

GEO-INFORMATION MANAGEMENT

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ABSTRACT:

The contribution deals with the contextual design of spatial data for the purposes of the regional development, land management and government, describes the role of remote sensing data and contextual modelling for the context oriented geo-information and tries to provide the framework for the object hierarchy of classes and propose the ways of structure and behaviour modelling. The digital geographic databases are rapidly growing and the problem has shifted from finding the data to finding meaningful geographic information or better *knowledge* from the large volumes of data. GIS technology is changing to GIM technology (Geographical Information Management). Many users have their own specific requirements for the access to data, with regards to the administrative units where the evaluation is provided and considered the relations and contextual and temporal background for the data processing. Object-oriented image analysis is based on an object-oriented approach to image analysis. In contrast to the classical image processing method, the basic processing units are image objects or segments. Further motivation for the object-oriented approach is the fact that the expected result of most image analysis tasks is a set of real world objects. The topological relations of single or adjacent pixels are given by the raster implicitly. The increasing resolution of the sources results in the increasing number of objects of course and moreover the complexity of object structuring hierarchy is rapidly growing too. The automation of the classification and interpretation process gives better results when the fuzzy elements are implemented.

1. INTRODUCTION

1.1 Spatial Data Collection

It is evident now that the combination of spatial and temporal components of information and incorporation of computational intelligence into spatial data analysis will bring the new qualitative reasoning of geo-information. The progress in new sensor technology for Earth observational remote sensing continues and increasingly high spectral resolution multispectral imaging sensors are developed and these sensors give more detailed and complex data for each picture element.

The increasing resolution of the sources results in the increasing number of imaged objects (classes), increase the dimensionality of data, and moreover, the complexity of object structuring hierarchy is rapidly growing too.

In addition, the geo-society calls for temporal data, temporal oriented spatial databases. This need comes from natural necessity of registration of changes appearing around us on one hand and the need of monitoring of long-term processes and trends and their interrelations on the other one (Klimešová, 2001). The great development of geographical databases and GIS technology oriented on spatial data at all has been caused

by the fact that it corresponds very closely to our understanding of the around world. The same scheme is valid in case of the concept of time.

There is no life without the time consideration. There is no past and no future. And the natural process connected with time accounting is analysis of changes.

1.2 Temporal Analysis

Automated process of evaluation of temporal data sets is called – temporal analysis. We need to know the history to be able understand the trends and model our future. The management of any thing, including acceptance of the important decisions, it is not possible to do having the inventory information. To be successful in management of things it means to account the changes, understand the trends and effectively plan the changes if possible.

The temporal context model characterizes the processes of contextual coding, storage and retrieval. To retrieve context, we introduce an item-to-context matrix M^{FT} , that connects the F layer (space) to T layer (Howard M. W., Kahana M., 2001). The input is obtained by presenting current stimulus to the matrix M^{FT} :

$$t_i^{IN} = M_i^{FT} f_i. \quad (1)$$

t_i^{IN} is the input state of context at time i on layer T and f_i is the state of context at time i on space T .

The evolution equation for t is as follows:

$$t_i = \rho_i t_{i-1} + \beta t_i^{IN}, \quad (2)$$

where β is a free parameter and $0 < \rho_i \leq 1$ is chosen to satisfy the constraint that $\|t_i\| = 1$.

Spatial-temporal databases represent huge amount of data, new technologies of processing and a new access and management of large databases.

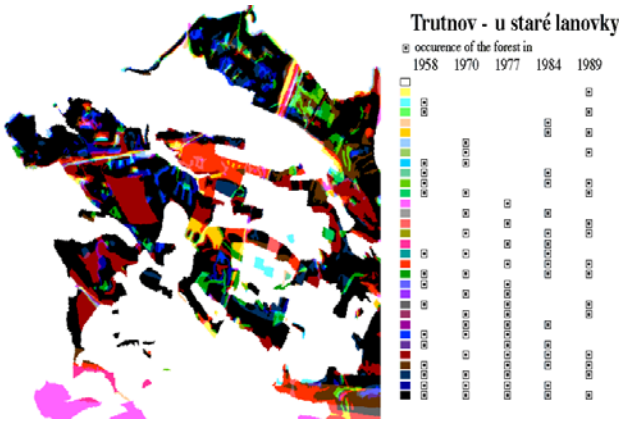


Figure 1. The result of temporal analysis is shown - the forest body between years 1958-1989 in Trutnov neighbourhood (closed to power plant). Aerial data sets evaluation.

On the other hand, specific temporal based queries should be used to analyse spatial-temporal oriented databases like:

Retrieve all locations that changed between t_i and t_k about at least 1/10 of current value.

Calculate the changes between t_i and t_k on given areas.

