

Geospatial data issues in the provision of Location-based Services

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Abstract Much of the recent research attention in Location-based Services has focused on issues such as user interface design, capabilities of the mobile device operating system and software, wireless network connectivity, user privacy etc. Given that the technologies used to deliver Location-based Services (LBS) are changing and developing so rapidly it is understandable why research energy has focused into these areas. This paper attempts to step back from these particular topics to provide an overview of the role that geospatial data plays in LBS. Geospatial data is data where a functional dependency exists between the data itself and the location from which an LBS is accessing this data. If there are problems related to the geospatial data for: (1) a particular geographic region in which the LBS is being used or (2) the intended domain application of the LBS, then the LBS will not be popular amongst its intended target users. We argue that data is an ubiquitous issue for the broad spectrum of LBS applications and services - from friend finder applications to wayfinding and navigational assistance. If geospatial data is not available which is fit for the purpose of the intended LBS then it is unlikely that the LBS will be a success among users. The paper discusses the issues related to geospatial data which are most likely to be influential to both the developers of the LBS and the users. The paper concludes with some recommendations about access to geospatial data intended for providers of spatial data and developers of LBS. Overall the paper aims

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to stimulate research interest and focus more attention on the problems of accessing geospatial data for LBS.

1 Introduction

Location based services (LBS) are a “killer application” [2, 3] in mobile data services thanks to the rapid development in wireless communication and location positioning technologies. This ubiquitous computing paradigm brings great convenience for information access. People with Internet-enabled wireless devices can find out information like: Where is the nearest coffee shop? What time is the next bus at this station? Where is the highest rated seafood restaurant in town? The constraints of mobile environments, the spatial property of location-dependent data, and the movement patterns of mobile users pose a great challenge for the provision of location-based services to mobile users [4]. Users of LBS are usually looking for information about their current spatial location or some spatial location which they intend to move to at some later time [5]. The work of Raper [6] gives a good current survey of LBS applications in which he states “already span a very wide area”. The most widely used applications are personal navigation systems offering routing to Points of Interest (POI) queries; however, these systems are already offering traffic updates and friend-finder functions. The accepted definition of LBS is given by Virrantaus *et al.* [7] who defines LBS as “information services accessible with mobile devices through the mobile network and utilizing the ability to make use of the location of the mobile device”. The vast majority of definitions of LBS have grown from this for example with Jacobsen [8] describing LBS more generally “as any value-added previous service offered in a wireless environment that exploits mobile device location position information”. Jiang and Yao [9] uses this definition to help emphasise the significance of geospatial data where the author calls geospatial data “one of the key components of any LBS, as in essence LBS are a form of data or information service”. Of course LBS are available to static users - users accessing LBS through their Internet-browser on their computer in their office or home. In this case the location must be specified in some other way: clicking on a map, selecting location from a given set of preset locations, etc. Obviously LBS are most useful to users who are moving about in an environment such as town or city with an Internet-enabled mobile device (laptop, PDA, mobile phone). In this paper we do not concern ourselves with the positioning component of LBS: that is how the current locational coordinates of the user in geographic space are determined. Data aspects of LBS are acutely emphasised by Acharya [1] who states that “location dependent wireless data dissemination has become an integral part of our day-to-day activities”.

The research contribution of this paper is to provide a report on the first phase in work to establish a set of robust geospatial data requirements for LBS. These requirements will provide a framework to elicit the maximum benefit for developers of LBS (and consequently users of these services) by understanding the characteristics of geospatial data for LBS: access policies, formats and distribution means, pro-

protocols, semantics, models, etc. The paper is organised as follows. Section 2 reviews existing work on LBS in which geospatial data issues are specifically addressed. Section 3 follows with a more formal description of data requirements for LBS. The section discusses the issues related to various aspects of development in LBS: access to data, usage of data, accuracy etc. Section 3 uses a casestudy of OpenStreetMap to illustrate some of these concepts. The paper closes with Section 4 which provides a review of the paper and draws some conclusions. The closing section discusses upcoming opportunities for LBS to access previously inaccessible geospatial data. Some indications for future work are outlined. While the paper attempts to provide a generic overview of geospatial data management issues for LBS in cases where case-study data is required OpenStreetMap is used.

