The third dimension in LBS: the steps to go

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Abstract

Computer technology has evolved to a position of being able to handle large three-dimensional (3D) data sets. The third dimension is already taken for granted for visualisation on desktop machines. Nasa World Wind and Google Earth demonstrate the possibilities of 3D to all users of the Web. The same way, mobile computing is experiencing a similar evolution. Despite the fact that 3D mobile hardware and software technologies are currently still behind desktop 3D in terms of capabilities, the expectations are for 2-3 times faster maturing. Are the geo-specials ready to step into the third dimension?

Location-based services (LBS) are among the first applications that naturally should consider the third dimension. In this paper we analyze the readiness for 3D LBS. The paper concludes on the role of the geo-specialist in this process.

1 Introduction

Location Based Services (LBS) are often referred to as 'location-dependent' GIS. Starting form this point, the analogy between 3D GIS and 3D LBS is quite straightforward. LBS have two more components compared to GIS: position determination and wireless communication. The simplest, trivial way of position determination is using global navigation satellite system. The accuracy and reliability of 3D satellite positioning has improved drastically in the last several years and the GPS receivers have become cheaper and affordable for everyday use. The bandwidth of the communications also increases. In many countries UMTS is already operational, which promises sufficient speed for transmissions of 3D data (often resulting in large amounts). What are then the bottlenecks for 3D LBS?

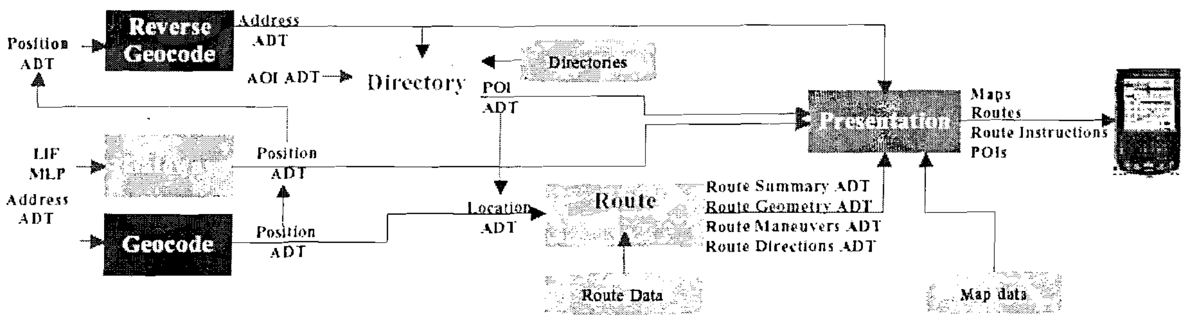
Open Geospatial Consortium (OGC) has prepared Location Services (OpenLS) Implementation Specifications for core services. In these specifications, the role of 'GeoMobility Server' is providing requested information considering the location of the user. The minimum number of services is also defined as *directory*, *navigation* (route), *location utility*, *gateway* and *presentation* (see Figure 1). The five core services are considered sufficient for a variety of use cases such as proximity (find something in a given area), fencing (alert users in a given area), navigation (compute route) and tracking ('record' the way a user) as specified in Torg et al 2005.

3D LBS have to be able to ensure the same set of services, i.e. proximity, fencing, routing and tracking but in 3D. Example of 3D requests would be 'show to me all the electrical switches in a building' (proximity) (see Figure 2), 'tell me when I am outside a dangerous section of a building '(fencing), 'compute a route to a safe exit' (routing), 'track this visitor all the way in the shopping centre' (tracking).

In terms of core services as specified in OpenLS, 3D LBS have to provide:

- 3D location utility, i.e. 3D positioning and geo-coding
- 3D navigation, i.e. route in multilevel constructions (buildings, viaducts, bridges, etc.)
- 3D directory, i.e. access to 3D data for example for tracking and fencing
- 3D presentation, i.e. 3D visualisation on mobile, hand-held devices and the appropriate interface for this.

