TRANSFER OF ROAD PRODUCT MODEL USAGE FROM ACADEMIA TO PRACTICE

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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 life cycle activities in the construction of individual objects. These activities are being weakly connected. Working on it, we have been focusing specially in the road design field. In the past few years we have developed a road model, called MCT, which is based on geometric road design. As a part of this project, we have also made an application prototype that uses advantages of MCT and enables simple transfer of road data among particular life cycle phases.

Yet, in the early stage of our research project we were aware that our findings have to be tested in practise as soon as possible. Project was funded in part by the government institution that controls road building in Slovenia. For this reason, we expected the investor to animate contractors to exchange data with our model. Unfortunately, our expectations were not completely fulfilled and therefore the model was not verified in practise. Since we believe our model can rationalise road building procedure, we decided to carry out some extra activities, which would stimulate model usage. Therefore, we established direct contact with some contractors involved in specific road life cycle phases. This was not an easy job, because a great number of small organisations are involved. Contractor's work is usually very clearly defined and computer is just a tool that helps him to do it quicker and better. For this purpose, some extra functional modules of Road life-cycle environment (RO) were made and the existing ones were conformed according to the contractors needs. Since contractors are already using particular software to support their engineering process, we also persuaded software producers to include MCT in their programs for road design. This way, we gained broad software support for our model.

Article fully describes a road model MCT, Road life-cycle environment RO and especially our efforts to introduce MCT into engineering practice.

Key words: road product model, RO software environment, theory-practice conflicts

INTRODUCTION

Product models

From the practice, it can be noticed that engineering process is well-supported in particular phases, but communication among different engineering and other groups is not so good. However, internal or communication among organisations is of a crucial importance for effective organisations operation. Product models enable data transfer among particular phases of the product life cycle. The data accompanies the product from conception to design to manufacture and to maintenance. Engineering application development, framed with product models, enables integration of product life cycle phases and effective data exchange among different project contractors. In such a way, the data can be successfully supervised by users responsible for those data and all the users have an opportunity to reach the data that they need. There is minimum redundancy and no need for multiple retyping of the data into different programs. This reduces appearance of errors and saves a lot of time because of skipping unnecessary activities. Therefore, if we wish to improve computer support to the mutually integrated processes – which the processes in the road life cycle surely are – it is reasonable to begin this task with the question about preparation of corresponding data.

The elementary problem, in civil engineering, does not lie in the technology. We have object oriented technology, from which RAD (rapid application development) concepts and tools derived, standards for the description of products (as e.g. STEP), and more. The problem is rather in the approach – the arrangement of work and software, which copies and supports this organisation. Most software almost exclusively originates from methods of work characteristic for the pre-computer era of engineering (although they are nicely wrapped in object-oriented user interfaces). Although the method of work is highly interactive within one process, the inter-processing communication could be compared with the already long surviving batch processing, with its characteristic linear single direction. However, new information technologies, whose importance and applicable value are greatly increased by the Internet, also enable interaction among the processes and participants in the life cycle of the construction object (a nice example, unfortunately not in the field of civil engineering, is presented in Hardwick 1997). If we wish to use contemporary information technology effectively, we have to begin with the conformation of organisational concepts. We should not begin with the use of new technologies with out-dated methods of work, which is with the use of computers usually the case in the field of civil engineering.

For the vast majority of known software used in road construction, badly linked or unconnected data structures, which are above all subordinated to the procedure of conventional road design, are greatly significant. This is particularly true with the upgrades of different universal CAD software. Here extra-specialised functions for the road design are included and are above all directed to the composition of drawings.

Software also exists which contains a suitable integrated road model as a base – data structures therefore, where the basic elements, like the road axis, crossection elements and terrain are mutually linked. But as a rule, the road model contained in the program of this kind is closed. This means that the program can not export its model to other software without considerable loss of information. This is especially characteristic when standards for description of geometrical data are used (e.g. CGM, DXF).

New standards in the field of information exchange offer greater possibilities for more integral external descriptions of building construction models – including roads. We could for example integrate axis elements with crossections to form a more compact model, with the standard for the semantic description of the graphical layers (Björk 1996). However, the description of complex constructions with the help of layers has other disadvantages. It is unsuitable when we wish to derive one model from another, in order to produce a different view of a building construction, because direct integration of particular data in different layers does not exist as such.

