Providing Context-Aware Information in a Mobile Geographical Information System

Anderson Resende Lamas, Jugurta Lisboa Filho
Ronoel Matos de Almeida Botelho Júnior and Alcione de Paiva Oliveira

Universidade Federal de Viçosa, Departamento de Informática
Viçosa, MG, CEP: 36570-000, Brazil

Abstract. This paper presents the development of a Mobile Geographical Information System (Mobile GIS) capable of managing context information. This system was established from an architecture based on the specification of an ontology-based context model and a set of Web Services to access information remotely stored in a geographic database. This mechanism allows Mobile GIS users to receive personalized information in their mobile devices, combining the information on their profiles with the display of geo-spatial data.

1 Introduction

A number of fields of knowledge have been expanded through the use of technologies that exploit mobility and communication between users and devices. The steady expansion of the infrastructure wireless network and high proliferation of mobile devices, such as PDA `s (Personal Digital Assistant), Smartphones and mobile phones are some of the technologies that have favored this scenario.

In the field of Context-Aware Applications, for instance, one can use the dynamic context of mobile devices users, caused by the mobility and constant change in environment, and then to delivery personalized information. Context sensitive applications are characterized by use of context information to provide services and information relevant to users during a task execution [3]. In this scenario, context can be defined as any information that can be used to characterize a person, a place or object, relevant to an interaction between a user and an application [3].

As for the field of Geographic Information Systems (GIS), the intersection of geo-spatial data with mobile devices has led to the field of Mobile GIS. According to [8], Mobile GIS can be defined as a framework that integrates hardware and software to access spatial data (maps) through a wireless network, using mobile devices.

The integration of context information in a Mobile GIS environment can add great value to the information that is displayed to an application user. This is due to the possibility of delivering personalized information to the user in combination with the display of geo-spatial data. In this scenario, this paper presents the characteristics and existing solutions for both the field of Mobile GIS and context sensitive applications

and proposes an architecture for developing applications of Mobile GIS capable of managing context information.

Section 2 presents the architecture proposed for the development of context sensitive Mobile GIS. Section 3 presents a case study built to validate this architecture. Section 4 describes some related works. Finally, Section 5 presents the conclusions of this work.

2 The CM-GIS Architecture (Context-Mobile-GIS)

The architecture proposed in this paper, named Context-Mobile-GIS (CM-GIS) aims to construct integrated context sensitive mobile GIS applications.

The development of Mobile GIS applications, as defined by Tomko [10], requires attention to: (a) storage and data query in a spatial database; (b) provide a mechanism for querying and accessing data remotely located; (c) the correct use of technology.

Regarding the geographic database (a) one must use a Database Management System (DBMS) that is capable of storing and managing geo-spatial data. Some DBMS available today provide this functionality through an extension for spatial data, such as Oracle, SQLServer, PostGreSQL, among others. To deal with remote access to information (b), a frequently adopted solution is the use of Web Services, because of their ability to provide services that can be dynamically accessed by a network. Finally, with respect to the adopted technologies (c), it is important to choose a tool capable to manipulate and display geo-spatial data, both in its graphic and descriptive form in mobile devices.

In the case of context sensitive applications is important to establish a mechanism capable of representing and manipulating the context involved in the domain being treated by the application. Strang and Linnhoff-Popien [9] discuss that the key to the development of a context sensitive application is the definition of an appropriate context model, which can be defined by using ontologies.

The ontological characteristics of formality, explicit semantic and implementation abstraction enable software systems not only to infer new information from ontology-modeled information, but also to share the information among themselves so as to integrate, in a transparent way, the services that handle it [1].

Based on these characteristics, Bulcão Neto [1] proposed the Semantic Context Model (SeCoM), a domain-independent ontological model described in Web Ontology Language (WOL), which serves as basis for the definition of information in context. This model consists of a set of inter-related ontologies based on semantic dimensions of identity, location, time and activity. Since the SeCoM model was generically defined, in this paper we suggest its use in the definition of the context model.

