TOWARDS 3D LBS - CHALLENGES AND OPPORTUNITIES

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ABSTRACT:

Geospatial locations are increasingly considered as a very important factor for providing diverse kinds of public or proprietary services, such as map services including the real time navigation function, and social network services such as the buddy-finding feature. These services are always based on the geospatial locations and therefore named as Location Based Services (LBS). LBS as a special stream of GIS have been widely researched in the GIS community. As the rapid developments of mobile devices, wireless networking, location sensing techniques and other ICT, LBS have boomed in the industry and achieved great revenues all over the world. However, most existing LBS can only deal with two dimensional geospatial data and offer related 2D geospatial services. They lack in supporting three dimensional datasets as well as 3D services. To use the existing and newly emerging 3D datasets and implement different 3D based LBS systems based on existing 2D LBS systems or from scratch, some important issues have to be investigated. This paper discusses core components of LBS in detail and also provides a prototype for demonstrating the methodology of upgrading a 2D LBS system to the 3D LBS one.

1. INTRODUCTION

Nowadays, geospatial data are increasingly used in many different domains. The users are also moving from GIS professionals to the laymen. More and more people know how to find their houses or surrounding restaurants via the web map services like Google Maps. In the mean time, various location sensing technologies are becoming mature and have already started to serve mobile devices to obtain their location information. Typical technologies are GPS and telecommunication infrastructure assistant positioning using a number of known points, etc. Location information thus becomes a basis and an enabler for acquiring ubiquitous geospatial related services.

LBS defined by Open Geospatial Consortium (OGC) as "*A wireless-IP service that uses geographic information to serve a mobile user. Any application service that exploits the position of a mobile terminal*" (ISO, 2005) are becoming more and more useful in our daily life, such as the car navigation, tourism system, emergency rescue, disaster management, social networking and many other value-added applications.

The big advancements of mobile devices, wireless networking, locating techniques and other ICT technologies lead LBS as a special stream of GIS. In the last few years, LBS have boomed in the industry and achieved great revenues. According to a latest report from ABI Research, LBS revenue is forecast to reach an annual global total of US$ 13.3 billion by 2013 (ABI, 2008).

In the mean time, 3D information is rapidly increasing, which is partly due to the fast data acquisition techniques such as terrestrial laser scanning and photogrammetry. 3D data can bring people more vivid presentations of the real world, for example, a person walks in a virtual world surrounded by 3D simulated reality objects for tourism or shopping, or a scientist estimates the climate disaster via an interactive 3D scene. Therewith 3D GIS has been paid more attentions in GIScience (Zlatanova et al., 2002), including researches on 3D data modelling, visualisation, query and analysis (Penninga and Oosterom, 2007; Pigot, 1992). Although implementing 3D GIS is not an easy task, those promising and attracting features represented by 3D virtual world will be widely spread and extended to the current 2D GIS step by step.

However, most existing LBS can only deal with 2D geospatial data, that is, to receive 2D locations from the mobile user and to respond 2D maps to the user. They support little or nothing to 3D geospatial data. As mentioned, 3D information brings more useful benefits to GIS and will be the next scenario for upcoming LBS (Zlatanova and Verbree, 2003). Therefore, it is necessary to investigate the method about how to upgrade a 2D LBS system to the 3D LBS one, in order to fulfil the progressive user demands.

Either 2D or 3D LBS can be considered as a collection of various technologies. This paper firstly analyzes LBS as the following core components: *mobile devices, location sensing techniques, data standards and standardized geospatial web services*. The detailed description of the above LBS core components is introduced and necessary changes when upgrading 2D LBS to 3D LBS is discussed. Afterwards, a prototype using the methodology of upgrading an existing 2D LBS system to the 3D LBS system is explained. Finally, conclusions and the outlook are given.

2. LBS COMPONENTS

2.1 Mobile Devices

Mobile devices also mean the terminals used by LBS users, which can be smart phones, Personal Digital Assistant (PDA) and other handheld computers. However, mobile devices have been mostly limited to the 2D graphic rendering, and only recently focused on the 3D graphic rendering. Two inherent characteristics of mobile devices bring people more difficulties for handling graphic data comparing with normal PC systems: they have very small displays and limited amounts of resources of rending. That means mobile hardware chips, memory bandwidth and energy capability are the dominant factors for handling the 3D graphics (Akenine-Möller and Ström, 2003).