2 Review of existing work

Many authors identify the importance of the availability of accurate, high quality, geospatial data for LBS. However at the time of writing no comprehensive review of geospatial data requirements for LBS is documented in the literature. [10] agrees with this observation and states that “the data involved in LBS has not been really examined in depth”. In Jiang and Yao [9] the authors give a review the influence of GIS on LBS. Jiang and Yao [9] argue that the current “geospatial data infrastructure is not particularly suitable for LBS applications”. There are many reasons for this: the symbology used is often not suitable for the small screen space of most mobile devices; there is limited storage space on these devices which prohibits the download of large “chunks” of geospatial data. Tryfona [10] provides a categorisation of data based on data semantics. The authors discuss the advantages for LBS if modelling of data is carried without using categories and ontologies. Another measure of the current state of play for geospatial data for LBS is evident from LBS application-oriented papers. In Jacob *et al.* [11] the authors use OpenStreetMap for a navigation system on a university campus. The authors describe data collection for OpenStreetMap which allowed them to build a rich geospatial model of their university campus. This option was chosen as a result of the high cost of third party commercial geospatial data coupled with the poor coverage and accuracy of Google Maps and Bing Maps for that part of Ireland. Ishikawa *et al.* [4] examined the effectiveness of using a mobile navigation system in comparison to paper maps for wayfinding in a city. Among the interesting observations of the study was “how much of the surrounding area needs to be covered by map data” with the authors indicating that local landmarks took on equal importance to global landmarks for many of the wayfinding tasks. Breuing and Baer [12] present the conception, implementation and first evaluation results of a bicycle route planning system with mobile clients. The work describes in detail the building of data structures for graph-based geospatial data and database query issues. The authors do remark that “missing data” at a local level prevented the development of a more complete model of the bicycle route network. Sayda [13] describes results of experiments involving par-

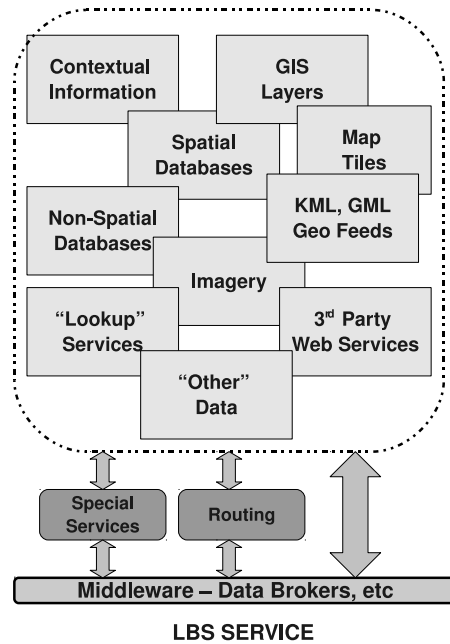


Fig. 1 A model of a hypothetical geospatial data server system available for access by Location-based Services

ticipants in an LBS study capturing spatial data for trails/routes with their mobile devices targeted at locations where good navigational data for hikers and bikers was not previously available.

3 Geospatial Data and Location-based Services

It is often said that for an automobile to run out of fuel is far *better* than to run out of engine oil. If an LBS was an automobile then spatial data would be the engine oil. Without it LBS cannot operate. Running out of fuel - analagous to wireless connectivity problems, user positioning error, etc is certainly inconvenient but once properly restored the LBS can continue to serve the user. There are many different sources of geospatial data. It is true that few of these geospatial datasets have been collected specifically for LBS. The developers of applications which consume LBS are very often (almost always) not geospatial data producers, collectors, or custodians. LBS do not access the spatial data directly - rather these data are usually delivered by mapping/GIS/database services in response to request by the software application calling the LBS. This is illustrated in Figure 1 where a geospatial data

