Research Issues in the Development of Advanced Mobile Web-Based Geospatial Information Services

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ABSTRACT

This paper considers the development of the next generation of mobile web-based geospatial information services and the underlying research issues that need to be tackled. These include the human factors, (including device related issues and geosemantics), architectural issues and efficiency, complexity of processing and security issues.

KEYWORDS

Geographic Information Systems, Mobile Web Services, Advanced Geospatial Processing

1. INTRODUCTION

The convergence of four complementary technologies, namely web-based cartography and geographical information systems (GIS) [1], real time satellite positioning, third generation (3G) multimedia communications providing wireless internet [2] and high performance mobile devices, now makes it possible for advanced web-based geospatial information services to be provided to individuals on the move (Figure 1). To what extent current location based information services can be considered "geographical information systems" is debatable, though the ability of mobile devices to access the internet and web applications such as "Google Maps", to obtain location information via GPS, and to query geographical databases and retrieve information of interest in a locality certainly approaches GIS functionality.

Although there is much promise of further mobile location based services becoming available to the general user, there are a number of issues that need to be investigated in developing what might be regarded as *advanced* mobile geospatial information systems offering full GIS functionality, such as the possibility of performing sophisticated spatial queries and spatial analysis using complex multi-source geographic data sets whilst on the move. These issues relate to the overall architecture of the mobile geospatial information systems and services, to human-computer interaction factors (which depend on the type of users and application needs) and to the complexity of data, data sources, and analysis methods to be used. This paper introduces these issues and presents some of the key future research requirements.

