NEXUS – Acquisition of Position Information for Location Aware Applications using Multi Sensors and Mobile Photogrammetry

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BIOGRAPHY

Darko Klinec is research associate at the Institute of Photogrammetry. He received his diploma in surveying from the University of Stuttgart in 1997. From 1998 till 2000 he was employed in the start up project NEXUS that aimed at the development of a generic platform for supporting location aware applications with mobile users. In 2000 the research project NEXUS become upgraded to a so-called research group financed by the German Research Foundation (DFG). Within the research group his work is related to sensor integration, image processing and positioning mechanisms for pedestrians.

Dieter Fritsch is Full Professor and Director of the Institute for Photogrammetry. Since 10/2000 he is also Rector of Stuttgart University. He held many positions in Geodesy and Photogrammetry, he published 10 books and more than 190 papers dealing with statistical inference, photogrammetry, remote sensing and GIS. He is co-founder of the NEXUS project and here responsible for geodata collection and visualisation as well as positioning.

ABSTRACT

The research project NEXUS aims at the development of a generic platform that supports location aware applications – also called 'Location Based Services (LBS)' – with mobile users. Within NEXUS the world is represented by spatial models, which describe the real world supplemented by virtual objects. The virtual objects act as brokers between the platform and external information sources and services. Interactions between the mobile users and the virtual or real world objects are realized by using the actual position information.

To determine the actual position of the mobile users in different areas, it is necessary to use different positioning techniques. GPS, compass and mobile photogrammetry are able to provide the important location information. The use of small DGPS receivers integrated in PDAs e.g. provides the users actual position in the outdoor area. In situations and areas where GPS fails, mobile photogrammetry is a possibility to overcome this problem. Using a small digital camera and image processing techniques the system is able to determine objects as well as the (indoor) position of the person wearing the camera.
The telepointing device, which is a part of the NEXUS system, offers the possibility to identify objects, e.g. buildings, etc. By pointing to a building the object becomes located using the spatial model of the world and the computed telepointing parameters. Once the location of the object is available any stored information about the object can be provided.

The paper will show the main ideas and concepts of NEXUS, describing a multi sensor tool and mechanisms for locating pedestrians. The access to information sources, location aware information and services as well as telepointing using mobile photogrammetry will be pointed out.

1. INTRODUCTION

In the last years location based applications or location based services become more and more public to support mobile users. With the emerging availability of small and increasingly powerful devices a new type of applications becomes feasible. Little helpers like Personal Digital Assistants (PDAs) will be able to access the Internet with a pleasant bandwidth. Additionally they are able to locate themselves, e.g. with GPS or mobile photogrammetry. This leads to location based services like navigation or location aware information systems [8], [9]. To provide location awareness the NEXUS system relies on a model-based concept, called the NEXUS Augmented World Model. The model federates information and represents the real world, e.g. as a detailed 3D city model augmented by virtual objects. The objects in the model are location aware and imply links to external information as well as they structure information dependent on the location, see Fig.1.

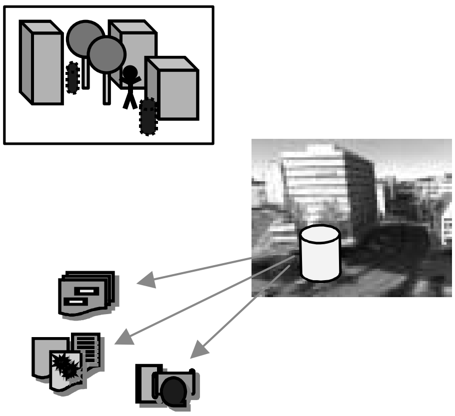


Fig.1 3D representation of a building augmented by virtual objects

To provide information in the framework of a location aware environment, the actual position and orientation of the user has to be available. Using direct geo-referenced terrestrial images offers the possibility of spatial queries by so called telepointing. By pointing to respective image sections, a spatial model has to be mapped to an image of the users environment. This enables an intuitive access to object related information.

2. LOCATION AWARE APPLICATIONS

In this section we describe a scenario for the NEXUS platform and show the basic services for mobile, spatially aware applications.