server system is described. Not every organisation providing LBS will utilise every data source illustrated in the diagram. The inverted pyramid of geospatial data usage in LBS is shown in Figure 2. *General Geospatial Data* such as topographic maps, Point-of-Interest (POI) databases, map tile imagery, web services such as real-time weather, traffic reports, etc are the most common and most frequently used geospatial data and services in LBS. The bottom of the pyramid is *Purpose Specific* data which has been collected and used for a very specific purpose. This is compatible with the “*Other*” data in Figure 1 which refers to the integration of data to form new derived datasets. Many datasets are not collected specifically for LSB so they often need to undergo some data management work and in some cases have a spatial component embedded inside them. Examples include geocoding a collection of images/photographs or adding geographical coordinates to a set of postal address. As is evident from Figure 1 there is no common format or single database from which an LSB can access the information and geospatial data necessary to answer user queries and requests. Rather LBS work as described by Tryfona and Pfoser [10] by accessing a combination of sources of geospatial data which are “predominantly non-conventional databases and other databases characterised by the spatial and temporal dimension, i.e., spatiotemporal databases”. The data limitations of an LBS, if they are known in advance and are quantifiable, should be clearly stated and explained to the users. Proper safeguards in software code should be provided to deal with spatial inconsistencies such as if there is no data or information available for a location. In the next section we summarise the categories of LBS which are most prominent applications.

3.1 Categories of Location-based Services (LBS) Services

To assist in our discussion of geospatial data requirements for LBS we now present a broad classification of the types of LBS. The three service categories are as follows: Points of Interest Queries, Routing and Navigational Assistance, and Other services. These three categories overlap in many ways with the distinction often arising from how the LBS is presented to the user in both the query interface and the query results. For example the beginning of a shortest path routing request from the current location L_0 to some location L_n requires the LBS to establish the current position and retrieve spatial information about both L_0 and L_n . This would usually involve a geospatial database query similar in form to a Point-of-Interest query such as {Where am I now?}.

- **Points of Interest (POI) Queries**

- Where is the nearest X ? where X can be any amenity - pub, hotel, car-park, place of worship, etc from the current location L_0
- What features, in general, are around the current location of the user L_0 ?
- POI Buffer query: What features, in general, are around the current location of the user L_0 inside a circular buffer of radius x meters centered at L_0

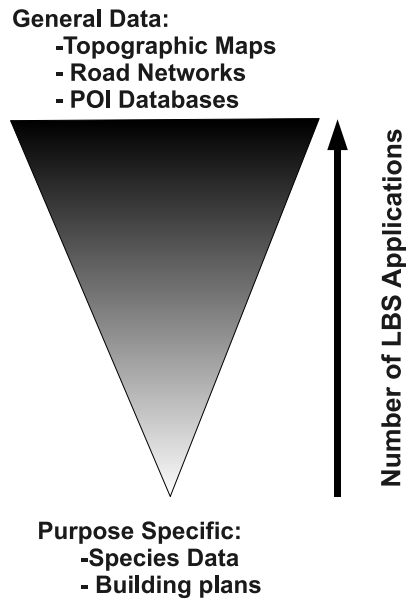


Fig. 2 Inverted pyramid of geospatial data usage in LBS. (Adpated from [14])

- **Routing and Navigational Assistance**

- Shortest path from the current location (or specific buffer zone around current location) to destination point B .
- Shortest path from the current location (or specific buffer zone around current location) to the nearest destination B_i from a chosen set of n destinations $\{B_1, B_2, \dots, B_n\}$.
- Shortest path from a specific location A a distance d from the current location to the destination point B

- **Other Services**

- Information queries: What is the weather forecast for the location I am at?
- Auxillary information: Information in the form of downloadable documents - menus from local restaurants, cinema movie show times
- Timetabling: Timetable information for a bus stop or train station nearby
- Advanced Queries: For engineers - what services (electrical, gas, sewage, etc) are under the ground at this location?

This section summarised the three principal categories of LBS services and has set the context for the discussion of geospatial data requirements in the next section.

