THE FUTURE OF MULTIMEDIA VISUALIZATION

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Abstract

Geospatial data is changing in nature and form. Computer-based multimedia visualization tools (multimedia maps) are replacing paper maps and their equivalent computer-based maps. Data sources such as video, audio, panoramic views, virtual reality, laser scanning data, spectral data, and temporal data are combined with static vector data and static digital images to generate new multimedia representations.

Multimedia visualization tools are becoming a reality in our daily life. One of the first practical implementations is the one by Goggle Inc., as the backbone of Google Maps. This free web mapping service integrates satellite images of the Earth with or without landmark names, line map features, terrain, street view images, current live traffic, or traffic at a given time (based on past conditions) among other things.

The Google Maps system is an excellent multimedia prototype. But, several major issues have not been addressed on the development of multimedia visualization tools such as: a theoretical framework, how to get precise measurement from these diverse data sources and how to make “smart” images that are able to provide explicit information in a cost-efficient and timely manner.

The issue of a theoretical framework is critical. We are developing new visualization tools but geospatial data models and theories remain unchanged. Current geospatial data models and theories limit the representation of our perception of reality to two models: the exact object model and the continuous field model, which in turn limits our analysis capabilities. We need either to integrate, extend, or change these models to deal with the different data sources in an integrated fashion.

Precise measurement from new multimedia visualization tools requires a precise knowledge of scale and quality of the information. This requires defining a consistent metric. Images of the Earth should be displayed at any ratio (or scale) but, the displays always need to be complemented by the scale and quality of the information in a similar or in a more complete way than in conventional maps. The scale information should be related to the current representation and the quality information should include warnings for those cases where the geographic data is displayed at scales beyond what is appropriate.

The issues of three-dimensional representations of the terrain and the objects on it in a computer environment have to be addressed. Conventional contour lines used in maps or even digital elevation models do not offer a good visualization solution in multimedia. Then, new types of relief representation need to be developed.

Another major limitation of current maps is the fact that they display the environment at a particular moment in time. This is a major limitation because of the Earth’s dynamic nature

and phenomena related to it. A large number of problems we deal with are dynamic in nature. Generally, GIS analysis can be applied to many of them, but their visualization is limited to a particular moment in time. New visualization tools must be able to display dynamic changes on a background of static objects.

This paper starts addressing the theoretical aspect of a multimedia visualization. Specifically, the issue of the Main Steps from Perception of Reality to GIS is by introducing a new model which incorporates all types of data sources. Also, a consistent framework to express different types of data sources is introduced. This framework uses a multi-parameter approach. Finally, the future of multimedia visualization and its research will be discussed.

Introduction

Geospatial data is changing in nature and form. New sensors and more powerful computers are two of the major reasons for that change. Today space based sensors in combination with air and ground based sensors provide a continuous flow of data. The geospatial information community has recognized that automatic extraction of geospatial information from a single sensor is an ill-posed problem. Automation will only be possible if several different types of sensors are combined to collect data and process it simultaneously. This is the current trend. Multi-sensor collection systems will become the standard.

Data sources such as video, audio, panoramic views, virtual reality, laser scanning data, spectral data, and temporal data are combined with static vector data and static digital images to generate the new geospatial data. Analysis and interpretation of geospatial data is also changing. Results need to be generated in a shorter amount of time and generally from diverse data sources including non-geospatial data sources, such as textual and tabular information from emails, colloquial reports, newspapers, and web sites.

Visualization of all this data is evolving but there is not a “universal” approach to replace conventional maps. There are many possible alternatives to visualize geospatial data. Some of these alternatives are: Holography (analog or digital), Virtual Reality, Anaglyph, Computer Animation, Polarization Technology and Multimedia. In general, all these alternatives make use of computer technology.

Of all these visualization alternatives, Multimedia visualization is becoming a reality in our daily life. One of the first practical implementations is the one by Goggle Inc., as the backbone of Google Maps. This free web mapping service integrates satellite images of the Earth (currently GeoEye-1 satellite images, 42 cm resolution degraded to 50 cm). These images are collected by GeoEye Inc. (former Space Imaging Inc.), the company that launched IKONOS in the late (1990’s). These images are shown with or without landmark names, line map features (mainly transportation and hydrographic features with their names), terrain (contour lines and hill shading overlaid on the line map), street view images, current live traffic, or traffic at a given time (based on past conditions) among other things.

