A DIFFERENT APPROACH TO THE SPATIAL DATA INTEGRATION

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KEY WORDS: GIS, Obstacle Limitation Surface, Visualization, Spatial Data Integration, Analytical and Visual Integration

ABSTRACT:

The rapid changes in map-based technologies caused a complexity in spatial data and increased user demands and expectations from Geographic Information Systems (GIS). Considering this reality, Spatial Data Integration (SDI) needed to be taken into account by National Mapping Agencies and companies for developing strategies to have better data (complete, standard, robust and flexible) for a wide public use of GIS applications. On the other side, visualization became an essential process in data integration facilities as it was used in every stage in GIS, besides providing useful cartographic representing capabilities in 3-D environment. This paper presents an overview of spatial data integration from different aspects and explores the role of visualization in this context. In the content of this paper it is also examined how to use analytical and visual types of derived information in solving spatial problems by presenting an implementation study related to the construction of obstacle free zones for aerodromes. Obstacle Limitation Surfaces (OLS), the topography and man-made objects were used as cartographic input layers in determining dangerous objects for aircraft and final analyses results were presented with 3-D screen displays. Consequently, it was perceived that visualization removed the limitations of GIS and modern cartographic developments provided visual cognition of multi-dimensional spatial problems.

1. INTRODUCTION

Until the last decade, simple data models have been used in different GIS projects to provide specific solutions to meet the user needs in different organizations. The rapidly expanding ranges of spatial data and increasing application needs caused some gaps and problems in the data integration processes about their combined use associated with data handling and application procedures. Information means power for decision-makers, but the question: Is it possible to integrate easily all kind of collected data with other available information? Here arises an important necessity for a strong integration of complex data sets used in wide range of GIS applications.

Basically, a Geographic Information System deals with spatial data varying from different sources. Recent developments in mapping fields have increased the number of potential users of GIS users in many sectors including transportation, forestry, land registration, agriculture, environment and facility planning. All these disciplines are trying to obtain better data for better solutions. The data structure built upon a data model became more complex due to the nature of geographic data, which holds the records of locations, attributes, relationships and time characteristics of the spatial phenomena. The locational definitions are very complex because geographic objects tend to occur in irregular complex patterns such as a sinuous shoreline or a web of transformation routes (Aronoff, 1991). Now there are just as many problems _and possibly more_ on the management side of implementing an information system as there are on the technical side. In order to highlight the importance of data integration, section 2 presents an overview of integration needs and trends; section 3 explores a framework of an integration model.

In the applied GIS projects decision-based or data-based models were used to obtain the rapid answers. These approaches and traditional techniques used in GIS applications may not be adequate for distinct problems. Current geographic analyses require more than giving attributes or location information. Today new techniques _like cartographic communication and visualization_ are used for better understanding of dimensional problems. With addition of 3-D visualization and animations into the general design of cartographic model, several alternative methods and choices have been provided for understanding and solving complex spatial problems with complex data. Visualization may be used in any phase of geographic processes and in representations to display the shape and geometry of the features and to examine the results of geographic analyses. These new trends became a process of spatial data integration as they were used in representation phase. Now digital maps are the interactive interface to the database for cartographers. They are used in the analyses and explorations by predicting the information and in representation of the results. Consequently, it is also possible to support map-makers and decision-makers by visualizing the data characteristics and extracting the secret trends in data with visual outputs or screen displays.

This paper shows visual and analytical integration in an airport application by deriving information about objects and using combination of geometric and attribute data. In the application study data sets from different sources were integrated in Arc/INFO software, which is an ESRI (Environmental System Research Institute Inc.) product. In the application, the Obstacle Limitation Surfaces, which was calculated according to ICAO (International Civil Aviation Organization) criteria, the DTM (Digital Terrain Model) of the area and the classified planimetric data were used as cartographic layers to determine the dangerous objects for aircrafts around aerodromes. Some predictions and geographic analyses were made in 3-D environment to identify the exceeding objects and the results were presented with 3-D screen displays. The implementation showed that visualization sometimes might be a critical and essential process in geographic analyses requiring third dimension of the related objects. The results also showed that the obtained cartographic 3-D displays help users in the validation of mathematical calculations and in the other processes in geographic information systems.

