of potentially corresponding edge pairs that can have cardinalities from 1:0 up to n:m. Then, the pairs are rated by feature-based and relational indicators. Thus, the list can be continuously refined by eliminating improbable assignments. In order to achieve a quality measure of the matching process, the result of the automatic procedure is compared to a manually derived reference list.

Another approach was developed in [5]. It first of all identifies junctions of different street networks with a high likelihood of correspondence by comparing strictly defined geometrical, attributive and topologic parameters. The found pairs are defined as start points. They are used for an affine transformation to adjust the data sets. Basically, running in each direction from any start point and comparing each adjacent node and again their adjacent nodes, and so on, the whole network can be examined.

After having identified all corresponding node instances, the algorithm merges these objects into one resulting representation. It only calculates the arithmetic mean of the node coordinates and updates the line features. A more sophisticated technique would have to consider the data quality properties of the objects like position accuracy, topicality, completeness, etc. Thus, a weight measure could be assigned to each instance that expresses, how much influence an object has on the shaping of the resulting feature.

## 4. Conclusion and outlook

This paper contains an overview of the Nexus platform, a common environment for mobile GIS. It describes the architecture and the data model of the system and explains why spatial data integration is a crucial prerequisite for the generation of such a generic infrastructure. The basic concepts for matching and conflating multiple representations are outlined.

Future research will focus on a further development of the spatial data integration process. A detailed model for representing relations between different multiple representations is going to be built up that helps to optimise feature matching, as well as the conflation and update of corresponding instances.

## 5. Acknowledgements

The Nexus project is supported as Special Research Field 627 (SFB, Sonderforschungsbereich) by the Deutsche Forschungsgemeinschaft (DFG - German Research Foundation).

## References

[1] Bauer, M. and Rothermel, K. “Towards the Observation of Spatial Events in Distributed Location-Aware Systems”, in: Wagner, Roland (ed.): Proceedings of the 22nd International Conference on Distributed Computing Systems Workshops, 2002.

[2] Coschurba, P., Rothermel, K. and Dürr, F., “A fine grained addressing concept for GeoCast”, in: Proceedings of the International Conference on Architecture of Computing Systems 2002 (ARCS '02), Karlsruhe, 2002.

[3] Fritsch, D., “Electronic business and mobile photogrammetry”, in: D. Fritsch & R. Spiller, eds, 'Photogrammetric Week '01', Heidelberg, pp. 329–336, 2001.

[4] Fritsch, D., Klinec, D. and Volz, S., “Nexus – Integrating data and services for mobile users of location-based applications”, GIS 3/2003, Heidelberg, pp. 21-25, 2003.

[5] Kraut, M., “Zuordnung und Conflation heterogener Straßendaten“, Diploma Thesis at the Institute for Photogrammetry, University of Stuttgart, 109 pp., 2003.

[6] Leonhardi, A., Rothermel, K., “Architecture of a Large-scale Location Service”, Technical Report 2001/01, Department of Computer Science. University of Stuttgart, pp. 1-17, 2001.

[7] Nicklas, D., Mitschang, B., “The NEXUS Augmented World Model: An Extensible Approach for Mobile, Spatially-Aware Applications”, Proc. of the 7th Int. Conf. on Object-Oriented Information Systems, Calgary, 2001.

[8] OpenGIS Consortium, www.opengis.org, 2003

[9] Volz, S., Grossmann, M., Hönle, N., Nicklas, D., Schwarz, T., “Integration mehrfach repräsentierter Straßenverkehrsdaten für eine föderierte Navigation“., Informationstechnik und technische Informatik 2/2002, Jahrgang 44, pp. 260-267, 2002.

[10] Volz, S. and Bofinger, J.M., “Integration of spatial data within a generic platform for location-based applications”, Proceedings of the Joint International Symposium on Geospatial Theory, Processing and Applications, Ottawa, Canada, 2002.

[11] Walter, V. and Fritsch, D., “Matching Spatial Data Sets: a Statistical Approach”, International Journal of Geographical Information Science 13(5), pp. 445–473, 1999.