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PROSPECTS OF GIS APPROACHING THE 21 CENTURY[1]

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Abstract

Reviewing the GIS development in the fields of software, hardware, data sources and applications since the beginning of this decade one can face enormous changes even in the trends stated five years ago. To cope with this sophisticated system on the one hand, some of its elements, on the other hand, the interaction of applications and GIS functionality should be analysed in detail. By this analysis we should consider such intrinsic developments in the GIS software concept as object orientation, hybridisation of data model, intelligent databases, virtual reality, etc. At the same time we can observe typical changes in the application field, too. The inventory systems are near to be merged into the general information system of the enterprise, the systems for modelling and engineering design need complementary non-linear tools for the proper, high quality solution. Thus, the idea of a general GIS software is no more acceptable. In the future we should use at least three types of open systems. The base system should be a common data base management system for both the spatial and attributive data with truncated GIS functionality plus an inference machine and a frame for a rule base. The systems for planning should play the role of an I/O device for the processing program supplying it with data and rules. The systems for resource management, environmental modelling and protection will be the very similar to the present general GIS systems, but they should be changed, too, in sense of dimensional extension of the data model and should include the scalar and vector field processing capability into its resources. The largest change will occur in the place of GIS in the information society. This will be due to the plenty of standardised spatial data. The first steps in this direction were made by the USA government announcing the policy of establishing the national spatial data infrastructure.

Keywords: data models, GIS, GIS functionality, GIS applications, hybrid systems, information technology (IT), modelling, object orientation, spatial data infrastructure.

1. Introduction

Geographical Information Systems have begun their practical application in the mid seventies. It was only a decade later that DBMS connected with systems of office or business information have commenced to proliferate

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over the world. Until now, the general use of GIS is affected by the delay at the start.

There are several arguments to explain the delay at the beginning. First of all the modest hardware conditions of that time especially in relation of the computer graphics are mentioned. Secondly the abundance of data in the space related systems, the low storage capacity and data transmission rates are often contrasted. However, the primary reasons of the delay, that still hold now have financial and educational roots. The main moving forces of the alphanumeric databases and the spatially *not* related information systems were the spheres of finances and business. Because of the nature of data these sectors used to apply the direct spatial aspects even did not come up. The most of the data itself of course has spatial relations, but even if they were incorporated it was made only using coarse acquisition and evaluation models. In other words the users did not know and did not worry about how the spatial relationships influence their data. and how these influences are taken into account.

This relation to the spatial impacts may be interpreted as a consequence of the insufficient geographical education of the specialists in management and economics as well as the deficiency of reliable digital spatial data. In addition should be mentioned that the production of spatial digital data is a cost and time consuming process, that has returns on the investment only on a long term basis.

Hence, the spatial information systems began their development independently from the general flow of information systems. The first overseas systems were compiled for the tasks of natural resource management and this application strongly influenced the general tool kit of the GIS software products. Although to the end of the last decade most of the operating applications were active in the fields of inventory recording (cadastre, plant systems) or in facility management (suppliers of water, electricity, etc.), the software products did not reflect the situation. The systems have continuously grown including the new applications into their customised function collections. As I stated in 1989 (SÁRKÖZY, 1990) we can observe a unanimous trend towards uniformity in the functionalities of different GIS software products independent of their applications. In order to halt the growth of the software we should answer the question whether it is useful to develop general type GIS software. If the answer is yes, then we should find the limits of generality.

Nevertheless these limits are not static, they depend on many factors, first of all on the fitting of the GIS in the general information technology.

Beside the external conditions the development of GIS is influenced by intrinsic motivations, too. Moreover the intrinsic development has an effect also on the sensibility of the system concepts to accept the exterior conditions. All these three components will be analysed in the following sections.

2. Elements of Intrinsic Development

The crucial element of the GIS is the data model. All other issues of the software are closely depending on it. The hybrid systems for example are based on a dual data model, or the modelling possibilities and the dimension extension are directly connected to the data model. At the same time the influence of the informational environment on the GIS development is also a function of the prevailing data model in GIS. Therefore, it is natural to begin the analysis of intrinsic development tendencies with the data models.

