TEMPORAL GIS FOR ANALYSIS AND VISUALISATION OF CULTURAL HERITAGE

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ABSTRACT:

Based on the results of a workshop in 2001, a research project for development of a geographical information system (GIS) for cultural heritage has been started at the Techn. University of Munich in co-operation with municipalities and other regional authorities in a rural and on agriculture and tourism depended region of the free state of Bavaria. In many institutions valuable data of the history of the region and the culture landscape and of architectural monuments have been collected and stored. Overlaying and combined information in GIS with considerable analysis and visualisation methods can supply an important contribution for the sustainable development of the rural area. Thereby temporal survey and analysis of cultural data are playing a special role. As a result of the combination of current and historical data valuable hints arise from the procedures in cultural history and can be used for future planning. The paper describes aspects of object-oriented temporal data modelling and application in a large-scaled cultural heritage geo information system.

ZUSAMMENFASSUNG:

Die Technische Universität München beschäftigt sich seit mehreren Jahren auf Initiative eines Workshops mit Gemeinden und anderen behördlichen Verwaltungen mit der Entwicklung eines Geoinformationssystems (GIS) für kulturelles Erbe in einem von Landwirtschaft und Tourismus geprägten, ländlich strukturierten Gebiet in Bayern. An vielen Stellen werden wertvolle Daten über die Geschichte einer Region, über die historisch Kulturlandschaft und Baudenkmäler gesammelt und gespeichert. Die Zusammenführung und gemeinsame Auswertung in einem GIS mit umfangreichen Analyse- und Visualisierungsmethoden kann einen wichtigen Fachbeitrag zur nachhaltigen Entwicklung ländlicher Gebiete liefern. Eine besondere Bedeutung hat dabei die zeitliche Erfassung und Auswertung der Daten. Durch die Kombination der aktuellen mit historischen Situationen ergeben sich wertvolle Hinweise über die Veränderungsvorgänge in der kulturellen Geschichte und können in zukünftige Planungen eingebracht werden. Das Manuskript beinhaltet Aspekte zur Modellierung objekt-orientierter temporaler Datenmodelle und deren Anwendung in einem großmaßstäbigen Geoinformationssystem für kulturelles Erbe.

1. INTRODUCTION

For some years the Techn. University of Munich has been working to develop a GIS for cultural heritage in co-operation with municipalities and other regional authorities.
The area under investigation is the *Achental*, a structurally rural region of the free state of Bavaria at the north edge of the Alps, near the border to Austria, witch depends on agriculture and tourism (Figure 1).
In many public and private institutions valuable data of the history of the region, the culture landscape and of architectural monuments have been collected and stored. Overlaying and combining this information in GIS with wide analysis and visualisation methods can supply an important contribution for the sustainable development of the rural area.
Closely working together with the regional authorities for preservation of monuments and historic buildings, with the district office, with the district office for rural development, municipalities and citizens there was made an analysis of requirements to the possibilities of using a GIS for historical questions about cultural heritage.

The paper introduces some results of the analysis of requirements and some aspects of modelling a temporal GIS for cultural heritage using UML (Unified Modelling Language).

Figure 1. Location of investigated area

In the following chapters a prototypic realisation of a temporal GIS for cultural heritage is shown, in which the object oriented, temporal data model has been implemented in an object relational database (Oracle 8i) and therefor is combinable with available data in a spatial database (ESRI).
A platform independent software application based on Oracle Extensions to JDBC has been developed to query and visualise the historically interesting spatial and attribute data. The access from the application to the geo-referenced data and ESRI-SDE is made by MapObjects (ESRI).

At the end of the paper the status of the project will be described.

