Developing Context Aware Support in Mobile GIS Framework

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SUMMARY

Development of geographic information systems for mobile and hand held computer devices requires significantly modified approach in comparison to development of more traditional GISs. Main issues to be addressed are efficient handling of limited memory and processing power, appropriate management and presentation of information on highly restricted devices and design of appropriate user interfaces. User interface design is rarely discussed in research but can significantly impact usability of the system. Communication of data and commands between a user and an application is explicit in most traditional user interface designs. This has the effect that information concerning environment of the user mostly remains unused or has to be formalized by the user. In the mobile environment the goal is to reduce workload for the user and automate, as much as possible, the process of application adaptation to the operating environment conditions. This paper presents basic categorization of context and data structures and algorithms developed for automated context management, interpretation and usage in an application based on mobile GIS application framework.

KEYWORDS: *Context awareness, Location based services, Mobile GIS, Context representation*

INTRODUCTION

A new breed of computing devices is taking more and more ground in highly dynamic market of computer hardware. We are referring to Smartphones and PocketPCs which are redefining typical usage procedures we are all familiar with in traditional, desktop information systems. The most obvious differences are of hardware and software (supported API) nature. 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 motto “availability always and everywhere”.

Hardware and software characteristics of aforementioned devices require somewhat modified approach when developing software for them. Not only technical characteristics should be considered in this process but also general set of functionalities such 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 user’s environment. The term that is used most frequently and describing user’s environment is context and applications that are able to independently interpret user’s context and autonomously adapt to it are named context-aware applications. Mobile GIS applications and Location Based Services (LBS) are no exception to this. Their full potential is demonstrated when used in the geographic environment they represent [Raento, 2005]. Regardless of the type of the LBS and mobile GIS application the part of the system that is handling context is fairly independent and can be separately developed and reused.

Second chapter of the paper gives definition of the context that is used in development of algorithms for context handling. It also contains analysis of different types of contexts and their influence on behaviour of a LBS and mobile GIS application. Third chapter presents the LBS and mobile GIS framework and architecture that include components and services for context management and handling. Fourth chapter deals with context on logical level. It contains descriptions of data structures and a rule-based expert system for maintaining and handling contextual data and its use in customizing LBS and mobile GIS application behaviour and response. Fifth chapter gives details of the context-aware LBS application demonstrating proposed concepts and developed context-aware support integrated in the application framework.

CONTEXT AWARENESS

In interpersonal communication, significant amount of information is transmitted without explicit communication of such information. If we take verbal communication as an example, nonverbal signs will significantly influence completeness of verbally communicated data. We are referring to facial expressions, body postures, voice tone, nearby objects and persons including past history of communications. All this is helping the process of interpretation of verbally transmitted data. In a typical human-machine communication there is very little context information available in a form that can be interpreted by machine. Therefore our first step should be to define the context. No matter how obvious this may seem, the definition of the context influences significantly all the decisions in the further process of context-aware application development. Dey et al. in [Dey, 2000] give relatively abstract definition of context influenced by their work on “context toolkit” architecture:

We define context as any information that can be used to characterize the situation of an entity, where an entity can be a person, place, or physical or computational object.

Schilit et al. in [Schilit 1994.] give a very concrete context definition which is therefore rather local in their applications:

Context refers to location, identity of spatially nearby individuals and objects and changes that are relevant to aforementioned individuals and objects.

Summarizing numerous definitions of context we can notice three aspects of context that are standing out:

- Technical characteristics of the environment: Hereby we are mainly referring to technical characteristics of the client device, processing power, available memory capacity, display characteristics as well as characteristics of network connections available to the device (bandwidth, latency, price…).
- Logical characteristics of the user’s environment: This group contains geographic location, identity of individuals and objects nearby and generally social situation.
- Physical characteristics of the user’s environment: This group contains levels of noise, light, movement parameters (speed, direction, etc.).

