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Geography to the Server: Geographic Databases, Internet Mapping, Geographic Application Services

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Abstract. This paper presents a concept to integrate GIS into mainstream information technology. Component and multi-tiers architectures will be the environment for future geographic services. The use of standardized components and a focus on geographic tasks will help deliver the goods GIS was promising for so long.

1 Introduction

For years, Geographic Information Systems (GIS) have been tightly linked to powerful graphics workstations. Though more and more personal computers entered the GIS engineer's office, GIS software architectures remained archaic. Major issues were – and still are in some systems – the ease of use and the integration with other personal and enterprise software systems. As a consequence, GIS projects are usually much more expensive than planned and the resulting information is used in a much narrower context than they potentially could.

Geographic reference provides a useful concept for the integration of information from heterogeneous sources. Information integration is still mostly done in the heads of decision makers. Business intelligence solutions (data warehouse, data mining, enterprise resource planning, customer relationship management) try to model this mental task on complex computer systems. However, geographically enabled business intelligence solutions could finally make the break-through in decision and process support systems because they provide a relatively simple but powerful integration framework.

To be able to leverage the potential of GIS, its technology has to be put on a new foundation. The general trend is towards a server-centred component-based architecture. This not only reduces complexity and cost of GIS use – particularly in large organisations – but it also enables GIS to integrate with enterprise and Internet solutions. This paper presents an architectural framework for modular GIS application services. Prove of concept has already been given in several installations of GeoTask's Internet Mapping Framework (IMF). Low system costs, ease of use and considerable cost saving in planning and production processes impressively demonstrate the potential of the geographic server technology.

2 Core Concepts of the Server-based GIS

GIS cannot be replaced by a single new technology. Particularly a modular software design approach asks for an individual analysis for each function group. Some elements of a GIS like for example a graphics engine might already exist elsewhere and could be used for a new GIS after minor adaptations. Other elements like data management systems could be used only with some specific extensions for geographic data handling. Yet other elements like cartographic projection conversion might not be available in a suitable form as a standard technology and would better be taken over from existing GIS applications. A standard GIS design never existed and becomes even less probable with modular distributed GIS applications. What remains to be done is to develop general guidelines on how to build a geographically enabled information system with standard information technology components and specific geo-components.

2.1 Distributed Application Environment

With desktop solutions, one single software package is supposed to handle all aspects of an application. The desktop model is very end-user-friendly. This advantage, however, has to be paid with limitations in data sharing leading to redundant data holdings and high maintenance costs in a multi-user environment. The Web model with the simple http-protocol and the browser interface, on the other hand, is well suited for data sharing. Its weakness is a limited application support by the browser. It is unlikely that a combination of the desktop and the Web model can be found to overcome the shortcomings of each. First, they are in competition with each other and, second, operation system dependence of the desktop model and related security issues limit the reach of a combined solution.

A widely used approach is to support the Web-browser on the client while distributing application logic and data management over several server systems. In this so-called three- or multi-tiers architecture the Web-server operates as data and application service broker between the Web-browser and the rather vaguely defined server systems. An early form of application and data access services was based on the common gateway interface (CGI). A more flexible form is provided by the Java servlet concept where small application modules can be called through parameterised URLs. Another frequently used approach is to extend Web-servers directly with application logic over a proprietary application programming interface (API). Application services can be anything from providing the current time to multi server transactions. Interfacing existing applications with a Web-server is quite simple compared to the complexity in synchronizing multi-server applications in e-business applications.

Like in client/server systems, data management is a crucial element of a multi-tiers architecture. As long as the system is only used for data presentation, each application service can use its own file or database management system. Such distributed data management becomes problematic, if transactions and online data analysis is allowed. Message queuing and transaction servers come into play if existing systems need to continue accessing their own data stores. However, if ever possible data management should be made independent of a single application.

For GIS, the concept of application services and integrated data management mean a significant change in software architecture. Data management is handed over to a spatially enabled database management system with a standardized query and manipulation interface. Applications thus have only limited possibilities to optimise data structures for fast execution. It is the task of the database management system to provide fast spatial access in a universal way serving multiple applications. Complex data analysis also means to hand over data from one application service to another, maybe even on another machine using a different operating system. Standardized interfaces and new multi-server optimisation techniques need to be developed.

2.2 Modular Systems with Standardized Components

Modern software design favours modular systems based on objects, patterns and frameworks. Modern multi-tiers architectures further strengthen modularisation, particularly when using servlet-based application services. As with every modern trend one can argue that a next wave will make it obsolete. However, from experience in real world applications it can be shown that modular design and multi-server integration considerably simplify application development. This should already be good enough a reason to follow this trend and to further develop the underlying concepts and technologies.