2. WORKSHOP TO ANALYSE THE REQUIREMENTS OF A TEMPORAL GIS FOR CULTURAL HERITAGE

Regional distinctions are among other things characterised by historical traces of the cultural heritage, which are still visible in the cultural landscape and settlements. According to requirements extensive stocktakings of the historical village structure are made in the run-up of projects of the district office of rural development in Bavarian villages.
These contain surveys to nature area and locality, settlement history, development of the village structure, buildings and monuments characterising the historical local picture as well as the historical cultural landscape. On the one hand they serve as valuable planning basis for projects of redevelopment of villages and on the other hand they are of great value for municipalities and their citizens and should therefore be made available to a large circle of persons.
Since this information in maps, texts and pictures is acquired and mapped so far in analogous form, the question came up, whether this information should be stored in the future in a geographical information system, in which the historical data could be archived, as well as analysed and visualised with regard to their spatiotemporal relations.
Therefore in the year 2001 several representatives of municipalities, preservation of monuments, rural development, tourism and education met to a workshop in the *Achental* and discussed the requirements and possible user scenarios to a GIS for the cultural heritage.

2.1 Content and object areas

A GIS for cultural heritage should be open for all contents and object areas, which refer to anthropogenic historical activities, which had been reflected in the landscape and in the settlements in the form of elements and structures and/or which transformed and influenced landscape and settlement structure. Thereby it is useful to organise the objects into different functional areas, e.g. religion/state/military, settlement, traffic, agriculture, trade, spare time etc..

2.2 Data

A substantial advantage of a GIS is the combined use of geometric and alphanumerical data. Geometric and alphanumerical data about the cultural heritage of an area must be gathered from many different sources of authorities, institutions, companies and private people. These data are often available in different formats and with different quality and can be integrated in a GIS only by conversion and adjustment (cp. Figure 2).

The **geometric data** consists mainly of maps, which are available partly digitally or in case of historical data frequently only in analogue form.
More current maps are partially available in vector data form, older maps only as raster data sets. Historical maps also have the problem of equalisation. Above all very old maps are rather works of art, which would lose their special character after a transformation into a today's geographical reference system.

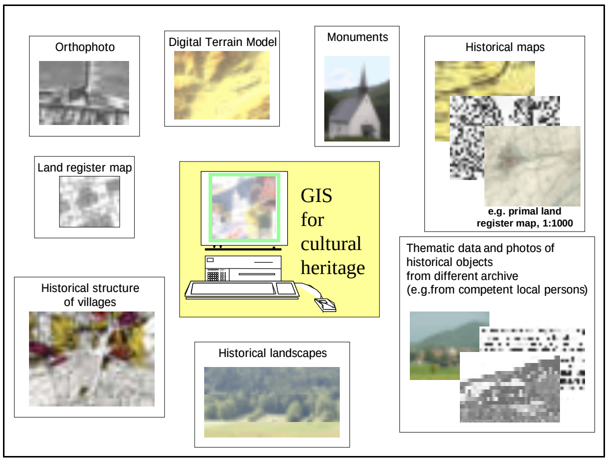

Figure 2. Several data in GIS for cultural heritage

The **alphanumerical data** is available as different historical texts from private archives and official data collections, e.g. the register of real estate tax. Many of these sources are not in a computer-readable form and also not suitable for text recognition software.

Additionally to the text data **multimedia data** offer themselves for the affiliation to a geo information system for cultural heritage, e.g. historical or current photographs, video material of certain objects, or audio records of surrounding nature.

All these data have to be provided with **meta data** when they are stored into a geo information system. Meta data contain additional information about the actual data sets, like data source or quality of data, and they are especially important for historical data in order to assure the verifiableness and authenticity of the data.

All in all collection and evaluation of historical data can be difficult, because historical data often are not exactly detectable, not in digital form, additionally incomplete or contradictory .

2.3 Functionality

Generally following demands are made on the functionality of an temporal GIS for cultural heritage:

- Sustainable stocktaking and documentation
- Combined spatial, temporal and thematic selection and analysis of culture-historical objects
- Visualisation of spatial and temporal processes
- Simple access to information for different target groups

2.4 User szenarios

A GIS for the cultural heritage in the Achental should particularly be useful for development of economy and tourism. Beyond that further usage should be considered in preservation of monument and historic buildings, in different planning procedures, in local history and education.