The more universal standard for the description of product models - STEP (*ISO10303* 1994) is certainly more suitable, for we can integrally describe a building construction with it. STEP is slowly, yet rather successfully getting importance, especially for use in very complex projects (like those already mentioned in Hardwick 1997), but the only known description of a road (Willems 1996) did not confirm itself in the practice.

In our research group for the last few years, we have focused on the integration of computer supported processes of the life cycle of building constructions – especially roads. We have designed a more simple open road product model, which is much easier to implement (the development can be followed through Rebolj 1995a, 1996a, 1996b and 1997). The road body model (MCT), as we named it, serves as a starting-point for an improvement of data exchange among existing software that supports different phases of the road life cycle.

Road body model and RO application

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.

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.

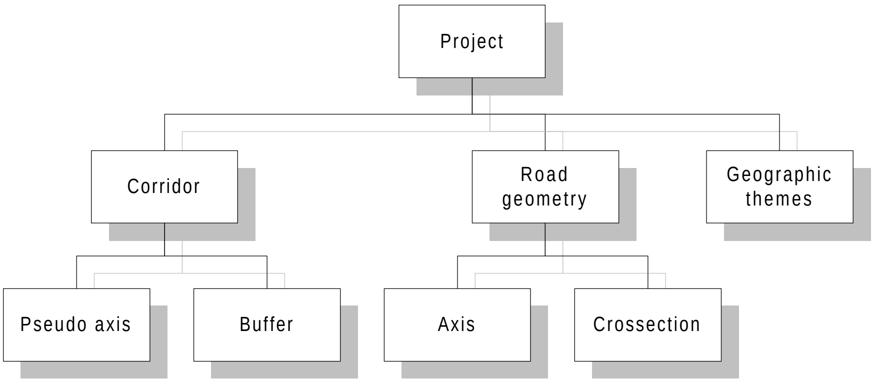

Figure 1: Main structure of the road product model.

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 simple upgrading of the system functionality.

Functional servers have a direct connection to the RO database (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.

<table>
<tr><td colspan="4">RO</td></tr>
<tr><td colspan="4">Functional modules (corridor, land acqusition…)</td></tr>
<tr><td>RDBMS</td><td colspan="3">MO</td></tr>
<tr><td>Attributive data</td><td>shape</td><td>cover</td><td>SDE</td></tr>
</table>

Figure 2: RO architecture.

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.

TRANSFERE TO PRACTICE

As many other innovations development of Road body model began in the academic environment. It was in years 1991 and 1992. In the following section we are describing its development and first of all its transfer to practice. This section ends with our ideas for further model development.

History

Road body model, which is a base for Road life cycle environment RO, originates from doctoral dissertation (Rebolj 1993). Road geometry model was conceived as a by-product during implementation of integrated, object oriented Road design and assessment environment. This was an attempt to integrate different existing programs, which are used in the road life cycle in somewhat unusual way (with a method of object shells, which did not turn out so well). Our attempt was focused specially on RDS (Road design system) and GIS (Geographic information system) integration.

A product of these activities was an application, named RoDEE, which performed quite well. With this product, we connected the following phases of a road design process: corridor definition in GIS environment and with spatial database support, road geometry design with RDS support and design variant evaluation within GIS or 3D graphical environment. We presented our application on several workshops and conferences. In spite of expert approval, application had many deficiencies. For example:

- Prototype operated on VAX with VMS/VWS operating system. In practice, this was not very frequent operating system.
- It used very expensive GIS (ARC/INFO). Road designers were not willing to invest in such a system only to access some RoDEE functionality.

- Geographic layers were needed for effective prototype use. These were adding additional costs.
- Prototype was supported by only one RDS (Cador). With this RDS, implementation of object shell, which enabled integration on the object level, was difficult.
- For 3D visualisation HOOPS graphical system was used. It rendered 3D picture of the road. It was too expensive for users as well, in spite of its automatic 3D-picture generation from MCT.
- Road designers used tools for road design without MCT interface. Because of that, MCT could not be a base for life cycle integration.

Experts who recognised the advantages of unified road model and RoDEE environment use, admitted that quality of a project developed in this environment raised. However, in a process of transferring RoDEE to practice, it turned out that investors are not willing to pay this quality raise. This attitude influenced contractors, which had to make some initial investments in this process too and interest was deceased rapidly. Our opinion is that publicly accessible database of digital spatial data is very important factor for such integrated system to carry into effect. In Slovenia, this database is now emerging. Activities are including forming of digital terrain model in 25 meters precision. Present model is in 100 meters precision, which is completely inadequate for road design. Also digital cadastre is emerging and at the time of writing it covers about 15% of entire area. Second prerequisite for project life cycle integration is compatibility of data among different programs used in the process. This aspect is covered by Road body model (MCT).