In this paper, it was not aimed to make a comparison between spatial data integration methodologies; but only contented with

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exploring a framework for integration of complex geographic datasets.

2. SDI CONCEPTS AND NEEDS

To understand the requirements of SDI, a firstly description of the basic concepts of spatial phenomena is needed.
The term ***"spatial"*** generally means, having extensions in space or pertaining to space.
Other descriptions are as follows;
Spatial Data: 1) Can be most simply defined as information that describes the distribution of things upon the surface of the earth. In effect any information concerning the location, shape of, and relationships among geographic features (Walker, 1993; De Mers, 1997).
2) Being those that can be individually or collectively referenced to a location (Tomlinson, 1990)
Spatial Feature: A user defined geographic phenomenon that can be modeled or represented using geographic data sets (ESRI, 2002).
Integration: The process of integrating data to obtain and deliver robust and practical solutions.
Geographic Data: Those are fundamentally a form of spatial data (Aronoff, 1991).
For GIS applications the primary requirement is to define an entity by its location in a unique way. But it is not enough to know the location of geographic objects. There are some other important requirements for a geographic entity like;

- attributes,
- relationships with other geographic features,
- time,

An attribute is known as non-spatial information that does not represent location information. The relationships among geographic features may be very numerous and complex. The degree of importance of relationships depends on the application used in GIS, because it is not possible to store all the information about all the relationships. Generally needed relationships are stored and defined in GIS applications. The time component is very important because it directly affects the appropriate usage of data. Knowing the time is very critical in GIS projects because location data attributes often change independent of one another with respect to time. This causes a difficulty in management of spatial data. Therefore, effective spatial data management requires that location data and non-location data be variable independent of one another. Attributes can change character but retain the same spatial location, or vice versa (Dangermond, 1990).
As it is seen, the nature of geographic data is very complex and it is hard to store and handle all the data and relationships in large databases. But for years GIS technology provided the basis for many types of decisions ranging from simple geographic analyses to management of complex spatial problems. The scientists have developed some useful techniques and tools in the computer environment to store, manipulate and analyze geographic data. But integration methodologies have not improved as developments in the data collection and solution of geographic problems. Now it arises as a problem to integrate spatial data sets, which they may be collected:

- in different time periods,
- for different purposes,
- from different sources,
- in different scales,
- in different accuracies,
- in different Datum,
- in different projections,

The articles listed above are giving an idea about SDI processes. A user must have a complete understanding of the content of digital spatial data sets and their qualities in order to make maximum use of its information potential. Scientists and general public want to be able to conflate multiple sets of spatial data i.e. integrate spatial data from different sources (Saalfeld, 1998).
Today spatial data integration using multiple geo-based data has been regarded as one of the primary GIS application issues, because improved geographic data should lead to better conclusions and better decisions. In various GIS applications integrated data provide many advantages to the users and they facilitate interoperability of spatial data, because they include greater positional accuracy and logical consistency and completeness. But each new data set and item can only be utilized only if it can be placed correctly into the context of other available data and information (UCGIS, 1998). Many organizations and data users have developed and promoted standards for spatial data collection and representation. Besides national agencies, Open GIS Consortium and International Organization for Standardization (ISO) are working to develop standards for interoperability. A good summary can be found in GETF (1996) and NAPA (1998).
Increasing environmental consciousness around the world is driving companies and national agencies to consider environment issues in their decisions. Therefore, they are using the international standards to better manage their environmental affairs (UCGIS, 1998).

