Context-Aware Mobile Geographic Information Systems

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INTRODUCTION

A new breed of computing devices is taking more and more ground in the highly dynamic market of computer hardware. We refer to smart phones and PocketPCs, which redefine typical usage procedures we are all familiar with in traditional, desktop information systems. Dimensions of this class of computing devices allow users to keep them at hand virtually at all times. This omnipresence allows development of applications that will truly bring to life the motto: "availability always and everywhere."

Hardware and software characteristics of the aforementioned devices require a somewhat modified approach when developing software for them. Not only technical characteristics should be considered in this process, but also a general set of functionalities such an application should provide. Equally important is the fact that the typical user will be on the move, and his attention will be divided between the application and events occurring in his environment. Fundamentally new and important input to mobile applications is constantly changing the user environment. The term that is used most frequently and describes the user environment is a context, and applications that are able to independently interpret a user's context and autonomously adapt to it are named context-aware applications.

Recent developments in wireless telecommunications, ubiquitous computing, and mobile computing devices allowed extension of geographic information system (GIS) concepts into the field. Contemporary mobile devices have traveled a long way from simple mobile phones or digital calendars and phonebooks to powerful handheld computers capable of performing a majority of tasks, until recently reserved only for desktop computers. Advancements in wireless telecommunications, packet data transfer in cellular networks, and wireless LAN standards are only some of technological advancements GIS is profiting from. This mobile and ubiquitous computing environment is perfect incubation grounds for a new breed of GIS applications, mobile GIS. Advances in mobile positioning have given a rise to a new class of mobile GIS applications called location-based services (LBS). Such services deliver geographic information and geo-processing services to the mobile/stationary users, taking into account their current location and references, or locations of the stationary/mobile objects of their interests.

But the location of the user and the time of day of the application's usage are not the only information that shapes the features and functionalities of a mobile GIS application (Hinze & Voisard, 2003). Like other mobile and ubiquitous applications, mobile GIS completely relies on context in which the application is running and used. The full potential of mobile GIS applications is demonstrated when used in the geographic environment they represent (Raento, Oulasvirta, Petit, & Toivonen, 2005). Thus, development of mobile GIS applications requires thorough analysis of requirements and limitations specific to the mobile environment and devices. Practices applied to traditional GISs are usually not directly applicable to mobile GIS applications. Limitations shaping future mobile applications, including mobile GISs, are ranging from hardware limitations of client devices to physical and logical environment of the running application. Considering the fact that mobile applications are used in open space and in various situations, the ability of the application to autonomously adapt itself to a user's location and generally a user's context significantly increases the application's usability. Regardless of the type of LBS and mobile GIS application, the part of the system that is handling context is fairly independent and can be separately developed and reused. The proper management of contextual data and reasoning about it to shape the characteristics and functionalities of mobile GIS applications leads to a full context-aware mobile GIS.

The second section presents concepts of mobile GISs and context awareness, and the principles of how context can be incorporated into traditional GIS features adapted to mobile devices. Data structures and algorithms supporting context awareness are also given. The third section presents GinisMobile, a mobile GIS and LBS application framework developed at Computer Graphics and GIS Lab, University of Nis, which demonstrates the concepts proposed in this article. The last section concludes the article, and outlines future research and development directions.

CONTEXT AWARENESS IN MOBILE GIS

Even though the concept of mobile GIS is in its infancy, technologies that were prerequisite for development of this niche of GIS applications are today widely available and well known to GIS developers. It is reasonable to expect that there are prototypes available demonstrating all the advantages mobile GIS offers to field fork personnel. ESRI, as one of the leading companies in the GIS field in its palette of products, offers a mobile GIS solution targeting the PocketPC platform. It is called ArcPad (http://www.esri.com/software/arcgis/ bout/arcpad.html). It is a general type of mobile GIS solution with open architecture allowing easy customization and tailoring according to a specific customer's needs. It therefore offers a set of basic GIS functionalities and tools that are used to extend application with functionalities needed for specific usage scenarios. ESRI bases its ArcPad on four basic technologies: mobile computing device (PocketPC), basic set of spatial analysis and manipulation tools, global positioning system (GPS), and wireless network communication interface.

Basic GIS functionality understandably supported by ArcPad is geographic maps visualization in the form of raster images. In order to avoid the need for maps conversion into some highly specialized proprietary raster map format, ArcPad supports usage of all of today's widely used raster image formats, like JPEG, JPEG 2000, and BMP, as well as MrSID, which is common in GIS applications. Thematically different maps in the form of raster images can be grouped into layers. Apart from raster type, layers can also contain vector data. Also, standard vector type data formats are supported, most importantly the shapefile format. That is the most common vector data format in use in GIS today and is also well supported by other ESRI GIS software like ArcInfo, ArcEditor, ArcView, ArcIMS, and others. Other optimizations which enable sufficient speed in handling spatial data include spatial indexing schemes. Spatial indexing significantly increases speed of spatial objects visualization and search, especially on portable devices with limited processing power. Indexes are prepared on other desktop-type ESRI applications, and afterwards are transferred to a mobile device and used by ArcPad. In order to support usage of ArcPad throughout the world, a majority of map projections are included.

ArcPad is conceived as an integral part of the ESRI GIS platform consisting of other products, so there is the possibility of ArcPad functioning as a client for ArcIMS or Geography Network (http://www.geographynetwork.com/). Data is transferred to ArcPad using TCP/IP protocol and any sort of packet-based wireless networking technology (wireless LAN, GSM, GPRS, EDGE, 3G, etc.). Possibly the strongest advantage of ArcPad is its extensibility and adaptability. Forms used for thematic data input and manipulation are created and customizes independently using ArcPad Studio and Application builder development tools. Application toolbars can be adapted to specific user needs. More importantly, specific interfaces can be developed and added to ArcPad, enabling it to acquire data from different database types and sensors (GPS location devices, laser rangefinders, magnetic orientation sensors, etc.).

One academic project that encompasses the development of mobile GIS is "Integrated Mobile GIS and Wireless Image Servers for Environmental Modeling and Management," developed at San Diego State University (2002). The project includes an integrated GIS platform where, in the field, data collection must be performed using a mobile GIS client platform. Effectiveness of the developed system is tested in three different services: campus security, national park preservation service, and sports events. The development group's decision was not to develop a mobile GIS solution from scratch, but to upgrade and customize ArcPad. Similarly to other mobile GIS solutions, this project is based on modified client/server architecture. Fieldwork personnel are using a PocketPC device with a customized ArcPad version installed. Customization includes components developed specifically for testing on campus. PocketPC is connected with an external GPS device, and therefore it has constant access to user location information. Considering wireless communications, campus grounds are covered with a wireless LAN, and all client PocketPCs are equipped with WLAN adapters. The server side of this system includes a typical set of servers and tools from ESRI including ArcIMS and ArcGIS.

When this system is employed by the campus security service, field units use mobile GIS components to locate a reported incident location more easily and swiftly. Mobile GIS is also used to report new incidents to central. Following report-in, information about a new event taking place is momentarily available to all units. Therefore, reaction time is shortened and all patrolling units within campus are synchronized more easily.

Demonstration use case shows the field unit receiving a warning about a fire reported at the specified site. The closest field unit is being notified. Using the campus WLAN, the central ArcIMS server is contacted and a map of that part of the campus is acquired, as well as blueprints of buildings endangered by fire. The central server also contains thematic data about the estimated number of people in these buildings, evacuation plans, and similar information. Simultaneously, units on site can update fire reports with more detailed information and therefore shorten response time of other units enroute. The ArcPad application customized for this use and being used in this scenario is shown in Figure 1.

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