Based on the above-made considerations, we proposed the CM-GIS architecture for developing applications of context-sensitive Mobile GIS, as in Figure 1.

This architecture requires the following elements for the development of mobile GIS applications able to manage context information:

1. The mobile GIS application, which will be the interface for the clients from their mobile devices. An important requirement for this application is to be able to manipulate and display geo-spatial data;

2. A set of Web Services to manage the communication and provision of services and information to the user. The use of Web Services has a great importance in this architecture, by allowing that operations demanding a high load of processing can be performed on more robust machines and not directly on the mobile device;
3. A module that communicates with Web Services and performs spatial queries, via SQL language, on information stored in geographic database;
4. A set of ontologies used to model the context involved in the application. We suggest using the SeCoM model for modeling the context;
5. A defined module from the context model based on ontologies that communicates with the Web Services to provide information in context. The information in context should also be stored in the database and queried via SQL;
6. A geographic database that manages all the geo-spatial data and descriptors involved in the application.
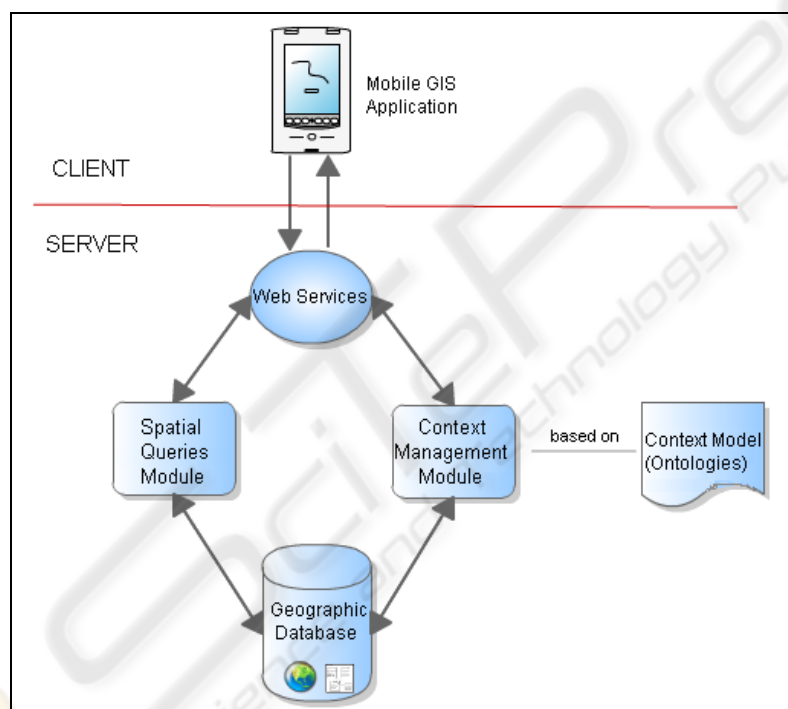

Fig. 1. Context-Mobile-GIS Architecture (CM-GIS).

These items must be detailed according to the application that will be developed. The next section presents a case study, built upon this architecture.

3 UFV-GeoMobile: A Case Study

This section describes the development of the UFV-GeoMobile system. This system

was to target the campus of the Federal University of Viçosa (UFV), which is a public institution of higher education, with the main campus located in the city of Viçosa, Minas Gerais State. The university offers several under-graduate and graduate courses in numerous fields of knowledge. It receives annually a large number of people visiting or establishing some kind of relationship with its campus. Among these people, there are new students (~ 2000 per year), conference participants, visiting researchers, or simply people who want to visit their facilities. Moreover, there are also people who already have some connection with the University, such as professors, clerks or students. The common feature among these people is their often difficulty in identifying sites or services in campus, given its large area and the appearance of new buildings and facilities.

The university's present scenario seems to be ideal for implementing a system to validate the CM-GIS architecture proposed in this work. The existence of a practical and automated information source available to the user seeking guidance in the campus is a necessity. It would be even more appropriate that the options for querying and obtaining the information were customized according to the context in which the user is. For example, a visitor is probably not interested in the time of the next class, but on the directions of campus services (bank, pharmacy, etc.) or even the place of any event.