Fig. 1: Request/response of GeoMobility Server as the position is provided by the communication netwrok



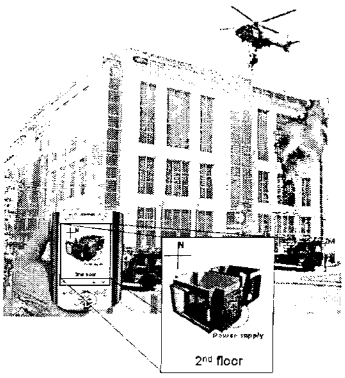


Fig. 2: request/response 'important power supply'

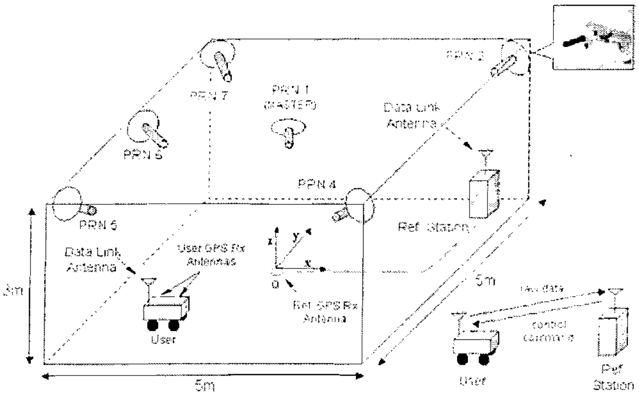


Fig. 3: Centimeter-Accuracy Indoor Navigation Using GPS-Like Pseudolites

The following sections address these challenging aspects in detail.

2 3D positioning and geo-coding

It is also in the name: a location-based service needs to be aware of the location of the user. Position determination can be done is several ways: by coordinates, address, ZIP code, etc. In fact, coordinates are hardly used. Descriptive postcodes and addresses, and linear reference systems like mileages marks along roads, are far more common to express a location than Cartesian reference systems. However, none of the exciting LBS or GIS-packages offer a kind of a Z-coding, thus a translation of e.g. 'at the base of this dyke' to '4.73 meter above NAP'. And no LBS can tell you what floor you are when you specify your location by only a GPS-coordinate.

2.1 3D positioning with GNSS

Theoretically, obtaining 3D coordinates at global scale is available. GPS-devices, and other receivers to Global Navigation Satellite Systems (GNSS) like Galileo can compute either Cartesian (X,Y,Z) or ellipsoidal (latitude, longitude, height) WGS84 coordinates. In multi-level 3D structures, the problem may come from two sides: geo-coding of the height and availability of satellites. The altitude is given as the distance to the WGS84 rotational ellipsoid and it is difficult to be linked to expressions used in daily (3D) life by references like 'on/under the bridge', 'floor', 'base', 'ceiling', 'top', etc. It is well-know that a GNSS-receiver cannot work inside or at other places with a poor satellite coverage. Many systems exists that claim to solve that problem by applying another type of measurement technique, although all these systems are bases at either a kind of distance measure, a kind of angle measurement, or a combination of both. If it is not possible to detect enough GPS satellites in line-of-sight, some close-range pseudolites transmitters could be also used. For example, the company Novariant offers the so-called Teralite XPS systems, a single frequency ground-based signal generator broadcasting XPS signals to mobile GPS+XPS receivers, (www.novariant.com/mining/index.cfm). For indoor use a more dedicated pseudolite-only setup could be used, like the system shown in Figure 3, (Kee, 2001). However, if the user is free to move in height, the transmitters should be arranged in a more enclosed setting to obtain a reliable 3D-position fix.
It seams improbable, but television synchronization signals may be used to position a range of wireless devices that require location information. The system developed by Rosum provides according to their website: 'accurate, reliable location indoors, outdoors and in dense urban location' (www.rosum.com). The Rosum TV Measurement Module (RTMM) receives local TV and GPS signals, measures their timing, computes the pseudoranges and sends that information to the Location Server (LS). The LS computes the position of the RTMM and sends that location back to the RTMM or to the tracking application server (see Figure 4). In addition to the wide-area positioning system, Rosum also develops a limited-area, 3D positioning system. This system is used by first responders in emergency situations. Rescue personnel can be tracked from a field command center, reducing precious time spent giving location updates and eliminating blind searches in man-down situations, (see Figure 5).
Assisted GPS (AGPS) combines the better of two worlds: GPS and Mobile Networks. Simple stated (www.snaptrack.com/pdf/How_aGPS_works.pdf): When a caller makes a location request, the wireless network sends the approximate location of the handset (generally the location of the closest cell site) to the location server. The location server then tells the handset which GPS satellites should be relevant for calculating its position. The handset then takes a reading of the proper GPS signals, calculates its distance from all satellites in view and sends this information back to the location server. But still, in hard conditions like inside locations, it is still difficult to impossible to 'see' enough satellites and thus to obtain a position fix. Moreover, inside conditions and urban canyons are known to have multi-path problems, causing unreliable pseudo-ranges and thus fault determined positions.