2.1 Conceptual GIS Data Models

The GIS maps the entities and phenomena of the 4 dimensional reality into two or (only in very few cases) three dimensional constructs. The type of the construct used by a particular system is called data model. We can distinguish at least two stages in the mapping process: the conceptual modelling on the one hand and its implementation on the other. *On the conceptual* stage the real world can be modelled by **simple objects, complex objects, function fields and interpolation arrangements usually in form of grids.**

The **simple object** approach supposes that the real world entities have to be transformed into geometrical primitives: points, lines, areas (surfaces, solids) with tagged attributive data. The main assumption of the concept is that the simple object is homogeneous.

Complex objects mean for us entities, e.g. houses, factories, roadways, etc., that have parts, and their parts can have further subdivision. The complex object itself has an identity and some common attributive data, but its parts have also attributes, that is the attributes can change from part to part. The theoretical foundation of this model is the hypergraph theory (BERG, 1973), its development for geographic application one can find in several papers of BOUILLÉ, e.g. (BOUILLÉ, 1987).

If some phenomenon changes its value in function of the place considered we map the changing attribute by a two or three dimensional **function field.** If we are interested in the impact of different phenomena spread over the same region, we can model those by **function fields.**

For the sake of easier processing some interpolated (approximated) values of the changing attribute can represent the function field itself. In these cases we gain further benefits performing the interpolation in regularly distributed spots for example in a regular grid.

2.2 Implementing the Conceptual Model

Implementing the conceptual model different *practical* data models were created. Most of these models have implemented the same simple object concept with different tools.

From practical point of view the simple objects can be modelled by *vector* or by *raster* tools. At this point we should add some explanation about the raster implementation data model to avoid the confusion often appearing in different GIS textbooks, for example in the well-known NCGIA Core Curriculum (NCGIA, 1989).

The raster systems originated as a practical model *for the direct implementation of the conceptual model of grid interpolation.* It should be mentioned that for the conceptual model has no importance whether the grid points have measured values, interpolated values using scattered point data or their values are sampled from existing records. The main issues are as follows: the resolution of the model depends only on the density of data capture, the range of attributive data corresponds to the range of function values of the mapped phenomenon. This is the explanation why the early raster systems were not fitted for high positional accuracy as well as for the management of a lot of attribute types implementing the simple object conceptual model. Of course from technical point of view (aspects of storage capacity and run time) it is unreasonable to store and manage high accuracy, rarely located, point type simple objects in a raster structure.

The classical and until now best implementation model for the 2D simple object conceptual model was realised in the mid seventies by the ESRI with the software product ARC/INFO. The so called *georelational* data model consists of two main parts. The geographic (or geometric) data are organised in vector topological structure and stored in a hierarchical data base. The attributive data are organised and managed in a relational data base. The two parts of an object are connected by identification numbers. The system corresponding to the simple object concept uses the layer structure and the planar enforcement.

In the 3D domain the GIS software did not have large achievements until now. The existing programs use for the implementation of the grid conceptual model the voxel approach. More development one can find in the CAD systems. The implementation model of boundary description and especially that of the constructive solid geometry leads us towards the realisation of the complex object conceptual models. More about the dimension expansions see in (SÁRKÖZY, 1994).

Since the end of the eighties the idea of hybrid data models is in transition from the research to the reality (FRITSCH 1988). This new model has not only practical but also conceptual benefits. The starting point of the concept is based upon the fact that the number of available digital spatial raster data is growing enormously. In most of the cases, at least in countries' with developed spatial infrastructure, we can have got vector and raster data for the same region. In hybrid systems we use both data together utilising the advantages of each structure. The raster data as well the vector data and attributive data are stored separately in the way best satisfying the requirements of the particular model. The procedures are performed in the model more convenient for the given task using the vector to raster or raster to vector conversions before and after the operations. Until this stage the hybrid data model is only an implementation tool, perfecting the realisation of the simple object conceptual model. However, this model is capable also to realise the grid variant of the function field conceptual model and therefore by proper conditions can be used for scientific spatial analysis.

