SOLUTIONS BASED ON GIS TECHNOLOGY IN COMPONENTS OF URBAN MANAGEMENT APPLICATIONS

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Articolul descrie componente ale aplicațiilor de management urban ce integrează tehnologia GIS. Contribuția principală a autorilor constă în sinteza de funcționalitate a componentelor bazate pe GIS ce au fost identificate în soluțiile existente. Aceste soluții pot rezolva problemele asociate tendinței actuale de sisteme informatice pentru management urban integrat şi de creştere a calității vieții urbane. Funcționalitatea specifică oferită de aceste soluții reprezintă un avantaj important deoarece exemplifică bunele practici şi înlesneşte dificultățile dezvoltării componentelor bazate pe GIS.

This article describes components of urban management applications integrating GIS-based technology. The main contribution is the synthesis of functionality of several GIS –based components identified in existent implemented solutions. Solutions of various problems are required by the needs of integrated information systems for urban management and increased urban quality of life. Specific functionality provided by these solutions represents an important benefit by exemplifying good practice examples and thus reducing GIS-based subsystems development difficulties.

Keywords: information systems, GIS, urban management, analysis, components

1. Introduction

Urban management has grown interest into Geographic Information Systems (GIS) use due to the needs of integrated city management and to increase urban quality of life. However, the first challenge is getting human resources with technical skills to design, implement and maintain systems using GIS technology [1]. This problem is even more serious with users. GIS systems are generally considered to be quite complex, not only in terms of understanding the interaction elements present in the interface, but also the knowledge embedded in the tasks

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that can be accomplished by these systems. Even an expert user usually faces significant difficulties using GIS tools. [13].

By authors' experience acquired in development of software architectures for various applications domains the first observed feature is its great potential to reuse previous solutions [5] [4]. In urban management application domain the reuse solutions may be either from different departments inside the same administration, or even from different administrations [6]. Analysis of these solutions provides a considerable potential to reduce these difficulties since it makes possible for less experienced software architects and analysts to reuse knowledge that has been tested and validated previously. In urban management the basic environment that compose the digital cartographic base (e.g.: streets, open areas and neighborhoods) may be reused by several applications.

The key points behind large information systems' success are the precise application domain analysis and design through well-known solutions. Experiences have shown that application domain analysis and conceptual design stages are complex activities that take a lot of time. According to [12], the reasons for this are that the application domain knowledge and the system requirements process are done almost always from the beginning of each new system under development. Also a study based on ethnographic techniques reveals that the requirements engineering field for the GIS specific domain requires better methodologies [2].

GIS applications may have some special requirements (e.g.: geographic referenced data manipulation), but must be developed using the same processes as any other information system [9]. One of the many processes that are receiving special attention is the use of a domain knowledge base that allow software components reuse through template definitions, which is mainly the domain analysis community. A recurring solution is a combination of components that occurs in some context. Recurring solutions may be considered patterns if they are well documented and may be used in any of the several software development stages, therefore receiving different names as analysis patterns, design patterns, architecture patterns, languages (implementation patterns), and others.

This paper investigates several solutions applicable to requirement analysis and conceptual architecture modelling stages. Section 2 presents GIS technology concerns in the context of urban management application domain. Section 3 presents and analysis existent solutions of GIS components integrated in urban management information systems. Five solutions are described and analyzed based on a comparison framework. Only essential input and output data and the main conceptual functions in the given solutions are shown to keep the discussion manageable. They were identified by researching in the literature of the urban management applications domains. The paper describes GIS-based subsystems that provide services such as work order management, emergency management, municipal officials' customizations, city natural resources, urban traffic analysis and other services that aim to increase workflows and data management in public administrations. Section 4 is a discussion regarding the development and execution environments. It presents possible criteria to be considered when these environments must be decided. The last section concludes with the main contributions of our work and the perspectives over future work.

2. GIS technology in urban management applications

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project in a thematic map (Fig. 1). A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of a city, and add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to biology. A good GIS software application processes geographic data from a variety of sources and integrate them.

