OBJECT-ORIENTED APPROACH TO GIS DATA MANAGEMENT

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Abstract

The paper deals with modelling and management of spatial (3D) data representing real World. Two main software tools are mostly used – GIS and CAD systems. We analyze their functionality from several points of view. There are two main issues. The first one is the characteristics of environment modelled. CAD systems are oriented towards modelling individual man-made objects and structures with relatively high level of details and short-term usage. On the other side GIS applications maintain large-scale models of real world with significantly lower amount of details and long-term usage. The second issue is the way of storing spatial (3D) data. While CAD data are usually stored in individual files (like DXF, IGES), GIS data require databases and DBMS. Those two data-storing methods make data from GIS and CAD applications hard to combine. Answering the interoperability requirements of recent GIS development, the paper describes possibilities of bridging GIS and CAD systems using another approach to data management. This approach has to be object-oriented database management system.

Abstrakt

Článek se zabývá modelováním a správou prostorových (3D) dat reprezentujících reálný Svět. V této oblasti se nejčastěji používají dva druhy softwarových nástrojů – CAD a GIS systémy. Analyzovali jsme jejich funkcionalitu z několika úhlů pohledu a rozpoznali dvě základní otázky. První je charakteristika modelovaného prostředí. CAD systémy se zabývají modelováním jednotlivých člověkem vyrobených objektů konstrukcí s relativně vysokou úrovní zachycení detailů a krátkodobým použitím. Oproti tom GIS aplikace dlouhodobě spravují rozměrné modely reálného světa se znatelně nižším množstvím detailů. Druhou otázkou je způsob jakým jsou v obou systémech ukládána prostorová (3D) data. Zatímco CAD data jsou obvykle uložena v samostatných souborech (např. DXF, IGES), GIS data vyžadují databáze a SŘBD. Tyto dva odlišné způsoby ukládání dat způsobují to, že data z obou systémů se těžko kombinují. Vzhledem k požadavkům na interoperabilitu v současné době vyvíjených GIS systémů se tento článek zabývá možnostmi spojení GIS a CAD systémů a to použitím nového přístupu ke správě dat. Tímto způsobem je objektově-orientovaný databázový systém.

Motivation

At the beginning of our work we started thinking about an information system capturing our World with the most detailed level of abstraction. This system has to be able to describe real-world entities in both their visible and invisible properties and in the manner to be useful in our common life. At first we tried to think about a visible part of this system. That means about the tools for a virtual presentation of our World on the computer displaying devices.

Two main categories of systems that do this are GIS and CAD applications. The aim of both of them is to model the real world, but each one does this by its own way. GIS applications are constructed for maintaining information in connection with its geographical location. This serves people when they need to find the exact place where information belongs to. On the other side CAD applications assist people when modelling thing to be constructed. The first difference that we can see is that GIS tend to maintain information about things that are and CAD about things that will be. Combining these two principles we could have a system, which is able maintain information about both. We suppose that it would be very useful system for the observation of what we have done and what good is it and what we want to do and what good it will be.

Introduction

Survey of strengths and weaknesses of 3D modelling systems mentioned above pointed to a conclusion that the main weakness of both of them was data management. File system used by CAD systems makes data hard to reach for other applications. On the other hand relational databases and their DBMS widely used in current GIS applications have certain limits when storing real world entities. We propose to move from relational to fully object-oriented databases. This approach fits well into object based CAD modelling techniques. Our aim is to make a bridge between CAD and GIS software development. The idea is to utilize object-oriented high-resolution modelling methods from CAD and large-scale database management approach from GIS thus forming a novel, robust and complex environment for deal world modelling, storing and visualization.

Previous Work

We tried to investigate where the problem of integration of those two worlds lies. That led us to find out following areas of interest: CAD/GIS integration, 3D GIS data modelling, an object-oriented approach and 3D GIS data management. In following chapters we try to explain the problems mentioned above introducing the ideas of leading experts.

GIS/CAD integration

Observing the situation in the area of CAD and GIS integration, we found out that it is so problematic, that almost nobody knows the universal solution. Van Oosterom [2] and Weinstein [5] describe differences between CAD and GIS as follows.