Some practical ways of implementing the conceptual model of comprehensive objects are provided by the **object oriented approach.** Although one can face with some scepticism in relation of the method's name (BOUILLÉ, 1994), there is no doubt that it is a powerful tool that helps better model some entities of the real world.

Originally the object orientation was used as a programming concept leading to the construction of programming languages as Simula, C++, Flavors, Smalltalk-80, Eiffel, etc. However, the object orientation developed further to create data base concept and data base management systems, e.g. the GemStone and the SIM.

Some decisive concepts are common in the programming and DBMS languages (PARSAYE, 1989). The first concept is the *encapsulation.* It means that the object or some group of objects (class) and the procedures (methods) defined on it are stored and managed together. To activate a procedure the program sends a message to an encapsulated data-procedures set, in the consequence of the procedure's activity the set can send another message to another set, etc. The second concept is the *inheritance.* The inheritance is related to the class hierarchy. If we have a subdivision of a class, then the subclasses inherit from the class data and methods. The third concept is the *object identity.* It means that despite different transformations the object's name should not change. There is a fourth concept the so-called *polymorphism* (AYBET, 1994). We can interpret the word polymorphism as different responses to the same message depending on the object in the address of the message. For example we can send a message: 'plot' to the addresses a, b, c. If into the object a is encapsulated a procedure of a circle, in the object b that of an ellipse and in the object c that of a square, then depending on the addresses, the command 'plot' will result a circle, an ellipse or a square.

The object oriented approach can appear on different levels of the system. So far, in most of the object oriented GIS the object orientation is realised on the level of user interface (CAMARATA, 1993). In this case the advantages of the method as software development tools are utilised. The properties of the object orientation make much easier to perform consistent changes in applications pertaining the operations or/and the data model. However, the real growth of system performance can be realised only in the case when both the data base and the user interface are compiled in object oriented manner. Nowadays the main obstacle on this way is the hesitation of the software producers to change the reliable, tested for a long time relational data base systems with the new object oriented ones.

2.3 Applying Intelligence

The idea of an **intelligent GIS**, that is a GIS with **intelligent query language** has appeared several years ago (BOUILLÉ, 1987). However, until now we did not have the opportunity to find these principles realised in a customary GIS software. The delay, in my opinion, is caused by the ambiguity in the choice of the field of activity that demands an intelligent GIS. A general cartographic intelligence recommended by Bouillé is too wide and consequently too shallow to satisfy the demands of different specialities. On this stage we should consider that the GIS of the future can develop in two directions. The first is the continuation of the existing way, that of independent development. In this case because of simple financial causes, the GIS software should contain only the *frames* of the knowledge base with the more or less general inference machine. The knowledge base will be filled up with the knowledge of the particular domain in the process of the system deployment. The other way has more prospects but less probability to be realised. Following this way the GIS will consequently merge into the general information system of the particular domain. In this case the GIS is a database with standardised data model and a visualisation tool. The expert system belongs to the general information system, but uses the data of the GIS and in its turn the GIS displays the decisions worked out by the expert system. Some instances of this solution has emerged in the last few years in the form of **intelligent highway car navigation systems.**

3. Fields of Applications

If we try to classify the applications from the point of view of the GIS data model, then we can define two large classes. The first is the class of applications dealing mostly with artificial entities. The second class stores and manipulates data mapping the natural entities and phenomena.

3.1 Applications Dealing with Artificial Entities

Most of the applications belong to this class. As the largest part of it we can hint at *the facility management systems of the different utility companies.* These systems have besides asset recording objectives also goals aiding the solution of management, dispatching, maintenance, emergency reaction and design problems.

For these systems the use of the 3 dimensional variant of the comprehensive object conceptual data model implemented in object oriented database and application software is the natural solution. These systems can make the best of the *prototyping*, an important concept of some object oriented dialects (Bouillé, 1994/a).

However, the importance of the intelligence of these systems should also be underlined. In a water supply system, for instance, the analysis of the pressure conditions provided by the system leads to recommendations about reorganising the systems resources or to detection of a break on the trunk pipe with the possible measures to avoid it. Except of emergency issues, the advices of the system should interact with the human knowledge before taking the final decision. This process can be effectively supported by such visualisation tools as multimedia and virtual reality.