In the process of context modeling and management, the system can use information that is both, automatically collected or manually entered by the user. Although the first approach is attractive and seems to be the only true manner of handling contextual data we believe that manual input should not be excluded. Also, some characteristics of the context (e.g. user preferences, history and predictions of actions) are much easily acquired by manual input at the current level of advancements in context management algorithms.

The important step in development of context aware LBS and mobile GIS is to define the set of functionalities the application should provide to the user, implicitly or explicitly. Numerous types of contextual information produce adequately numerous potential functionalities. We can group them as follows:

- *Display of information and services* – In order to reduce user workload the system adjust the set of offered information and functions according to detected and deduced environment of the user. For a typical GIS section of the map surrounding the current user's location is displayed. According to user's speed and heading, central point of the map view is chosen and speed vector displayed. Also, font and color scheme is adjusted to situation user is in (e.g. user is steering a vehicle at night).

- *Automated execution of commands* – Example would be a navigation GIS application that detects the user has missed the intersection and automatically initiates rerouting to find new shortest path to destination.
- *Storage of contextual information* – Potential use of stored contextual information would be to enable application to autonomously extract user preferences from previous actions using data mining techniques.

GinisMobile - CONTEXT AWARE LBS AND MOBILE GIS FRAMEWORK

To support development of context aware LBS and mobile GIS applications we have developed and integrated context aware support and components in GinisMobile, a LBS and mobile GIS application framework [Predic, 2005]. GinisMobile is a mobile extension of GinisWeb - Web GIS application framework [Predic, 2004]. As such it includes support for management and presentation of raster and vector spatial data, as well as dynamic data about mobile objects [Stojanovic, 2005]. The first obstacle encountered when developing LBS and mobile GIS applications is highly constrained mobile client platform. Therefore, these applications are already aware of the hardware characteristics of the device it is running on and able to automatically adapt to it, enabling full utilization of device's capabilities. The type of sensors relevant to context aware LBS and mobile GIS applications are widely available, and either are already integrated in modern devices (GPS sensors, Bluetooth radios, level of light sensors, etc.) or are available as add-on devices connected via PAN (Bluetooth). Each of these sensors implements its internal data format. Therefore, each sensor has a software interface attached to it. Its task is to convert data from the format used internally by the sensor into format appropriate to the application. Contextual data concerning technical characteristics of the device is accessible directly by the application and therefore does not require separate software interface. Compiled set of contextual data is encoded according to defined XML scheme and transferred to the server for analysis and storage. Proposed architecture of GinisMobile, a context-aware LBS and mobile GIS framework is illustrated in figure 1.

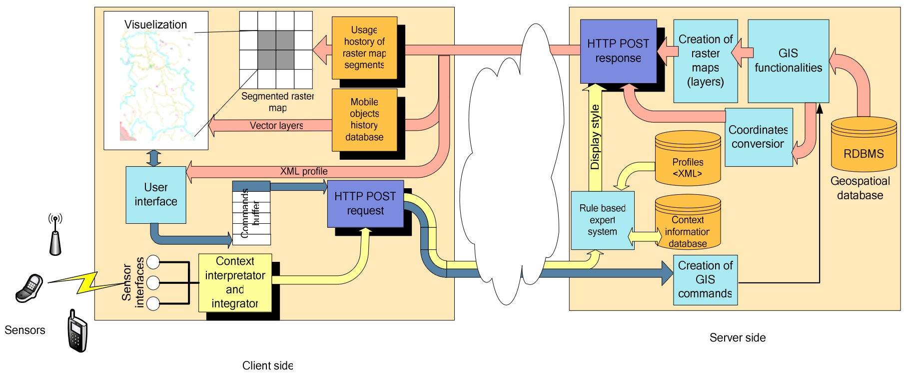

Figure 1: Mobile GIS architecture with context aware support

This model requires minimal changes to starting mobile GIS architecture and minimizes processing requirements on the client side. On the server side, context information is handled separately from the user commands. It is inserted into rules and facts database and analyzed by rule based expert system. Every change in rules and facts database can lead to either insertion of new context information at the higher logical level into database or entering new state. Reaching new state results in picking out profile that most adequately fits new change in user's context. Handling of other spatial data is the same as in [Predic, 2005] and will not be further discussed in this paper. Profile, packed with static spatial layers (rasterized to a single map layer) and dynamic map component (e.g. moving objects) is transferred to the client.