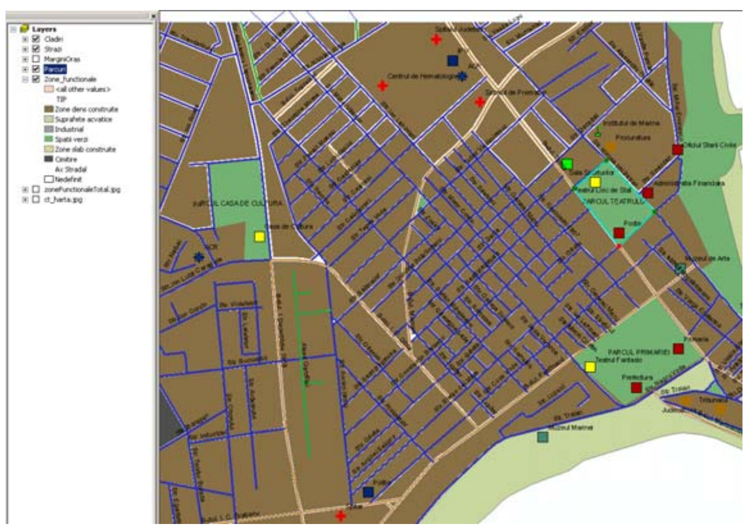

Fig. 1. A map document of a Constanta city with several data layers

Many cities have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of a city. Nowadays public administration departments are constrained to quality of their services. Their personal should perform tasks actively through real-time responses in crisis situations, through management of huge volumes of data or through a fluent workflow. In the context of increased quality of services required by city communities and efficient workflow in departments activities and between various collaborative departments GIS technology represents one of the useful and practical solution. Geographical data is organized such that the user can select them and perform operations upon them (e.g. streets repairing, cutting of trees, traffic accidents analysis. Applications in the domain of urban management based on GIS technology include functionality associated to work order management, site selection, concrete operations, urban traffic, assets management, emergency service, projects management, citizens service, engineering, mobile services, verifications, logistics [7]. Implementing a complex computer system in a large organization is challenging. Ensuring that each work process is clearly understood and modeled accurately requires a lot of time and attention. Complex implementations often get delayed and sometimes completely stalled from lack of experience. Public agencies are under increasing scrutiny to ensure investments in technology are worthwhile and cost-effective. Several methods are considered to ensure success when implementing new business systems. One way to address the challenge is to build a knowledge base of reusable solutions.

3. GIS components integrated in urban management systems

This section is a description of several solutions that could be considered for GIS-based technology subsystems for urban management.

3.1. Work order management

The Streets Department of a city can integrate a GIS-based component for a computerized work order management system [7]. Fig. 3 presents the components of the subsystem. These are *Concrete Operations Component*, *Alley*

Lighting Component, *Streets Inspection Component* and *Streets Repairing Component*. The last mentioned component has been conceptually obtained by extending functional features of the *Concrete Operations Component*.

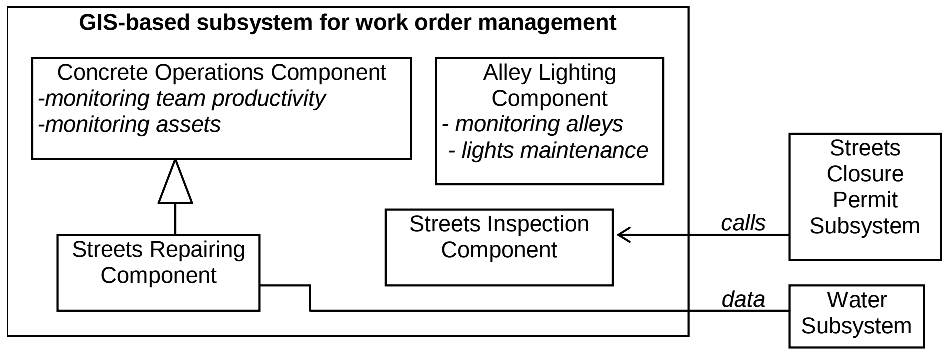

Fig. 2. GIS-based subsystem for work order management

The functionality and the data of each component are:

Concrete Operations Component. The main functions of this component are monitoring of the team productivity and monitoring of the assets. The input data is a list of work order templates for each work order type. Also input data is the *Streets Network* map layer that is conceptually stored in two feature classes, arcs and nodes. Output data are represented by work orders.

Alley Lighting Component. The information system for streets lighting is extended with a new functionality for monitoring alley lighting and maintenance. The new function provides the capability to respond citizens' requests and it requires five years of existing data from a server. New workflow diagrams are created to analyze and enhance the business process before the maintenance management system is deployed. The input data represents is accessed from the server without any changes to the data structure or data maintenance process.