The UFV-GeoMobile was implemented, allowing a user of a Mobile GIS application on PDA to query or receive personalized information about the UFV Campus. This application is based on a map of the campus properly managed by a component for geographic data handling. In addition, it has a set of query screens and a mechanism for information display based on the user context. More precisely, the context definition is based on a calendar of activities to be performed by the user and so to display the geographic location of the place where this activity will be performed.

The whole process of development is described in the following sections.

3.1 The Context Model: Ontology of a University Campus

The context model for the case study UFV-GeoMobile must contain information on the structure and activities carried out in a university campus. Information that must be modeled to reflect this domain includes:

- People: in this case students, staff and visitors. Employees may be teachers, researchers or technical and administrative staff;
- The administrative structure: it reflects the hierarchical organization of a university, including rectory, centers of education, departments and councils;
- The academic structure: involves activities related to teaching, research and extension;
- Calendar of activities: is the set of tasks that a person can perform on campus. This item is essential for the system to consider context information;
- Geo-spatial data: used to represent spatially the elements with geographic location on campus. Examples of these elements are buildings and services installed in each of these buildings.

From this information it is initiated a formal representation of a context model. The context model of the UFV-GeoMobile system was based on the SeCoM model, pro-

posed by Bulcão Neto [1], using the ontological concepts *Actor, Activity, Spatial Event* and *Temporal Event*.

The context model has great importance to develop the application, as it was used as basis for the modeling of geographic database and the implementation of features available in the context management module. Due space limitations, the formal representation of the context model is not shown in this paper.

3.2 Building the Geographic Database

The geographic database of the UFV-GeoMobile system was built from the aggregation of a geospatial data set, kept by the university administration, associated with a set of relational databases used by a variety of administrative systems, also maintained by the institution. The geographic data have been modified to fit formats of data handled by the Mobile GIS application. Initially, data were stored in the format of the AutoCAD system and were converted to Shapefile format, using the Cad2shape software [2]. The following layers were produced: thoroughfare, buildings and specific facilities within a building, such as administrative offices and laboratories.

The conceptual modeling of the database, as shown in Figure 2, was determined from the information modeled in the domain ontology of a university campus. For this task, we used the UML-GeoFrame model [6], which is a specific model for geographic database. Subsequently, the conceptual model was implemented using DBMS PostGreSQL with its spatial PostGIS extension.

The class diagram of Figure 2 shows that the system has classes with and without spatial representation. According to the UML-GeoFrame model, classes and subclasses Clerck, Professor, Admin Technician, Person, Student, Visitor, Calendar, Activity, Council and Type of Facility are specializations of non-geographic objects (Π), i.e., with no spatial representation. The classes Building, Thoroughfare and Facilities are perceived in object view (O) and have spatial representation of the type Area, Line and Point, respectively. Finally, the classes AerialView and ContourLine are perceived in the field view (Θ). The first has spatial representation of the type GridCells (K), whereas the second has representation of the type Isolines (ϑ).

3.3 Mobile GIS Application

The graphical interface of Mobile GIS was developed using the framework Microsoft Visual Studio 2005, C#.NET language and the Pocket PC 2003 emulator. SharpMap software was used to display geo-spatial data, which is a set of controls based on the platform .NET to build GIS applications in mobile devices [7]. An initial version of this prototype was published in [4].

To allow access to information stored in the geographic database a Web Service was implemented in Java (SOAP), using NetBeans IDE 6.1 and the Glassfish server. For every feature available in the application of Mobile GIS, a corresponding operation in the Web Service was developed to receive the parameters and pass them to the Spatial Queries Module or to the Context Management Module. To illustrate these

