GIS in the process of road design
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Abstract
In Civil Engineering Informatics Centre at the Faculty of Civil Engineering, we are engaged in product models of construction objects. In product models, we see the key for integration of individual objects construction life cycle activities, which are now weakly connected. Working on it, we have been focusing specially in the road design field. Construction of a road is great interference into the environment. Therefore, spatial data are very important in separate phases of the process. In our Centre we developed prototype of application which exploits road model advances in data transfer among particular life cycle phases. It is consisted of several modules, which covers different phases of the road construction. For example: corridor definition, land acquisition support, emission calculation. In spite of quite different aspects of road design covered by these modules, almost all of them are supported with component-based ESRI MapObjects geographic information system. In this article, we describe our Road lifecycle software environment (RO). Through examples, we show abilities and advantages of component technology use concerning GIS integration into functional modules.

Introduction
Geographic Information Systems of today are getting increasingly complex. Their functionality in many cases exceeds the domain of “geography” in a great extent. They are linked to engineering as well as economic and other fields. In many cases, existing computer programs (= information systems) are linked to GIS to enrich their functionality with spatial information and functions, or new programs are designed to be “GIS supported”. In both cases, it is desired to design and implement the target information system with standard methods and
tools. Some problems emerge, however, if we try to use conventional GIS development tools:

- Most application development tools offer non-standard specialized procedural languages (e.g. AML, SML, Avenue, MapInfo basic).
- Applications have to be run in the GIS environment where they were developed. Therefore, the original GIS software has to be installed on every computer where the application would have to be used.
- Often, there are difficulties with application transfer to different operating environments.
- GIS functions cannot be used in standard programming languages in a simple and efficient way.
- Different spatial data formats cannot be used in the same application.

Not all stated problems emerge in every GIS development environment. However, at least one of them is always present. Therefore, attempts to functionally enhance GIS always lead to non-homogenous systems with modules written in at least two different programming languages as reported in many articles and research reports (see Bao, Rebolj and Zura).

Today, software development is increasingly object-oriented and is based on component technology. This trend is indicated also with rapid standard development in this field. In software design, the industry is rapidly adopting Unified Modeling Language (UML) which now appears as a default standard in CASE tools. The Object Management Group is developing a comprehensive component standard, the Object Management Architecture (OMA), which will incorporate revised CORBA standard. Standard will include different vendors’ component interactions descriptions. In addition, major software and tools developer companies are taking steps to component technology use. (see Hines and Kiely)

In Road lifecycle software environment (RO) development, we have considered modern trends in software industry. Software for road construction support mostly requires GIS functionality. Object oriented development and component technology have enabled us to incorporate this functionality effectively and with ease.

The desired development tool for GIS supported applications

Component technology is a way of building software, where the main goal is application development from independent and reusable
components. These components are accessed through well-defined interface. Component internal structure is of no importance for a user. Programmer is only interested in specified functionality, which is reached through a component interface. Since component functionality is accessed only through their interface, they can be developed in any programming language. Programmer can use them in a development environment with which he is familiar.

Therefore, for GIS supporting our application we were searching for component based GIS. ESRI MapObjects appeared to be our solution. MapObjects is a set of mapping software components that let the programmer adding maps to his applications. Basic idea of MapObjects is in breaking complex GIS environment in components. The programmer then uses only those components, which functionality he really needs.

This approach has several advantages. RAD tool Visual Basic and programming language C++ could have been used. These are tools that we usually use for software development. In common Windows application, the use of relational data base and spatial data were integrated and this was crucial for building our application. We were able to build RO environment as modular as possible and therefore end user can now use only those functional modules, which he really needs in his working process. Our application therefore requires less demanding computer without extensive GIS overhead.

RO Architecture

Road model

Even a ground plan survey of the road axis can be called the road model. However, such a survey represents only a small part of whole structure. We can not talk about an integral model of an object until all the components of the object and the connections between them are included. Often CAD software for roads includes all the necessary components, yet the connections among them are hidden in the software itself and not in the model – or they are not included in the computer, but exist only in someone’s mind. Of course, a road model can be defined more widely or more narrowly, depending on the phase of the life cycle, or the criteria with which a road is being assessed. In the phase of ground preparation, the polygon, which represents a boundary of the road body, can be a fundamental component of the model. In the phase of the construction, this is the technology, which is tied to a certain activity in the time schedule of construction.
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The road model, called MCT, which has been developed in our research group, derives from the phase of geometric planning (road designing), because geometry is the basic attribute and function of a road. The model is object-oriented and open, which enables us to gradually supplement it with the elements that are needed in other phases of the life cycle. To achieve optimum compatibility with the prevalent software, we have preserved the fundamental structure of the model, which originates from the conventional procedure of road design.

The linking element in the model structure is the Project, which includes the main information about the road project, as well as the essential attributes for the rest of the structural parts (Figure 1). The whole model is defined in such a way that it enables addition to and modification of the individual segments, without affecting other sections of the structure.

The Corridor is a simple structure, which defines the possible borders within which a road may be located. It is important in the early phase of a road life cycle, when the most suitable road corridor is selected and the first approximation of the road axis is elaborated. The corridor is again used in the road geometry definition phase (road design), since it determines the design area. After the geometry of the road is defined, the corridor represents the external borders of the observed area.

The road is a geographical feature, therefore the Corridor and the Road geometry can be seen as thematic components of a geographic information system (GIS). Furthermore, other spatial data in the form of geographic themes (or layers) is required in several phases of the road life cycle. For this reason, a link to Geographic themes is provided in the model.

Since the model is GIS supported, any geographic theme, which covers the area of handling, might be seen as part of an external presentation. Access to the explicitly and implicitly linked geographic themes is left to more or less standard spatial databases and their network distribution or import/export facilities.