Using the existing network, other spatial objects, then nowledge base, we can design new branches of the network. However, the capabilities of a system with the complex object conceptual data model are limited. We should consider that the design process of an entire water supply system should involve also the modelling of the catchment, that of erosions, the deposit balance in the stream, the propagation of pollution, etc. (Gorokhovich, 1994). For these purposes we should use a GIS with the function field conceptual data model or some kind of its approximation.

As another wide spread example *the cadastral systems* can be mentioned. These systems store and manage two dimensional simple objects the lots (parcels). Although we can meet efforts to complete the cadastre with other more complex objects for example buildings these ideas have not been realised until now. For the existing systems the two dimensional simple object conceptual model implemented by the traditional georelational approach is entirely satisfactory. These systems do not require high intelligence, the standardised graphical and alphanumeric queries can be easily created on the macro language of the system. However, if we think about the future we should keep in mind that all particular system instances have to be considered as elements of the networked spatial infrastructure. In this context we have two choices. By the first one we use for *all* systems dealing with *artificial objects* the 3 dimensional complex object conceptual data model implemented in object oriented way or if selecting the second solution, the cadastral system remains unchanged but a network interface will transform the data into the data model commonly used for artificial objects. By the first solution the third dimension, the height can be left empty for the time the cadastre does not recognize the importance of this measure. In the case of the second approach larger problems can arise in relation of the heights. If the cadastre as an official surveying institution will capture the heights of the lots' corner points, then they can be stored in the 2-D system only as attributes, thus the transformation program of the network interface should be capable to incorporate these values into the geometry of the model. More dangerous but also more probable would be the case when the cadastre could not be involved in the capture of heights. In this situation the heights are collected by different other organisations that can result an inhomogeneous in accuracy and distribution data set.

Several applications are associated with the *administration* of different levels. In this country the *systems of local authorities* are especially in current. These systems have comprehensive nature in sense of data and functionalities. All departments of the city administration can get support from those in the decision making and design. For the solution of different tasks the systems should use the data of other databases of the city, too. In the decision making and design the systems should use different knowledge bases collected for the particular branches. For example designing the traffic lights the system possesses knowledge about the distances between the cars in dependence of the recommended speed, traffic density, weather conditions, etc. and gives solutions for different traffic conditions. In this example the GIS has the duty to provide input distances, numbers of lanes, data of crossings, etc. to the expert system. As another example, we can relate to the process of endorsing building permits. The knowledge base contains the prescriptions of building law. As input data we can consider the design of the building in digital form and the lot and its neighbourhood from the GIS. The expert system queries the GIS about the zoning, parcel area, distances from the neighbouring houses, etc. compares the designed data with the prescriptions and makes the decision. We can bring a lot of other examples relating allocation problems (school districts, shopping centres), public transport scheduling, vehicle rooting, etc. In all these cases the GIS works as an input device providing stored or calculated data, and in many cases the results are reported using the visualisation capabilities of the GIS.

Thus if we want to sketch out a reasonable architecture for the future GIS applied in the communities it should consist of the following parts:

- an object oriented database implementing the complex object type′ conceptual model;
- a truncated asset of functions related first of all to the geocoding, geometric transformations, measures, buffering, SQL queries, visualisation, data conversion;
- an interface to the external (relational) databases;
- an inference machine connected to the GIS data base and GIS core program from one side and to the frame of the knowledge base from the other.

To this class of applications belong a lot of different highway systems. Principally these systems are very similar to the systems of utility companies with differences in the scale (positional accuracy). However, these systems are worth mentioning because of the system concept of development pertaining this field. As we mentioned in the previous section the GIS development has two ways. The first way is the transformation of GIS into an intelligent spatial database with an empty frame of the knowledge base and with interfaces to the general information system of the speciality or institution in question. The intelligent highway car navigation systems concept can be considered as an example of the second way. In these systems very sophisticated measuring and telecommunication equipmens are connected with a digital map, with an intelligent query language and with advanced display methods. Although some elements of the system are standardised and can be used in other applications, the system in its entirety is strongly specialised and cannot be suited for other purposes.

