A Framework for Handling Mobile Objects in Location Based Services

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SUMMARY

In this paper we present the Web based framework that provides efficient management, tracking and displaying of data about mobile objects in Web based Geographic Information Systems (Web GIS) and Location Based Services (LBS) applications built on top of it. The proposed framework heavily exploits contemporary Web data exchange and display technologies such as XML, GML and SVG integrating geospatial data and services standards developed by OGC, OpenLS and ISO TC 211. Such features make Web GIS and LBS applications developed around this framework fast, dynamic, interactive and easily adoptable to users needs. The component nature of the framework makes it flexible, scalable and extendible to satisfy specific application requirements. The framework integrates common geospatial data and processing services with specific services enabling mobile objects data management, querying, analysis and presentation over the wired and wireless Web. Furthermore, standard communication protocol based on XML makes the framework services interoperable with a wide array of currently available location technologies, and third party e-commerce services.

KEYWORDS: *GML, Web GIS, Location Based Services, Mobile objects*

INTRODUCTION

Advances in wireless communication technologies and mobile, Internet-enabled devices have enabled global Internet connectivity and ubiquitous Web-based computing and services distribution. The recent convergence of Internet, wireless communications, mobile positioning and Web geographic information systems (GIS) has given rise to a new class of location-based applications and services. Location-based services (LBS) deliver geographic information and geo-processing power to mobile users in accordance with their current location and preferences, or to stationary users in accordance with location of the mobile/stationary objects of their interest [Hjelm, 2002]. Such services are pervasive and useful in traffic control, road navigation, vehicle and person tracking, fleet management, tourist guiding and military exercises. Moving to the new, mobile operating environment presents developers with additional constraints and requirements. Bandwidth utilization, response time, limited screens size, processing power and power consumption are important issues in development of Web GIS and LBS applications and services. Web GIS and LBS application architectures are service-oriented and represent integration and chaining of various geospatial data and processing services distributed over the wired/wireless Web [ISO/TC 211, 2002, Jagoe, 2003]. To enable fast and effective development of Web GIS and LBS applications that satisfy specific user requirements there is a need for the set of geospatial data and processing services organized within the framework that represent the core for Web GIS and LBS application development [OGC, 2002; ISO/TC 211, 2002]. Such framework must use contemporary XML based data description technologies for geospatial data representation and exchange between distributed framework and application services intended for storing, processing, analyzing and displaying data on distributed, heterogeneous platforms.

LBS applications are inherently based on mobile objects and management of their continuously changing location data. Thus the framework for LBS applications development must include specific services dedicated to management, storing, spatio-temporal querying, presentation and exchange of data about mobile objects. The focus of this paper is Web based framework that supports development of LBS and Web GIS applications particularly for handling mobile objects.

GINISWEB: A WEB GIS APPLICATION FRAMEWORK

The starting goal of our research was to create the framework that is completely capable of supporting development of GIS applications in the Web environment that include integration, management, querying, analysis and visualization of geospatial data [Predić, 2003]. The main requests that had to be satisfied by such service framework was integration with and conformance to the contemporary OGC and ISO service standards [OGC, 2003; ISO/TC 211, 2002] and implementation based in actual Web technologies like Web services and XML-based data exchange formats (GML, SVG and XSLT). These requests lead to creation of the GinisWeb framework capable of accessing different data and processing services distributed on the Web and adjusting its output to the type of the device acting as the client (desktop or hand-held). GinisWeb was conceived as client – server GIS application framework with WEB based thin client front end. The main characteristic of its initial demonstration application was implementation of GML and SVG (Scalable Vector Graphics) as geospatial data exchange and visualization formats [Predić, 2003]. SVG is an XML based vector graphics format developed by W3C [SVG, 2004] increasingly used in research of wired/wireless Web GIS solutions [Brinkhoff, 2003; Bauernfeind, 2004, Hjelm, 2002]. Further expansion of SVG usage is expected with ongoing integration of SVG plug-ins in new versions of most popular desktop Web browsers as well as mobile devices (Symbian Smartphones Series 60 by Nokia and Sony-Ericsson).