The Google Maps system is an excellent multimedia prototype. But, in order to have a system from which distances, elevations, and directions can be extracted in a reliable and accurate fashion several major issues have to be addressed in the development of multimedia visualization tools. Examples of these issues are: a theoretical framework, definition of a metric, integration of different data formats into a more efficient one, and the issue of time. This paper will discuss some of these issues in detail.

The Theoretical Basis of a Multi-Media Visualization System

"A picture is worth a thousand words" is an old saying reflecting the importance of visual images to capture and display information. Our environment is very complex and difficult to understand, specially the interaction of the many forces (humans and nature) acting upon it. Visualization is the best way to display, understand and analyze our environment and the forces acting upon it and to show the results of the study and analysis of the environment and their forces.

Conventional maps have been around for thousands of years. As indicated by Hall (1992) "the great virtue of a map is its ability to tell a complex story in a single visual swallow." Robison et al. (1995) indicate, "one of the older authentic maps to survive is a clay tablet nearly 5000 years old showing mountains, water bodies, and other geographic features of Mesopotamia." But, even thought maps have been made and used in every country for a very long time, there is not a well defined theoretical framework for their production, understanding and interpretation. The introduction of computers in mapping resulted only in the replication of manual methods, and as a result, no automated map production exists.

From the view point of new terrain visualization techniques, the issue of a theoretical framework is critical if a high degree of automation is our goal. If we consider the incredible amount of geospatial data collected daily and its limited use, it is evident that highly automated methods of geospatial data visualization and analysis are needed. We have been developing new visualization tools for the last twenty years but geospatial data models and theories remain unchanged. Current geospatial data models and theories limit the representation of our perception of reality to two models: the exact object model and the continuous field model, which in turn limits our analysis capabilities. The exact object model has been represented using the graphic model of vector structures. The continuous field model has been represented using the graphic model of raster structures. Therefore, the only two data types with known theoretical models are static vector and static raster data (Burrough, 1996) as shown in Figure 1.

In the Conceptual Model of the Word in Figure 1 there are three types of world entities: (1) fully defined and definable entities (for example, a house), (2) smoothly varying surfaces (for example, the surface of the Earth as defined by a digital elevation model), and (3) incompletely defined and/or undefined objects (for example, the fuzzy edge of a road). However, there are only two representations: vector (for fully defined objects), where edges and corners are crisp and well defined, and raster (for smooth field variations), where continuous fields can be represented. If the world entity belongs to neither, then there are only two choices of action. These choices are: 1) approximate the world entity to one or the other of these two sets, as shown in Figure 1; or, 2) not represent the world entity.

