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NEW GENERATION ENTERPRISE GEOGRAPHIC INFORMATION SYSTEMS

JAUNĀS PAAUDZES UZŅĒMUMA ĢEOGRĀFISKĀS INFORMĀCIJAS SISTĒMAS

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Abstract. *This paper addresses common problems like poor reusability, closed vendor proprietary framework, limited customizability which are associated with use of traditional Geographic Information Systems (GIS) and proposes architecture of new generation GIS. The architecture described in this paper is based on Service Oriented Architecture and open standards. It consists of Geographic Information Service Provider, Geographic Information Service Consumer and Geographic Information Mediation Infrastructure. The new generation GIS allows achieving high level of reusability both on GIS logic and orchestration layer. Its broad customizability capabilities make it suitable for wide user audience.*

Keywords: *GIS, Internet GIS, Service Oriented GIS, Distributed GIS, Enterprise Application Integration.*

Introduction

During the last decade popularity of Geographic Information Systems (GIS) has significantly increased. These systems play an important role in many organizations and are an integral part of their information system. GIS are used in asset and service management, property management, cadastral management, sales and marketing, location based services, emergency services and wherever information has a spatial attribute. As evaluated by Bossler roughly 80% of business data can be geo-referenced [Bossler]. The rapid rise of GIS during past years has been affected by many factors. One of them is evolution of supporting technologies like Global Positioning System (GPS), Radio-frequency identification (RFID) and wireless networks during the last decade. Certainly development of modern systems like Google Maps, Microsoft Live Maps, Yahoo Maps and ViaMichelin has also played an important role. These systems have made GIS accessible to a wider audience by orienting towards internet, using intuitive, user-friendly interface and relatively simple Application Programmable Interfaces (API). Another important factor is potential of GIS in making business processes more efficient and autonomous. We can consider GIS as a spatial component of business decision making [Pick].

Despite wider usage of GIS there are still many problems related with them. The vast majority of GIS available at the moment are all-in-one suites that may contain many unnecessary features at the same time lacking some important ones. These systems have vendor proprietary, closed and isolated frameworks with poor reusability [Zhong]. Organizations are forced to use multiple GIS applications simultaneously, because desired functionality can't be found in a single product [Douglas]. Usually these systems need to be integrated with each other as well as with other enterprise applications to increase their efficiency and usability. Such integration is very complex due to the heterogeneous nature and architecture of traditional GIS. It also requires serious GIS background, because most of the traditional systems are designed for GIS professionals [Zhong]. If company isn't satisfied with a concrete part of the GIS or their requirements have changed over time, most likely they will have to replace the whole GIS solution and repeat the sophisticated integration process once more. Most of the traditional GIS are tied to concrete data formats. If there is a need for data from various sources with different formats, data conversion could become an issue. Situation has slightly improved by evolution of Geographic Markup Language (GML) [Lake], which allows storing data in XML format, however it is not yet fully accepted industry standard [Pick] and has a number of issues [Chang-Tien]. Traditional GIS architecture also leads to delays in data update since product databases often don't have a direct connection to the data source. Implementation of GIS in most cases could be referred as vendor driven rather than problem oriented. Companies focus more on available GIS solutions than business problems.

To overcome the issues mentioned above the architecture of GIS must be revised. It should be based on principles of Service Oriented Architecture (SOA) and open standards. This paper defines characteristics of such GIS and gives a brief description of its architecture. Vision of new generation enterprise GIS is presented in Section two. Common architecture is described in Section three, more detailed architecture is given in Section four, Section five concludes.

Vision of new generation enterprise GIS

GIS are used to solve certain problems or to optimize processes like automatic routing. Every company has its unique requirements and finding a suitable GIS might be problematic. In the optimistic scenario there is a GIS that meets those requirements, however it has some functionality that company doesn't need, but has to purchase as part of the entire solution. If requirements are more specific, it could be impossible to find an appropriate GIS. In such a case a company is forced to purchase multiple heterogeneous suites with overlapping functionality and integrate them. There is no doubt that it is impossible to produce a GIS for every possible combination of requirements. However, it is possible to divide GIS functionality in multiple standardized Geigrpachic Information Services (GIServices) that can be used to compose a GIS according to the unique requirements of each company. Organizations don't need to adapt their business processes to inefficient all-in-one GIS suites. On the contrary – they must be able to compose GIS from multiple GIServices in such way that it would contain all the necessary functionality. If requirements of the company would change, there won't be any necessity to replace the entire solution. It would be enough to add or remove certain parts of the GIService orchestration. Cases when users are not satisfied with a certain part of the system can be solved the same way – by replacing the inadequate component with more appropriate. Use of SOA leads to high level of reusability, customizability and efficiency. Standards like GML and platform independent technologies substantially reduce complexity of GIS integration with other systems. GIS composition of multiple standardized GISservices will also encourage smaller IT companies and individuals to develop services, which is hardly possible in case of massive GIS suites [Zhong].