Many efforts have been done to improve the 3D rendering performance for mobile devices in the industry.

Figure 1 illustrates a number of mobile 3D rendering techniques for games, navigations and so on.

Figure 1. Examples of 3D rendering techniques on mobile devices (Zlatanova and Verbree, 2003)

3D geospatial datasets always occupy more storage spaces than 2D data, e.g. a virtual 3D city model containing many different city feature types. Therewith, when upgrading the 2D LBS to 3D LBS, the appropriate mobile devices must be selected according to the particular needs and goals of different applications. For example, the navigation system mainly using 2D map with assistant of 3D labels can select devices with small displays, but the system displaying 3D city buildings with detailed textures should consider devices with big displays and powerful graphical chips.

2.2 Location sensing techniques

Hightower and Borriello discussed three principal techniques for automatic location sensing: Triangulation (using multiple distance measurements between known points, or measuring angle or bearing relative to points with known separation), scene analysis (examining a view from a particular vantage point) and proximity (measuring nearness to a known set of points) (Hightower and Borriello, 2001). These techniques are applied into different location systems individually or in the combination, for example GPS, cellular network, Wireless network, Radio Frequency Identification (RFID), Infrared (IR), and Bluetooth. Some of them are explained in the following.

GPS and Galileo: Global navigation satellite system using a constellation of low-orbit satellites to cover the entire earth's surface is the most widely publicized system to provide wide area location coverage, e.g. GPS and Galileo system. GPS originated as a US military system that was designed to provide location signals to US military users, while afterwards also allow location signals to civilian users. Galileo built by the European Union and European Space Agency is mainly aiming to set up a civilian system that allows anybody to use it, and it is planed to be operational by 2013.

Normal cost GPS receivers can provide around 15 meters horizontal accuracy and around 23 meters altitude accuracy. Differential GPS allows errors correction using a network of fixed ground based reference stations, and thus offers a better locating performance, around 5 meters horizontal accuracy and 10 meters altitude accuracy. However, due to the so called "urban canyon" effect, e.g. the radio signals sent by the satellites are too weak to penetrate the buildings or high density of trees in cities, GPS works well outdoors but is not able to obtain a good result indoors or under an obstructed situation. Galileo plans to deal with the above exposed problems by emitting strong radio signals which can be used inside most buildings, as well as greater accuracy.

Cellular network: Another wide-area location sensing technology is provided by mobile phone service companies, and uses cell tower (base station) observations of cell phones to determine the location of a GSM mobile telephone. Cell ID and enhanced-observed time difference are two methods to calculate the position. The European and U.S. governments (Enhanced 911) have mandated that providers should be able to locate cell phones within certain accuracy (e.g. The E911 accuracy requirements are 100 m (67%) for network-based solutions, and 50 m (67%) for handset-based solutions). Comparing with GPS, the big advantage of cellular positioning is that the signal is much stronger and therefore can operate indoors. And it is unaffected by the urban canyon effect (subject to GSM coverage). Moreover, the cell phone is the most ubiquitous mobile devices daily carried by a very large amount of users. Therefore it is an excellent candidate for location-based service deployment (Borriello et al., 2005; D'Roza and Bilchev, 2003).

Local Wireless Network: Wi-Fi is supported more and more by modern personal computers or mobile devices. Wireless LANs (WLANs) have the fast networking speed of even higher than 100 Mbps and are rapidly deployed in many places, such as offices, university campuses, homes and coffee houses. In a WLANs environment, it is possible to use the software to infer the location of a wireless networked device by analyzing the signal strength or signal-noise-ratio of the wireless access points with respect to that device (Castro et al., 2001). The only condition is that your mobile device has a wireless connection function. For example, Microsoft Research's RADAR system (Bahl and Padmanabhan, 2000a, b) is a software-only system built over off-the-shelf 802.11wireless LAN, which can provide location estimates with a few meters accuracy on standard laptops. This makes a wireless LAN more valuable and increases the chances of large-scale deployment.

Others: IR system was used to provide accurate location information by (Want et al., 1992). In this system, a badge worn by a person emits a unique IR signal every 10 seconds. Sensors placed at some known positions within a building check the unique identifiers and deliver these the location manager software to calculate user's positions. 3D-iD RF tag local positioning system using the concepts of GPS was built based on a proprietary infrastructure (Werb and Lanzl, 1998). Detailed introduction about adopting Active RFID for position determination through comparing different approaches was provided by (Retscher and Fu, 2007).