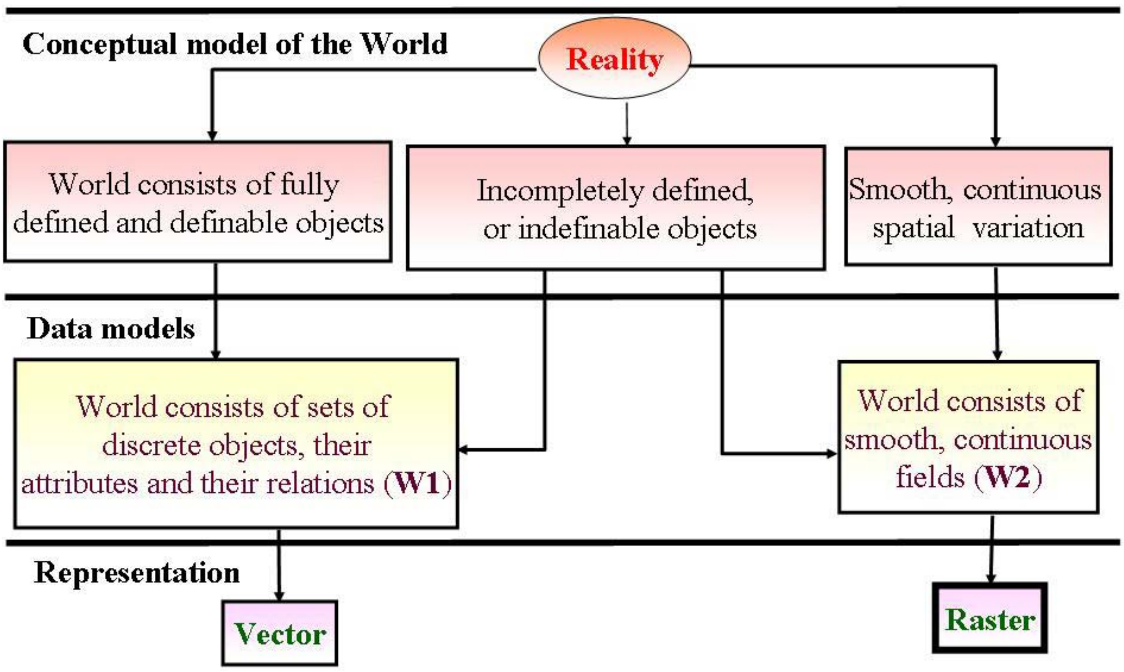

Figure 1. Main Steps from Perception of Reality to GIS (adapted from Burrough, 1996).

Main Steps from Perception of Reality to GIS - Extended Model

In this new era of data acquisition and visualization, the shortcomings of the existing geospatial models and theories become more prominent. For example, if we compare the amount of geospatial data directly collected in the Exact Object Model, which is represented by vector structures, against the amount of data directly collected in the Continuous Field Model, which is represented by raster structures, we will find that more data is collected in the Continuous Field Model. High-resolution commercial and military satellites collect terabytes of data in the raster domain in a year. Each raster image covers an area on the Earth. On the other hand, the amount of vector data collected in a year is much less. Each vector describes only a specific object in a given area.

Raster images constitute the bulk of geospatial data collected. Direct use of raster image information with minimum human interaction is limited. The reason is quite simple: the amount of explicit information in raster images is very limited. Explicit information is the kind of information that can be expressed without vagueness, implication, or ambiguity, leaving no question about meaning or intent. The only pieces of explicit information contained in raster images are the location of each pixel in a two-dimensional array and the value associated with each pixel. The type of data mostly contained in raster images is tacit information. Tacit information is the type of information that is difficult to express, it is often personal or context specific, hard to communicate, and even harder to represent in a formal way. Since computer programs can only recognize explicit information and raster data mainly carries tacit information computers can not be used to process raster images without human help.

In most cases, we need to transform raster into vector data to extract information and acquire knowledge using computers. Conversion of raster into vector data is costly and time consuming and requires human intervention. Also, existing geospatial models present additional problems when we try to use new kinds of geospatial data: text, text charts, video, voice communications, panoramic views, laser scanning, hyper-spectral data and other outside sources. These new kinds of data cannot be fitted into existing models, their representations, or current visualization tools.