The interface used to compose service oriented GIS contains multiple levels of abstraction. It provides customizability options for both professionals and less experienced users. Professionals are able to manually alter the GIService logic and orchestration, while non-professional users rely on predefined GIS logic and its automatic conversion to executable business process. This promotes wider usage of GIS and emergence of new spatially enabled services.

Architecture of new generation enterprise GIS

The architecture of new generation enterprise GIS was designed considering the disadvantages of traditional GIS and tendencies in enterprise application design. Components of proposed architecture are shown in Figure 1.

The two main roles of proposed architecture are Geographic Information Service Consumer (GIS-C) and Geographic Information Service Provider (GIS-P). GIS-C represents a potential GIS user who requires certain GIS functionality. It could be a group of enterprise GIS users, an individual GIS user as well as an enterprise application. GIS-P hosts GIServices or data that is requested by GIS-C (GIS-C and GIS-P in detail are reviewed in Section 4). Interactions between these two parties can become very sophisticated.

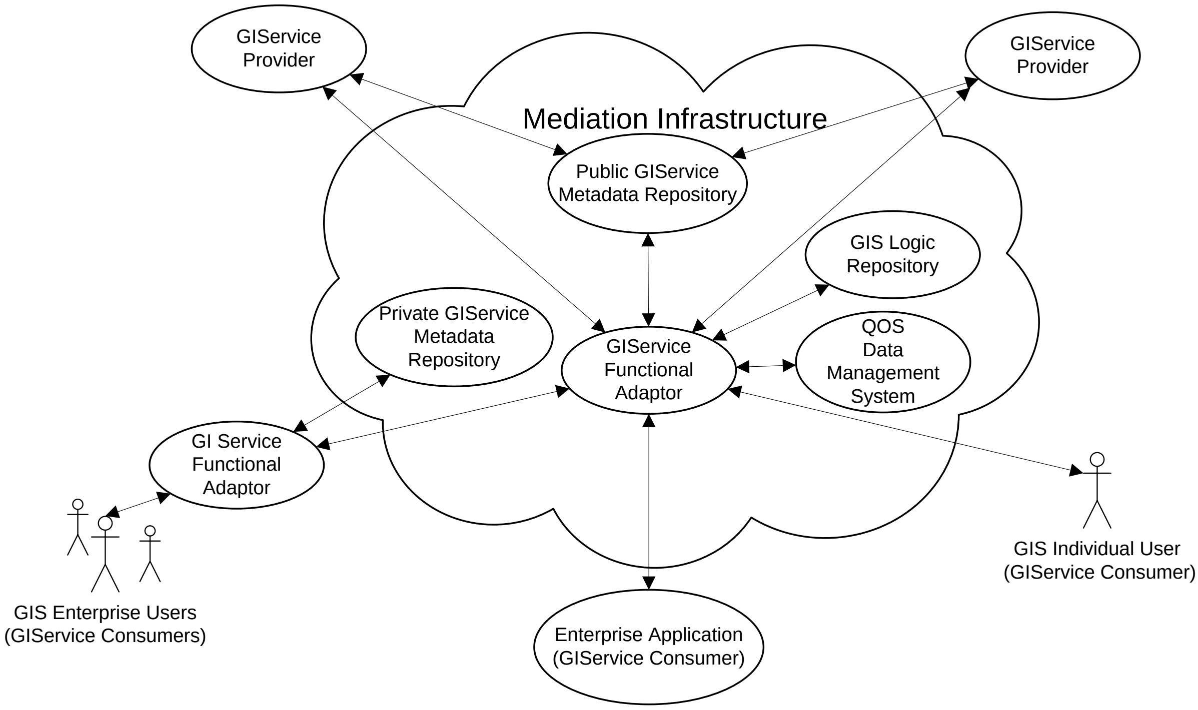

Fig. 1. **Architecture of new generation enterprise GIS**

Normally GIS-C is unaware of the specific GIS-P that suites its needs. In fact multiple GIS-P could be considered as appropriate however their quality of service (QoS) might vary (different network capacity, response time, processing time). There also could be major incompatibilities between GIS-P and GIS-C varying from utilization of different messaging systems to diversity in geographic data storage formats or coordination systems. If the functionality requested by GIS-C is not provided by a single GIService, certain level of GIService orchestration is needed. To make the interaction process between GIS-C and GIS-P less cumbersome, Geographic Information Service Mediation Infrastructure (GIS-MI) is required. At the center of the GIS-MI is GIService functional adapter (GIS-FA). GIS-FA is responsible for multiple GIService orchestration and interaction with user, retrieval of QoS information from QoS Data Management System and service discovery using public or private metadata. To promote reusability in defining certain GIS related processes, use of the Geographic Information Service Logic Repository (GIS-LR) is proposed. Entire GIS-MI in greater detail is discussed in Section 4.