Above-mentioned obstacles led us to improve our RoDEE application. The second version of RoDEE environment was operating on PC computers with PC ARC/INFO (Rebolj 1995a) and 3D visualisation was made in AutoCAD (Tibaut 1994). We developed additional modules for variant analyses. The majority of work was focused on Dynamic emission model. This model implemented in program module and in a connection with MCT enables instant emission calculation and its visualisation in GIS environment and therefor performing of many further analyses (Rebolj 1995b).

This step to the PC platform was in the right direction but still too small. GIS was still too expensive for designers and AutoCAD for investors, because they didn’t need this kind of software for other work but for using RoDEE. Geographic data accessibility problem and problem of programs (especially road design programs) connectivity remained. Programs for road design, used in Slovenia, are mainly based on AutoCAD. The road is represented as a set of lines instead of structured object. For this reason, implementation of adequate MCT interface for these programs was almost impossible. In spite of several obstacles, we made an agreement with two RDS software developers: firm Ziegler Informatics from Germany and firm CGS from Slovenia.

It has to be noticed that this kind of cooperation demands a lot of time. Software developer has to include agreed interface into his product and new version of application has to be released. After that, users have to upgrade or buy new version of application. Ziegler started this project with enthusiasm, but in 1996, implementation was stopped. German association IAI started with their own road model development. CGS implemented MCT interface and it is integrated in their last version of RDS program Plateia.

Present activities

During 1996 and 1997, we developed present version of RoDEE environment. We renamed it into Road life-cycle environment (RO). RO architecture is described above and elsewhere (for example Rebolj 1996a, 1996b). GIS functionality and 3D graphics are included into application by components. This approach does not overload the user with functionality that he doesn’t need. What is more important, it does not increase the price of the product.

Thanks to several improvements, this system is now ready for use. However, in its transfer to practice some difficulties remained. It seems that life-cycle process’ connectivity and higher quality is of anyone interest! After extensive discussion with some road design organisations, we realised the reason for this lack of interest, lies in process fragmentation throughout several firms. Of course, participants in the project prefer input data in a way they can use them directly (in MCT for example), but no one is willing to pay for it. At the same time, contractors are not eager to share their data with others. For example, they don’t want to transmit previously prepared data to other firms or put them into shared databases. The largest interest for that co-ordinated use of data has an investor. In Slovenia, in the field of road construction, the investor is the state. Therefor, we have been intensively acquainting state officials (investor representatives) with the advantages of MCT usage. In these efforts, we have been quite successful. The advantages in data semantic preserving, documentation generation, presentation abilities and other benefits of the integrated model use has been presented. However, the administration is very slow.