Compare the changes in given time strips.

Briefly speaking, great amount of data asks for automation of the classification and interpretation process of spatial data without the necessity to collect and utilize the large training sets (Tyree, Long, 1997, Ocelíková, 2002). The useful approach in the face of such conditions is to utilize hierarchy in analytical process.

2. DECISION-TREE DESIGN

2.1 Tree Structure Design

Decision tree is often called multi-level classifier. It reflects the fact that we deal with multi-class, multi-node and multi-peak distribution. The tree structure hierarchy simplifies the problem of multi-class recognition and convert it into more convenient space where the step-by-step decision-making can be applied. The advantage of this approach is that the model construction is approximately low cost and it is easy understand.

There are three main parts to solve:

- Tree structure design
- Decision rule selection
- Feature selection

The relations defined by the class hierarchy cause the inheritance of class descriptions (attributes, relations and methods, it means for example the operations for the computing of different parameters without depending on the selected scale of the image, respective the size of the object) of child classes on one hand and semantic grouping of classes on the other.

Inheritance: Class descriptions defined in parent classes are passed down to their child classes. The class can inherit descriptions from more than one parent class. The inheritance hierarchy is a hierarchy of similarities that can reduce the redundancy and complexity in the class descriptions.

Groups of aggregation: It is the combination of classes to a class of superior semantic meaning. Beyond that, the group hierarchy has the direct functional implication. Each feature that addresses the class is automatically directed to this class and all its child classes in the group hierarchy. The class can be part of more than one group.

Structure: Differs slightly from the other two hierarchies, although the structure can have parallels to the hierarchy of groups. Different classes can be put together in structure groups as a basis for the classification-based segmentation. This tool make possible fuse even of previously heterogeneous regions to single objects.

2.1.1 Boolean Matrix

To express any relationship of objects to each other objects we can use the matrix. To model the hierarchy of objects, it means inheritance relationship between object we can utilize Boolean matrices. The true will be entered in the matrix element where the row object (class) inherits from the column object (class) and false everywhere else.

We can define the simple operations to identify the level of inheritance transitivity, groups of aggregation, accounting of restrictions and assumptions tailored exactly to the solved application.

Boolean matrix expresses the inheritance of classes S1 – S9. We can read it as follows: S2, S5 and S8 are subclasses of S1, S3, S4 are subclasses of S2, S6 and S7 are subclasses of S5 and S9 is subclass of S8. In case of multi-class decision we deal with sparse matrices.

$$S = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix} \quad (3)$$

The inheritance hierarchy and the group's hierarchy complement each other in the following sense. While the inheritance hierarchy is used to subsequently separate and differentiate classes of the objects in the feature space, the group's hierarchy permits the meaningful grouping of the resulting classes.

The local government, land management and regional development solve many tasks where the above described approach is applicable on the different levels in the field of monitoring, mapping, inventory, change detection or parameters estimation.

The class hierarchy and related restrictions and assumptions, which can be continually changed during the processing, it is the base of knowledge for the image object classification. In many applications the desired geo-information and the objects of interest are than extracted step by step, by iterative process of classifying and processing. It is very similar to human image understanding processes.

This kind of circular processing results in a sequence of partial states, with an increasing differentiation of the classification result and the increasing abstraction of the original image information.

On the each step of the abstraction new information and new knowledge is generated and can be used beneficial for the next analysis step. High beneficial is the fact, that after successful analysis, a lot of interesting, additional information can be derived.

There are many reasons for the knowledge-based spatial data network building and sharing. The pixel-oriented classification can be accepted as the pre-processing phase that is followed by object-oriented contextual classification applied through decision tree design.

2.2 Decision-making process

The average resolution of image objects can be adapted to the scale of interest and resulting information can be represented in the scale based on the average size of image objects. This fact is coherent with the hierarchical networking and representation of image objects. In the hierarchical structure each object knows its neighbours, sub objects and super objects.

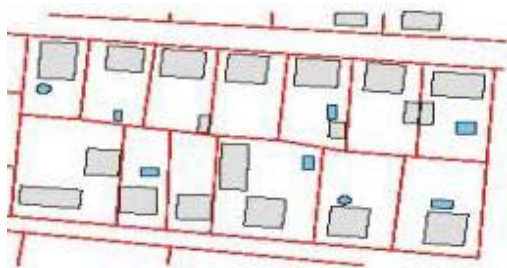


Figure 2. Part of cadastral plan.

We distinguish three types of elemental object features:

- ❑ Attribute (physical properties of objects that follow from real world or image or different information layers related to the object).

- ❑ Topological features (describe the geometric relationships between the objects or the whole scene).
- ❑ Context features (represent the objects' semantic relationships. The gardens are inside the urban area; the island is surrounded by the water, and so on. It means between class (object) relationships).