The main advantages of using XML based technologies, GML as geospatial data transport format and SVG as geospatial data visualization format, were increased interactivity, increased usability through usage of the thinnest clients possible and portability across diverse set of client platforms [Hjelm, 2002]. Flexibility of the framework design is reflected through possibility of using distributed geo-data sources, all transmitting information coded in GML format or some other application specific XML schema, and usage of XSLT transformation and XSL style sheets to transform data between different formats and finally to SVG format for visualization on the client side.

The architecture of the first iteration of GinisWeb framework is represented by the top portion of the figure 1. At the client side standard web browser capable of scripting (e.g. JavaScript) is used as front end. At the moment, the support for SVG is not included out-of-the-box in most popular web browsers, but since it is a W3C recommendation it is expected to be included in future releases. At the moment, the most widely used is Adobe's plug-in for SVG viewing. Full interactivity, integration with host xHTML document and dynamic change of graphic elements is achieved using scripting procedures. The framework enables access to external distributed geospatial data services, e.g. OGC Web Map Service and Web Feature Service through specified interfaces.

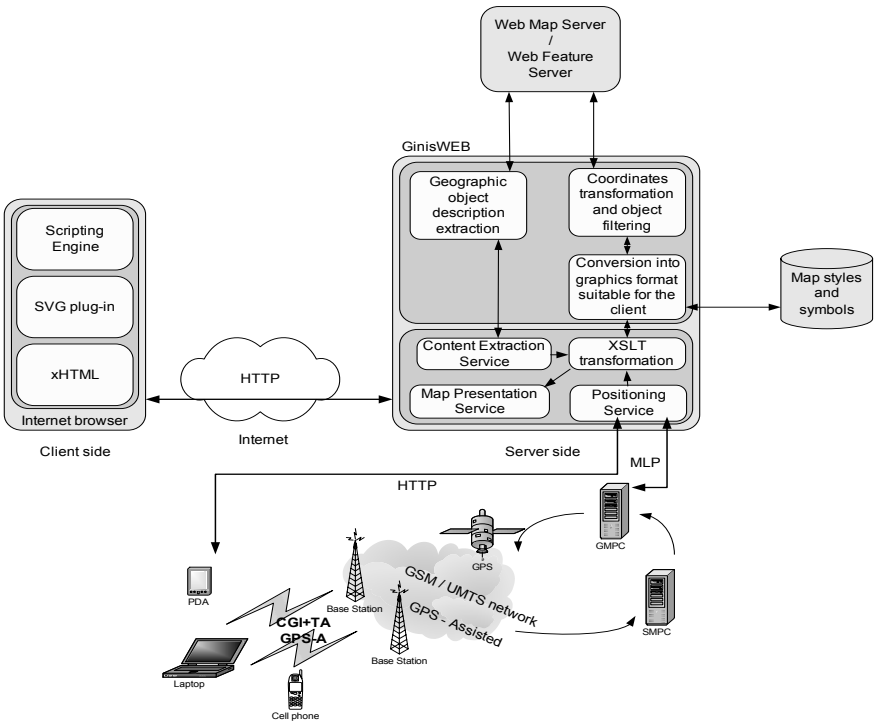

Figure 1: The architecture of the GinisWeb framework

ARGONAUT SERVICES FOR MOBILE OBJECT HANDLING

The services integrated in GinisWeb framework are primarily intended for static LBS features and do not provide capabilities for dynamic nature of the LBS introduced by the mobile objects, for their tracking and control useful in many LBS application domains. Also, OpenLS initiative within OGC does not provide support for mobile object handling within its specification of LBS services organized in a service framework called GeoMobility Server [OpenLS, 2004]. Since mobile objects are the foundational concept in location-based services, we propose the services for management of mobile objects data that can be integrated in the service-oriented LBS framework, as extension of GinisWeb and called ARGONAUT.