Elaboration of new generation enterprise GIS architecture

This section elaborates the proposed architecture in more detail. System, described in this paper, can be adapted for enterprise users by placing centralized GIS-FA on an enterprise server and sharing required functionality as services to individual GIS-FA used locally by enterprise users. In this case GIS-FA located on the enterprise server acts as GIS-C and GIS-P simultaneously (as shown in Fig. 1). Corporate users or individual users that require specific functionality can compose their own GIS using locally installed GIS-FA. It is also possible to configure GIS to work completely without user interaction as a part of another system or business process. The flexibility of proposed solution is achieved by dividing GIS-FA in multiple modular layers. The modules and layers of GIS-FA are shown in Figure 2.

The top-most layer is called the Presentation Layer. It is used to support interactions between users/administrators and GIS-FA. Customizability and extensibility of this layer is achieved by dividing it in unlimited number of modules.

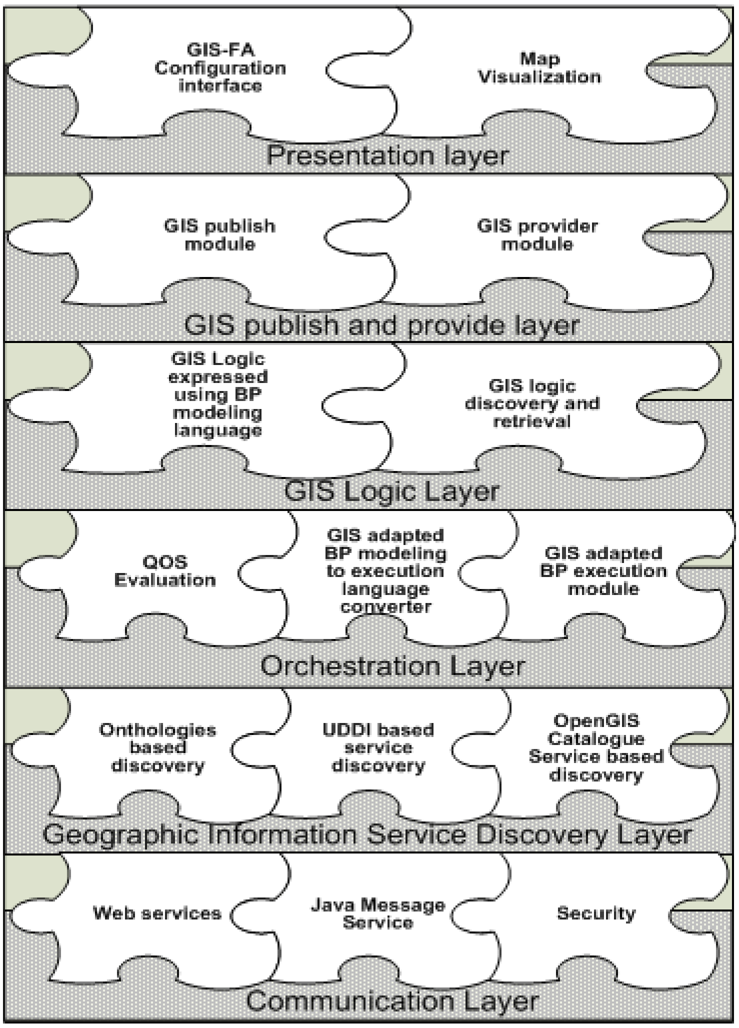

Fig. 2. **Multilayered architecture of GIS-FA**

For example if GIS is used as a part of a business process and there is no need to show results on a map, use of a map visualization module is unnecessary. Swapping one map visualization module with another would allow using GIS in multiple environments like handheld and personal computers. Another important part of the Presentation Layer is GIS-FA configuration interface, which allows adapting GIS-FA to specific requirements by adding, removing or reconfiguring specific modules. There are two configuration interfaces – simple and advanced. Simple configuration interface is intended to be used by nonprofessional users. This interface is less complex however it allows limited customizability of GIS-FA adapter. The advanced configuration interface is intended for GIS/IT professionals and fully employs potential of GIS-FA customizability.