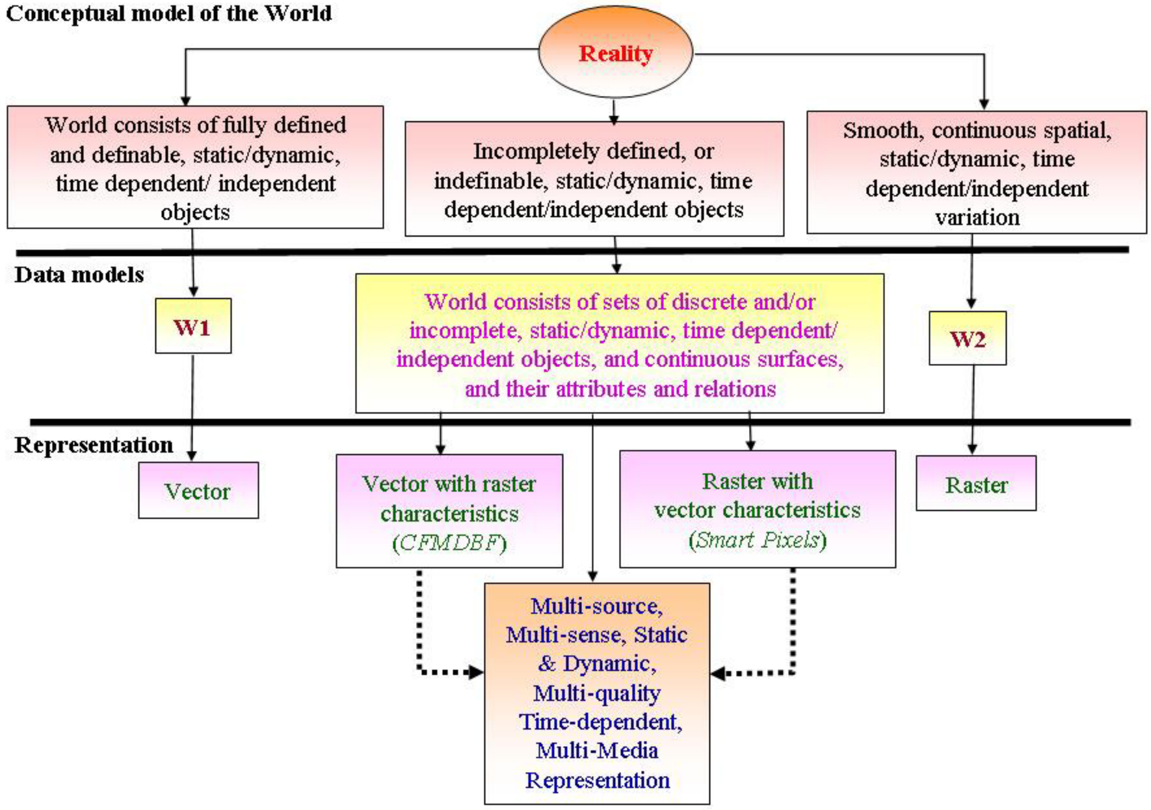

Figure 2. Main Steps from Perception of Reality to GIS - Extended Model

We need to integrate, extend, or change Burrough's model to deal with the different data sources in an integrated fashion. We are working on an expanded model that better portrays how the environment is perceived (Ramirez, 1999, 2001, 2005). This model is shown in Figure 2 (W1 and W2 were defined in Figure 1). In this model a new type of objects no defined in Burrough's is defined (incompletely defined or indefinable). This dynamic model assumes that representational models are not limited to raster and vector but are part of a continuum which extremes are raster and vector representations and incorporates other types of data such as audio and special effects (blinking lights, sirens, direction arrows, etc.). Between these extremes there are an infinite number of sets with different degrees of raster and vector characteristics and possibly other type of data. Out of these sets, we have focused our attention in two implementations: a vector-based model with some raster characteristics, the Center for Mapping Data Base Form (CFMDBF), and a raster format with some vector characteristics, the Smart Pixel format. A third and more important set in study is the Multi-source format. This is the one corresponding to multimedia visualization, and it could have 100% of vector characteristics, 100% of raster characteristics and incorporates audio, special effects, other data types and time variations.

Figure 3 shows a concept of such a system (Ramirez, 2005). In this particular case horizontal, vertical and 360^{o} raster data are integrated with horizontal and vertical vector data, hyper spectral and laser scanner data, digital video and audio. This includes geometric description of features and terrain with graphic and non-graphic attributes, quality of information, time variations and special effects. Multimedia visualization is shown in a set of windows. In this particular case, horizontal vector data is shown in a window, vertical raster data in another, 360° raster data in other, and contour lines in another window. There is a 5th window dedicated to virtual reality display.