GIS aspects

- landscape-level analysis and mapping
- advanced information tools
- mostly 2D modelling
- database based
- optimized for data retrieval
- 1:5000 scale and below
- constrained editing environment

CAD aspects

- object-level design and drafting
- advanced drawing tools
- 3D modelling
- file based
- optimized for data design
- 1:40-5000 scale
- unconstrained editing environment [2],[5]

Zlatanova [1] presents CAD as to be primarily designed to maintain large-scale models without attributes and geographical coordinates systems a GIS is able to manage small-scale models with attributes and a variety of different geographic coordinate systems. Van Oosterom [2] adds that CAD usually represents the man-made world while GIS also captures the natural environment combined with man-made objects. He also says that CAD generally works on a temporal project basis, while GIS is suitable to very long period of data collection and maintenance. CAD systems use an orthogonal world as a projection environment, while GIS systems must be able to convert many different coordinate systems, which are used to model spherical world.

As could be seen the integration process inevitably leads to use the CAD for data capture, design and modelling, while GIS for data management, analysis and visualizing. The solution could be found in mapping both data into the neutral 3D data model [5]. So the first issue may be to develop a proper 3D data model that could then be integrated into current GIS applications. This model might be our solution of GIS and CAD integration. Because of the most common feature of CAD and GIS that is 3D representation, we will mention only 3D data models. Surveying those models, the paradigm of object-orientation frequently appeared. Because it seems to be very important for GIS researchers, we have to explain it briefly.

An object-oriented approach

Egenhofer [7] indicates definition of object-orientation as: *structural object orientation* - any entity, independent of whatever complexity and structure, may be represented by exactly one object, no artificial decomposition into simpler parts due to technical restrictions should be necessary, *operational object orientation* – operations on complex objects are possible without having to decompose the objects into a number of simple objects, *behavioural object orientation* – a system must allow its objects to be accessed and modified only through a set of operations specific to an object type.

On the other hand Sarközy [9] describes four main concepts covering object orientation. The first concept is the *encapsulation*. That means that the object attributes could be accessed by only methods stored in the same object. The second concept is the *inheritance*. If there's a subdivision of a class, then the subclasses inherit data and methods of a superclass. The third concept is the *object identity*. It means that object's identification should not change

during the object's life. There is also the fourth concept called *polymorphism*, which could be described as different responses to the same message depending on the sender or the acceptor object.

3D GIS data model

Zlatanova [13] states the conceptual model as the key element in 3D GIS solution. She considers conceptual 3D model as integration of semantics, 3D geometry and 3D topology. She also supposes the object-oriented approach to provide a mechanism to model real objects in more natural way.

Zhou and Zhang [14] consider most urban objects as man-made. They also state that compared with natural objects, the urban man-made objects are relatively regular in the terms of shape, distribution, and structure. This makes it possible for data model to abstract and represent urban spatial objects with some primary geometric elements. In addition, some complex urban objects can be considered as the combination of relatively simple objects.

Among the important 3D data models for GIS applications belongs: Molenaar's FDS [14], Zlatanova's SSS [13], Wang and Gruen's V3D [14], Coors's UDM [15], Pilouk's TEN, Shi et al.'s OO3D [16] and Balovnev et al's GeoToolKit [17]. Here we introduce a brief summary of their features. We do not want to describe them in detail or compare each other, because it has been done previously. We just want to get an idea, how the problem is solved.

First of those model was the FDS, which partitioned the space into non-overlapping objects. FDS describes the basic geometric elements: node, edge, arc and face and four spatial objects: point, line, surface and volume. As a first model it was broadly discussed and frequently extended like in V3D [14]. The distinct feature of V3D model is that the geometric information is combined with attribute information. The TEN includes node, arc, triangle and tetrahedron as the basic elements. The SSS model is a further development of the FDS model. Shi, Yang and Li [16] think that compared to FDS, the SSS keeps the explicit relationships between body and face and eliminates the edge and arc object. On the other hand, the SSS keeps the relationship of geometric objects and attribute data such as texture. Their OO3D uses node, segment and triangle as basic elements [16]. Coors considers his UDM quite similar as SSS. Both don't support the arc and the edge elements [15].