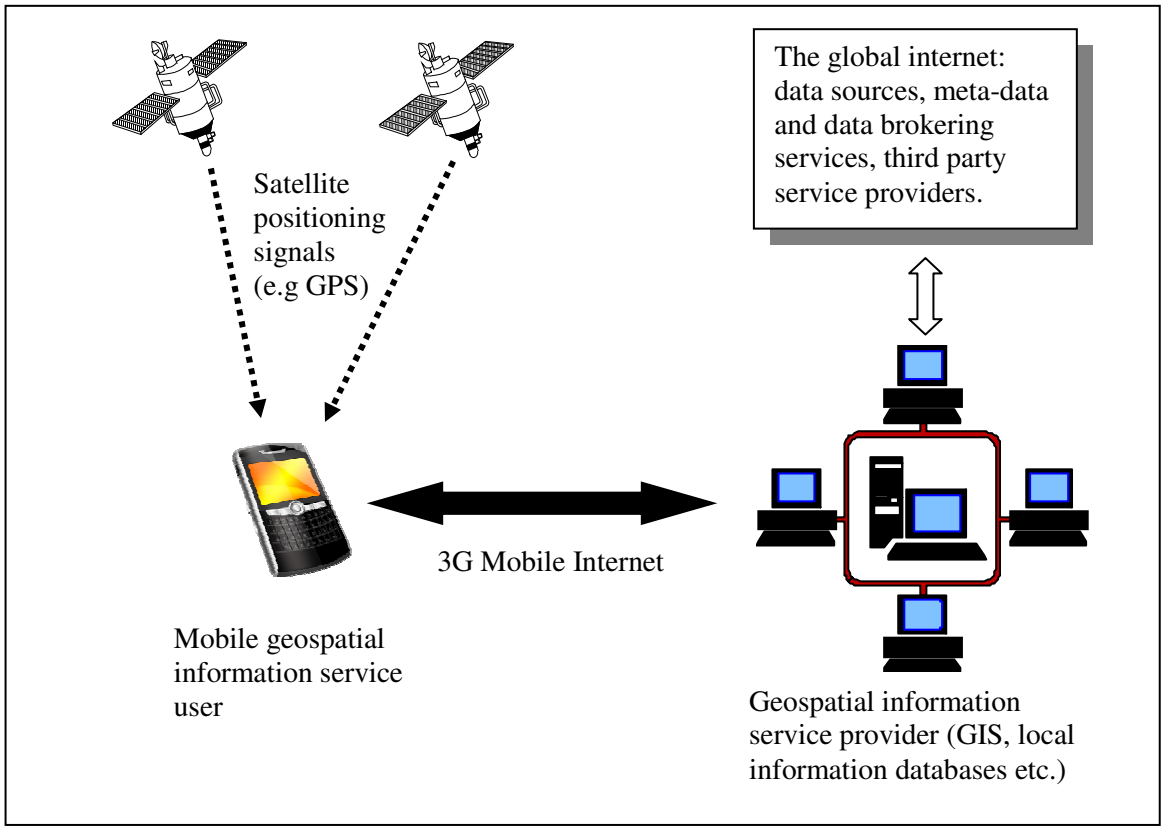

Figure 1. The context of advanced mobile geospatial information services

2. TYPOLOGY OF MOBILE GEOSPATIAL INFORMATION SYSTEMS

Before examining the technical issues related to advanced mobile geospatial information systems in detail, it is worth attempting to characterize the range of conceivable systems that might be regarded as mobile geospatial information services. The advent of the internet and the Web has had a dramatic effect on the world of GIS. Fifteen years ago, few people, other than GIS specialists, would ever have made use of computerized maps. Today, searching for information about localities, performing route queries for travel plans, downloading street maps and aerial imagery and finding nearby amenities are frequent every day uses of the Web for many people, both in a fixed and mobile context. In this context, the mobile internet may be considered as the latest technological development driving the evolution of GIS offering the prospect of GIS functionality to users on the move.

If we consider the possible range of complexity of mobile geospatial information systems, we can envisage a spectrum of classes of system of increasing sophistication, depending on the types of interaction and processing that take place (Table 1). Assuming a mobile device is both 3G mobile internet and GPS enabled, at the most simple level a geospatial information service involves web-based interaction (downloading, viewing, searching) with geospatial data (maps, traffic data etc.). Systems may offer the user hyperlinks to web content in real time. These hyperlinks may be triggered by a system of virtual beacons and websigns associated with physical locations, buildings etc. [3].

Table 1. Spectrum of mobile geospatial information services and uses

Type		Description	Typical Application
Simple ↓ Highly complex	1	Mobile device is both location aware (GPS) and internet-enabled (3G mobile Web) and can download maps and related near real time information such as current road traffic status and interact with Web service for simple analysis.	Route planning and traffic congestion avoidance. Public user.
	2	As above except that Web service allows user to interact with and update simple non-spatial database information.	Finding a restaurant and reserving a table. Public user.
	3	As above except that user may update both non-spatial and geospatial data held by service provider using Web interactivity.	Mobile mapping and map updating. Specialist user.
	4	User interaction can involve complex spatial queries and spatial analysis (may be performed either at mobile client or at Web host using data held by the Web host).	Geographical analysis for planning applications. Specialist user.
	5	System provides mobile user with access to, and the ability to integrate, analyse and interact with, an extensive range of highly complex geospatial data sets, including maps from a wide variety of international sources and ancillary data such as current satellite imagery, weather forecasts etc.	Complex multi-criteria decision making (e.g. in dealing with humanitarian emergencies). Specialist user teams.

At a more sophisticated level, a mobile web-based geospatial information service would permit a user to interact with and even update either geospatial or non-geospatial data (or both) in real time. Applications of this would include live restaurant table booking (non spatial data) or map updating by utility companies (geospatial data). It is expected that only the more sophisticated users would update spatial data.

At a more complex level, the geospatial information service would provide the user with the ability to undertake complex queries and perform spatial analysis almost like a fully functioning GIS. This might be done with a small number of spatial datasets held by the Web service provider or in some cases with many highly variable and highly complex datasets drawn from a wide range of sources in many countries. This can be considered advanced web-based geospatial information analysis. The complexity of the application and analysis can now become constrained by a wide range of issues that need further research such as the impact of the mobile device characteristics, the human factors involved and the architecture of the system -particularly the distribution of data and processing in the client-server context.

3. RESEARCH ISSUES FOR ADVANCED MOBILE GEOSPATIAL INFORMATION SYSTEMS

In order to be effective in meeting user requirements, there are a several key issues that need further research in order to provide fully functional advanced geospatial information services in the mobile web context.

3.1. Physical Human-Computer Interaction (HCI) Issues

One of the principal limitations associated with mobile geospatial information services is the limitation of the HCI created by the physical characteristics of small mobile devices. Although the latest generation of mobile devices offer not only mini keyboards, touch sensitive screens, and pointing devices as well as voice recognition, there are significant restrictions to the possible types of interaction with geospatial data permissible in the mobile context. Most fixed lab-based Geographical Information System installations make use of workstations with larger than average display screens, as well as digitizing tables. Effective visualization is a key aspect in the human understanding of geospatial data. Large displays are taken as a necessity by geographical data analysts. Many users continue to find web-based maps unsatisfactory because of their small size and the inefficiency in continually panning and zooming through a web-delivered map in order to find something of interest. For many GIS applications, simple panning and zooming is not an appropriate way of visually comprehending spatial information. Generalization approaches are needed which adapt to the user's context or requirement and emphasize important local information from the point of view of comprehension by a process of intelligent simplification. Such a process may smooth out features in data, group together objects and even re-label them. This requires a highly complex process of spatial data manipulation adapted to the user's objectives. Whilst the topic of generalization is well known in the cartographic field, current approaches to generalization are still inadequate for mobile GIS. The user effectively has a very small "window" through which to look at and understand what might be an enormously complex geospatial dataset covering a large geographical area.