Streets Inspection Component. The user of this component is the department unit which is responsible for the inspection of work performed on the city streets. The source of the majority of work orders is the *Streets Permit Subsystem*. The *Streets Inspection Component* is called to read the *Street Closure Permit Subsystem* database and to create work orders. This component includes the creation of a digital copy of the permit as an attachment to the work order. Inspections are done using the custom inspection templates in the system. Photos and drawings are stored in an attached spreadsheet created by the inspectors.

Streets Repairing Component. This is an extension of the Concrete Operations Component that is supplemented with five additional tasks to the work order types, plus many different alternate tasks to accommodate special situations. This component is associated to a requirement that specifies the acceleration of street repairs with the goal of repairing potholes the next business day and performing the permanent restoration of ditches within a specific number of days of their creation. The extension requires the addition of new work order types, special event layers to display data, new reports, and documents for customer affairs representatives and inspectors who would determine the validity of citizen calls. There is also an extension with wireless laptops for users that are authorized to introduce data. This process requires the training of users. The component is Web accessible to allow citizens to report potholes. It uses Web services to verify addresses and assign districts. This data is automatically imported into the system as part of the nightly inspection. The component provides a personalized configuration that delivers exact and immediate results to end users, allowing system expansion and modifications to be quick and easy.

3.2. Management of the natural resources

The management of the natural resources can be implemented in an information system by using modern GIS technology. The management of the natural resources requires maintenance, protection, and replacement of trees [7]. Also another function is the identification of hazards, such as dead branches that overhang parking spots, streets, or sidewalks, and the remedy of these hazards in a timely manner before they cause injury or damage to property. Examples of hazard identification are locations where tree roots are lifting sidewalks and driveways, situation especially important to the elderly. Mainly the *GIS Subsystem* performs a detailed and comprehensive street trees inventory (Fig. 4). The inventory tracks data regarding species, size, location, and tree condition. It is important that this information must be easily accessible for managing the maintenance priorities of the tree crews.

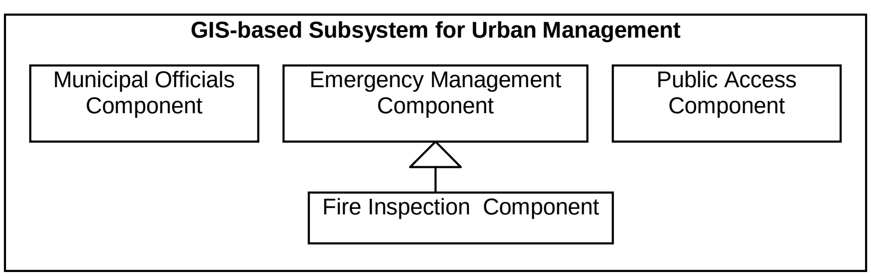

Fig. 3. Management of a city natural resources in a GIS-based subsystem

3.3. GIS for analysis of urban traffic accidents

An urban traffic analysis subsystem takes its existing data and applies analysis that will help it improve the safety and function of its roads [7]. Such a subsystem needs to be a traffic diagramming system that incorporates the spatial orientation of the roads where the accidents occurred. Not every intersection consists of two roads that come together at a 90-degree angle and accidents occur in the real world where roads intersect at irregular angles and have curves. An analysis of traffic accidents should consider factors such as: if a road angle contributed to the accident, if the sun could have been in the driver's eyes or if a tree was blocking a driver's view. Also there should be considered midblock accidents. Midblock accidents are classified as all accidents that occur between intersections.