operations, this work describes the option of locating a facility or service and the mechanism that shows the geographic location of an activity to be performed.
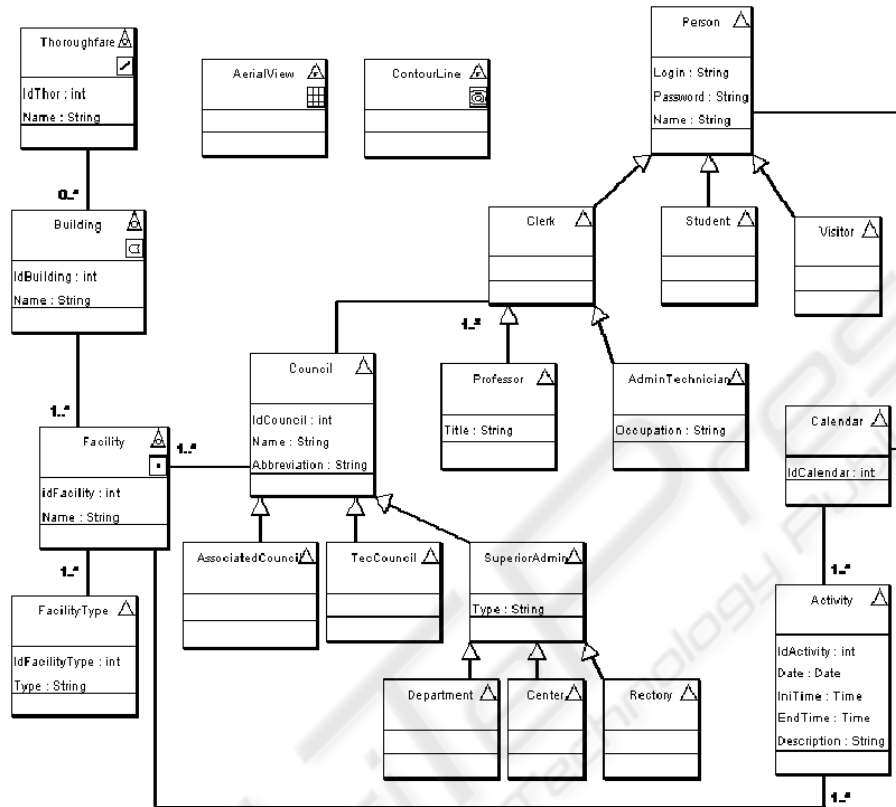

Fig. 2. Modeling of Geographic Database for UFV-GeoMobile.

To locate a service or facility, initially the user enters the full or part of the name of the desired item, using the screen shown in Figure 3-a. When typing the name and clicking on Search, the GetLocation operation is called, as described in Table 1.

This operation receives as parameters the typed name and the user's coordinates (x,y) via GPS or via a mechanism implemented in Mobile GIS, which allows the users to indicate their location by inserting an icon on the map. This second choice was implemented so the user can use the UFV GeoMobile application, even with a PDA without an embedded GPS.

The operation GetLocation passes its parameters to the query module, generating a SQL query, also described in Table 1, which returns the names of sites that match the name entered, the distance of each facility in relation to the user's position and the coordinates of the building's center point in which the facility is allocated. The selection carried out by the SQL query is returned to the mobile device that displays a list of available facilities (Figure 3-a). By selecting one of the items in this list, the application indicates, through a small icon on the map, the location of the chosen facility.

(a) Facility query   (b) User notification.

Fig. 3. (a) Query screens for facilities in the UFV-GeoMobile system. (b) Screen to notify the user the occurrence of any activity.

The mechanism to notify the Mobile-GIS users on the geographic location of any activity registered in their diaries was developed as a sensitive choice to the user's context. Initially, to have access to this feature the user must be identified in the system using a login and password. From this moment, every minute the operation GetEvent is called, as in Table 2. This operation receives as parameter, besides the login and password, the current time, which is obtained from the mobile device. This operation passes these parameters to the context management module which generates a SQL query (Table 2). This query returns all the user's recorded activities to start in 10 minutes, describing the activity in detail, initiation and completion time, name of the facility in which the activity will be performed and the coordinates of the building's center point where the facility is allocated. From this information, the Mobile GIS application displays a text box and indicates to the user the activity location through an icon, as in Figure 3-b.