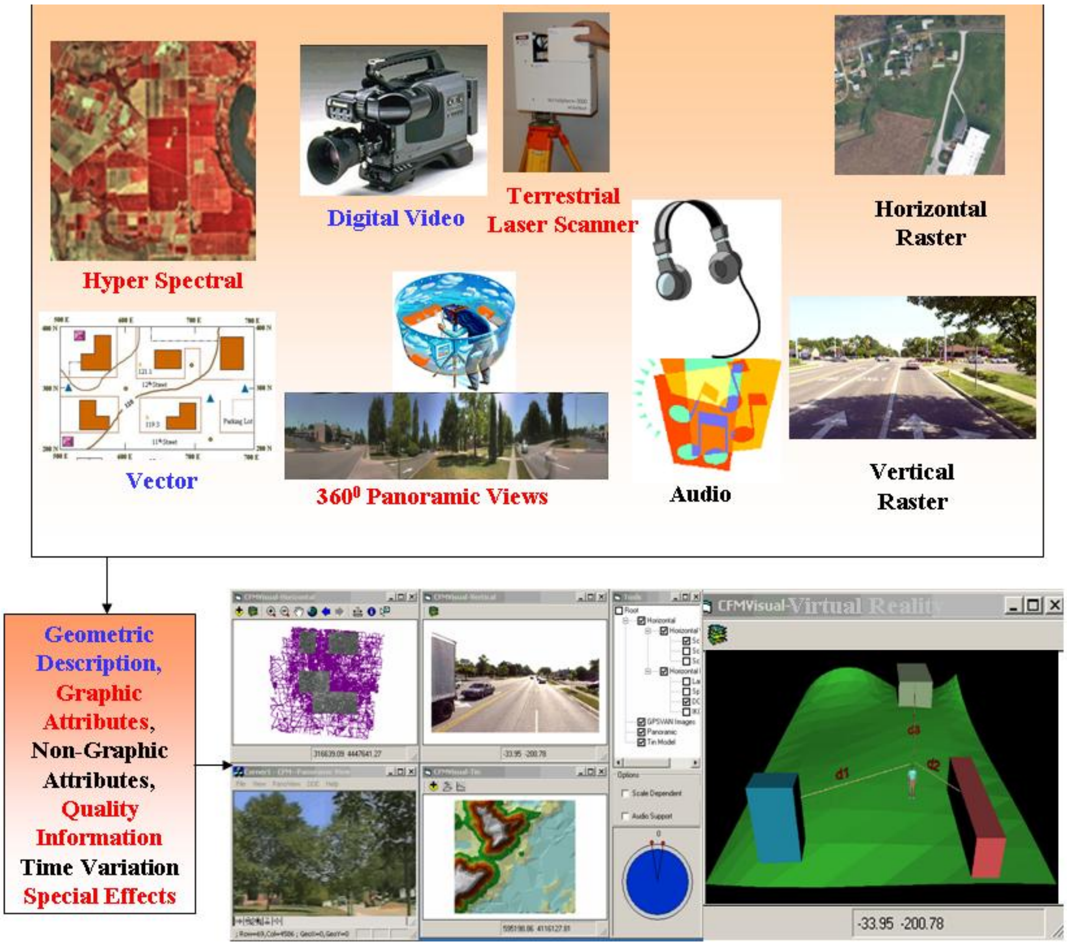

Figure 3. A Multimedia Visualization Concept

A Multi-Parameter Approach to For Multimedia Information Visualization

We are developing a theoretical framework for multimedia information visualization and analysis for computer-based data sources using a multi-parameter approach.

In this theory we assume that all data sources are in digital form and stored in computer devices. We also assume that each data source is stored in one or several computer files. Our basic unit in the theoretical framework will be a generic computer file (a block of arbitrary information). Our theoretical framework will be based on a multi-parameter model.

We propose a six-parameter model. The six parameters are: *information, location, priority, purpose, quality, and time*. We believe that any type of data source used by the personnel in Air Operations Centers can be classified under these six parameters and, therefore, provide the common framework for multi-media visualization and analysis. These six parameters are briefly described below.

Information is "the communication or reception of knowledge or intelligence" (Merriam-Webster dictionary, http://www.m-w.com/dictionary/). In this research we will limit our study to explicit information. Explicit information is the type of information that can be expressed easily in words, in declarative statements, and can be understood and manipulated by computer programs. Tacit information is not considered.