2.4.1 Preservation of monuments

Historical data about monuments and historical buildings are partly contained in very valuable and fragile documents. They should be made accessible for a larger public to promote the

interest and the understanding for monuments. At the same time a long-term preservation of these documents is necessary.
Mapping and collection of registered monuments in a GIS for the cultural heritage on basis of digitised, older maps enable the automated analysis of developments of a region or a settlement area and simplify the error tracing in the existing monument list.

2.4.2 Planning

Municipalities, citizens and representatives of the economy spent much time and energy in the regional development of rural area to acquire and evaluate basic data, to formulate ideas and to produce an acceptance of these ideas in the broad public. An important task of the rural development is to be seen in preservation and passing on of the cultural heritage. Often earlier steps of development are conserved as vestiges in the culture landscape and in the settlements. Increasingly such certifications of the past are included into the documentation and analysis of planning procedures in order to come to identity-securing and at the same time future-arranged solutions. The collection and documentation of historical information and vestiges about culture landscape and architectural monuments, place names etc. in a GIS can thereby supply a significant contribution to planning procedures like landscape planning, project planning or regional developments.

2.4.3 Tourism

In the field of tourism the historical places of interest show the characteristic of the region.
In this case the request and visualisation possibilities of a GIS for cultural heritage could be used for the advertisement of the region. Examples are information about historical architectural monuments, churches and monasteries, castles and chateaus, museums, as well as culture landscapes such as protected areas, nature and cultural monuments in the landscape or local recreation areas.

2.4.4 Local history and education

A GIS for the cultural heritage could contribute to the intermediation of historical values out of the preservation of monuments and local history to citizens and schools.
More and more traditions are lost and knowledge about the own local history is often limited to a few persons, like interested private people or the honorary persons, who take care of all things concerning local history.
On the one hand this knowledge should be archived in order to receive it to future generations, on the other hand to make it accessible for a larger public.

Through the integration or co-operation with a portal offerer and therefor the presentation in the world wide web, the GIS can be opened for a wide field of users.

3. CONCEPT OF SOLUTION

3.1 Temporal GIS

While conventional GIS offer extensive possibilities for the collection and analysis of spatial and thematic geo data, a temporal GIS should support the user during decision making in complex temporal questions. Today there are already several beginnings to handle temporal data in GIS, e.g. as time attribute in the Snapshot model. For a more versatile appliance a temporal extension of the GIS database is necessary, which permits the user to provide objects of the application with a differentiated time relation and to create inquiries or forecasts.

A **temporal GIS** generally connects the stored, georeferenced database objects with a time term: in the ideal case it spans a 4d-space (spatial + temporal relationship of the thematic data) in contrast to 2,5 and/or 3d-GIS (only spatial + thematic data).

A **historical GIS** is a special case of an temporal GIS. Here particularly historical data of the past are stored. So far as possible these data are spatially and temporally referenced. Then the analysis of spatiotemporal data over several epochs enables pointing out changes of objects and making statements about their prospective development.
Objects in a historical GIS cannot only be determined in fixed time intervals like it is mostly accepted in current database systems (e.g. time series option of Oracle 8i). It should be possible to define free times and time intervals, which are determined by incidental events of the real world.
Also the uncertainties of temporal definition of the historical events must be considered.

In an temporal GIS spatiotemporal inquiry types can occur, which can refer to individual objects as well as to larger structures (Ebeling 1999):

- a simple temporal inquiry of a point of time, e.g. an object status
- a temporal inquiry concerning a period, e.g. the change of an object during a period
- a simple spatiotemporal inquiry concerning a sector of 2d/3d space at a point of time
- a inquiry of a space-time span, i.e the variation of a sector of the 2d/3d space during a period.