The prerequisite service for every LBS application is a mobile positioning service (location service) that enables methods for locating an user in space and time using GPS and/or some of the wireless network positioning techniques (GSM, UMTS, or WLAN) [Hjelm, 2002]. The location of a mobile device can be determined by device itself or by wireless network equipment and then transmitted through a wireless/wired communication interface to the appropriate location server. The service provided usually by a third-party service provider enable access to the location data through a standard interface based on XML schema. The first extension to GinisWeb framework in mobile object domain includes a service performing acquiring position data from moving objects being tracked. Ericsson, one of the largest suppliers of cellular telephony equipment has a user locating system ready called MPS (Mobile Positioning System). There is a MPS simulation available that completely mimics the real system and was therefore perfect for our purpose. Bottom portion of figure 1 represents this part of the GinisWeb based application. Ericsson's MPS 6.0 system fully conforms with MLP (Mobile Location Protocol), which is a XML based communication protocol for

exchange of location data [Jagoe, 2003]. The *Positioning Service* integrated in the GinisWeb framework application is used for interfacing with MPS [Predić, 2004].

The ARGONAUT services is based on an object-oriented mobile objects data model (*m*STOMM - *mobile* Spatio Temporal Object Modeling and Management) developed to support conceptual modeling and querying of discretely and continuously changeable properties of geographic features, i.e. mobile objects [Stojanović, 2003a]. The data model is based on the comprehensive framework of data types and rich algebra of operators with emphasis on the object-oriented modeling paradigm and to the compliance and appropriate extension of the OGC and ISO TC 211 standards [OGC, 2003]. Also, the ARGONAUT data model provides representation of the complete motion of the mobile object from the past to the future, with the main emphasis on modeling the mobile point objects moving on the transportation network that are prevailing in real LBS applications. The implementation of the developed data model provides development of foundational ARGONAUT *Mobile Object Trajectory* service for mobile objects data and trajectory management and query spatial and temporal mobile object properties. It enables clients to access trajectory related information about mobile objects of interests, as well as to store motion information, location (in space and time), speed, direction and intended route, if it is obtained in advance, for specified time period and sampling frequency. Using the sequence of location updates, the *Mobile Object Trajectory Service* forms the mobile object's trajectory. The trajectory of a mobile object is a polyline in three /four-dimensional space (two/three-dimensional space and time) defined by a sequence of points (x_i, y_i, z_i, t_i). Such trajectory is only an approximation of the object's motion, because the object does not move in straight lines at a constant speed. The number of points along the trajectory is proportional to the accuracy of such approximation. The interface of the *Mobile Object Trajectory Service* represents a mobile extension to the OGC Web Feature Service [OGC, 2003] providing access to the mobile objects' motion information and to enable querying and retrieval of the mobile object trajectory data using spatio-temporal criteria and conditions. The response of the *Mobile Object Trajectory Service* is formatted using appropriate GML extension, developed for representing and encoding continuously changing locations of mobile objects, called MobileGML The MobileGML schema is developed as XML-based implementation of the ARGONAUT data model. MobileGML encoding is used for transfer and exchange of data about mobile objects between LBS framework and application services distributed over the wired/wireless Web.