Modularisation in GIS means rethinking the overall architecture. We have already seen that data management could be separated from the core GIS applications. With GIS being on a bridge between computer graphics and database management it could also make sense to replace the graphical part of a GIS with a widely used graphics components. Developments like the XML-based graphics languages VML (Vector Markup Language) and SVG (Scalable Vector Graphics), or the extensive graphics capabilities of Java's 2D and 3D APIs impressively show, that the mainstream computing technology moves much faster than similar developments in GIS once a common need is identified. GIS will only survive in a larger market if it uses as much as possible standardized components from mainstream technology and concentrates its efforts on geographic tasks. Geographical components like a geographic data management extension to a relational database system, geo-referencing and geo-coding services, map layout composition tools and spatial analysis procedures can then help bring GIS into play in larger enterprise wide information systems.

3 Geographic Server Concept

What is so special about GIS that it deserves further attention in the mainstream information technology? The following points are hints to find an answer:

- Spatial reference: most data currently stored on computers can be linked to geographic space. Geographic reference can be used to bring data together even though there might not be an explicit link in-between.
- Spatial visualization: modelling real world objects with a spatial component allows for the visualization and synopsis of complex information. In many instances spatial visualization and synopsis act as catalysts to considerably speed up decision making processes.
- Spatial query: some questions are formulated easier in terms of spatial relationships than in the form of attribute value combinations. Spatial query languages help simplify the formulation of complex queries.
- Spatial analysis: Geography has developed a large repertoire of spatial analysis models. Properly integrated with other tools and modules, they can be of value in complex data mining and scenario planning applications.

The following figure shows a simplified concept of a geographic server. For each of the five main tasks “input”, “modelling/structuring”, “data management”, “query/analysis” and “output” it is indicated how they could be implemented in a multi-tiers architecture. In view of the modular design and the flexibility to distribute applications, only hints can be given. In each particular instance, an analysis of targets and frame conditions should lead to the optimal system. But this individual treatment of each case in a specific environment is what the modular component design is made for.

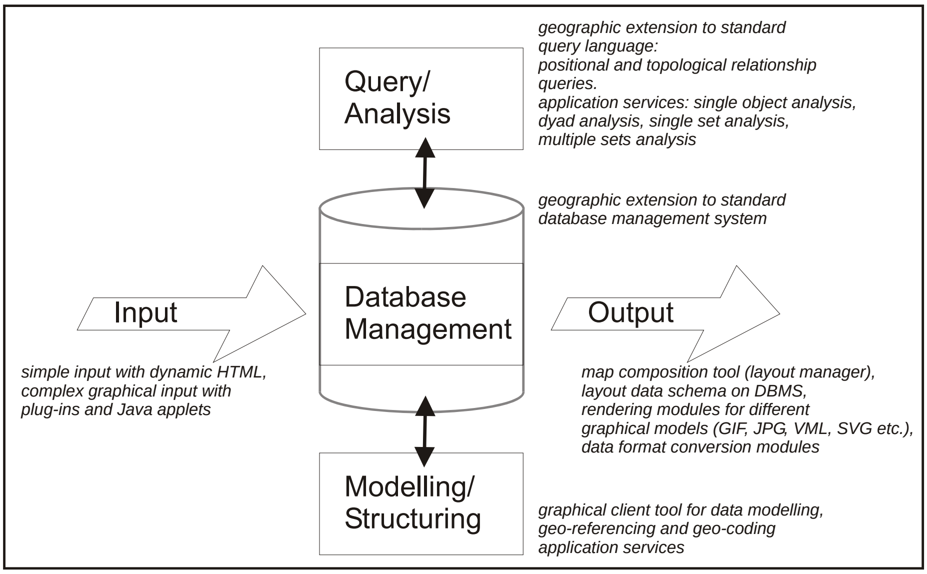

Fig. 1. A simplified geographic server concept complementing a multi-tiers architecture with geographic services

4 Conclusions

Integrating geographic services into a modern multi-tiers architecture is not based on a continuous development of existing GIS technology. Similarly to the shift from horse carriages to cars, GIS is facing a technological discontinuum. Rather than interfacing existing GIS software with Internet technology, it is proposed to redesign geographic services in a modular way. Geographic services will run in a distributed component architecture and will use standard technology as much as possible. A new application development process will focus on interfacing and synchronizing components. When focussing on core geographic tasks GIS will finally fulfil its promises in planning, decision support and process control systems.