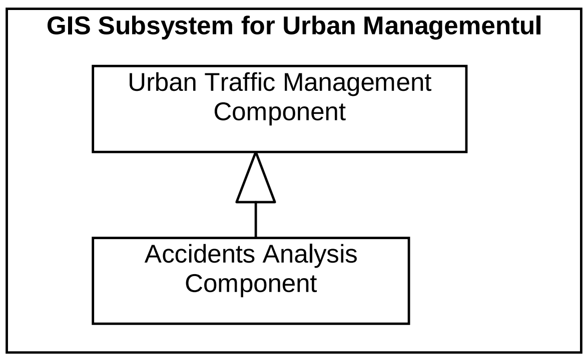

Fig. 4. GIS-based traffic analysis subsystem

A GIS-based traffic analysis subsystem is a solution to all the problems exposed above (Fig. 5). Such a subsystem may produce spatially oriented diagrams of accidents where they happened, whether at intersections or midblock. In order to provide such a capability this subsystem must query a database for all the accidents that have occurred at a selected intersection or midblock location. The data stored in the database contains all the characteristics of an accident, including accident type, vehicle direction of travel, street names, vehicle maneuvers, and so on. The Subsystem analyzes accident and places it in the appropriate location on the map. The map view can include any additional features that the analysts want to evaluate. These features include edge of pavement, road centerlines, or signs.

An urban traffic analysis subsystem help to improve the safety of the citizens and the function of the city roads by providing an accurate diagram of the places where these occur and by identifying factors that contribute to their occurrence.

3.4. GIS technology for public administrations

The city governance requires a user-friendly GIS subsystem that would update data more frequently, streamline inefficient workflows, and facilitate data sharing. A new organizational strategy moves GIS functionality away from desktop software and onto the Web [3] [8]. This movement makes the management of updates and adjustments to the GIS easier and allows more people within city government to take advantage of GIS-based technologies. To meet this goal a city management system can be developed as an enterprise GIS (EGIS). This solution solves problems such as: (1) delayed data updates by updating data system on either a one-week or five-week cycles (2) poor workflow for city employees by cutting and pasting address data from an e-government enterprise software into another type of documents to organize the work of the field employees or by printing out corresponding maps from Internet search engines by the employees to visualize the addresses. This time-consuming and inefficient process can be better organized and data can be updated more frequently.

The conceptual structure of EGIS is presented in Fig. 6. Four components are considered as parts of EGIS for Urban Management. These are *Inspector Activity List Component*, *Public Works Management Component*, *Thematic Map Generator Component*, and *Mailing Address Report Component*. *Public Works Management Component* is obtained by generalizing *Gas Valve Maintenance Component*. *Thematic Map Generator Component* provides a Web accessible user interface. The first two components give field staff access to property and utility data, respectively. The third component creates real-time maps of utility assets, and the last one notifies residents in a selected area of upcoming construction.

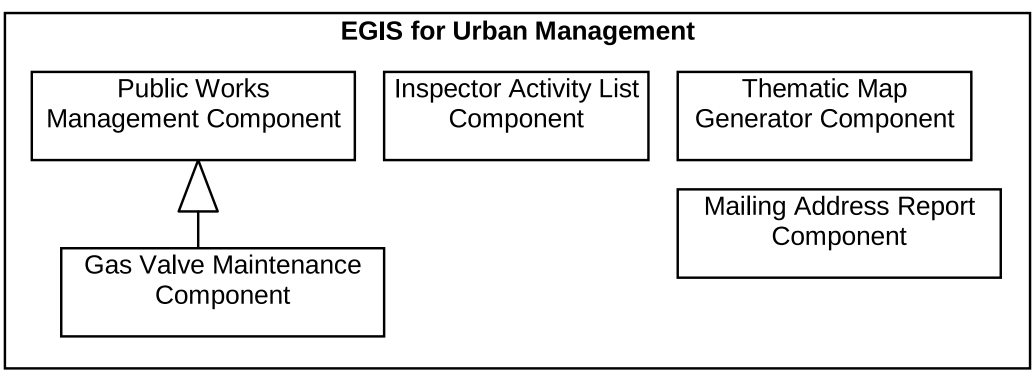

Fig. 5. EGIS conceptual structure

4. Discussions regarding the development and execution environments

The development environment for the GIS-based subsystems could be selected from open-source [14] or commercial tools. The selection decision depends on the achievement of the following important technological constraints: (1) it should allow the integration of the current Web practices, such as C# or Microsoft® Visual Studio® for Web development and so on, into the components of the GIS subsystem; (2) it should provide access to an object-oriented library that enables the creation of a customized GIS component that solves the city's unique business problems; (3) it should provide users the ability to manage map layouts so they can control and manipulate maps effectively;

Also the integrated development platform is established such that it allows seamless integration and interoperability with other database technologies such as Oracle, MySQL or Microsoft Access.