Last but not least animations and dynamic interactive maps do contribute to the efficient visualisation of spatiotemporal data of the database.

3.2 Modelling

The requirements analysis from the workshop entered into a modelling process (cp. Figure 3). Goal of modelling is the transformation of the real world into a model in order to be able to process it in a computer system. Objects of the real world are represented in a data model with their attributes and relationships as well as their behaviour. Data modelling starts with the choice of a sektor of the real world. In the case of a temporal GIS this sektor is not only determined by spatial coordinates, but also by temporal characteristics, e.g. over a period of the past.

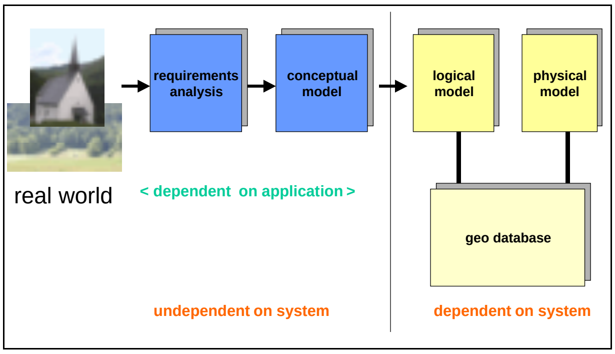

Figure 3. Modelling process from real world into a geo database

Subsequently to this conceptual modelling process there follows the system choice, in which the used computer systems and programs are selected, for example the GIS or the database system. The system choice depends on application and the conceptual model.
For Implementation a logical model is developed from the conceptual model considering the characteristics of the selected computer programs and database system.

3.2.1 Conceptual model with UML

The current quasi-standard UML for the diagram of conceptual data model was used to stay abreast of the object-oriented extensions. UML stands for Unified Modelling Language and offers different features during the object oriented design of application. In the illustration in Figure 4 only class diagrams have been used. Further possibilities of UML are e.g. use case diagrams or features to represent dynamic aspects of object behaviour (Booch et al, 1998).
UML class diagrams mainly consist of single classes with their attributes and methods.
In Figure 4 a clearly simplified fragment from the UML class diagram of the data model for a temporal GIS is shown. Here was considered that an object of application can have thematic, spatial as well as differentiated temporal characteristics.

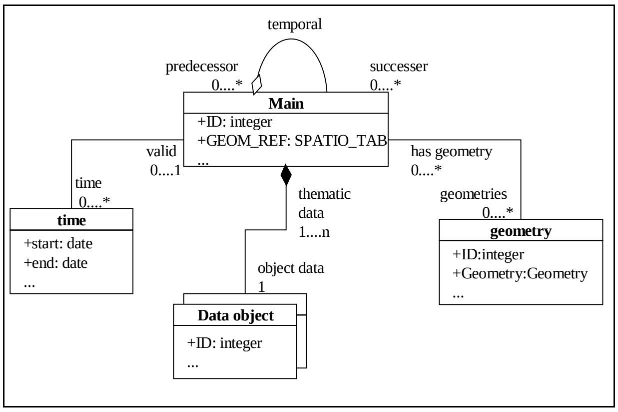

Figure 4. Fragment of the UML class diagram

Several classes have relationships. For example there is a 1 to n relationship between the classes *DATA OBJECT* and *MAIN*. A*ggregation* and *composition* are special kinds of relationships. The *aggregation* ( ) expresses only a " is part of" – relationship. That means that an object can exists of other objects, however without bringing in additional semantics restricting the object.
The *composition* ( ) restricts the object and its components in such form that an individual component of the object, which participates in this composition may not exist alone.

3.2.2 Implementation in Oracle 8i

The data model was implemented into the object-relational database management system Oracle 8i. Therefor in the conceptual model it was already considered that no sufficient means of inheritance have been available and so a hierarchical structure was simulated by the use of the table *MAIN* as a super object.