Summary: Navigation satellite system like GPS and Galileo enables providing the global position determination. Once a user purchases a receiver, one can get the normal position service for free and the accuracy is good enough for many LBS applications like car navigation and tourism service (the commercial service needs payment but offers better performance). However these systems have drawbacks like urban canyon effect which make indoor navigation almost not possible.

GSM cellular network also provides location service in a wide area through most used mobile phones indoors and outdoors. But users have to pay monthly or per request for the service, and the location accuracy is not high. Therefore, it is only suited for LBS applications like emergency calls to get a rough location extent.

Wireless network is rapidly growing in the centralized downtown areas, and the location sensing technique depends on the software framework. No hardware except wireless card is necessary, which is available for most of the modern mobile devices. Comparing with GPS, the achieved accuracy is better in urban areas but worse in rural areas because the wireless network coverage is not wide enough in rural areas or many developing countries.

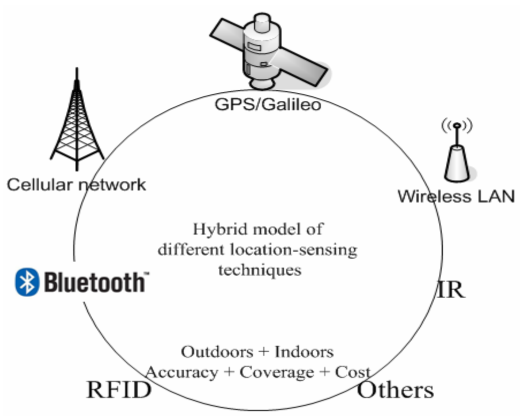

Figure 2. The hybrid model of different location sensing techniques

Other location sensing techniques like IR, 3D-iD RF tag and Active RFID can obtain very high accurate locations indoors or outdoors. However some drawbacks can not be easily avoided such as: they incur significant installation and maintenances costs when considering large area coverage, their performance may be strongly decreased by many surrounding factors like the weather and obstructed objects, and so on.

Thinking over the pros and cons of the above location sensing approaches, it is widely accepted that fusing multiple sources of location sensing techniques will be the optimal solution for the ubiquitous LBS applications (Borriello et al., 2005). 错误！未找到引用源。 shows the hybrid model that combines different techniques, e.g. using the GSM cellular network to acquire a general location, and then using wireless network or GPS to get the exact location can greatly improve the speed and accuracy to determine the user's location.

Although the location sensing techniques for 2D LBS and 3D LBS are equivalent, 3D LBS applications deal with detailed indoor objects and thus greatly demand high accuracy indoor positioning in many cases. The hybrid model allows getting location information through shifting among different location sensing techniques, e.g. GPS used in widely open areas, GSM, WLANs or RFID used in built-up areas. Such model has been carried out in the industry like the Skyhook wireless network. When adopting this model to future 3D LBS, three factors including accuracy, coverage and cost should be the dominant determination to combine different location sensing techniques.

2.3 Wireless Networking:

For LBS mobile devices, basically there are two main approaches for transferring the data from server to client. The first one is using the protocols of the cellular network. From so called the second generation (2G) GSM network, to 2.5G GPRS/EDGE, to 3G UMTS network, LBS span these mobile telephony technologies. As the development of new generation of mobile network, data transferring speed is increasing from theoretically 171.2 Kbps (GPRS, internet based) to 1Gbps (IMT Advanced). The second one is the wireless LAN network (WLAN), whose data rate varies in the range of 1 to above 100Mbps using 802.11x standards.

Ma et al. analyzed both approaches and concluded that: cellular networks provide always-on connectivity in large area with relatively low data rates to users with high mobility; WLANs give much higher data rates to users with low mobility over local areas. Then they investigated a hybrid method to seamlessly integrate both approaches using the Stream Control Transmission Protocol for getting better data transferring performance (Ma et al., 2004). Obviously, 3D LBS using large amount of datasets require more bandwidth and fast data transferring techniques.

2.4 Data standards

There are many standards for 2D and 3D data in the GIS world. Normally, 3D data standards allow defining 2D data as well. As stated by Kolbe et al. (Kolbe et al., 2005), semantic and spatial interoperability are two vital principles for defining a useful 3D city model in GIS. Thus, we introduce several well known 3D data standards and figure out their different characteristics based on the semantic and spatial aspects.