3.2. Ontological Human-Computer Interaction (HCI) Issues

A further significant issue in relation to Human-Computer Interaction is that of semantics and language. Working with geospatial data can become difficult because of the different words or terms used to describe geographical objects as well as different ways of classifying physical features in the natural environment. This is the highly complicated area of geosemantics. Although some attempts have been made to develop sophisticated geospatial ontologies using frame-based ontology modelling tools, e.g. [4], so far little has been done to incorporate such approaches in mobile web-based geospatial services.

3.3. Data Mixes and Sources

Some straightforward applications of geospatial information services can be met with a small number of geospatial datasets held by the Web service provider. However some of the most sophisticated uses of geospatial information services involve the integration of datasets from multiple sources such as multiple layers of digital geospatial map data together with multiple up-to-date satellite images from different sensor types (optical, infrared, radar), especially for environmental applications, natural resource management, and disaster relief applications. This can require the integration of image processing tools within a web-based geospatial information service [5] as well as tools to gather data from crisis areas [6]. Furthermore it is fast becoming possible to access geospatial datasets from a wide range of sources (especially government agencies) in different countries through initiatives to define and adopt metadata standards and to implement international web-based infrastructures and protocols to give access to such datasets (e.g. the European INSPIRE initiative [7]). However, whilst such initiatives are to be welcomed, until more work is done to integrate them in web-based geospatial information services, the availability of data will continue to be a problem for advanced applications of mobile GIS.

3.4. Complexity of Analysis and Processing and Efficiency of Geospatial Processing in the Mobile Client-Server Environment

Some processing of geospatial data in the mobile context can be relatively straightforward, such as route finding or making a restaurant reservation based on simple spatial queries, such as point-in-polygon queries and proximity analysis based on a single layer of geospatial data. However the real power of GIS comes from far more complex analysis, which might involve multiple criterion decision making based on integrating together multiple layers of data at different scales. Datasets can be very large and processing can be very intensive and slow. Much more research is needed on system architecture and in particular on issues such as:

- How to divide data between the client mobile device and the web server
  -Should the entire spatial dataset, or part of it, be transferred to the mobile device to enable the user to perform more analysis without communicating with the web host? Does this improve efficiency or does the data transfer time become a significant unwanted overhead on performing geospatial analysis?
- How to divide processing between the client mobile device and the web server
  -Should the analysis of the geospatial data take place exclusively at the web host with the mobile device acting only as the interactive front end, or should the mobile device carry out some processing using downloaded application software as well as data?

Whilst in a simple geospatial processing context (types 1 and 2 in Table 1) such questions have little significance, in a context in which many datasets are being used of large volumes each (many GByte) and in which very complex spatial analysis and interaction with data is required (e.g. types 4 and 5), such software system architecture issues can become very important. We have hardly seen any attempt to address this topic in research so far, though performance improvement of web-based GIS and the efficiency of writing to web applications in a mobile client – server environment have begun to be investigated –see [8], [9] respectively.

3.5. Security Issues

A further issue that requires research in the development of advanced geospatial information services is the security of data and transactions. Geospatial datasets are usually very expensive to create because they involve tedious surveys on the ground or the elaborate and time-consuming interpretation of satellite data or aerial imagery. Approaches that share geospatial data between web server and mobile device potentially put the data into unauthorised hands. The issue of data security is therefore inextricably linked to the issue of system architecture and efficiency as above.

CONCLUSIONS

Web-based geospatial information services are still in their infancy in the mobile computing context. However there are significant human benefits in developing advanced systems that can use highly complex datasets to perform highly sophisticated geographical analysis, for commercial as well as societal benefits. There remain some significant research challenges to make advanced mobile systems a reality of a type and sophistication of current lab-based GIS. It is clear that the Web will be the engine for such developments, but the human factors involved, the software architectures for the Web applications in the mobile client-server environment together with efficiency and security issues, all need further research and development.

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