2.1 BASIC NEXUS SERVICES

We envision that for common mobile devices there are basic NEXUS services available, comparable to WWW browsers. They provide a simple query interface and basic communication functions with the platform and a standardized sensor component for different location systems. Additionally, there might be a simple NEXUS browser for the Augmented World Model and an Application Finder to detect new location based services and applications.
New NEXUS applications can use these basic services to provide more sophisticated spatially aware functions and better user interfaces, just like web services do use HTTP and browser technology in the World Wide Web. The following two sections describe examples for such applications.

2.2 MUSEUMS GUIDE

Consider an automobile museum, which offers a mobile museums guide to its visitors. The application runs on a common operating system for PDAs and can be downloaded at the ticket booth. When a user enters a room, the information about the exhibits is displayed. For this reason the museum maintains a model of the rooms in its building and stores it on a Spatial Model Server (SpaSe). Spatial Model Servers are distributed servers containing the model for a particular area. Additionally, the information about the exhibits, which is already available as web pages with text and images, is linked to the locations in the exhibition room.

2.3 NAVIGATION TOOL

Another NEXUS application is a Tourist Navigation Tool which uses the location information on several servers to find best tours with most sightseeing points. For implementation purposes, it gets most information from Spatial Model Servers in the area, but from the museum SpaSe, it only uses the location of the building and the fact that it's a point of touristic interest.

3. THE NEXUS ARCHITECTURE

The NEXUS platform delivers location-based information and provides additional supporting services enabling intelligent location-based applications. Its architecture is open for both new applications and new information providers, similar to the WWW. Today spatially aware applications are available as single applications e.g. car navigation or museums guides, but only as isolated applications. NEXUS aims at integrating all these isolated applications into one open platform. The architecture therefore is organized in three layers: The top layer contains the client on which the applications run. The bottom layer consists of various servers that store the data provided by the NEXUS system. 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 application, see Fig. 2.

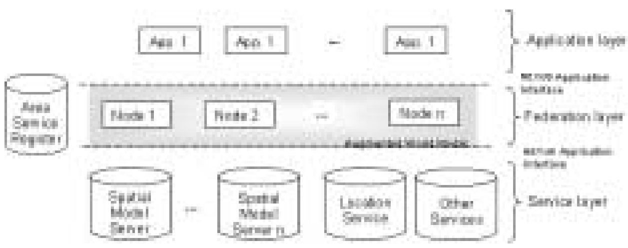


Fig. 2 Overview of the NEXUS architecture

4. WORLD MODEL

4.1 THE AUGMENTED WORLD MODEL

The Augmented World Model is a common data model that bears the basic semantic for location based information. It is the glue between the data of different information and service providers since it enables a federation of the data sources and allows a unified view even in an open and ever changing infrastructure. The basic idea is that the user of a NEXUS application lives in a world of real objects (buildings, streets, cars, ...) that is augmented by virtual objects [7]. These virtual objects are metaphors for external information.
In Figure 3, you see a clipping of the Augmented World Model, displaying the most important base classes. NEXUS Object is the root object for the Augmented World Model. The most important child of NexusObject is Nexus-DataObject, the super class for all those objects, which contain data of the Augmented World.

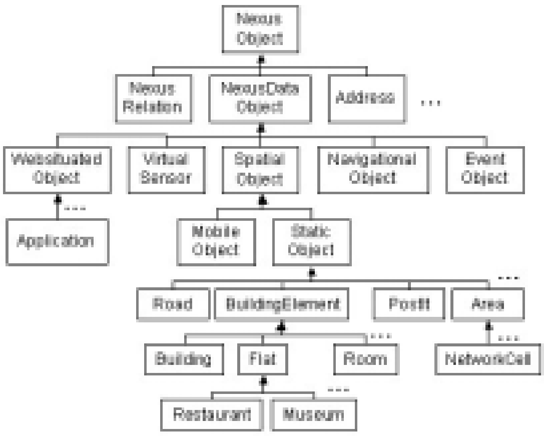


Fig. 3 The Augmented World Model

4.2 3D CITY MODEL

The 3D city model, which is a part of the Augmented World Model, is a highly detailed representation of the world. Data of the 3D representation offer the possibility on creating views for visualisation. Therefore within the 3D model the buildings of a city are represented in different levels, from highly detailed to low-level representations. In Fig. 4 you can see a wire frame representation of a building extracted from the 3D city model.