The described model MCT is the basis of the RO software. RO has been developed with the purpose of integrating the data structures of existing software for the support of individual life cycle phases, into one united information flow of information (3). The basis of the flow is the MCT road model, which guarantees, that the information about the object does not become lost during the transfer of data between life-cycle phases.
Figure 1: Main structure of the road product model.

Architecture

The RO has been planned as a component-oriented client-server information system, with a flexible and modular structure.

The objects and methods at the user’s disposal, are distributed in three different parts of the system:

- The definitions of the main objects are held together in the compact RO kernel – the kernel is linked to the system database and to the external methods, executed by functional servers.
- The attributive and spatial data structures are defined in the system database, which consists of two main parts: the attributives section (a relational database) and the geographic section (a spatial database).
- Most of the methods are separated from the system kernel into separated modules – functional servers, which enable a high degree of flexibility and also simple upgrading of the system functionality.

Functional servers have a direct connection to the RO database (see Figure 2).

Open, component oriented architecture of the RO environment, enables adding and modifying of the methods (system functions), without affecting other parts of the system. In our opinion, all the tasks in the road life cycle can be covered with the simple addition of the new functional servers.
Up until now, we have created some elementary and some special methods in the form of software components, which support the following functions:

- corridor definition,
- land acquisition support,
- emission calculation and
- rapid 3D visualisation.

This architecture enables user-oriented environment configuration to be built.

**Implementation**

Industry standard programming environment MS Visual Studio was used for application development, which we normally use in our Centre for software development. Visual programming tools allow us quick prototype development. With end user assistance, we then derive applications from those prototypes. The majority of our programming work we have completed in Visual Basic. Some parts of application with greater performance demands have been built in C++.

Independence among functional modules is evident from the architecture. They can be used as stand-alone windows applications as well as in conjunction with other modules in an assembled application.

GIS support is built in all modules but rapid 3D-visualization module. We have provided this support with ESRI MapObjects components. In MapObjects, a map is central component. It is standard Active X component and can be used as other standard Active X components like buttons, check boxes, edit boxes, menus, etc.

With a few simple mouse clicks, the map component can be added to the standard Windows form. In the development environment we can assign map properties and define which layers we want to see on
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the map at run time. We can also easily change these properties through the program code. Map can display several thematic layers. These layers can be of different type such as point, polyline or polygon layers. Map can also display bitmaps, like aerial photographs, which can be used as a background. As thematic layers, we can use ESRI shape files or ARC/INFO covers. We can also connect to spatial databases hosted by Unix servers through Spatial Database Engine (SDE). Map component provides functionality like zooming and panning almost without programming.

Map component with other MapObjects objects also allows editing existing or creating new thematic layers, graphical and SQL selection of displayed elements, map printing and many other features. As it can be seen this is very powerful component. With adding this component to the Windows form, we simply add all this functionality to our application.

Throughout our work, we have followed object oriented development approach as much as it is possible in Visual Basic. We have encapsulated data and methods for particular functionality like drawing a corridor or a parcel selection into classes. This resulted in a clear program structure where its parts are as independent as possible. This is very important in achieving better reusability.

Module descriptions

Corridor

Different thematic layers can be displayed by this module in different user defined colors and attributes of geographic features can be examined and rendered. The main aim of the module is pseudo axis and corridor definition. User can create the axis, save it and later add, move or delete axis points.

We have developed an algorithm for generation of buffer with unified width. This buffer is called corridor. Corridor border can be manually adjusted; some points can be added or deleted. It can be manually defined from scratch also.

Land acquisition

The purpose of this module is a process of land acquisition tracking. It allows for the investors’ supervision viewpoint as well as the viewpoint of their contractors. The process of land acquisition is an example where
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GIS support is just incidental feature. Main module functions as purchasing events record keeping and contract preparation for example are based primarily on RDBMS. In this case, GIS support only improves the data overview.

Like in Corridor module, also in this module different thematic layers can be displayed and attributes examined. In addition, spatial and attribute searching and selection is possible.

Function, which deserves special attention, is overlaying of the defined road corridor over parcels and cross-sections searching. This function returns parts of parcels, which are covered with a road.

Emission analyses

Lately, ecology is increasingly important aspect of every industrial activity. This led us to development of the module for emission calculation, which will be caused by the road in construction. Results of these calculations are huge tables of numbers. Purpose of GIS support in this module is visualization of this data. Results in tables are displayed as a buffer around the road.

Figure 3: Emission analysis visualization example.
Conclusion

Road lifecycle software environment (RO) has been developed in our Civil Engineering Informatics Centre with the purpose of integrating the data structures of existing software for the support of individual life cycle phases into one united information flow of information. Development of RO environment logically follows development of a road product model (MCT) which is a base for road lifecycle phases integration. Up until now, we have created some elementary and some special methods in the form of software components. Into our environment it is possible to incorporate applications from other independent developers, like software for road design for example. In the process of this open environment construction the object oriented development and component technology has been of the great help. Almost every functional module, which we have developed, is GIS supported. Through examples it is evident how component oriented GIS like ESRI MapObjects can assure problem solving in situations where GIS support is essential for an application as well as in situations where this is of incidental importance only. In the latter case, component technology provides simple and effective integration of the GIS with RDBMS functionality and GIS application in scientific visualisation.

In the future, we will extend our RO software that it could be used as an Internet application. Component technology will take a great part in this future project too. For this reason, we are testing ESRI MapObjects Internet Server and its components.

At the end let us mention GIS software developer forecasts, which says that in the future they will enable “classical” GIS tools like ESRI ARC/INFO to be available as components.
References

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