The ARGONAUT *Spatio-Temporal Query Service* provides access and retrieval of spatio-temporal data from distributed spatio-temporal data sources according to various spatial, thematic and temporal criteria. The instantaneous queries for which the answer is evaluated immediately and transmitted to the user is not useful in dynamic, mobile environment of an LBS application. When users issuing the queries an/or objects representing the result of the queries are mobile, the answers of such queries are obsolete and incorrect. The queries in LBS application environment are mostly continuous in nature. Continuous queries remain active over period of time and have to be continuously evaluated during this time to provide up to date answers. Such queries may also represent triggers that enable location-based event notification to the registered users. The ARGONAUT *Spatio-Temporal Query Service* provides methods and capabilities for continuous spatio-temporal query management and specification of the user profiles. It includes sophisticated techniques for continuous query processing to achieve satisfactory continuous query performance critical in real-world LBS applications. Such service now enables client to be notified about relevant events related to its location or location of the mobile/stationary objects of his/her interest. The event in this context represents the satisfied spatio-temporal relationship between mobile objects and geographic features of interest. The client is expected to register for such service issuing continuous query that remains active over period of time and that have to be satisfied in order to send the user appropriate notification and relevant information [Stojanović, 2003b]. If it is satisfied, user can be informed using any of asynchronous client/server techniques, like WAP-push, SMS, MMS etc. Continuous query management mechanism in *Spatio-Temporal Query Service* is supported by another ARGONAUT service, *Event Observation Service*, which monitors changing of the data values residing in distributed data sources that are included in

the query condition and after the change of such a data value activates evaluation of continous query. If the query condition is satisfied, the user can be informed using any of asynchronous client/server techniques, like WAP-push, SMS, MMS, etc., for user notification mechanism through ARGONAUT *Event Notification Service*.

In order to enable dynamic presentation of the mobile objects data within the LBS client, ARGONAUT *Dynamic Portrayal Service* is developed that extends GinisWeb *Map Presentation Service* and is based on SVG animation capabilities. To support such service a transformation from MobileGML to SVG encodings by using XSLT transformation and XSL style sheets, is specified. Such service enables both real-time animation of mobile objects' motion and animation of motion history for subsequent motion analysis within the Web-based LBS client.

The ARGONAUT services are implemented as Web services and integrated with general OpenGIS services (WMS, WFS, etc.), as well as with core LBS services defined in OpenLS service framework (GeoMobility server), namely: *Geocoder*, *Reverse Geocoder*, *Directory*, *Route*, *Navigation*, *Gateway* and *Mobile Presentation* services [OpenLS, 2004]. A new *Service Integration & Chaining* service is implemented in GinisWeb framework to support application specific integration and chaining of those services and provides appropriate response to a mobile and stationary client. Its role is also to control the process of chaining external services and components and appropriately synchronize their functioning. For example, the *Spatio-Temporal Query Service* rests upon the *Mobile Object Trajectory Service* to access trajectory related information and to check the satisfaction of the continuous query condition using spatial information about geographic features of interest retrieved from the *Directory Services* and *Web Feature Service* (figure 2). The *Map Presentation Service* extended by the ARGONAUT *Dynamic Portrayal Service* provides real-time visualization of the objects' motion and dynamics of the query result gained from the *Spatio-Temporal Query Service,* along the appropriate responses from OGC and OpenLS services. This, services chaining, principle is depicted in more detail in figure 2.

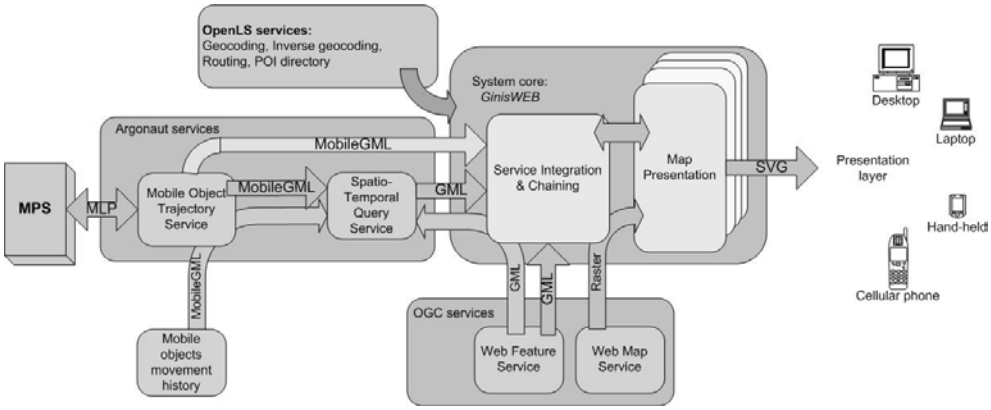

Figure 2: Service chaining in GinisWeb framework

Independence of GinisWeb external services in terms of realization is the key in achieving flexibility and scalability in LBS and Web GIS applications development. Each of these services can be improved, modified or even completely substituted by services developed by third parties as long as its communication interface conforms to the OGC and OpenLS standards [OGC, 2003, OpenLS, 2004]. Depending on required application functionalities, appropriate service chains are built and managed by *Service Integration & Chaining* service.