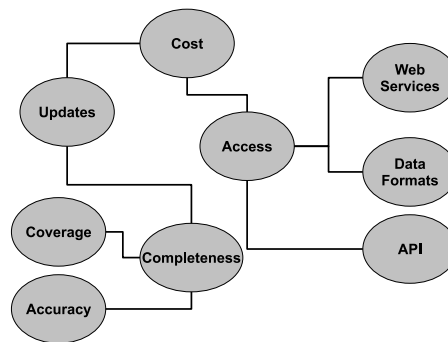


Fig. 3 Data issues, and their linkages, for consideration before using a geospatial dataset or resource in a Location-based Service

3.2 Data issues and their linkages

In Figure 3 we show a network representation of the data issues, and their linkages, that developers of LBS should consider before building an LBS around a particular geospatial dataset or collection of geospatial datasets. A critical node in the graph presented in Figure 3 is *Access*. When *access* to geospatial data is possible the next issue is how much will this *cost*? If there is a *cost* involved then what is the *update* cycle. The *update* cycle should be considered in the wider context of ensuring that the geospatial data source is maintained and offers an acceptable level of *completeness*. The issue of *completeness* should be evaluated by the *coverage* and *accuracy* characteristics of the data. Moving from the *access* node in the other direction - access to the actual geospatial data can be provided directly through an *API* as in the case of Google Maps. Alternatively *web services* may be available for the distribution of the geospatial data. Web map services (WMS) usually provide map images. For other types of web services the *data file formats* that the geospatial data is provided in should be considered. The following discussion elaborates on some of the nodes in Figure 3:

- **Cost of Geospatial Data:** There is growing pressure on Governments and National Mapping Agencies to provide free access to national level mapping and geospatial data. Revenue and costing is a “complex problem” in LBS [6]. This problem is compounded by the fact that most LBS are consumer orientated and operate within an Internet market which is dominated by a “free-at-the-point-of-use” business model [6]. Google Maps and Bing Maps offer free access to their geospatial data. OpenStreetMap offers free access to geospatial data with the added advantage that users can change the underlying geographic feature data.
- **Access to sources of Geospatial Data:** Outside of data sources such as Google Maps, Bing Maps, and OpenStreetmap there are vast quantities of geospatial data that remain undiscovered. One such example is data generated by scientific research in universities, colleges, and research institutions. Universities and public

research institutions perform more than 35% of all research undertaken in Europe [15]. Environmental research data is an obvious example. However very little of this geospatial data is made available for public access.

- **Updates to Data Sources:** Users of LBS expect that the geospatial data they are accessing is up-to-date. It is important for developers of LBS to consider the update frequency of their geospatial data sources. Tee [16] outlines a loose time-frame indicating when the sources of spatial data for LBS should be updated and checked for ground-truth accuracy. He estimates that street level mapping should be checked and updated if necessary approximately every three to six months. Points of Interest (POI) data should be checked every six months also. Sadoun and Al-Bayari [17] agree with this and states that “update of GIS databases are a critical aspect of data quality for LBS”.
- **Geospatial Data Formats:** Currently heavy database access and the movement of geospatial data via the network are two major bottlenecks impeding the efficiency of mobile applications [18]. LBS developers should avoid the situation where users must download large “chunks” of geospatial data to their mobile devices. Outside the issue of network bandwidth many of these mobile devices may not have sufficient processing power to perform the necessary processing on the data in an acceptable time for the user.
- **Coverage of Data:** A common problem amongst Google Maps, Bing Maps, and OpenStreetMap is that may often be great variability in the spatial coverage of these geospatial data sources. While coverage of buildings, roads, streets, public amenities, transportation etc is very good for most large cities in the Western world smaller towns and villages can suffer from little or no coverage. Referring back to Figure 4 the coverage of Maynooth town in Ireland in Google Maps is very poor. Tourists using an LBS on their mobile phones in a city could move out to a smaller town or city and find that the LBS returns little or no results as a consequence of poor spatial coverage in the underlying mapping database of the current location.
- **Accuracy of Data:** With the rapid development of spatial data capture technologies (such as high resolution satellite images and Lidar) and spatial data modelling methods (such as extending two-dimensional methods to three- and four-dimensional modelling methods), the size and accuracy of the spatial database has been increased dramatically [18]. Figure 4 shows an example from Maynooth, Ireland. A query of “where is the Glenroyal Hotel?” returns 7 locations - none of which are correct with an average error of approximately 300 meters. Alternatively, in Figure 5 an example from OpenStreetMap in London is shown. This shows a POI, in this case a bakery shop, where the address information including postal codes are supplied.