2.2 Sound based position

Bats are known to use ultra sound for tracking themselves. This property is also used by the Norwegian Sonitor Indoor Positioning System (IPS) to track and position tagged equipment and people indoors (www.sonitor.com). The tags transmit ultrasound and ones

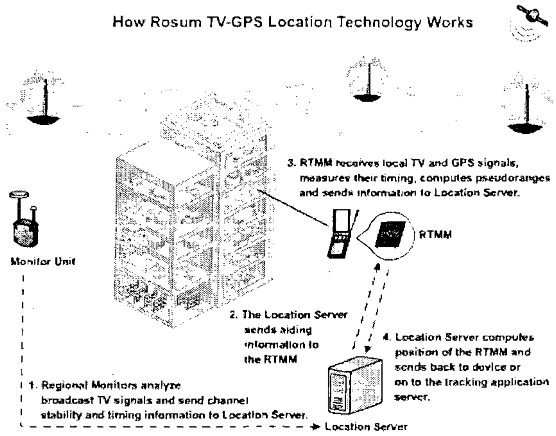


Fig. 4: Rosum TV-GPS Location Technology

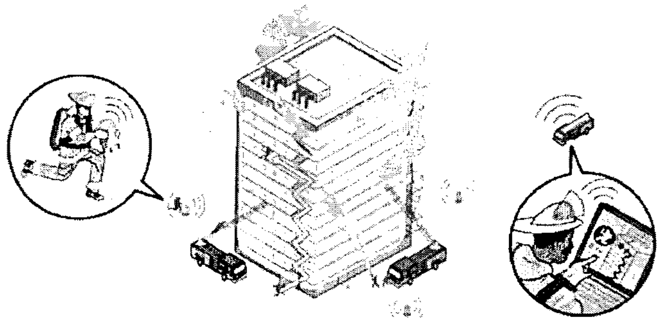


Fig. 5: TV-GPS Plus Fireground First Responder Tracking Application

received by a set of microphones inside a room or corridor the positions and movement is calculated in real time, see. This kind of systems works only in special equipped environments, e.g. buildings.

2.3 Positioning using telecom networks

Mobile communication networks, like GSM, are used for commercial LBS applications as it is quite easy to reach a group of cellular phone users within the area of a certain base station (Cell of Origin) and send them for example an advertisement SMS. It is however also possible to position the users within a certain sector and range of the base station by Uplink Time Difference of Arrival. If that information is monitored over time and combined with a road network, the position of the cellular phone user can be detected in a more precise manner. The company LogicaCMG has developed the so-called Mobile Traffic Service where these locations are aggregated to real-time traffic information for the Dutch province of Brabant (www.mts-live.com), (actueleverkeers-informatie.brabant.nl).
Precise Mobile Network positioning requires considerable adjustments to the current GSM network setup, or the use of next generation networks like UMTS. But due to the more or less planner configuration of the GSM/UMTS beacons, accurate and reliable 3D-positioning by mobile networks is not possible.