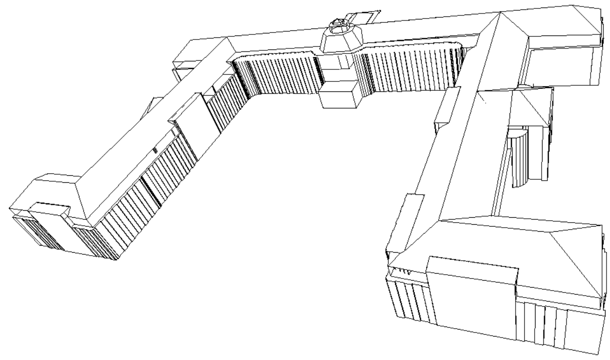


Fig. 4 Extracted building from the 3D city model

In case of NEXUS there are two different 3D city model data sets available. The fist data set was derived automatically at Stuttgart University based on a combination of laser DSM and ground plan information [1]. The second has been collected manually by photogrammetric stereo measurements of images at scale 1:10000 [10]. This data has been provided by the City Surveying Office of Stuttgart. For both datasets the outline of each building is defined by the public Automated Real Estate Map (ALK), which provides accuracies in the centimetre level.

5. POSITIONING IN URBAN AREAS

Often positioning in urban areas is done by GPS. In case of pedestrian navigation seldom other technologies are used in combination to overcome problems like multipath effects or signal shading in city canyons. Positioning errors caused by multipath effects can raise up to 100m or more. A possibility to support positioning and increase the accuracy is to use image information and photogrammetric methods. In the following this approach is called mobile photogrammetry. The next sections describe the required sensors and methods for positioning with mobile photogrammetry.

5.1 SENSORY FOR MOBILE PHOTOGRAMMETRY

The prototype sensory for mobile photogrammetry is built up as a system of four devices, which provide several data measurements. The components consist of (see Fig. 5):

- DGPS receiver
- digital compass
- digital camera
- laser distance meter
- (notebook for data capturing)

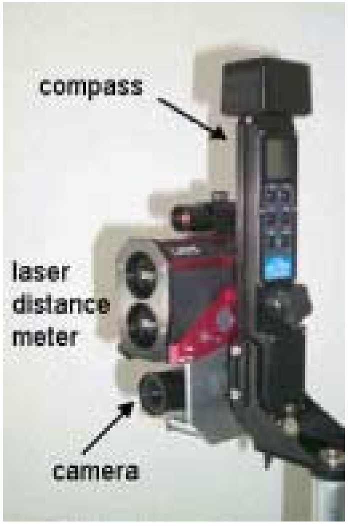


Fig. 5 Prototype device for mobile photogrammetry

The prototype device is capable to collect images as well as approximate values of the exterior orientation of the camera. The laser distance meter measures the distance between the object and camera as well as the vertex angle. Measurements of distances up to 250m to ordinary objects, e.g. buildings are possible. To extend the measurement distance of the laser distance meter up to 500m prisms can be used. The accuracy of the distance measurement is σ_{dist}= 5cm. The measuring range of the vertex angle is between +/- 90deg and its accuracy is σ_{vertex}= 0.1deg. To give an error analysis of the digital compass is more difficult, because it depends on the magnetic field of the earth, which can vary. The relative measurement accuracy of the digital compass is $\sigma_{comp,rel}$= 0.1deg but the absolute accuracy could be even less, dependent on the described effects.

5.2 POSITIONING AND TELEPOINTING

When users of NEXUS are walking through urban areas collecting images there will be also buildings represented within. If the exterior orientation of a user is available, the spatial model of the user's environment can be mapped to the collected image. The 3D model of the city containing each building highly detailed, offers the possibility to superimpose the buildings within the image by 3D model data, see Fig. 6. After this step access to object related information can be realized by pointing to respective regions of interest directly in the image. The functionality of identifying objects within the image we call indirect telepointing. As information is bound to a geographical place the link to the information is modelled in the Augmented World Model.