Table 1. Web Service operation and SQL query to locate facilities.

```
  @WebMethod(operationName = "GetLocation")
     public List<String> GetLocation(
       @WebParam(name  =  "LocationName")  String  Location-
Name,
       @WebParam(name = "x") double x,
       @WebParam(name = "y") double y) {
          .....
  }
```
```
  SELECT f.name, distance(b.the_geom,
     GeomFromText('POINT(x, y)',-1)), Centroid(b.the_geom)
  FROM Building b, Facility f
  WHERE (f.name like '%LocationName%') and
      intersects(b.the_geom, f.the_geom);
```

Table 2. Web Service operation and SQL query to notify events.

```
  @WebMethod(operationName = "GetEvent")
     public List<String> GetEvent(@WebParam(name = "login")
     String login, @WebParam(name = "password")
     String password, @WebParam(name = "actualTime")
     Object actualTime) {
          ....
       }
```
```
  SELECT a.description, a.iniTime, act.endTime,
     f.name, Centroid(b.the_geom)
  FROM Building e, Facility f, Activity a,
       Calendar c, Person p
  WHERE (a.horaIni – 'actualTime') = 10 and
         (p.login = 'login') and (p.password='password') and
            intersects(b.the_geom, f.the_geom) and
            (p.idperson=c.idperson) and
              (c.idCalendar=a.idCalendar);
```

4 Related Works

The development of context sensitive mobile GIS applications has been studied by
several groups. This section describes some of the works that contributed to accom-
plish the architecture proposed here.

Li et al. [5] provided a mechanism based on Web Services to display contextual
information to mobile device users. Contextual information is defined through the
user's location, via GPS, and information of used hardware and software. This context
definition does not consider information on the user's profile or even addresses geo-
spatial data.

Weibenberg [12] described the FLAME2008 platform, which was developed to be
used in the Beijing Olympics. This platform is featured as a solution to deliver perso-

nalized information to mobile device users. This work uses a set of ontologies to define the user situation, trying to infer the activities that users could carry out over a period of time. Starting from the definition of the user's position, the most appropriate information for that time is displayed via Web Services. Despite being a very wide system, this work does not describe the implications of integrating information in context into a Mobile GIS environment.

The CoMPASS architecture (*Combining Mobile Personalized Applications with Spatial Services*) [11] uses, in addition to information on profile and location, the user's trajectory to automatically deliver personalized information to a GIS-Mobile client. The definition and storage of context information are based on the use of a set of log files. This approach differs from the solution proposed in this article, which suggests the use of ontologies to define context information and the use of a geographic database for storing data.

5 Conclusions

This work presented the specification of an architecture for the development of GIS-Mobile systems capable of managing context information. The characteristics inherent in this type of application was studied in order to reach the proposed solution, which includes: the use of Web Services to allow remote access to information from the mobile device, ontologies for context modeling and use of geographic database to store spatial data sets.

The use of ontologies to specify a context model has as the main advantage the possibility of specifying the correct meaning and relationship between the terms, avoiding ambiguous interpretations of the domain being modeled. Choosing the Se-CoM model can facilitate modeling a great deal, because it addresses the various dimensions of contextual information and it was developed with the characteristic of domain independence.

The use of ontologies in this work could be better exploited if there were a mechanism to handle the ontologies and infer new information before returning them to the Mobile GIS user. This will be addressed in a future work.

Another feature that can be further exploited is the use of Geo Web Services, which are services defined by the OGC (Open GIS Consortium) to address specifically geo-spatial data. This mechanism would avoid the need for installing an application on PDA, as it was done with the UFV-GeoMobile system. Instead, the Mobile GIS application could be accessed with a browser.

However, the architecture here presented, together with the UFV-GeoMobile developed as case study, show how the use of a Mobile GIS application capable of managing information in context can be very useful, especially the ability to provide personalized information combined with the display of geo-spatial data. Thus, this work presents a very practical and feasible way to develop applications for mobile GIS, presenting solutions to address typical challenges of applications involving geo-spatial data, context and mobile devices.

Acknowledgements

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