On the client side, XML profile is parsed and used to customize user interface. Rasterized layers are stored on internal cache and displayed. Static objects are presented on the background map according to display settings, profile and with appropriate symbols. Finally, moving objects are superimposed on the map display. Since raster segments are static in nature and change rarely we keep a local cache of frequently used segments. This approach speeds up visualization process significantly. Adopted Least Recently Used (LRU) algorithm is used to keep memory requirements minimal.

CONTEXT REPRESENTATION AND MANAGEMENT IN GINISMOBILE

The user context that is of interest in LBS and mobile GIS applications is classified into specific classes. Each class of contextual information is assigned a context variable. Usually, in other papers published by researchers in this field authors have noticed hierarchical structure of context information so some sort of graph structure is used for context representation [Meissen, 2004]. Since one class contains contextual information of various levels of generality the most appropriate data structure for representing contextual information is directed acyclic graph. This data structure is the closest match to human cognition of structure and connections existing within a context data class. Another advantage of hierarchical context model is the possibility to narrow the choice of possible actions induced by detected context. In this manner, a set of rules used by rule based expert system is kept to a minimum of candidate rules [Biegel, 2004]. Rule based expert system is used to perform generalization of raw contextual data acquired from sensors and contained in leaf nodes. In this manner a "vertical" structure within each context class is built. As an example of rule based expert system that is widely used in literature we have opted for CLIPS (C Language Integrated Production System) [CLIPS, 2005]. The main advantage of CLIPS in our case is the existence of jCLIPS, library that enables Java programs to use CLIPS engine embedding it in a Java code [jCLIPS, 2005].

The typical context data flow path in a context aware application is as follows: raw data is collected by connected sensors, software interface associated with each of the sensors converts the data into facts and stores the facts into the expert system. After each modification of a rule set, CLIPS executes generalization process and generates the new facts at higher levels of generality. Also, the possibility of performing action is tested. The action is represented by forming a XML file containing configuration parameters for the client device. This XML file generally describes a profile that a context aware application will use as a response to a context change. The XML scheme of such profile is shown in figure 2.