Both ways have benefits and drawbacks. Choosing the first schema of development the software industry gets a very large market. The number of installations is very high, the software can be tested and improved on a very wide basis. The large market involves lower software prices and in consequence a considerable expansion of the space related informatics. As a drawback of the first schema we can mention the lack of possibility for full optimisation in the relation of individual applications. The challenge of the second schema is in the compact optimal design of the particular systems. However, in this case the number of the copies of a particular system is small, the prices are high and therefore the expansion of the space related informatics is slowed down.

3.2 Applications Using Natural Entities and Phenomena

The most frequent instances of this class are the systems used in *environmental monitoring and management.* These systems store data about the vegetation, soil types, streams, underground water, precipitation, air, industrial and residential areas, heights, etc. The amount of the possible data is infinitely large and therefore especially at the beginning of the GIS era these systems have used very coarse data acquisition methods and strong data generalisation. The main objectives of these systems are the recording of the present condition of the environment, the multitemporal analysis that is the detection of changes, the modelling of the consequences of real and simulated events. These systems are very similar to the systems of *natural resource management* used in regional planning and *siting systems* of the landscape architecture.

The main problem in relation of these systems was even in the past the 2 dimensional simple object type conceptual data model. It is very difficult to model and simulate 4 dimensional phenomena using such simplification. The new problems have arisen with the rapid growth of available data, due to the new sampling methods and equipments. Especially the data provided by the high resolution multichannel satellite remote sensing are going to explode the modest frames of the conceptual data model.

For these systems the first step of development will be realised probably by the introduction of a multilevel conceptual and implementation data model (SÁRKÖZY, 1994). In this model the first level object is the pixel or voxel linked to a row of the attribute table. The values in this table are measured ones. In lack of measurements the field is empty. On the second level the particular attribute fields are interpolated using an expert system. On this level we have so many matrices or matrix arrays as many attribute fields in a table row exist. The interaction computations of a high resolution analysis are performed with these matrices. The result is also a matrix or matrix array of the same resolution. Using attribute intervals of the phenomenon in question we can create the third level visualisation data model in the form of a 2 or 3 dimensional simple object. The system stores only the original data and the interpolation procedure should be performed in all cases when new data sets or individual measurements emerge. The idea is raster related because of the type of remotely sensed data. And if we have scattered point data we can fit those in a raster of arbitrary resolution without any difficulties.

The second step of development is related to the interaction computations. A large set of algorithms should be collected. In the selection of the proper algorithm an expert system will aid the user.

The *preliminary planning of linear facilities* (highways, railways, pipelines, power transmission lines, etc.) demands also a special system type in the future. The main part of the system remains the digital elevation model, nevertheless the better representation of the artificial and natural entities (existing lines, buildings, rivers, rocks, swamps, etc.) is also required.

The planning process aims at the finding of approximate placement for the facility the so-called corridor, that satisfies optimality conditions considering different constraints. Because of the insufficiency of data as well the imperfect algorithms the planning process produces different corridor variants. One of those will be selected on the basis of complementary human knowledge involving subjective aspects. After decision the selected variant will be designed in a 3 dimensional CAD system.

By recommending a data model for these systems we should take into consideration the character of algorithms, the types of input and output data. Most of the algorithms work in the grid system (LOMBARD, 1993), most of the input data (DEM, digital orthophotos) are in the raster format, the output data are lines that is vectors. The planning does not require the complex interpretation of the artificial entities. Thus we can combine in these systems the grid related function field approximation type and the simple object type conceptual models. Evidently the implementation has to be performed in a hybrid data model. The system should possess tools for generalisation (grid cell enlargement) and for 3-D visualisation. A large collection of optimisation algorithms is an organic part of the system.

4. Towards the Information Society

The key issue of an information society is the presence of attainable, and reliable data related to all fields of human activity. These data provide foundation to optimise the individual and collective efforts for creating new standards of life. Using the data we can produce information that supports the decision making in different political, social, economical, etc. questions, as well the engineering and the production of goods. The informations or raw data should be available in all geographical places where there is a demand in their utilisation. The implementation of these principles demands the fulfilment of technical conditions in data capture, proper software systems for transforming the data into information, developments in telecommunication networks and organisational arrangements for providing the data and information to the users and to the public.