In our research, *information* refers to the amount of explicit details in the data source. In the world of cartography the concept of explicit *information* is partially expressed by map scale and in the world of imagery by pixel size. For example, a map at a large scale, such as 1:500, will show a greater amount of information than a map of the same area at a smaller scale, such as 1:24,000. An image of 0.10 m pixel size will show more information than an image of the same area with a pixel size of 30 m.

Information goes beyond graphic presentation. For example, sound or text data may have different degrees of information. The following examples show this: *(1) The Kennedy brothers, John, Robert, and Edward, were members of the United States Senate; (2) The Kennedy brothers were members of the Senate; (3) The Kennedy's were members of the Senate*. Example 1 has greater information than Example 2, and Example 2 has greater information than Example 3.

Location is defined in the Merriam-Webster dictionary (http://www.m-w.com/dictionary/) as "a particular place in physical space." In this paper location indicates the relationship of a dataset to a particular place on the Earth's surface. Geospatial coordinates express this relationship. *Location* is a fundamental component of datasets used for analysis and presentation. However, there are a large number of datasets that are not geospatially referenced or cannot be geospatially referenced. How these types of datasets are handled in an integrated fashion is an important issue to consider

Priority is defined in the Merriam-Webster dictionary (http://www.m-w.com/dictionary/) as "superiority in rank, position, or privilege." In dealing with information is very common to have information that is superior in rank than other information sources for a given application. Also, there are tasks that need to be completed earlier than others.

Purpose is defined as: "something set up as an object or end to be attained" (Merriam-Webster dictionary, http://www.m-w.com/dictionary/). In the context of our research, *purpose* means the intended use for which the data was collected. A data source created to show and count buildings, for example, may be different from a data source created to show a transportation network. The transportation network may show buildings, but because of its purpose it may not show all of the existing buildings or show them in great detail. In some circumstances, the transportation network may be the only dataset available and, therefore, it may have to be used to count buildings for example. We believe that purpose is a fundamental parameter in dealing with multi-source information.

Quality of information is the 5th parameter of our theoretical framework. *Quality* is defined as the degree of excellence (Merriam-Webster dictionary, http://www.m-w.com/dictionary/). Harris discussing "information is power" indicated that "the truth is that only some information is power: reliable information (http://www.sccu.edu/faculty/R_Harris/evalu8it.htm)." How to decide if a data source is reliable or how reliable a data source is, are major issues for which there is not a clear answer. A major problem with the quality parameter is the fact that even for geospatial data the understanding of quality is limited.

The issue of quality in geospatial data is complex. The International Cartographic Association Commission in Spatial Data Quality (1995) recognizes three parts to the specification and use of spatial data quality information: (1) defining the elements of spatial data quality; (2) deriving an easily understood index of spatial quality, composed of a series of metrics that measure the elements of spatial data quality; and, (3) presenting or rendering the known quality in a visually form. Efforts over the past 25 years have resulted in the definition of the following elements of spatial data quality: lineage, positional accuracy, attribute accuracy, completeness, logical consistency, semantic accuracy, and temporal information. During the same time period, the second part of spatial data quality information has experienced little progress from the metrics development viewpoint for the different elements of spatial data quality. Ramirez and Ali (2005) developed part of a metric for spatial data quality.