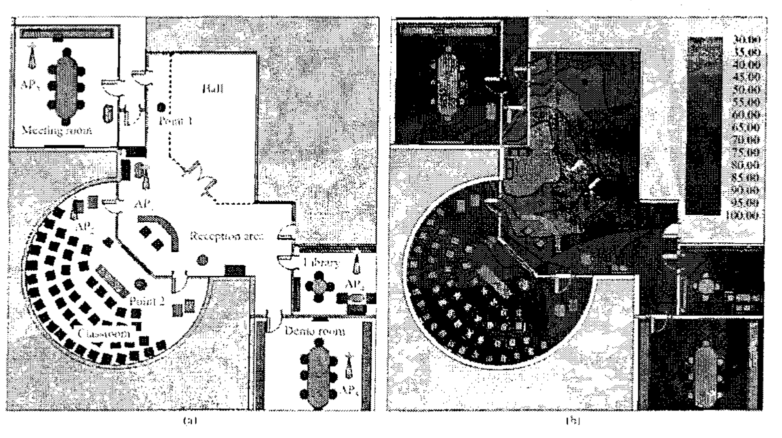
2.4 WLAN positioning

Each WLAN (Wi-Fi) network can be location enabled by signal strength calibration and fingerprinting. Within a neighborhood, i.e. an office, a map is made by a site survey of the reception of the WLAN access points. That is a challenging task, as the WLAN signals appear in an irregular pattern, since the propagation of signals is heavily affected by multipath effects, dead spots, noise, and interference in an indoor environment, see Figure 6 (Xiang, 2004) (Kaemarungsi, 2005). Once known, this map is 'turn around', to pin-point the location by a certain signal reception. One of the premier systems using this kind of 'fingerprinting' is the Ekahau's patented positioning technology (www.ekahau.com). One limitation is the calibration of the system; first of all known positions should be linked to the signal strength of the WLAN access points. This process should be repeated when a major change in the configuration of the WLAN access points is made.

2.5 RFID-UWB positioning and Sensor Networks

Radio frequency identification (RFID) is a generic term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves. There are different systems. Ultra Wide Band radio systems can be accurate to about 6 inch (15cm) indoors because they are much less affected by multipath distortion than conventional RF systems. Ubisense uses both Time Difference Of Arrival (TDOA) and Angle of Arrival (AOA) which greatly reduces the density of sensors required to cover an area over systems that use just TDOA (www.ubisense.net).

Fig. 6: Layout testarea (a) and Contours (b) indicating the signal strength of Access Points



3 3D data management

Once the 3D position is determined, 3D data have to be available and accessible. Currently, most of the 3D data are available as 2.5 surface data, 3D city models and 3D CAD models. Furthermore the 3D information exists but is 'split ' between different organizations. For example, within the Netherlands the planimetry and height are maintained by two governmental organizations. The 'Kadaster' is responsible for the 'horizontal component' and 'Rijkswaterstaat' manage the 'vertical component' through the NAP benchmarks. One consequence of that organization is the mapping of the topography, as in the Dutch 1:10.000 scale TOP10Vector, which does not take the height value into account. At the moment the relative vertical situation is only expressed at certain 'levels'.

Depending on the position and the requested service different types of models and spatial operations could be needed. If the user is on the street, perhaps a 3D city model will suffice. If the user is inside a building, a tunnel or a bridge, a detailed 3D interior model might be required. Furthermore, 3D outputs for LBS can be in two forms: only retrieval of data for 3D visualisation and performing spatial operations (which are needed for example for 3D route calculations, 3D proximity, etc). Currently, retrieval of 3D data can be relatively easily organized (via Open Web services) from any system. Spatial analysis (3D routing, proximity) would require spatial operations. The common problem here is a lack of 3D operations and functions. Mathematical background for such operations exists but it still needs to be implemented in the systems.

In this respect, last developments in Geo-DBMS are quite promising. Currently geo-DBMS can maintain different models *geometry, topology*, and *graph*. While the geometric structure provides direct access to the coordinates of individual objects, the topological structure encapsulates information about their spatial relationships. A geometry model has been implemented in all mainstream DBMS (e.g. Oracle Spatial, Informix, Ingress, PostGIS, MySQL). Although the implemented spatial data types are 2D, 3D objects still can be stored. Topological implementation specifications are still under development, but commercial topological structures are already available (Laser-Scan Radius and Oracle Spatial 10g). A graph model is currently offered only by Oracle Spatial 10g. The combination of geometry model and graph model, i.e. the Network Data Model, can become a quite appropriate structure for 3D route calculations. While route calculations can be performed on the graph, 3D geometry can be applied for 3D navigation along the route.