Fig. 4 Incorrect locations of a hotel on Google Maps



Fig. 5 An example of a properly addressed point feature in OpenStreetMap

3.3 Case-study example of LBS access to geospatial data

In this section we attempt to conceptualise the issues outlined in the previous section. In Figure 6 we provide an illustration of LBS “data space”. In this paper a user of an LBS is assumed to be mobile and moving through a given environment most commonly a town or city. They are moving through geographical space. Some LBS users may travel large distances while others users (possibly pedestrians) move through a smaller area. Figure 6 shows that the “data space” corresponding to the geographical space the LBS user is currently positioned in is not homogeneous. For example, in Figure 6 a user might access an LBS in a large geographical space, such as a city, where there is excellent geospatial data availability for LBS. However a different user may be attempting to access an LBS in a small geographical space such

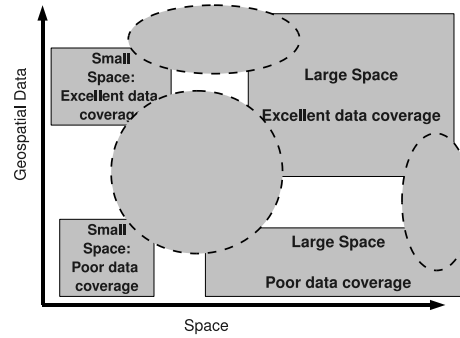


Fig. 6 An illustration of the categories of “data space” that users of LBS services can access these services in

as a university campus or small town. Geospatial data availability for this region of geographic space could be very poor with the LBS unable to access various data sources. It might also be the case that no geospatial data exists for that geographical space. The shapes with broken lines indicate that LBS users can move between areas exhibiting different levels of geospatial data coverage: for example moving from downtown in a city out to the city suburbs. To help understand this concept we carried out a small case study using OpenStreetMap. Table 1 shows the results of a some POI queries on the OpenStreetMap databases for a number of cities in Europe to support the ideas presented in Figure 6. Four countries were chosen for this case study: Ireland, Wales, Estonia, and Latvia. All countries are similar in geographical size and population. For the POI query for each city in these countries we chose the following query template: From a point p within a city return all points of interest (POI) within a 1km^2 , 4km^2 , and 8km^2 square. This square is created such that the point p is the center of the square where the diagonals of the square intersect. The point p was chosen as either the main railway station in that city or the street recognised as the high street or main street. It is reasonable to assume that a citizen or tourist using an LBS for POI queries would find themselves at either of these two locations attempting to navigate themselves around the city. Table 1 shows the number of POI found in a given square grid for each city. The (latitude,longitude) coordinates of the point p are provided. For small geographic spaces (1km^2) Tailin returned 106 POI with Maynooth returning 96 indicating very good data coverage. The example of a small geographic space with poor data coverage is Daugavpils (Latvia’s second largest city) which returned 7 POI. The example of a large geographic space (4km^2) with poor data coverage is Cardiff which returned just 80 POI while (4km^2) spaces in both Riga and Tailin returned more than 250 POI.

Table 1 An example of the number of Points of Interest in a given geographical area for four countries. The database used is OpenStreetMap

Location	(Lat,Long)	Area	No. POI
Ireland, Maynooth	(-6.59319,53.38166)	1km ²	96
Estonia, Tailin	(24.7371,59.440)	1km ²	106
Latvia, Daugavpils	(26.5280,55.8749)	1km ²	7
Wales, Swansea	(-3.9411,51.6254)	1km ²	65
Ireland, Dublin	(-6.2482,53.3525)	4km ²	170
Estonia, Tailin	(24.7371,59.440)	4km ²	261
Latvia, Riga	(24.12099,56.9463)	4km ²	255
Wales, Cardiff	(-3.17975,51.4756)	4km ²	80
Ireland, Dublin	(-6.2482,53.3525)	8km ²	390
Estonia, Tailin	(24.7371,59.440)	8km ²	356
Latvia, Riga	(24.12099,56.9463)	8km ²	370
Wales, Cardiff	(-3.17975,51.4756)	8km ²	117