The class ***TIME*** offers the possibility to differentiate as well as to combine points and periods of time with different accuracy. For example the storage could be made as a snapshot or as a development over larger periods.

The time was modelled in such way, that the limits of an interval of time can be unknown or can determined as intentionally open, e.g. if a development has not finished.

In addition different advanced **thematic data** has to be provided in the several classes of *DATA OBJECT*, e.g. content of the official monument list, which is associated to the object or specialised information for certain target groups.

Vector geometries are stored in the data model on a data type *GEOMETRY*, which is present in Oracle 8i in connection with the spatial cartridge. With the help of this data type the connection is made between the database model and a GIS. The column *ID* stores, like the table *MAIN*, a generic ID, which represents a simple possibility of accessing single spatial objects without to produce complete spatial inquiries. This is particularly helpful regarding the production of references in the Nested Table *TABLE(MAIN.GEOM_REF)*. The storage of instances of the class *SPATIO_TYP* takes place in the object table *GEOMETRY*. Especially newer GIS of the large manufacturers in the geo information market enables the direct access to the Oracle data type *SDO_GEOMETRY* for the storage of spatial information in the database. Thereby it is also ensured that the data model can be used in different GIS systems.

4. REALISATION AND GIS-TECHNOLOGY

The structural differences between spatial and non-spatial information led in the past to a separate data management. The dual organisational structure was gradually given up in the last decade in favour of an integrated data management.
In this context geo information systems have been developed, which store spatial data not in the form of files but in databases. The implementation of such information systems was realised with special external database extensions, which are also known as "GIS middleware".
This development has promoted and certainly initiated the spreading of a new generation of database systems: Now geographical database systems can be regarded as relational database systems with object-oriented extensions and have internal auxiliary modules for the access to georeferenced data.
Examples of these auxiliary modules are "Oracle Spatial", "IBM Spatial Extender" and the "Informix Spatial DATA Blade". These software products enable an integrated data management of spatial and non-spatial data and offer uniform (however usually manufacturer-specific) database interfaces - the supplied possibilities offer thereby certain basic functionality for complex geo information systems.

4.1 Architecture

The prototypic GIS solution at Techn. University of Munich is based on an object-relational alphanumerical data model implemented in the database system Oracle and the storage of the spatial data with the *spatial data engine (SDE)* of ESRI.
For the input of the alphanumerical data and pictures an input module was developed on the basis of *Oracle Objects for OLE* (Visual basic). For inquiry and visualisation of historically interesting geometric and alphanumerical data a platform independent request module (see Figure 5) on basis of *Oracle Extensions for JDBC* (Java) was developed.

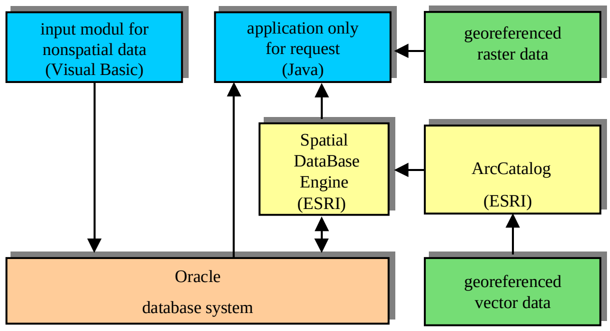

Figure 5. Architecture of GIS prototype for cultural heritage

The access to the georeferenced data and to the *SDE* model takes place by means of a *MapObjects* library from ESRI.
A large advantage of the *MapObject* library is the abstraction of the developed GIS application of (usually ESRI specific) data sources, because the application programmer does not need to know the internal details of the used raster or vector data structures. These kinds of abstraction levels belong to the most important advantages, when GIS applications are developed with the help of prefabricated components.

The most important data sources (supported of *MapObjects* and used in the developed software) are: vector files in the *shape* format, georeferenced raster files in *tiff world* format and the *SDE*.