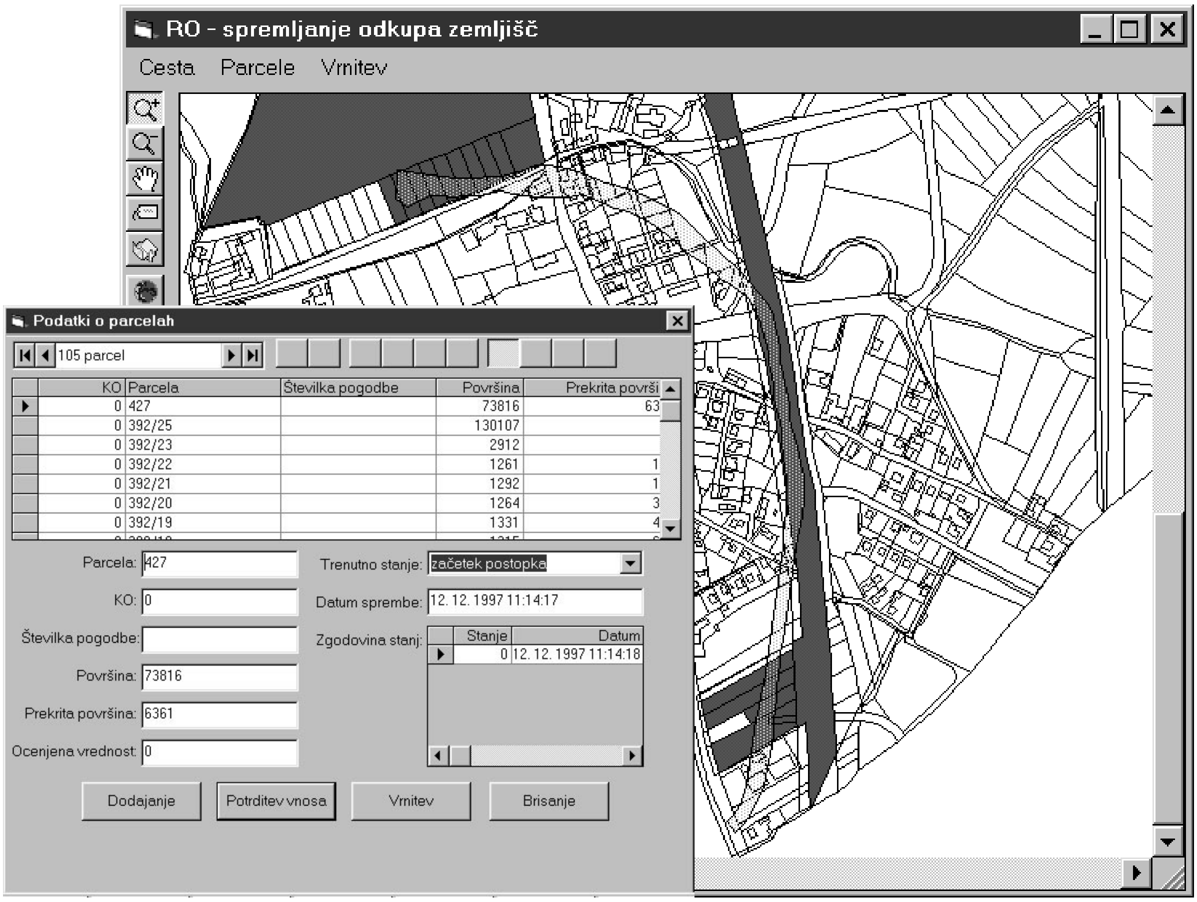

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Figure 3 Land acquisition module.

Attention for MCT has increased after the presentation of a program module for land acquisition, at the end of 1997 (see). It is evident that land acquisition is timely topic in the road life cycle, at least in Slovenia. Large interest for this module has been manifested by contractors, which are working on land acquisition and by investors, who have to track the project activities. We are using current interest in the model for stimulating other project participants, primarily road designers, who need to prepare geometry of the road in MCT. Namely, in land acquisition process we need road body circumference, which can be extracted from MCT. We have combined these activities in a project named Introduction of a program for land acquisition. The project is financed by the state – investor for the road construction projects, and slow administration has moved.

Further work

It is obvious that MCT is not completely adequate. Therefor, we are supplementing it in its contents and in its structure. In our work, we are adopting STEP standard. We are also trying to establish connections with other research groups, which are coping with STEP and road construction. These efforts are directed to TNO from Netherlands and to Sweden National Road Construction Institute. However, our work on the model up to the present and our development of the interfaces for existing programs are indicating that complex model would not be appropriate right at the beginning. At this point, when our simple MCT model already reached some popularity, there is an opportunity to go further. In a prevalent organisation of the road life cycle, the main obstacles were in an introduction of the road model as a basis of integration.

In addition, RO environment follows new directions in the field of information technology, primarily in the field of distributed processing. We have developed a component for 3D visualisation of a road over the Internet and we are testing components for map displaying over the net.

CONCLUSION

From our experiences, which have we got from the development and introduction of Road body model and corresponding Road life cycle environment to the practice, we can summarise following findings:

1. Product models are appropriate solution for integration of constructional objets life cycle. However, to introduce them smoothly we have to connect them with prevalent software.
2. To enable integration with common software the models should not be too complex.
3. Since constructional object life cycle processes, especially in civil engineering, are fragmented and dispersed among several contractors, proper motivation for integrated model use can hardly be achieved.
4. To increase the motivation, it is reasonable to begin in the phase, which gains s lot with the product model use. In our case, it is land acquisition. In this phase, we can generate road body circumference from MCT, which can be of significant help.
5. With the appropriate software support in the currently unsupported phases, we can gain additional motivation. Therefor, we developed emission calculation and visualisation module.

6. We have to develop convenient open and flexible program environment into which we can freely include needed modules (as plug-ins). This environment has to enable inclusion of existing programs.
7. Contents, structure and shape of the model should be developed incrementally.

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