In the last few months we can realise that these general principles have become near to application in the spatial informatics, too.

4.1 The National Spatial Data Infrastructure

11th April 1994, President CLINTON signed the Executive Order 12906 about the National Spatial Data Infrastructure (CLINTON, 1994). In this document the President orders to cooperate between the different agencies in spatial data capturing and for this sake establish the 'National Geospatial Data Clearinghouse' that means an electronic network of the data producers, managers and users. All spatial data producers on federal and state level should use the clearinghouse and produce spatial data keeping its standards. New data capture can be funded only in the case when the required data are not available in the clearinghouse. The data will be available to the public for a low charge, for the agencies free of charge. It is worth mentioning that 'statistical data may be included in this definition at the discretion of the collecting agency'. By January 2000 the initial implementation of the national digital geospatial data framework should be completed with establishment of the process of ongoing data maintenance.

Realising the project as first step the clearinghouse commission worked out a metadata standard and is going to create a metadatabase. The metadata are data about the spatial data files (co-ordinate system, projection, scale, accuracy, contents, co-ordinates of corner points, date of the survey, etc.). Using the metadata it is easy to find the data file fulfilling particular requirements.

Three main points should be underlined in this initiative. This is the first case that a government has recognized that also the *digital* spatial data compose a part of the system of nation-wide infrastructure and that the state has the duty to create and maintain the data. These data are created on the tax-payers' money and therefore it is obvious that the public should have access to the data practically free of charge. The next point is the standardisation and as its consequence the homogeneity of data. The third point is related to the statistical data. The order makes it possible to associate these data with the spatial ones, but does not prescribe it. An other *one way* link from the geospatial data framework to the census of 2000 is also expressed in the document. However, in my opinion there is missing at least a general hint at the successive accomplishing of two way linkage connecting the geospatial framework with all corresponding alphanumeric databases of the public domain.

In Europe the situation is less favourable. Although the first nation-wide large scale digital geospatial database was created in the UK by the state, this technical achievement, however, could not solve the problem of supplying the GIS with on line homogeneous spatial data. The difficulties are caused by two factors. The first is the lack of a networked clearinghouse, the second is the pricing policy. In the consequence of high prices a lot of

GIS users in the UK do not use the reliable Ordnance Survey data, but the data of doubtful origin or captured by themselves. In many cases such kind of data used in GIS can cause harm rather than benefit.

Some kind of electronic clearinghouse is in creation in Finland (RAINIO,1994). First the Geographic Information Centre of the National Land Survey of Finland has compiled a geographic data directory system that can be accessed via telematic service using a terminal. The directory contains the metadata of the spatial data files. The electronic interchange of files has begun in 1994 using the EDI (Electronic Data Interchange) system. The Finnish approach differs in two main points from the US project: the data are not necessarily free of charge and the data producers have no obligation for considering the EDI standards by data capture, the interchange will be realised using transformation programs on both sides of the transmission line. In the program will be involved data sets of statistical and demographic character.

In other parts of Europe the access to descriptive state databases is rather limited (LIEVESLEY, 1994). There is a hope, however, that the EC will initiate an opener access to these databases.

The MEGRIN project is something similar to the Finnish metadata base but extended over the European Union. This database is related only to the geographic data. The metadata base is in the prototyping stage (SALGÉ, 1994).

4.2 New Methods in Data Acquisition

The acquisition of digital geospatial data has been acknowledged as a very cost and time consuming process. However, two new satellite techniques, the GPS and the high resolution satellite remote sensing, have definitely reduced at least the time required for the data acquisition. It is not difficult to predict that in the near future the proliferation of satellite methods will affect also on the prices of the spatial data capture. But no technical development can change the ratio of the costs of geospatial and alphanumeric data, that is the spatial data will be always more expensive than the other ones.

There are two fields that need special efforts for accelerating the data capture in the near future.