The GeoToolKit requires particular attention, because it is not only a data model, but also an object-oriented geo-database system for the support of 3D geological applications [18]. Authors of GeoToolKit demonstrate the potential of object-oriented concept in 3D database. GeoToolKit deals primarily with two basic notions: a *SpatialObject* and a *Space* (a collection of spatial objects). The *Group* gathers spatial objects of different types into a collection and then is treated as a single object. GeoToolKit is a class library suitable for the storage of spatial objects within an object-oriented database. Currently GeoToolKit offers classes for representation and manipulation of simple (point, segment, triangle, and tetrahedron) and complex (curve, surface, and solid) 3D spatial objects.

3D GIS data management

As a last issue we have to describe the 3D GIS data management. Going through the ideas of many experts, we have to notice, that the discussion about the 3D GIS data management is concerned in comparing the relational and object database management systems. Egenhofer [7] states the relational data model as the most common one. He thinks

that this model seems to be suitable for modelling data with tabular characteristics, such as bank accounts, but too simplistic for modelling data that describe spatial objects. Since the relational data model does not match the natural concepts of spatial data, users must artificially transform their mental models into a restrictive set of non-spatial tables, thus the object-oriented data models have been developed to capture more semantics than the relational model.

Many researchers [6][7][8][10][11] comply that the spatial information systems will benefit from the use of object-oriented database management. The architecture of a GIS will become clearer. The maintenance of GIS software will be easier. And also the life cycle will be longer. GIS developers should not worry about aspects of the physical storage of data.

Garvey Jackson and Roberts [10] see the further motivation for the use of an object-oriented approach to the production of GIS system in the expectation that the this approach will result in a system which has a clean interface and is easier to maintain than an equivalent system built using conventional programming techniques.

Conclusion and future work

Now we can summarize the problem of the GIS and CAD integration. Because of the different characteristics of the two worlds, firstly there's need to decide for some suitable 3D data model, which can maintain the geometric. This model must be able to maintain the large-scale 3D models produced by CAD as well as low-scale objects used by GIS. Object-oriented approach seems to be the proper way to model such a problem, because it offers richer data structures and more intuitive representation of the real world objects. An example of a suitable object-oriented data model for maintaining geometric representation could be GeoToolKit.

Over the GeoToolKit we have to develop application-specific semantic data models for describing the real world objects of our particular interest. We are concerned especially in modelling of the cities, so our data model has to describe buildings, streets and other city components. In the Appendix we introduce an example of data models that was developed. The first one is the model of the city (Fig 1.). It describes the relations between the city parts. The second one is the model of the building (Fig 2.). It decomposes the object Building describing the relations between its parts. Those models are examples of object-oriented approach to GIS data modelling. Because those models could be stored by an object-oriented database, the data structure might be built exactly like you can see it in the model. In addition we can add behaviour to this object defining its methods. This way we can make digitalized abstractions of real world entities with all their abstracted characteristics. We suppose that modelling the real world using the object-oriented approach is the way to solve the interoperability problem between multiple data sources. The way to form the mentioned object-oriented universal and neutral data model which will serve as a layer between multiple data storing formats, for example between CAD and GIS.

We suppose that the other problem that is to be solved for storing CAD data in the 3D GIS database is find out the way to generalize and classify the high-scaled objects from CAD when storing it as low-scaled objects in GIS. And on the other hand how to restore the details of re-scaled objects stored in GIS to give them back into the CAD to be redesigned. That would be the subject of our future research.