3. VISUALIZATION AND SDI

If traditional GIS applications are criticized from different aspects, following considerations may be comprehended:

- The level of object data model in GIS projects tends to represent real world with a varying level of completeness. But it is not possible to build a general-purpose data model, which store and handle all the relationships representing different aspects of reality.
- Geographical data are generally incomplete and almost always have some degree of uncertainty (Goodchild, Buttenfield, Wood, 1994).
- Current geographic information systems have been designed for querying and maintaining static database representing static phenomena and give little support to those users who wish to represent dynamic information (Hornsby, Egenhofer, 1997).
- The use of geographic data from different sources, in different scale is totally inappropriate and may cause to significant errors in geographic data processing.
- Current GIS have some limitations in solving dynamic volumetric problems and visualizing characteristics of complex data sets.

However, it was required to obtain the maximum use from available data sets stored in large databases.
In the past ten years, the role of visualization has increased because of the developments in computer _hardware and software_ technology. Improvements in scientific visualization stimulated cartographers and GIS specialists to use its visual capabilities in various stages of GIS applications. Today, visualization provides visual thinking, cognition and interactive communication capabilities in solving spatial problems and gives some easy extraction methods for error detection in spatial data. Although visualization has been the cornerstone of

scientific progress throughout history, the term scientific visualization (ViSC) has recently come to refer to the exploration of data and information in such a way as to gain understanding and insight into these data. Generally this is conducted in powerful three dimensional graphical computer environments (Hearnshaw, Unwin 1994). It is clear that seeing is a good way towards understanding of spatial phenomena.

If made a description: traditionally, the term visualization has been used to describe the process of graphically conveying and presenting end results (Dibiase and others 1992; MacEachren and Kraak 1997).

Recent concern over spatial data integration comprising data quality has increased the interest to the visualization tools to comprehend the reliability of data. The current trends in development of information systems are to move from specific applications to complex environments. This requires integration of large amount of data from different sources and capability of integrated processing. Data integration processes should provide robust and reliable information to serve a wide range of GIS users. Integrating spatial data generally comprises projection, precision, accuracy and scale. Spatial Data Integration demands may be considered in two parts (Kobben, 1999). Visual Integration demands, which comprises the processes of,

- Matching coordinate system and projection
- Compatible scale (re-scaling should be possible only within certain limits)
- Compatible file formats (originally equal or converted)
- Visualization made by especially for the combination

Analytical Integration demands, which comprises,

- Visual integration demands
- Attribute matching (accuracy, classification)

These two steps including some processes are considered in digital cartographic model at different levels.

Visualization is used in every stage of GIS processes, traditionally in the;

- collection of data,
- error detection and quality control,
- checking attribute values,
- geographic analyses,
- representing end results.

and now it must be also used in SDI to have robust, complete, standard, classified and flexible geo-databases. The new trends in modern cartography and visualization provide following advantages:

- strong interaction,
- easy interpretation
- better understanding
- easy communication

But they all need is integrated _re-engineered_ spatial data. Although there is not any standardization in this context, it may be thought that they all fulfill the requirements of new trends in dynamic cartography and GIS.

After the integration of data and establishment of GIS, the degree of accomplishment can be measured by rating the following questions:

- Ability to accept (?%)
- Ability to process (?%)
- Ability to analyse (?%)
- Ability to present (?%)

If the total percent is high, then it means that the amount of reliable information and solutions to be extracted will be high.

Visualization encompasses the display of quantities or qualities of visible or invisible phenomena through the combined use of points, lines, a coordinate system, number, symbols, words, colour and animation (Beard K., William M., 1993).

Generally it can be said that visualization has become one of the most important process in geographic information systems and in data integration procedures for making data comprehensible, accessible and manageable. There is a strong need to integrate all the data before establishing large databases for nations.