4 Protocols/standards for data exchange

Present specifications allow even at this moment 3D outputs. The work of the Open Geospatial Consortium (OGC) and the World Wide Web Consortium (W3C) is the most relevant to the geo-information specialists with their specification for Web services and eXtensible 3D language (X3D). The Web services define request/respond interfaces between an application (e.g. running on a handheld) and GeoServer and X3D is the XML-based standard for 3D visualisation.

The Web services are currently four (WMS, WFS, WTS and WCS). The Web service for 3D is the Web Terrain Service (WTS). WTS specification defines a standard interface for requesting 3D terrain scenes from a server capable of their generation. A WTS service supports two operations: GetCapabilities and GetView. The view is defined as a perspective image. To be able to create this view, a number of parameters have to be provided to the server: Point-of-Interest (POI), i.e. x,y,z of user focus; distance between the user and the POI; the vertical angle between the user and the POI; the horizontal angle between the north direction and the horizontal projection of the 'user-POI' line; and the Angle of View. The server returns a raster image of the 3D data. To be able to use this service for 3D navigation for example, a series of images have to be generated (at the server) by continuous round-trips to the server. The images can be further organized in a movie and send to the user. The disadvantage is that an interaction with/navigation trough data would not be possible.

The Web Feature Service (WFS) is much more promising. The GetFeature request is an XML stream of vector data, i.e. Geography Markup Language (GML). GML geometry types allow for x, y and z-coordinates. Moreover GML version 3.0 introduces the 'Solid' geometry type, which can be used for 'full' 3D objects. GML 3.0 also offers the possibility to use a topological data structure (a 3D object as a TopoSolid with references to Faces, Edges and Nodes). This is to say theoretically GML does not have any limitations in maintaining 3D objects (geometry and/or topology).

However, the GML output of a WFS service is not a 3D scene yet. It has to be transformed into a graphic format for which visualization software is available. In this respect the best candidate is X3D. X3D is the XML version of the Virtual Reality Modeling Language (VRML). VRML was launched in the nineties and became an ISO standard in 1997, but never was widely used for geo-applications. The size of the VRML file could become very big (due to lack of appropriate streaming and compressing techniques), which could result easily in bad performance. X3D has improved structure (i.e. Core profile, Interactive profile, Interchange profile, and MPEG-4 interactive profile) and much more possibilities to control the size of the file and render efficiently. It is actually designed for implementation using a 'low-footprint engine' as on mobile devices. X3D was approved by ISO as International Standard ISO/IEC 19775 in early 2005.

To be able to visualize the 3D data, a X3D viewer has to run at the client (e.g. Cortona). De Vries and Zlatanova 2004 discuss an architecture that allows an application to request a 3D vector data. This approach can be applied for LBS as well, once accepted that the result of the request can be not only image but also other formats from the Standards Framework. The GeoMobility server then will act as a client to any GeoServer that contains 3D data.

5 3D presentation

Presentation of 3D data is still tricky. 3D visualisation (rendering) of the 3D outputs can be done in different ways: as a static 3D image, a video and as a vector model (allowing interaction). Furthermore, the parameters of the mobile devices can vary significantly: special devices (e.g. see-through glasses), portable PC to mobile cells. The type of device has huge influence on the possibilities for 3D visualization. In contrast to portable PC and tables, hand-held devices have many limitations: available memory, screen resolution and CPU. The type of operation system (Windows Mobile, SymbianOS, Smartphone, PalmOS, JV-Lite2, Linux, etc.) also varies. With these limitations even low-quality streaming video can be problematic.

Currently most of the 3D visualization on mobile is provided as a streamed video (Zlatanova et al 2004). VRML browsers for 3D interaction are offered only for PocketPC by ParallelGraphics (i.e. Pocket Cortona http://www.parallelgraphics.com/products/).