Thus, if for some reason mobile positioning is not available or not wanted (prohibited) by the mobile user, external OpenLS service can be connected to offer geocoding or inverse geocoding services, allowing user to manually define its location by entering street address or ZIP code. Based on Web service interface and conformance on contemporary geospatial standards (OGC, ISO/TC 211), GinisWeb framework can be easily connected to third party e-commerce service required for user authentication, personalization, security and billing.

WebTBIS – A MOBILE OBJECT BASED LBS APPLICATION

To prove the concepts and methodologies for handling mobile objects in location based services, built in ARGONAUT services and GinisWeb service framework, a mobile object extension of the tourist/business information service, WebTBIS, is developed (figure 3).

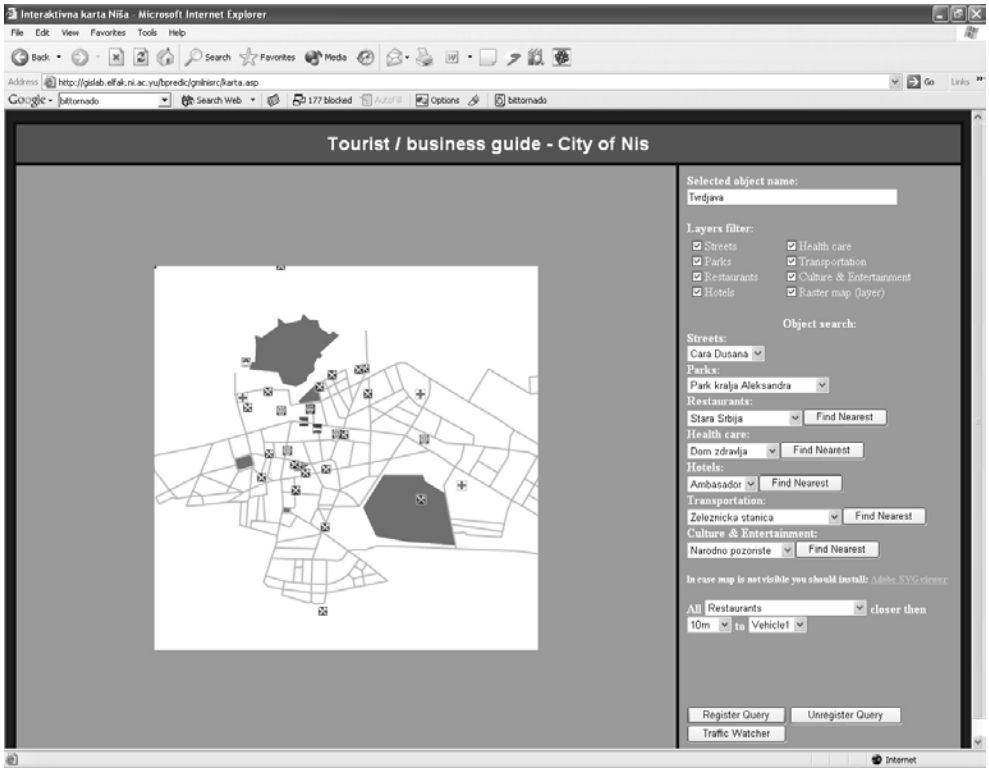

Figure 3: WEB user interface of WebTBIS application.