4.2 Features

The request application enables the user to select a geographical subarea as well as to select a historical point or period of time and gives back an appropriate result set of objects.
The selection can be combined with further (optional) selection criteria (e.g. keywords and restrictions on certain object areas).
Afterwards detailed information to the result set can be requested e.g. photos or describing texts (Figure 6)

Figure 6. Request modul of GIS for cultural heritage

In addition it is possible to visualise the requested objects (and/or individual objects of the received selection set) in the map with their geometrical forming – thereby the respective map sector with raster and vector data is accordingly changed on scale.

Another possibility of the request application is the spatial identification function of objects, which can then be shown with detailed information. There is also the possibility of accomplishing object selections by point or area-related selection tools and of computing intersections.

Visualisation of georeferenced raster and vector data, which can independently be faded in or out in superimposed levels, takes place in the map window of the GIS application.
The overlay and/or the opacity of each single level can be application specifically determined on the basis of different priorities.
Further "zoom", "un-zoom" and "pan"-functions are available in the respective map section.
Beside the inquiry and output of information concerning single objects of cultural heritage also surface changes can be analysed, for example the development of historical settlement and culture landscapes.

5. STATUS

Within the research project the feasibility of acquisition and documentation of valuable historical and current geo information in a large-scaled GIS could be revealed. This geo information is based on official geo basis data (e.g. primal land register map in scale of 1:1000, topographical maps and orthophotos), on further official geo data (e.g. data on monuments and historical culture landscape elements) and on private collections of residents. The architecture of the prototype has been chosen modular and platform independent especially to use further object-oriented possibilities, which are not yet available in conventional GIS.

From evaluation of possible user groups it arised that the tourism at this point of implementation drops out. As the prototype comprises a possibility for presentation of historic information in user defined time steps, utilisation is particularly interesting for local and regional planers as well as interested citizens and municipalities. In the projects for rural development (e.g. village redevelopment) a well founded rating of the grown structures of landscape and settlement is partially accomplished. Thereby a selective evaluation and documentation of the cultural heritage in a GIS can give municipalities a basis for further measures of future based planing and sustainable development of the rural region.
Usage in tourism demands a further work up of the information depending on the special requirements of the tourism industry that goes beyond the possibilities of the prototype. This could come along with the possible integration into tourism online portals in the column " object of interest " and " history of the vacation region" connected with mapping and routing functions.

As a historic database lives on the data variety with emphasis on local peculiarities, an extensive data acquisition and evaluation has to be achieved by single persons for which a standard program has not yet been accomplished.

The design of the prototype is in a way that an expansion of data sources is possible. To allow a transfer to other areas beyond the prototype, the several data structure given by the authorities can be adapted.

REFERENCES

Booch Grady / Rumbaugh James / Jacobsen Ivar, 1998. “Unified Modeling Language User Guide”, Addison-Wesley-Longman Bonn/Reading (Massachusetts).

Ebeling Dietrich (Hsg.), 1999. “Historisch-thematische Kartographie”, Verlag für Regionalgeschichte Bielefeld.

Hochhäusler Tobias, 2003. “Implementierung eines Geoinformationssystems in Visual Basic und Java auf Basis einer objektrelationalen Oracle-Datenbank”, Institut für Geodäsie, GIS und Landmanagement, Technische Universität München, unpublished.

Langran Gail, 1993. Time in Geographic Information Systems, Taylor & Francis Verlag.

Plabst, Stephan, 2001. “Theoretische und praktische Ansätze zum Aufbau geographischer Datenbanken”, Institut für Geodäsie, GIS und Landmanagement, Technische Universität München, diploma thesis, unpublished.

Scheugenpflug Stefan, 1999. “Raum-Zeit-Analysen in Geoinformationssystemen am Beispiel des Referenz-GIS ’National BayerischerWald”’, Institut für Geodäsie, GIS und Landmanagement, Technische Universität München, diploma thesis, unpublished.