4 Conclusions

This paper has provided a report on the first phase in research work which is establishing guidance on geospatial data requirements for LBS. These requirements provide a framework which allows developers of LBS to understand how to derive maximum benefit out of the geospatial data they can access and under what conditions they can use the data. A rigorous literature search has revealed that this issue has not received very much research attention. The paper provides a useful starting point for LBS developers in understanding potential obstacles they may encounter when trying to implement an LBS for a (1) specific function, (2) specific geographical region, and (3) specific set of users. The issue of access to geospatial data for LBS is unlikely to disappear in the near future. LBS are often cited as one service likely to continue driving the development of the “Mobile Internet”. Irrespective of the range of services encapsulated by the broad “LBS” term some authors comment that “all LBS will continue to require spatial data management capabilities to link position information with other data sources” [24]. Other authors remark that “ultimately the utility of LBS will be measured by their ability to meet user needs” [25] in the application domain where “*content is king*” [21]. The requirements from the LBS technological and user communities for better access to geospatial data can become a significant driver for the geospatial information industry to ensure better access to geospatial data in reality. In this paper we have used the term access in its broadest sense to include access in terms of: cost models for access to geospatial data, accuracy of the data, frequency of updates, and the conditions under which developers can “mash up” or integrate this geospatial data with their own data and information. Geospatial data access issues have been around as long as most people working in the GIS field can remember. The question remains: Does an individual or organisation limit itself to the development of an LBS providing functionality which is dictated by the flexibility of the geospatial data available? Alternatively does that individual or organisation expend time and resources “fitting” or “mash-

ing up” the geospatial data that currently exists so that it “works” for the LBS that want to build? We suspect that the answer is not clear with many LBS from smaller organisations with fewer resources falling somewhere in between.

4.1 Future LBS access issues for Geospatial Data

Open Access repositories are providing open access to scientific publications. However access to the raw data and information related to these publications is scarce. Access to these data is needed not only for independent verification of scientific results but also for secure longer-term preservation and “fresh analysis and utilization of the data” [15]. LBS could benefit from better access to these data streams. Large collections of environmental and other geospatial data have become data tombs [26] seldom visited or maintained, key datasets never emerging from “grey dusty archives” or “slowly rotting” because users do not know of their existence or are denied access to them. Metadata, a key aspect of data access and retrieval on the Internet, is seen by data owners and creators as “boring” [27]. Consequently many researchers see little or no academic or workplace recognition for the task of providing or maintaining metadata [28]. Some authors call the situation “ironic” that at a period where the volume of geospatial data generated in scientific research is at an all time high, the practice of documenting and accessing these resources is at an all time low [29]. We strongly feel that LBS could greatly benefit from more of this scientific research data, particularly the geospatial data, being made available for public access. The uniqueness of scientific research data both in the temporal and spatial dimension would render it an excellent source of geospatial data for LBS. While scientific research data may be positioned at the lower end of the inverted geospatial data pyramid for LBS (see Figure 2) it would prove a valuable resource.

The INSPIRE directive is an EU Directive which will collate spatial, geographic and environmental data, currently held by numerous organisations in Europe with the aim of providing a single access point to each EU member states geospatial information [30]. INSPIRE will enable planners, decision makers, citizens, scientists, and policy makers to have consistent and easy access to geospatial data and information in the European Union. Rules for financial cost models for the data is not explicitly set out in INSPIRE but the Directive indicates that “spatial data charges and licences should be compatible with the principle aim of sharing spatial data and services between public bodies”. Rather the Directive indicates that charging and licensing of this data should be addressed by each individual Member State. In the Directive 34 “spatial data themes” have been defined in three Annexes in order of needs and priority while specifically stating that no new data will need to be collected. From an LBS perspective INSPIRE offers great hope for access to national level geospatial data. Annex 1 includes “coordinate reference and geographic grid systems, geographical names and administrative units”, Annex 2 “elevation, land cover, ortho-imagery, geology”, while the finally Annex 3 includes many diverse geospatial data sets and sources: “statistical units, buildings, soil, land use, popula-

tion and demography, habitats and biotypes”, and many others. There are concerns that the INSPIRE Directive is moving too slowly and that it could take several more years for INSPIRE to become a viable reality for LBS. However, INSPIRE carries the possibility of much improved cross border and cross cultural geospatial data integration and exchange in Europe.

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