4. IMPLEMENTATION: DETERMINATION OF OBSTACLES NEAR AIRPORTS

Problem:

Developments in air transportation are presenting many problems besides its advantages. The most important problem is that the obstacles near airports which may cause accidents. These obstacles may be natural (trees, hills, etc.) or man-made constructions like towers, antenna, power lines and high buildings. There are Obstacle Limitation Surfaces that should be implemented around airports to provide safe zones (obstacle free zone) for aircrafts to fly safely near airports. These surfaces are:

- approach surface
- transitional surface
- conical surface
- inner horizontal surface
- outer horizontal surface

which having slopes and distances from runway accent. International Civil Aviation Organization - ICAO, has described the criteria and parameters of these surfaces to be implemented for all airports. These criteria may change from one another with respect to their characteristics. Detailed information about the surfaces and parameters can be found in Annex-14 of International Standards and Recommended Practises (ICAO, 1999). The problem is to determine automatically the obstacles (natural or man-made), which exceed the limitation surfaces and become dangerous for aircrafts. With the implementation study a user interface was presented to find and query all features, which are dangerous. Visual displays, which can be prepared interactively, provided better understanding of volumetric spatial problems relevant to OLS and other features with their attributes.

Solution and Results:

This part presents a quick review of data, calculations and processes used in GIS application and concentrates the visual results with highlighting the importance of 3-D cartographic analyses in understanding and solving dimensional problems.

The information about data sources used in the implementation and their structures are as follows:

- ICAO Criteria for OLS,
  ASCII file, used in the calculation of OLS like DTM,
- 1:25 000 scale digital contours of the area, in DGN format,
- Vegetation
  Digitized from existing maps in 1:25 000 scale
  Attributes were collected by surveys
- Buildings and other planimetric features, digitized from 1:1000 and 1:5000 and 1:25 000 scale maps
  Height attributes are taken from municipality
- Geological Data, digitized from 1:25 000 scale maps, attributes are obtained by geological surveys

- Hydrological data, digitized from 1:25 000 scale maps

All the digital data transformed to Universal Transvers Mercator projection system in European Datum-1950 and format conversions were made in order to use them in Arc/INFO software. The height values of Obstacle Limitation Surfaces were calculated with Fortran program and the output ASCII file was processed again in Arc/INFO software in order to obtain it in GRID format. Figure.1 presents a visual display of calculated OLSs.

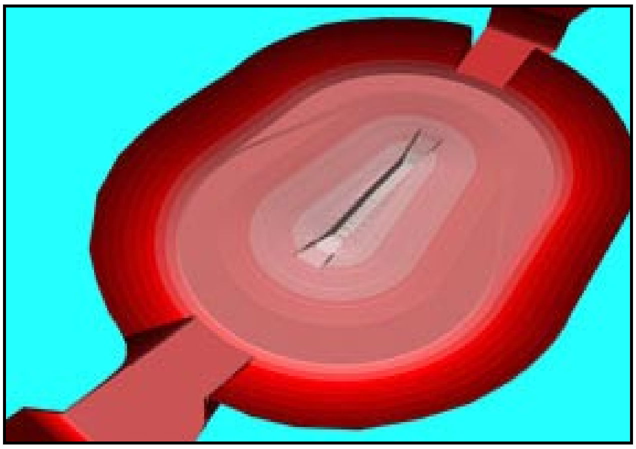

Figure 1: Obstacle Limitation Surfaces

The DTM of the area was obtained in TIN (Triangulated Irregular Network) module of Arc/INFO from contour information that is available. These two layers were processed cell by cell in GRID module to calculate the exceeding areas of the terrain. These areas can be calculated with the equation (Ulubay, 1999):

$$\text{Dangerous Area}^{\text{Matrix}} = \text{DTM}^{\text{Matrix}} - \text{OLS}^{\text{Matrix}} \quad (1)$$

The positive values obtained by above equation constitute dangerous area for aircrafts. The combined display of these two layers was given in Figure.2. In this figure it is obviously seen the dangerous parts of the terrain that form an obstacle for airplanes.

