ADVANCES IN MULTIMEDIA MAPPING

J. Raul Ramirez, PhD
The Ohio State University Center for Mapping, Columbus, Ohio, USA

ABSTRACT

The growing number of multimedia geospatial data sources is changing the mapping and geographic information systems (GIS) fields. Conventional vector data sources, space and/or airborne images of the surface of the Earth, aerial and terrestrial laser data and models, $360^\circ$ panoramic views, and mobile mapping images are examples of the diverse nature of multimedia data sources.

Multimedia maps are a combination of integrated vector and raster data sources and technologies, such as digital drafting, panoramic views, audio, virtual reality, and laser models, which display an area of the surface of the Earth from different perspectives.

This paper describes the current status of the multimedia mapping system in development at The Ohio State University Center for Mapping. The theoretical concepts behind the system are described as well as the components of the system and the experiences gained in the development of the prototype are discussed.

INTRODUCTION

Geospatial data are presented graphically to different audiences, each possessing different backgrounds and in many cases different access privilege. Therefore, presenting the same basic geospatial information at different levels of detail and sophistication in a smooth, integrated and automatic way is a highly desirable capability of modern visualization systems.

Also, different data sources of different degrees of credibility are used for these representations. How to handle, visually integrate or separate data sources having different degrees of credibility, and then conveying the proper level of credibility of each data source to the observer is another highly desirable capability of modern visualization systems.

The development of a modern geospatial visualization system requires studying two basic issues (Ramirez, 1999): (1) what needs to be shown in a multimedia map? and (2) how do things need to be shown? To answer the first question we need to consider what current maps show and what else should multi-media maps display based on the datasets collected today. The second question would be answered based on what current maps show and what we like and need to view today using geospatial visualization tools.

A list of what needs to be shown might look like this:

1. The surface being represented,
2. A finite number of objects on that surface (depending on the application),
3. Interrelations between the objects and the surface,
4. Interrelations among the objects,
5. “Exaggerated” objects,
6. “Augmented” objects and their relation to actual objects and the surface represented,
7. “Modified” objects,
8. Derived phenomena,
9. Any combination of the above, and
10. Quality information about the previous items.

A fundamental part of any geospatial-based representation is the surface of the object represented. In the case of the Earth, current maps implicitly represent the surface of the Earth by using contours as a planar approximation. With computer graphics, a set of grids or triangles is used for explicit representation of this surface. Grids or triangles are planar approximations of the surface of the Earth. If their size is small, the overall representation may be adequate. But, there are some problems with these representations. For example, they are locally uncorrelated; in general, two-dimensional; and coarse if you get closer to the surface. Fine details, such as small breaks, may be lost; imprecise (fuzzy) representations are not possible; and precise computations are difficult.
Ideally, we would like to have a three-dimensional representation of the surface of the object represented that overcomes all the problems mentioned above.

Depending on the application in consideration, current maps display a finite number of objects on the surface. Those objects are represented by their outline (iconic representation) or by symbolic or indexical representations. Most of these objects have volume, some are static, and some are dynamic. But, none of these characteristics are portrayed in current maps. Generally, we may be interested in selected objects on, over, or below the surface. Therefore, we would like to have multidimensional (considering time as a dimension) representations of these objects.

Interrelations among the objects and the surface are a fundamental component of the representation of geographic data. Current maps show the positional relationship of any object represented with respect to the surface in consideration. In some cases, and depending on how the object is represented, the map may also show size, area, and orientation relationships (for example, iconic representation of area features). New visualization tools must be able to display all objects (on, above, below the surface) in their true relationship with respect to the surface, under user-control.

Users of geographic data are, many times, extremely interested in the interrelations among the objects on the ground, above the ground, and below it. Current maps present the relationships among selected objects on the ground. For some of them it is possible to compare their size and location. Again, this depends on the nature (point, line, and area) and type of representation (iconic, symbolic, and indexical) used by the mapmaker. In the new visualization tools we would like to extend these representations to all kinds of map objects and to incorporate additional capabilities, such as comparing objects on, above, and below the ground surface, static and dynamic objects, relative movement, volumes, and direction.