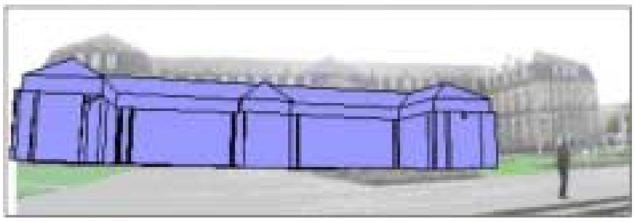


Fig. 6 Projection of an object from the Augmented World Model into captured image

For telepointing, as it is required in NEXUS, areas of interest within the collected image has to be defined. Often the building itself is an area of interest; therefore the mapping of its silhouette to the collected image is necessary. In a first step the directly measured exterior orientation ($X',Y',Z',\omega',\varphi',\kappa'$) is sufficient to provide acceptable results. As the measured orientation parameters are only approximate values an exact projection into the image is not possible. To realize applications e.g. that extract the texture of a building from the collected image a more accurate exterior orientation is required. A quite simple method to improve the orientation parameters is based on spatial resection using 3D coordinates of visible buildings within the collected image. This is also a way of locating a person equipped with a camera, because the location of the camera will be approximately that of the user.

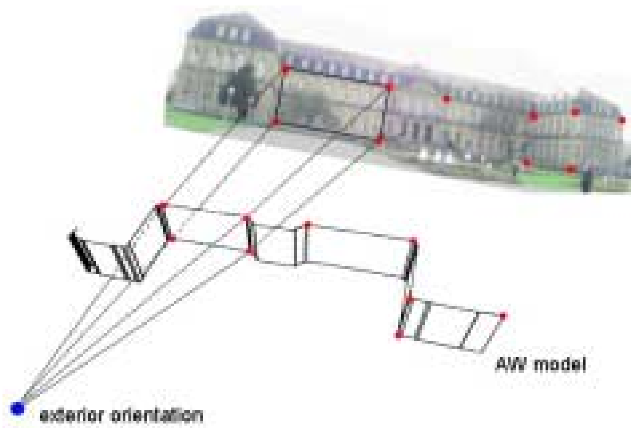


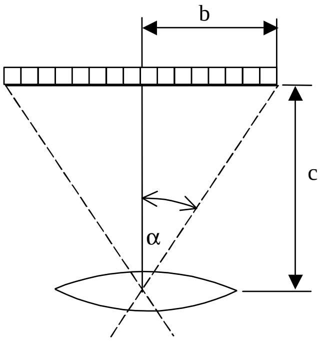
Fig. 7 Spatial resection using model and image

In case of spatial resection first corresponding points between image and object primitives must be identified, see Fig. 7. Currently the identification of the corresponding points is provided by manual measurements. A future task is to automate these process using object recognition algorithms. The calculation process result is the exact exterior orientation ($X,Y,Z,\omega,\varphi,\kappa$) of the camera or the person, respectively. Figure 8 shows an example of a refined transformation, which is based on the result of a spatial resection.

Fig. 8 Projection of the 3D city model after spatial resection

5.2.1 EXTRACTION OF VISIBLE BUILDINGS

As in NEXUS indirect telepointing and the positioning using spatial resection is provided, it is necessary to extract the object primitives from the model [3]. For the extraction process the camera sighting has to be defined. The camera sighting we call that area which can be collected by the camera. It is determinable dependent on the camera parameters like sensor size and focal length (see Fig. 9).



sensor size:
$b = 2.3803$ mm

focal length:
$c = 3.725$ mm

$$\tan \alpha = \frac{b}{c} \Rightarrow \alpha = 32.58°$$

Fig. 9 Camera parameters

To extract the building candidates, the camera sighting is represented as a plain triangle. In the extraction process the plain is used to search for objects in the 2D dataset of the city model. The 2D dataset is only a simplification of the 3D city model dataset. Once the objects within the triangle plane are detected, those must be extracted which are represented within the image. In the prototypical application using ArcView an algorithm was implemented which determines the visible buildings and extracts the model data from the Augmented World Model.