The first is the capture of high resolution centimetre order cadastral data. Until now in this range of accuracy the only suitable method is the field surveying by electronic tacheometry. However, this method is very slow and expensive related to the satellite based or even photogrammetric data acquisition. This statement is especially true for the countries that do not possess yet a contemporary digital cadastre in the urban or covered areas. As a solution we can recommend a two level survey in the stage of its creation and a one level continuous updating process. The first level uses electronic tacheometry surveying the framework of cadastre consisting of large blocks bounded by the main streets, the second level surveys the lots inside the blocks using orthophotos. The continuous updating process uses electronic tacheometry.

More complicated and diverse is the situation in collecting the data for the 3 dimensional modelling. These modelling methods deal with atmospheric, oceanographic and geologic problems. The data collection in these fields gets new tools with different speed. The active and projected remote sensing satellites collect a large amount of data related to such phenomena of the atmosphere as temperature of the clouds, integrated humidity index, wind speed, etc. however, they are not able to measure these phenomena in predefined spots inside the atmosphere, for this purpose the sensors on radiosondes are henceforward in use. Very similar is the situation in oceanic observations. The features on the surface of the oceans and in its close neighbourhood are detected regularly by remote sensing satellites but for measuring inside the water body we have to use traditional gauging methods. For the sake of underground modelling the sampling is performed using the expensive and time-consuming boreholes, thus we cannot expect a rush change in the amount of available data in the near future.

4.3 Trends in Information Technology

The GIS development is closely related to the development of general information systems (IS). In (CALDWELL 1994) we can find interesting figures characterising this process. First of all we can get an answer on the question what is the importance of the GIS in the opinion of the IS community. On a scale graduated from 1 to 39 for the years 1993, 1994 the order of GIS is 25 and 26 in North America, the respective figures in Europe are 28 and 27. Another five mark scale shows the maturity of the technology in the following way: '1=no activity', '2=researching', '3=piloting', '4=implementing', '5=using'. On this scale the GIS is valued 1.95 in North America and 2.02 in Europe. These figures point out the fact that the GIS is not accepted yet by the broader IS community. The situation is caused by different motives. The first is a subjective one. In most of the cases the GIS department is not organically connected with the general information system of the institution. The second motive limiting the role of GIS is the lack of reliable data. As a third factor we should mention the imperfection of the GIS data model. And finally we have to list an other subjective motive: the GIS software use is too difficult.

It is also curious what is the IS community's opinion about the new technologies that have important role by implementation of the new GIS architecture. On the same scales explained in the paragraph above the object orientation has the orders 8, 8 for 1993 and 1994 in North America and 3, 7 in Europe. The marks on the scale of maturity are 2.09 and 2.15, respectively. That means that the object orientation is in late research stage but will have fast development in the near future. The corresponding values for the expert systems are as follows: 15, 22 in North America, 21, 20 in Europe and the marks 2.25 and 2.36, respectively. These figures show that the efforts in development of expert systems especially in North America are slowed down.

5. Conclusions

The space related informatics has enormous tasks in the informational society. These tasks are of different character and therefore they require several approaches in GIS architecture, thus the concept of a general GIS is no more acceptable.

The better modelling of the reality demands more complicated conceptual data model that corresponds the requirements of the particular class of applications. In this context the dimension extension, the comprehensive object type conceptual data model and the function field type conceptual data model have to be used for particular applications.

The new conceptual data models should be implemented using new software technologies. For the systems applying the comprehensive object type conceptual data model the object oriented approach has large advantages.

The future GIS will be an intelligent spatial database with tools for transformations, visualisation and with standardised interfaces to the application programs.

To take its deserved place in the entirety of information systems the GIS can and should grow very rapidly in the next few years. Principally the conditions for this development are given. However, some practical requirements of the growth should be taken into consideration. I will mention only two key issues.

The first is the plenty of reliable, standardised, documented, inexpensive, attainable by network spatial and spatially referenced attributive data. To rich this situation the governments should take immediate and effective measures like the executive order in the USA establishing the national spatial data infrastructure.

The second condition depends on the fitting of the GIS in the general information system. While the GIS is a stand alone mystical department in the institution with strange and baffling function the core staff regards the GIS as a hobby of some eccentric guys rather than an important organic part of the general information system. Such situation does not promote the development of GIS. That is by the construction of new GIS software products the idea of the common information system should be taken into consideration.

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