Appendix

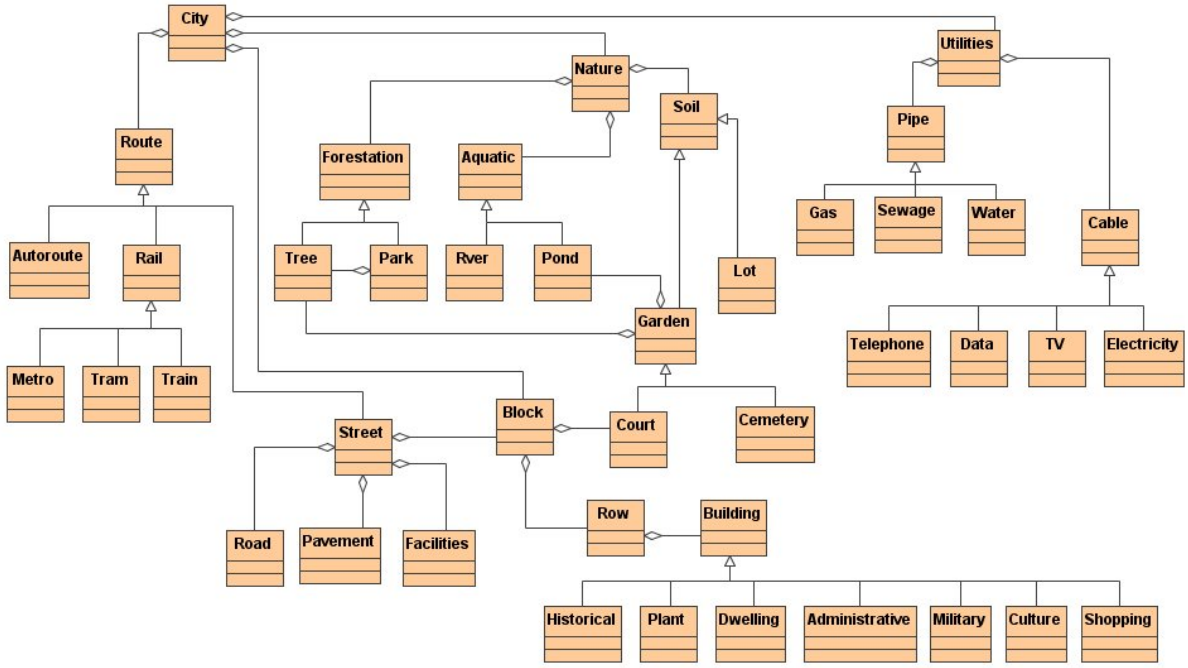

Fig 1. An example of city data model

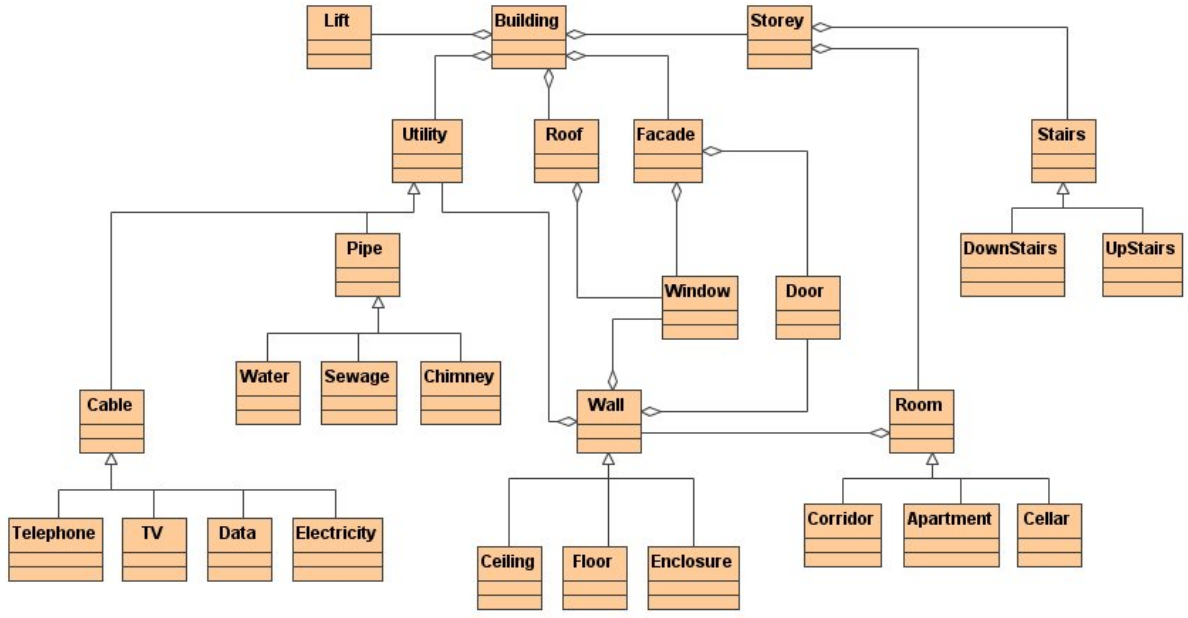

Fig 2. An example of building data model

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