VRML/X3D: are computer graphics standards (X3D is the successor of VRML97) that provide only the possibilities to describe the geometric structure of 3D objects. They do not have the support for the representation of thematic information. For example, you could not find out the meaning of an object or aggregate objects (e.g. a building), their attributes or relationships with other objects. Thus, it is very hard to perform complex 3D spatial analysis.

LandXML/LandGML: is a specialized XML/GML standard for civil engineering, land management, surveying and cadastre, used in the land development, transportation and pipe networks. However, it does not support complex 3D geometry types like volumes, but only represent 3D objects via their footprints.

Keyhole Markup Language (KML): is an XML-based language schema for expressing geographic annotation and visualization in the web. It has been widely used in the GIS community and recently approved as an OGC standard. However, for describing 3D objects it has similar shortcomings as VRML/X3D.

Industry Foundation Classes (IFC): is a standard for representing and exchanging Building Information Models (BIM), which is supported by most CAD software. IFC (or ifcXML, based on XML structure) standard developed by the International Alliance for Interoperability (IAI) and became an ISO standard. IFC objects model provides rich semantic elements in the AEC/FM domain, for example, walls, roofs, windows and stairs. Nevertheless, it does not provide enough city objects like streets, water bodies and vegetations, so it is not appropriate for building complex city models. Moreover the spatial and semantic coherence can not be automatically ensured in some IFC models (Stadler and Kolbe, 2007)

CityGML: will probably soon become the OGC standard for representing 3D city objects in a spatio-semantic coherence data model (Kolbe et al., 2005; OGC, 2007; Stadler and Kolbe, 2007). That means "geometrical objects "know" what they are. Semantic entities "know" where they are and what their spatial extents are".

The semantic model of CityGML based on the IFC model consists of class definitions for the most important features within 3D city models, including buildings, DTMs, water bodies, transportation, vegetation, and city furniture. It does not contain a whole set of IFC objects, but it can be easily extended according to users' own necessary 3D semantic objects. All CityGML classes are derived from the basic class 'Feature', defined in ISO 19109 and GML3 for the representation of spatial objects and their aggregations.

The geometric model of CityGML is equivalent to a subset of GML3 geometry packages, which is based on the standard ISO 19107 "Spatial Schema", representing 3D geometry according to the well-known Boundary Representation. Therewith, CityGML is regarded as a specific GML application schema.

Moreover, CityGML supports the concept of Levels of Detail (LoD) up to five discrete levels (LoD0-LoD4), ranging from outdoor wide areas to indoor architectural models like the furniture and interior installations.

Thus, users can define 3D city models at various degrees of complexity with respect to geometry as well as semantics. For example, for merely outdoor LBS applications, lower LoDs are adopted; otherwise higher LoDs are employed to represent detailed indoor 3D objects.

Summary: Comparison of other existing 3D data formats is described in (Kolbe et al., 2005; Stadler and Kolbe, 2007). CityGML as a special case of GML format, representing virtual 3D city objects with semantic and spatial information in different LoDs, is a very good candidate for 3D LBS applications.

2.5 Standardized Geospatial Web Services

Geospatial web services are indispensable parts of LBS. The mobile user sends its current location to a particular geospatial web service, and the server is able to response the geospatial data in many formats, such as raster maps or vector XML-based documents. We list some notable geospatial web services that often used in LBS applications in the following.

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Web Map Server (WMS): is an OGC standard for producing maps of spatially referenced data dynamically from geographic information over HTTP. The WMS responses can be pictorial formats like JPEG, PNG, GIF or vector based graphic elements like SVG.

Web Feature Server (WFS): is an OGC standard for requesting and serving vector geospatial data over HTTP. The WFS responses contain the data in the GML format. Furthermore, the transactional WFS (WFS-T) standard supports transactions (such as insert, update and delete) which allow the client to modify data on the remote server.

Web Terrain Service (WTS): is an OGC standard similar to (and builds on) WMS but provides a static 3D rendered image of a dataset instead of the data itself to the client.

Web 3D Service (W3DS): is developed as an extension of WMS/WTS by OGC and offers additionally the possibility to visualize 3D scene graphs. In contrast WMS/WTS only provides the representation of static views as bitmaps. The W3DS merges different types (layers) of 3D data in one scene graph and outputs it as the default VRML97 format, GeoVRML and X3D are also suggested. Then the scene graphs are rendered and interacted on the client side.