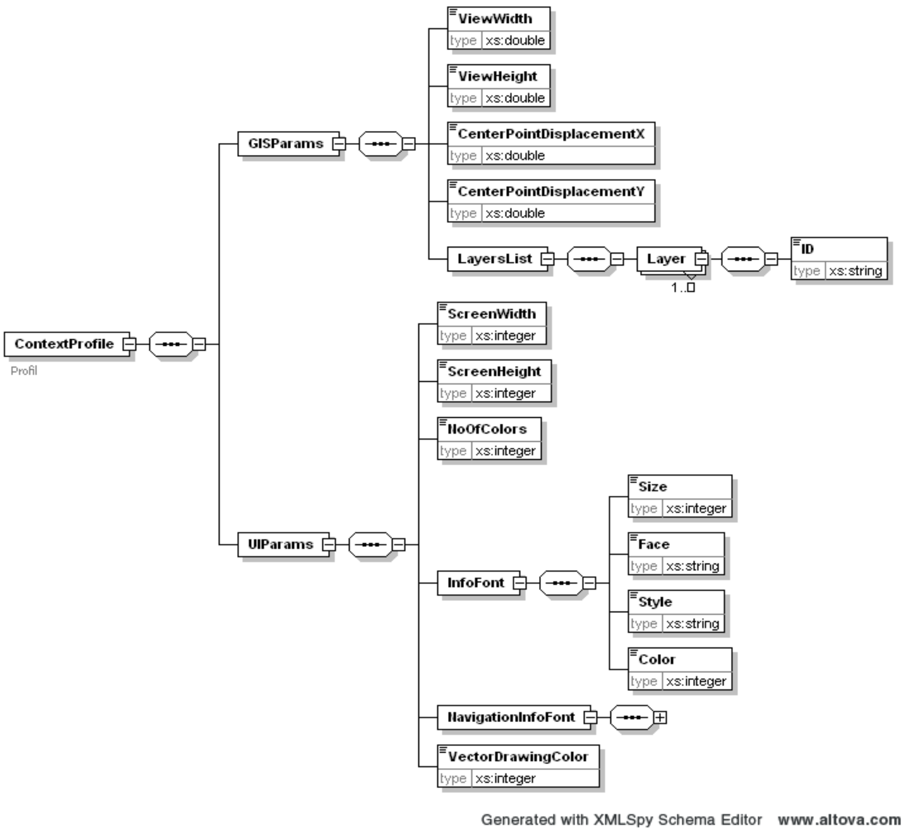

Figure 2: XML scheme describing profile.

The particular profile transferred to the client is represented as an XML file described in the figure 3.

```
<?xml version="1.0" encoding="UTF-8"?>
<ContextProfile xmlns="http://gislab.elfak.ni.ac.yu/bpredic" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://gislab.elfak.ni.ac.yu/bpredic:\Dragan\CONTEXT\sema.xsd">
        <GISParams>
                <ViewWidth>1000</ViewWidth>
                <ViewHeight>700</ViewHeight>
                <CenterPointDisplacementX>850</CenterPointDisplacementX>
                <CenterPointDisplacementY>0</CenterPointDisplacementY>
                <LayersList>
                        <Layer>
                                <ID>Gas_Stations</ID>
                        </Layer>
                        <Layer>
                                <ID>Fast_Food_Restaurants</ID>
                        </Layer>
                </LayersList>
        </GISParams>
        <UIParams>
                <ScreenWidth>200</ScreenWidth>
                <ScreenHeight>320</ScreenHeight>
                <NoOfColors>4092</NoOfColors>
                <InfoFont>
                      <Size>12</Size>
```

```xml
                    <Face>Courier</Face>
                    <Style>Normal</Style>
                    <Color>Yellow</Color>
            </InfoFont>
            <NavigationInfoFont>
                    <Size>24</Size>
                    <Face>Arial</Face>
                    <Style>Bold</Style>
                    <Color>Red</Color>
            </NavigationInfoFont>
            <VectorDrawingColor>Blue</VectorDrawingColor>
      </UIParams>
</ContextProfile>
```

Figure 3: The XML file representing the user profile according to his context

CONTEXT AWARENESS IN VEHICLE NAVIGATION APPLICATION

To test the context awareness support and context aware components built in GinisMobile framework we have developed a mobile GIS application for vehicle navigation and fleet tracking on top of the GinisMobile. The application setting assumed that the sensors connected to the user's device are able to determine speed and direction, time of a day, levels of noise and light. The higher level of contextual information is deduced based on basic contextual data. Based on deduced facts and rules within the knowledge based engine the server recognizes that the user drives a vehicle during the evening/night hours. According to this information appropriate profile is constructed which describes user interface with night colors. The navigation data is displayed on the screen with appropriate font size according to the speed of the user's vehicle. Also, appropriate zoom level is chosen with user's location displaced from the view centre. In this manner the user is enabled to see more of the map in front of him. Finally, the view contains vector speed as reference.

We assume the existence of GPS receiver attached to the mobile device since this is a very common type of sensor today. It provides data on user's geographic location as well as motion data (speed and direction). Another "sensor" relies on time of day to detect light conditions (day / night). More specific, level of light sensor that is present on mobile devices available on the market, could be used for this purpose for additional accuracy.