Execution environment selection is another issue of concern. A decision regarding this issue must consider the reuse of existent assets of the current information system of the organization (for example, the reuse of the data server that contains databases of other applications). Microsoft SQL Server could be considered as a solution for GIS data access. We can exemplify the database for the work order management subsystem can be implemented using SQL Server and the reports can be designed using Crystal Reports. However there can be other specific solutions for spatial data accesses that might be more efficient. Execution environment selection may consider a mobile one (laptops, PDAs) and wireless communication solutions.

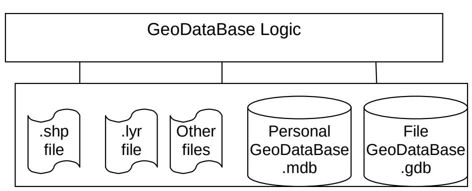

Fig. 6. Geographical data files

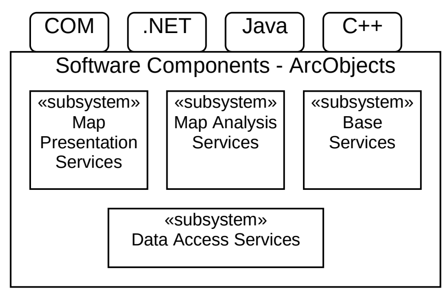

Fig. 7. ArcGIS Software Components

Some of GIS components are designed to provide Web access to the city citizens that can use them for various services such as information retrieval or to send requests regarding public domain quality usage. Subsystems that integrate

GIS-based technology often require a higher level experienced personal. Under this circumstances training activities must be planned for the users.

At present, all the mentioned subsystems can be accomplished by few of the GISs. The ArcGIS, distributed by the Environmental Systems Research Institute (ESRI) has been used for the proposed subsystems. The ArcGIS, a descendant of the widely used ArcInfo, can manage spatial data in various levels, such as shapefiles, coverages, and geodatabases (Fig. 7). Moreover, the ArcGIS functionality is expanded by the COM, Java, .NET and C++ technologies, which uses various programming languages (Fig. 8). The ArcGIS can be customized for particular applications of GIS or independent applications can be developed using specially designed data models and functionality.

Currently, a general data model has been published in for e-government domain. Data models for urban management applications can be customized based on this general model. The functionality of each subsystem can be accomplished by exchanging data between ArcGIS and other systems, by constructing tools attached to a project in the ArcGIS, or by customizing the behavior of the ArcGIS objects. The choice depends on the data model complexity and calculation requirements.

All data are stored in the database, which can be represented on the basic level by the personal geodatabase (Microsoft Access), or by the RDBMS (Oracle, Microsoft SQL Server). The data transfer among other software applications can be realized directly through the implemented database connections. In case of the ArcGIS's geodatabase, all the data are loaded into the relational database, so that the geospatial coordinate data of the GIS data layers are stored in the relational data tables. Since the relational database supports relationships between its tables, feature-to-feature spatial connections can be set up among the GIS data layers together with linking and joining of external data tables

5. Conclusions

In this paper we have discussed about the integration of GIS technology in urban management applications. In introduction we have justified the importance of our study and we have emphasized the advantages of this modern technology in the present context of increased needs of urban community and more efficient services provided by public administration departments. The examples of good practices have been described and analyzed based on the functionality at conceptual level of the subsystems that access, process and provide analysis of geographical information. The constraints for the implementation and execution environments for the GIS-based subsystems must consider several criteria that have been mentioned in the paper.

In urban management information systems there is a high potential of reuse of solutions that have been applied with success in other departments of the same organization or other cities. One particular property of GIS subsystems is that usually the data handled by these subsystems have a strong relationship among each other, because they describe geographic phenomena about one specific geographic region. The data type set that usually creates the geographic data for one GIS subsystem has a conceptual structure alike other GIS subsystems. This particular property makes GIS subsystems strong candidates to benefit from reuse of existing designs.

Our study has an immense potential to improve municipal management applications using GIS, as well as reduce time and therefore costs in stages such as requirement analysis and software architecture conceptual modelling. However, for this approach's success it is necessary to create a cooperation culture among researchers and system developers.

Reusability of a good and practical documented solution is a very attractive and useful idea. A good solution doesn't need to be original and innovative, but much important is that this solution should be a tested and validated one for well known problems. In urban management applications domain there are no unique problem solutions. Knowing the best practices that have been a success for other cities is an advantage.

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