Figure 3. Identification of outdoor pools inside the gardens.

The different segmentation techniques can be used to construct a hierarchical network of image objects and each level in this hierarchical network is produced by a single segmentation run. The hierarchical structure represents and contains the information of the image data at different resolutions simultaneously. Fine objects are sub-objects of the coarser structures. It means, that each object knows its context, its neighbourhood and its sub-objects.

3. FUZZY DESIGN

3.1 Membership function design

Each of the decision-making process is associated with some level of overall uncertainty. Human experience is often expressed using the expressions like: a little bit more, more than usual, less than last time, etc.

This uncertainty can rise from the facts that:

- ❑ We are not able to define exactly the problem, the class of objects.
- ❑ We utilize not quite correct spatial data with respect to define task.
- ❑ We are not able to verify all assumptions, and estimate and validate all restrictions we need to build out the hierarchical decision model.

The automation of the classification and interpretation process gives better results when the fuzzy elements are implemented into the decision structure.

One of the well-known approaches to decision making based on uncertain information is *Fuzzy Logic*. This framework is frequently used for decision making in case when the expert knowledge and rules are to be implemented into the decision

procedure. Since its introduction (Zadeh, 1965), fuzzy logic was applied to numerous problems and applications due to its ability to provide a framework through which non-deterministic problems could be addressed.

Fuzzy logic approach (Fuller, 2000) consists of five key elements:

- ❑ Input fuzzification –is done through the definition of functions that describe the degree of membership. It is the measure of the fact that input belongs to a specific fuzzy set. The set of input data can be assigned fuzzy membership values.
- ❑ Application of fuzzy operators utilize the set of *If – Then* rules that describe conditions (assumptions and restrictions) between several input variables, a conclusion regarding the membership of the output is drawn and an output value is assigned.
- ❑ Definition of consequences - the membership function of the output is obtained as a result of applying the fuzzy operator. The consequence of this decision is the retrieval of the fuzzy subset that corresponds to the conclusion drawn using an implication operator.
- ❑ Aggregation of consequences – from each of the rules stated a set of consequences is drawn. The aggregation of these consequences provides the fuzzy subset that result from these various rules.
- ❑ Defuzzification – usually, it is required to draw one single conclusion. In order to conclude a single conclusion from the fuzzy process, it is then required to select a representative element from the aggregated fuzzy set.

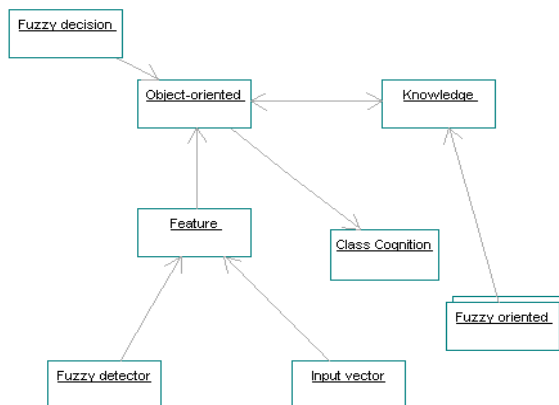


Figure4. Fuzzified decision.

Fuzzy rules can be generated from examples using various techniques. Kasabov presented a neural network approach for generating fuzzy rules. Clustering technique and statistical measures can also generate fuzzy rules. Decision rules work well when input data is noise free.

Fuzzy logic has also been widely recognized as a powerful scheme for decision-making processes in GIS. A high level of complexity and varying level of structure and formalization

commonly characterize such processes. Moreover, multiple objectives and constraints must be met

Fuzzy logic provides a powerful scheme in such decision-making processes as it allows formulating loosely structured expert knowledge. It should be noted that for this reason fuzzy logic has also proven to be highly effective in quantitative as well as qualitative decision making processes (Bolloju, 1995).

Applications of fuzzy logic for decision making and expert knowledge systems have already been demonstrated in environmental applications (Bolloju, 1995), semantic modeling and reasoning (Benedikt et al., 2002), and land cover mapping or categorical mapping (Zhang and Goodchild, 2002).

4. CONCLUSIONS

In this paper, the problem of the spatial data is addressed where the contextual information is identified and temporal aspect of spatial data is accounted. The running development of information technologies, image processing techniques and knowledge-based databases, together with the geographical networks environment, will provide quite new and considerably wider possibilities of using GIS. Our decisions are becoming increasingly dependent on understanding of complex relations and phenomena in the world around and GIS technology is able to incorporate new requirements like decision tree context, temporal aspects and fuzzy design. The main goal has been to show selected aspects of this process and compare the increasing possibilities of the sources with the difficulties of data contextual structuring and the object history implementation.

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