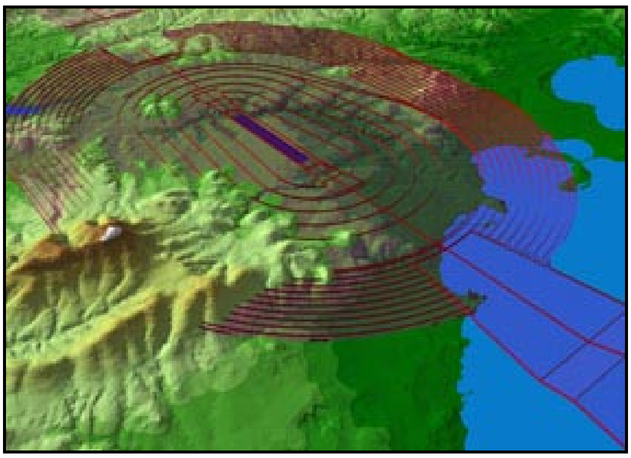

Figure 2: Combined view of OLS and DTM

The geological structure of the area shown in Figure.3 and buildings animated with height attributes shown in Figure.4 are other perspective displays, which provide a general view of the area. Figure.3 also shows that under ground can also be visualized with attributes that are very important for excavation of dangerous hilly areas.
In the final analyses, the spatial relations between buildings, OLSs and terrain in 3rd dimension was examined by visualizing the characteristics of the situation. Any perspective or zoomed views from any direction can also be obtained for specific investigations. Figure.5 and Figure.6 show generally the buildings and natural objects, which form obstacles for aircrafts.