The second layer allows publishing composite GIServices created in GIS-FA to public or private GIService Metadata Repositories. Requests from remote GIS-C are also received in this layer and sent further to GIService orchestrations in the Orchestration Layer and other GIS-P connected by the Communication Layer.

The third layer is called the GIS Logic Layer. The purpose of this layer is to store GIS logic which is not bound to specific service implementations. It allows defining GIS specific processes like vehicle routing. GIS logic can be expressed using specially adapted Business Process Modeling Notation (BPMN), UML Activity Diagrams, UML extension for business process modeling by Eriksson-Penker or other suitable business process modeling languages. Most of modeling tools allow exporting the model to XML files, which can then be stored in public or private GIS-LR. GIS logic can be created and stored locally, published to GIS-LR or retrieved from GIS-LR. This approach leads to higher level of reusability and wider range of available predefined GIS processes that are independent from specific service implementations.

GIS logic models are transformed to executable business processes in the GIS Orchestration Layer. There are several languages suitable for describing service orchestrations like Web Services Choreography Description Language (WSCDL), XML Process Definition Language (XPDL) and Business Process Execution Language (BPEL). Challenges of translation between BPMN and BPEL are reviewed by Ouyang et al [Ouyang]. Use of BPEL in SOA based GIS has been discussed in papers by Ma et al [Ma] and Fleuren [Fleuren]. Service orchestration that corresponds to specific GIS logic model is created by joining services with the highest Quality of Service (QoS) value. QoS of each service available is estimated in the GIS-QoS Evaluation Module. GIServices are evaluated based on parameters like response time, price, availability, reputation, data quality timelines, data quality accuracy, data quality completeness [Buccafurri]. Total QoS of each orchestration is equal to QoS sum of contained services. Certain QoS values for GIServices and entire orchestration are stored in the QoS Repository and can be retrieved during QoS evaluation process. A GIS logic model with the best possible orchestration is selected and executed in the GIS Orchestration Layer. Evaluation criterions of services and orchestrations as well as entire GIS orchestration can be altered by advanced GIS-FA configuration interface. In the case of an orchestration failure, information about the error is sent to QoS repositories reducing the QoS value of concrete orchestration and failed service. All appropriate GIS logic models and their orchestrations are reviewed once more; the best of them is selected for execution. Such an approach allows composite GIS to fix itself in the case of an error – for example failure of certain service.

To find all services that belong to certain category or comply with specific requirements the GIService Discovery layer is used. Service discovery can be implemented using various technologies therefore this layer can be composed of multiple modules and can easily be extended. The most mature web service discovery technology is Universal Description, Discovery and Integration (UDDI). Use of ontology-based Geographic Information Service discovery is discussed by Klien et al [Klien]. Another candidate is the Catalog Service presented by the leading open GIS standardization organisation Open Geospatial Consortium (OGC) [Nogueras]. Use of decentralized peer to peer based service discovery is also worth considering [Sioutas].

The lowest layer is responsible for secure and reliable communication between GIS-P and GIS-FA on client side. The main messaging technology employed by the Communication Layer is Web Services. However, thanks to its modular nature it can be extended to support other technologies like Java Message Service.

Services provided by GIS-P are based on open standards. Spatial data exchanged between GIS-P and GIS-C is expressed in OGC GML. GML is relatively immature language and issues like ineffective storage, parsing, querying and visualization can arise [Chang-Tien]. However, at the moment it is the most suitable language for spatial data exchange using SOA based GIS solution. OGC provides other standards like Web Feature Service, Web Map Service, Web Feature Service, Web Processing Service which can be used to categorize services provided by GIS-P. GIService interoperability issues like multiple data formats, different coordinate systems and accuracy can be solved using specific transformation services hosted on GIS-P.

Conclusion

The architecture proposed in this work suits wide user audience (individual and enterprise, professional and less experienced users). The reusability level of new generation enterprise GIS is high both on service and business logic level. Following modern enterprise application development tendencies, presented architecture is based on open standards and service oriented architecture. Use of multiple layers and modules gives virtually unlimited customizability potentialities. Nevertheless, implementation of proposed architecture brings several challenges. Technical infrastructure including service search protocols, messaging system and interaction protocols needs to be discussed. QoS evaluation mechanisms have to be adapted for geographic information based service estimation. The most suitable business process modeling, business process execution languages need to be adjusted for GIS needs, transformation mechanisms between them must be analyzed. To provide GIService discovery and modeling capabilities, categorization of GIServices based on open standards should be reviewed.

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