Owing to *Mobile Object Trajectory Service* and *Dynamic Portrayal Service* it is possible to track mobile objects (user himself, or objects of interest) who either report their positions obtained by GPS device in specified time intervals, or by obtaining their positions through *Positioning Service* and the mobile network infrastructure. Real-time positions of a fleet continuously moving over the background map is displayed and animated by *Dynamic Portrayal Service* using SVG animation capabilities (figure 4).

Figure 4: *Map view showing positions of a number moving objects(filled circles) and tracking them in real time.*

As mentioned, The ARGONAUT *Spatio-Temporal Query Service* enable specification and processing of range, k-nearest neighbour and distance queries that are prevalent in LBS applications, issued both as instantaneous and continuous queries. The query reference object as well the data objects constituting the query response can be both mobile or stationary. Thus, an important WebTBIS functionality implemented on top of ARGONAUT services is possibility for a user to create spatial query requesting visual representation of points of interest (POI) which satisfy certain spatial relation in regard one of the mobile objects or the LBS client himself. This is performed by choosing mobile object and POI type from the appropriate lists, which are automatically populated with valid values as they are received. Since the *Spatio-Temporal Query Service* spatio-temporal queries specified and processed by *Spatio-Temporal Query Service* can have a mobile object or a stationary object as the query reference object, and the query can be interested in both stationary and mobile objects, the WebTBIS application enable various queries to be issued by its clients:

- select the POIs in the range/at the distance/nearest to the specified moving object,
- select the mobile objects in the range/at the distance/nearest to the specified POI,
- select the POIs in the range/at the distance/nearest to the specified POI of the same or different type,
- select the mobile objects in the range/at the distance/nearest to the specified mobile object,

When the query is issued as continuous, such query is incrementally re-executed constantly and resulting set is updated on the map and appropriately highlighted. An example result of the first type of the query, i.e. selection of POIs within specified distance from specified mobile object, is shown in figure 5.

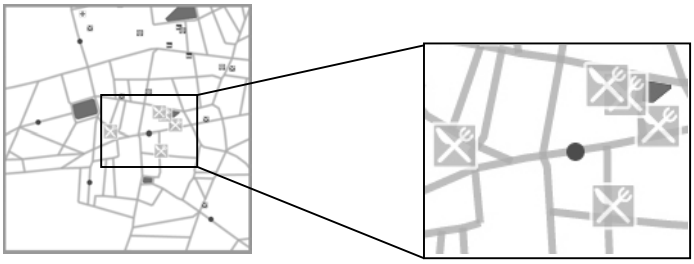

Figure 5: *A set of POIs (restaurants)* returned by the continuous distance query, highlighted on the map.

CONCLUSIONS

With the proliferation of mobile computing devices in the recent years different sorts of LBS applications will certainly be the driving force of mobile communication development. The nature of mobile computing implies that positional information cannot be disregarded when developing for mobile and hand-held devices. Also, mobile users have a different set of priority expectations when using applications on their devices. The most obvious problem appearing is the multitude of heterogeneous devices in use. Devices differ in processing power, screen size, operating system, wireless connectivity etc. Virtually, the only common capability of all mobile devices is capability of Web browsing. Therefore, in order to create the application capable of running on most of available platforms, we believe that the Web applications and services integrated in appropriate service framework is the most flexible approach.

The ARGONAUT services extends the GinisWeb service framework and provides comprehensive models and services for management of mobile objects data, including modeling, storing, querying, retrieval and presentation of such data in distributed LBS environment. It represents a powerful and conceptually clean foundation for design and implementation of LBS applications that involve mobile objects on top of it. The ARGONAUT services are implemented as Web services and integrated with general OGC services (WMS, WFS, etc.), as well as with core LBS services defined in OpenLS service framework (GeoMobility Server). Proposed service-oriented approach for management of mobile objects data is currently evaluated by development of the LBS application for tourist and business tracking, navigation and guidance implemented around the ARGONAUT services and GinisWeb framework. The developed framework should provide developers with basic skeleton that is robust and easily extendable into different sorts of LBS and Web GIS applications.

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