Building Information Models Web Perspective View Service (BIM-WPVS): is proposed to integrate and visualize both BIM and GIS data by (Hagedorn and Döllner, 2007). It is one of the high level high-level geoinformation services having several distinct features: enhancing geoinformation, provision of business functionality, integration of complex geoinformation, provision of high-quality geovisualization, and support of user interaction and context-awareness.

Summary: In fact, BIM-WPVS method can be regarded as a special case of mixing other different web services, because it can be built on top of the WFS when data-oriented, the W3DS when Scenegraph-oriented or WMS/WTS/WPVS when visualization-oriented. WMS and WTS only sever 2D bitmaps to the client, and thus are mainly limited to 2D LBS. The W3DS is able to offer real 3D scene graphs to the client for different renderings, which is reasonable to 3D LBS. However, a scene graph like the VRML format only contains geometric information but little semantic characteristics and relations of geospatial objects. Thus the W3DS could be an appropriate solution for the 3D visualisation in many 3D LBS, but is not satisfying for highly required semantic applications.

The WFS delivers the geospatial data itself to the client as the GML format, so it severs necessary semantic contents. For example, users can request geospatial objects within a bounding box, or with a specific identifier, or users even can perform complex spatial operators on the server such as getting buffer areas within a certain area. CityGML being one of the GML application schemas therewith can be used as the output format of the WFS in order to provide spatio-semantic coherence information for more complex 3D LBS applications, such as a disaster management system in built-up areas demanding not only 3D graph scenes but also 3D spatial queries.

3. A PROTOTYPE OF 3D LBS

This paragraph discusses a method about how to set up spatio-semantic 3D LBS with BIM and GIS data. A 3D LBS prototype emphasizing on data standards and geospatial web services is explained. Other components of LBS are not studied in this paper. The method used in this prototype can be considered as the groundwork for designing and building many different 3D LBS applications or upgrading the ones from existing 2D LBS.

3.1 Basic concepts

Many existing 2D LBS are using the WFS to provide diverse datasets because of its powerful data processing and analyzing capabilities. Those LBS providers also expect to keep the same framework when upgrading the current 2D LBS to 3D LBS in order to reduce the costs and make the maintenance task simple. As described before, CityGML as a special case of the GML for representing 3D data can be supported by the WFS, and thus the combination of the CityGML and WFS is a good option to provide 3D LBS. Therefore, the way of how to make use of existing 3D datasets and publish them as the CityGML through the WFS needs to be investigated.

There are large amounts of existing BIM data representing detailed 3D buildings with high LoDs containing such as floors, ceilings, walls and doors objects, which belong to the LoD4 in the CityGML. The BIM data is normally stored as CAD data format like IFC and DXF. To employ those existing 3D datasets into LBS or GIS, the interoperability issue has to be aware. An idea is to load those datasets into a spatial database for further data handling. However, there is currently no standard encoding for storing 3D geometry in the database, which hinders the WFS in serving 3D data (Müller and Curtis, 2005). Müller and Curtis proposed to model the complex 3D geometry types into separate tables which aggregate other geometries via table joins. Thus, the 3D geometry can be stored either as build-in database types or further aggregations through table joins.

After putting the 3D BIM datasets into the database, the WFS can be created to connect with the database and deliver the LBS client applications the GML data with 3D encoding (CityGML) via a standard interface. For the LBS client, it needs not know the internal changes of the LBS system.

3.2 Methodology

Based on the basic concepts, the workflow for setting up a 3D LBS system is illustrated in
Figure 3. In general, the source data of BIM format is firstly converted into the GML data by the data translation and transformation tool named Feature Manipulation Engine (FME) 2007 from Safe Software. Then the GML data is loaded into Oracle 10g database through Snowflake GoLoader. After that, a standardized WFS server based on the Oracle database is built through Snowflake GoPublisher toolset. Finally, through the WFS interface the client can obtain the CityGML data used for different 3D LBS applications.