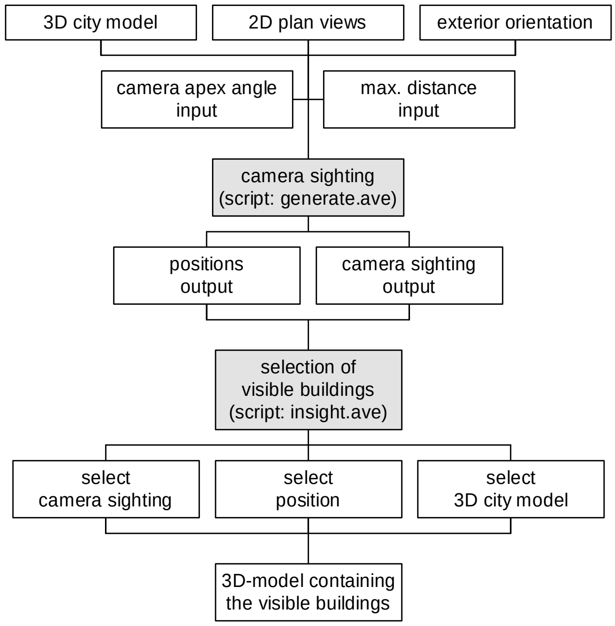
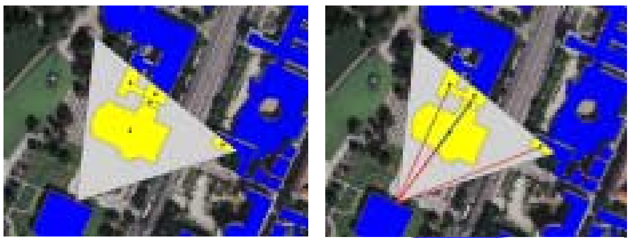


Fig. 10 Workflow of the algorithm for visibility check

The implemented algorithm (see Fig. 10) first calculates the camera sighting using the approximate exterior orientation and the camera parameters. In the next step the insight.ave uses the result of generate.ave and searches for visible buildings. For this purpose the camera sighting plain in 2D is blended with the city model data. Buildings inside the view plain are extracted and the centroid for any building within the view is calculated. Afterwards each centroid and the approximate position are connected with a line. The building, which intersects first is selected as visible, see Fig. 11. After this process the 3D model of the buildings are available for further processing like telepointing or spatial resection.



The triangle area represents the camera sighting in the 2D dataset.

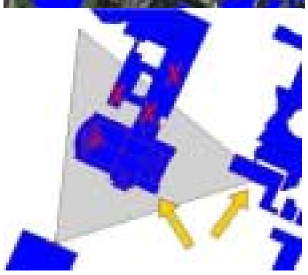


Fig. 11 Determination of visible buildings

6 ACCESS TO INFORMATION SOURCES

The exemplary telepointing functionality based on our prototype application is shown in Figure 12. For presentation the prototype was realized within ArcView, a standard GIS software package.
During the telepointing process an image is collected, simultaneously the orientation and position of the camera is determined. Afterwards the parameters are used to specify the objects of interest. Also the captured images are projected into a map or ortho image. By pointing to an object of interest in the image, corresponding object related information is provided by the graphical user interface. The provided information could be a website containing further and more detailed information. Also these websites give access to further services, e.g. ticket sales in case of the theatre visible (see Fig. 12).

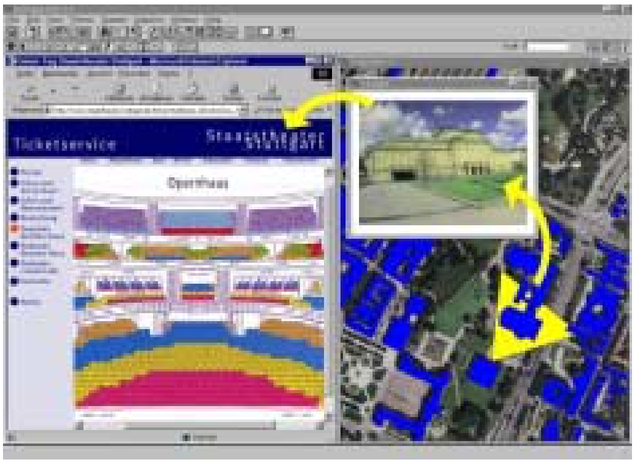


Fig. 12 Prototypical telepointing application

7 CONCLUSION

Within the paper the telepointing functionality as well as the essential ideas and concepts of NEXUS were shown. The short overview about location aware applications points out some exemplary applications. As the Augmented World Model is fundamental in NEXUS it was also described shortly. The closer description of the telepointing functionality and positioning with terrestrial images – also called mobile photogrammetry – was illustrated in the second part. There also the mapping of the environment model to the corresponding image and the intuitive access to additional object related information was explained.

The described application is predicted with mapping accuracies from decimetre to a few meters. Standard low cost hardware allows direct measuring of position and orientation within the required accuracy. To improve the mapping accuracy between spatial models and images further research will aim at the integration of the 3D city model into the orientation process.

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