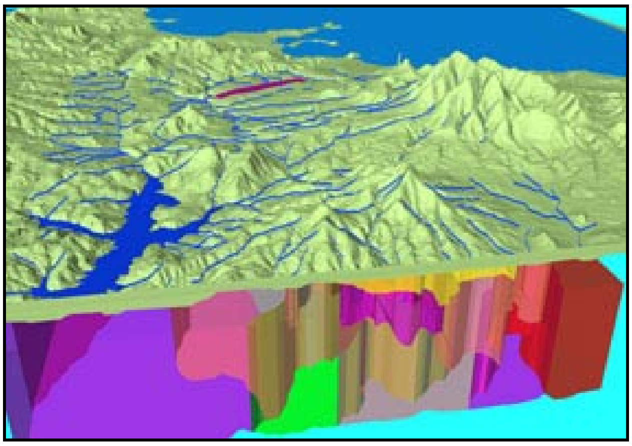

Figure 3: Geological structure

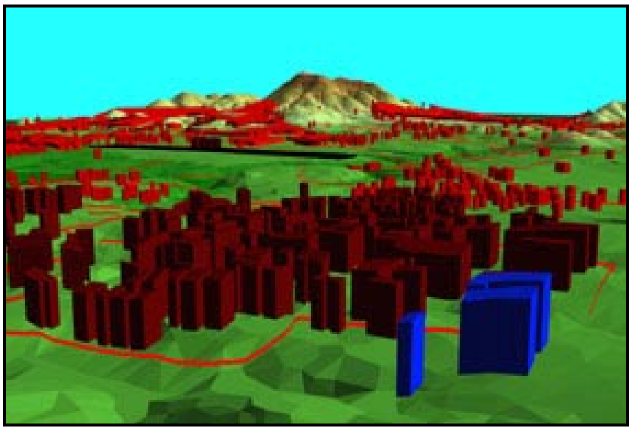

Figure 4: Buildings near airport

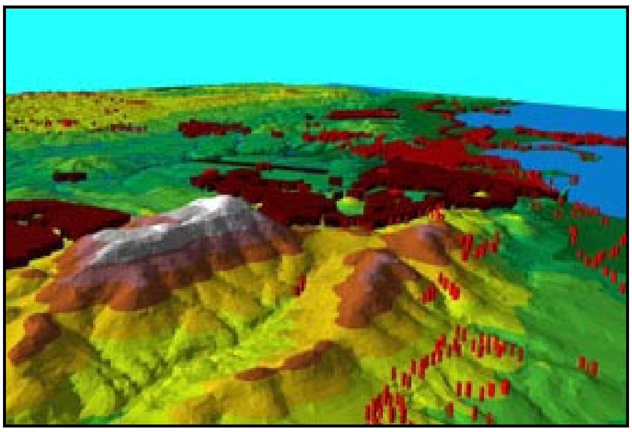

Figure 5: Perspective view of airport and buildings

A detailed cartographic analysis in 3rd dimension can be seen in Figure.7, which explains shielding method for new buildings to be constructed for determination of if they exceed OLSs or not. Different applications are used for shielding methods in different countries.

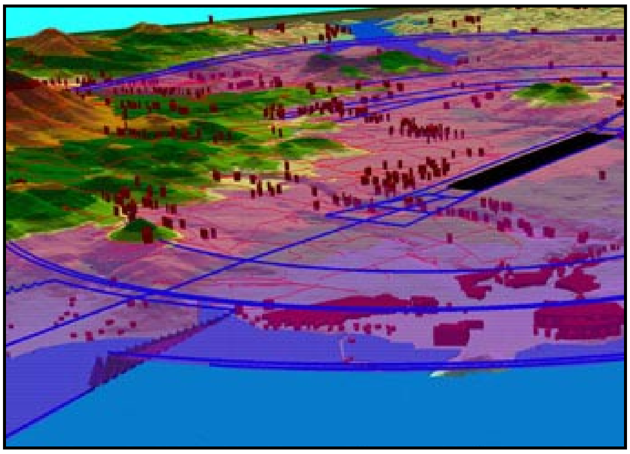

Figure 6: General view of dangerous areas

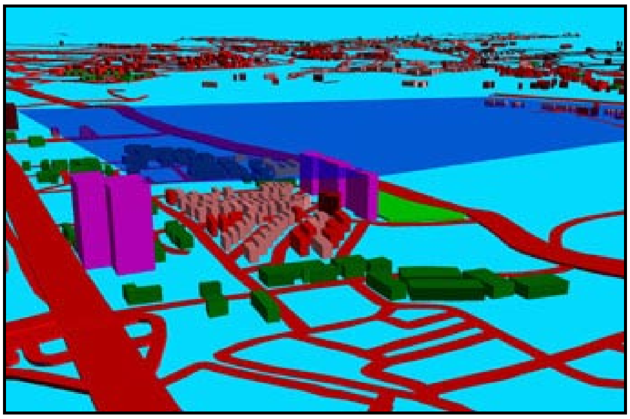

Figure 7: General view of dangerous areas

5. RESULTS AND CONCLUSION

This paper examined; spatial data integration with a focus on visualization and outlined that it is needed in every step of a GIS application and in solving dynamic spatial problems in 3-D environment. Investigations showed that spatial data integration and visualization are very essential to be able having rapid solutions and better understanding of complex dynamic problems. It was explored that completeness, robustness, versatility, efficiency and ease of generation in geographic data sets can be obtained by spatial data integration procedures. On the other hand visualization tools provide abilities to make interactive analyses, real-time modelling, future analyses and dynamic representations with these data in GIS applications.
The implementation study showed that integrated spatial data, from different sources and visual types of derived information, could be combined in solving 3-D problems with visualization tools. The results also showed that carefully constructed views and 3-D cartographic displays help users in showing data quality and analyses and they also may be used to validate mathematical analyses.
It was perceived that visualization removed the limitations of Geographic Information Systems and modern cartographic trends; visual thinking and interactive map communication provide visual cognition of complex dimensional problems.
Finally, can be said that future success of Geographic Information Systems depends on the progress in visualization and developments in data integration methodologies in order to establish global database for wide and easy public use.

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