As discussed in the previous section interfaces between GeoMobility server and mobile devices are based on Web technologies. In this respect, several technologies might be important for 3D rendering on mobile: X3D, MPEG-4 and PDF. X3D is quite promising technology not only because of the features offered but also because of the attempts of the W3C to come to an agreement with other groups developing standards. Moving Picture Experts Group (MPEG) has accepted X3D for the 3D capabilities of MPEG-4. Furthermore special mobile 3D technologies to extend X3D are also being defined for MPEG-4. Adobe Acrobat also has step into third dimension and provided interactive 3D browser inside the PDF file (http://www.adobe.com/products/acrobat/aec.html). Since PDF reader is already offered for hand-held under Windows Mobile, it could be expected that the next step will be a 3D PDF file for hand-held. The size of the PDF file (rounding to MB) and the lack of PDF streaming technology are currently the main drawbacks.

In general, the use of these standards in 3D application development for low-end consumer and embedded devices is still problematic, mostly because of the large footprint imposed by underlying implementations and heavy utilization of hardware acceleration. The two Java technology specifications the Mobile 3D Graphics API for J2ME (JSR 184) and the Java Bindings for OpenGL ES specification (JSR 239) were expected to help significantly in accelerating this process. Nokia working in collaboration with Motorola, Intel, Sony Ericsson, Symbian, Cingular Wireless and France Telecom led the Mobile 3D Graphics API. The Java Bindings was led by Sun Microsystems. While successful for game industry, they did not have a lot of influence on geo-applications. As it is well-known a large amount of geo-applications are running nowadays under Windows. But, Microsoft also increases its investments in mobile developments. For example Mio A701, the first GPS-enabled smart phone with Windows Mobile 5, is already on the market. The Microsoft interest in mobile computing can be a stimulator for many GIS vendors to provide browsers and applications for mobile.

Other non-standard solutions are also showing up. The typical polygon (triangle) rendering has a volume-based graphics, which might bring advantages also for mobile computing (http://www.ngrain.com/alliances/files/NGrain2.pdf). A very elegant way of 3D LBS might be the usage of see-through glasses based on augmented reality approaches. Augmented reality offers a lot of advantages compared to traditional desktop and especially telephone cells due to: better understanding (the background view is real world) and faster retrieval and rendering (e.g. only the computed 3D route is visualised). However these systems are still unreliable and quite expensive for a daily use.

6 Conclusions

This paper has discussed four critical components of LBS in the light of the third dimension: positioning, interfaces, data management and visualization. The general conclusion is that sufficient technology possibilities for 3D exist (also Zlatanova and Verbree, 2003) but they have to be appropriately combined and connected. The role of geo-specialist in 3D LBS is to provide the 3D position and find (and deliver) the requested 3D data.

Regarding 3D positioning we can conclude:

- As all systems are based on the same set of observable quantities (distance and angle) many correspondences exists in techniques and methodologies. To choose with system performs best in certain conditions depend on these circumstances. Important factors are: inside conditions, user controlled setup and maintenance of the reference beacons, active or passive targets, and the role of a GeoMobility Server.
- The integrity of the 'space segment' (the beacons) of all presented systems, except GNSS like GPS, is not controlled and maintained. This will lead to unreliable positioning of the targets.
- Most systems are presented as 'stand alone' solutions, due to commercial interests. As no system operates best under all circumstances, the reliability will be improved and ensured when the systems are more integrated.
- The OpenLS specification has to be further extended to work with Z-coordinates and provide 3D geo-coding.

Regarding the interface, we firmly believe that the communication between GeoMobility Server and the mobile client will be based on Open Web Services, which still require appropriate 3D adaptations, e.g. for exchange of parameters needed to complete WTS and WFS.

Apparently, it will not be possible to organize all the 3D data needed for 3D routing and other analysis on the same server where the GeoMobilty server will operate. 3D LBS will be based on a distributed system combining GIS, CAD and geo-DBMS. This poses great challenges to geo-specialist towards improving the performance by developing better 3D data organization, indexing, generalization and compression. All issues are already addressed in literature on 3D GIS.

3D visualization on mobile is not a problem anymore, but the geo-data have to be adapted for the device and the user. 3D generalization, usage of textures (or not), 3D symbolization, visualization clues for attention attraction, etc. are all tasks of geo-specialists.

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