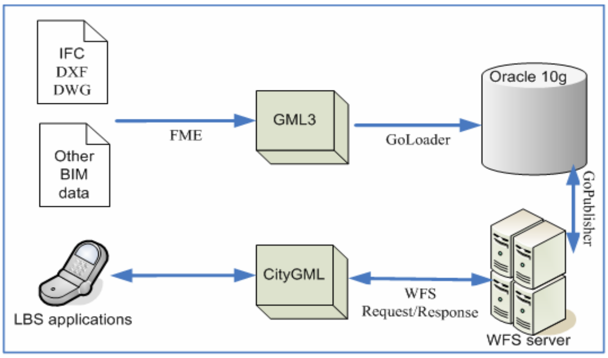

Figure 3. A prototype of 3D LBS using CityGML and WFS

To testify the proposed workflow, a simple building is firstly created using AutoDesk Architectural Desktop in the DWG format. The DWG file is then converted to a GML3 document by FME. However, FME has not yet fully supported 3D proxy objects of the DWG format, so the achieved GML document needs to be restructured in order to keep the semantic information, e.g. which polygon geometries belong to a "window" object. After that, Snowflake GoLoader and GoPublisher tools are employed to fulfil the following tasks. Finally, we can retrieve a CityGML file containing the same spatio-semantic content as the original DWG file through standard WFS requests. It then can be visualized in the 3D GML Aristoteles viewer as shown in Figure 4.

The results have also shown that the functions of an existing WFS server are not affected with the newly added 3D datasets, because the interface to the LBS client is not changed. Thus, a 2D LBS system may be upgraded to a 3D LBS system in a similar way.

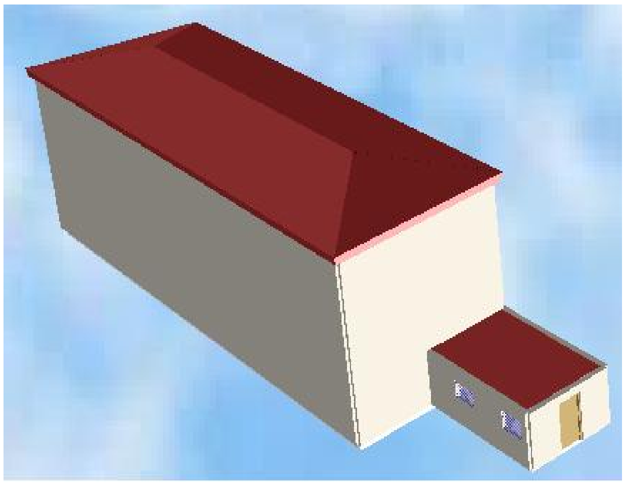

Figure 4. The small building as the CityGML data visualized in 3D GML Aristoteles viewer

4. CONCLUSIONS AND OUTLOOK

In this paper, we have discussed the important issues when upgrading 2D LBS to 3D LBS based on several core components: *mobile devices, location sensing techniques, data standards and standardized geospatial web services*. However, the introduction of 3D LBS encounters a number of challenging issues. Because of the high demands of 3D data processing and visualization, 3D LBS need the improvements on all the above aspects. For example, mobile devices with better performance are required; more accuracy and coverage positioning service is preferred, and thus the hybrid model of different location sensing techniques should be considered; suitable spatio-semantic 3D data formats like CityGML can be the role to serve 3D LBS; existing standardized geospatial web services like WFS can be upgraded to meet complex 3D data requirements without changing its standard interface.

A prototype has been given to show the possibility of upgrading an existing 2D LBS system to the 3D LBS system. The CityGML and WFS are the key roles to fulfil the tasks. Though

several software tools can greatly help to implement the workflow, the programming work still has to be done to make up the missing functions. In future, this workflow should be tested by more different BIM data. And the feasibility and performance of the CityGML data rendering on small mobile devices like smart phones should be testified.
More researches about 3D LBS should be compared in future to find out new emerged features. For example, 3D annotation techniques in (Maass et al., 2007), 3D LBS application on a PDA client for navigation purposes in (Fischer et al., 2006) and indoor navigation using 3D web services in (Mäs et al., 2006).

Along with the development of ubiquitous and high speed telecommunication systems, 3D digital map becomes feasible to offer richer LBS. We see the merit of scalability owned by the 3D information system matching to different capabilities of the communication networks. In order to guarantee a certain level of business volume that protects the heath of the industrial chain, appropriate standardization effort on 3D LBS is needed.

How to employ the recently publicized 3D map services using Google Earth, Virtual Earth or SkylineGlobe in 3D LBS applications is also very attractive. For the enterprise level of complex 3D LBS according to actual circumstances, the proprietary software suits like SkylineGlobe Enterprise may be employed.

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