The role of context detection and interpretation subsystem is to decrease the workload needed to operate typical vehicle navigation system and therefore increase safety. In the demonstration application the following scenario is employed: a mobile user drives a vehicle in the urban environment during a day and a night. Following screenshots are taken at different levels of adaptation that an LBS application has performed autonomously in response to changing user context. Figure 4.a shows a user traveling at 20km/h along a city street. It is worth noticing that user's location (indicated by the cross symbol) is decentralized and velocity vector is drawn on the map view. The map view also includes speed and heading.

As the user increases its speed font size for displayed motion data (speed and heading) is increased, amount of map view decentralization is increased and velocity vector is updated accordingly. This is illustrated in figure 4.b. As the speed further increases above certain threshold (figure 4.c) map view zoom scale is changed (decreased). This, along with additional decentralization of a map view allows the user to see more of the map laying in front of him, in the direction of the velocity vector. Effects of further increase of speed and change in direction of velocity vector are shown in figures 4.d and 4.e. When the application detects night conditions it switches to using set of colors customized to night conditions. The map view customized to night conditions is shown in figure 4.f. This choice of colors minimizes the distraction effect for the user (driver).

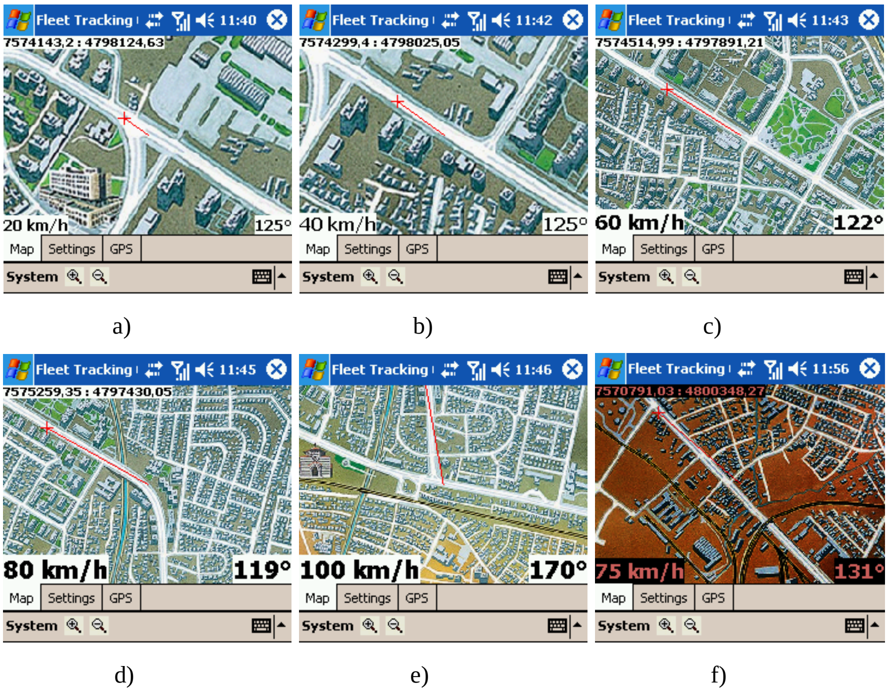

Figure 4: Screenshots taken from the sample LBS application for monitoring and tracking mobile objects.

CONCLUSION

Considering current state of the art we believe that mobile GIS applications are perfect testing grounds for context aware concept. Being used in unconstrained free space while the GIS application is only auxiliary tool for some other task context awareness considerably enhances usability of the application. Hereby, context aware applications are super set of location based services. As this paper stressed, location information is only one class, although very frequently used, of context information. This information will be used to automate many procedures and decisions and relieve the user of repeatable and tedious tasks of frequent reconfiguration.

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