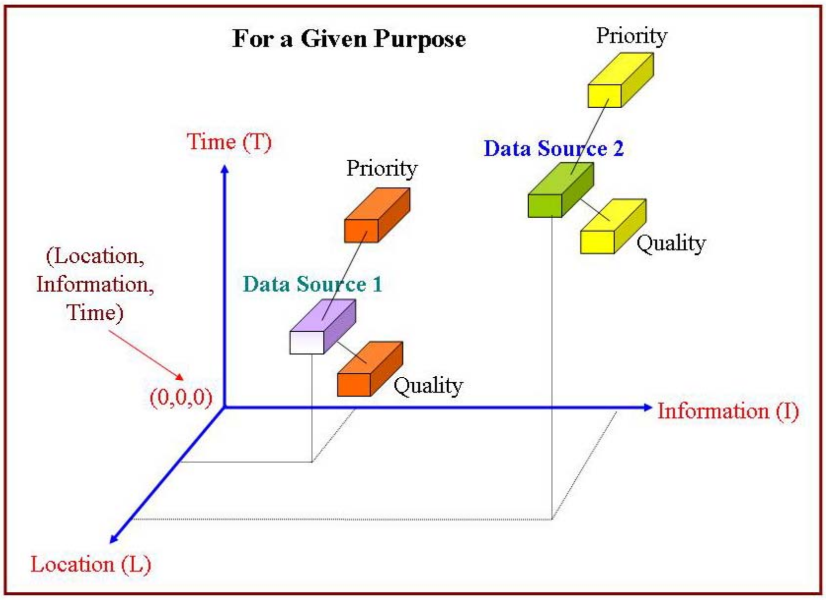

Figure 4. Representation of the Six Parameters

Time in this context is related to the chronological age of the data sources. Defining the chronological age of a data source is by itself a complicated issue. From the mapping viewpoint, there are at least three different dates or times to be considered to determine the age of a data source. The first of these times is the date of data acquisition, for example, the date of aerial photo acquisition. The second time is the date of data compiling (for example, the extraction of information from the aerial photos and the transformation of this information into a vector data set). The third time is the date of publication, which is typically later. Similar situations can be found with other data sources.

We believe that for a given *purpose*, it is possible to represent the parameters of *location*, *information*, and *time* with a three-dimensional coordinate system, where each file represented has *priority* and *quality* information attached (see Figure 4).

The Next Steps: Developing Appropriate Scales and Theory Integration

We need to study the development of appropriate scales for each parameter. These scales will allow the comparison of data sources from different sources. The easiest way to visualize the issue of scale is to consider that each parameter can be represented by an axis. The intersection of the axes defines the zero position. From the zero position when moving to the right or to the top, the values on the axes will increase. Larger values indicate better data in agreement with the parameter in consideration. For example, from the viewpoint of location, data with better ground resolution will have a larger value in the location axis than data with a poor ground resolution. Data a few hours old will have a larger value in the time axis than a year old data.

Once the scales are developed, we will start integrating the pieces of our theoretical framework. Special emphasis will be placed on the interaction of the time parameter with the other parameters. We will also study the issues of multi-scale representations, continuous representation over time, and intermittent events. For a given purpose, multi-scale representation can be studied using the information axis alone; using the information and time axes; or using the information, time, and location axes. Intermittent events can be random or systematic. The aftershocks following the main shock of an earthquake is an example of random intermittent events. The blinking light at the top of high towers is an example of systematic intermittent events. The results of these studies will be incorporated as part of the unified theoretical framework.

Quality needs to be considered for each representation as an additional issue. In a similar manner continuous representation over time can be studied along the time axis alone, the time and information axes, or along the time, information, and location axes. The issue of quality needs to be researched in greater detail because there is no a clear understanding of how the quality of a continuous representation is affected through time.

Three dimensional representations need to be researched. It is evident that conventional contour lines are very limited in a three-dimensional environment. Digital elevation models need to be investigated to see if they can be improved to provide a realistic representation of the terrain. Surface representations could be a possibility, but at this point we have a long way to go before a solution to the problem of three-dimensional representation is found.

The Future of Multimedia Visualization

Multimedia visualization is becoming a reality in Cartography and GIS as an alternative to conventional maps. Multimedia visualization can accommodate data generated today by different types of data acquisition sensors. But, we need to avoid the errors made in the development of conventional maps. Conventional maps were developed without a strong theoretical background which resulted on the impossibility of developing highly or fully automated production methods.

We feel that highly or fully automate solutions for generation of new visualization images of the Earth’s surface and its objects are a must in order to be able to satisfy the increasing needs of civilian and military users and to take advantage of greater data collection capability. Automated solutions will allow us to monitor changes on the Earth’s surface caused by nature or men in a faster manner and to respond efficiently to emergencies. Automated solutions require a good theoretical background. The development of this theoretical base is a very challenging problem. This paper presents some of the theoretical aspects of multimedia visualization. This is just the beginning. We have listed some other topics that need to be researched. That is not an all inclusive list. We feel there is much additional work to be done.

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