Current hardcopy and even digital maps show all the objects of a particular area at a “constant” scale. Sometimes, as part of a particular application, we are interested in focusing the user’s attention on a particular object or objects represented on the map. A typical example is when we want to calculate how far two objects are from each other. “Exaggerated” objects to be displayed using the new visualization tools are those that differ from surrounding map objects by their size (as related to a given scale) and/or visual attributes, or by any other means of making them different from the other objects in order to attract the attention of the map reader.

One of the most important applications of computers and computer graphics is the capability to present and analyze “what-if” situations. Computer simulation is a well-established part of computer sciences. It includes several profound concepts, such as artificial intelligence, the simulation of human intelligence processes by computer systems, to very practical concepts, such as traffic flow in a city. Current maps are static structures representing an area of interest for a moment of time and, therefore, hardcopy or digital maps are not designed for simulations. We would like to have “augmented” objects as part of the new visualization tools. “Augmented” objects are virtual (non-existing) objects (including text and audio) merged with real ground objects in a map. The actual map representation would be automatically modified to reflect what would happen if such objects exist. These objects would be removed and placed on the graphic representation under user control. Augmented objects will carry additional information, such as anecdotal information and description of inside spaces.

“Modified” objects are a special case of “augmented” objects. They are a combination of objects represented in the map and virtual objects. The combination can be additive or subtractive. Therefore, the resulting object may be equal to the original ground object augmented by some virtual component, or may be equal only to part of the original object. The actual graphic representation would be automatically modified to reflect what would happen if such objects exist. These objects would be placed and removed on the graphic representation under user control.

Thematic maps show derived phenomena of all kinds. We expect the new visualization tools to continue doing so, but to extend this capability to incorporate the additional characteristics described in the previous paragraphs.

A very important condition for the new visualization tools is adaptability. We expect these tools to be able to display the ground and its objects in different fashions, under user-control. This includes from the schematic representation to the realistic representation. Therefore, these visualization tools must be able to display parts of the area of interest or the whole area, using any combination of the characteristics described above.

Multi-sources of geographic data are more and more common today. Some of these sources contain high-quality geographic data and sometimes other sources contain low-quality data and even contradictory data. Graphic and/or numeric quality indexes are very important to convey the appropriate degree of confidence to a graphic representation of the environment. This capability must be part of the new visualization tools.
Focusing our attention toward the second question, *How* do things need to be shown, a list of possibilities may look as follows:

1. By realistic, iconic, symbolic, indexical representation, or any combination,
2. At a given ratio with respect to the actual size,
3. At different ratios,
4. At the "optimal" ratio,
5. At several spatial/temporal dimensions,
6. Statically and/or dynamically,
7. Incorporating other perception senses,
8. Incorporation of natural elements and forces,
9. With crisp boundaries,
10. With fuzzy boundaries,
11. With crisp and fuzzy boundaries,
12. By specific characteristics (object class, geographic extent, security level, etc.),
13. By user-defined priorities,
14. User’s immersion or as observer, and
15. From intuitive to sophisticated quality information under user-control.

Those signs that look very much as the objects represented generate *realistic* representations. Those signs that represent the objects in a stylized way achieve *iconic* representation. Those signs that do not resemble the objects represented and are related only by convention are *Symbolic* or *conventional* representations. Those signs that represent locations obtain *indexical* representation. As with current maps, the new visualization tools must be able to use iconic, symbolic, and indexical signs. Also, new visualization tools must be able to use realistic signs and any combination of the four sign representations.

New visualization tools would be displayed at any ratio (or scale). But, the display always will be complemented by scale and quality information. Ideally, the user would select how this information will be shown. The scale information will be related to the current representation and the quality information will include warnings for those cases where the geographic data are displayed at scales beyond what is appropriate or when contradictory information is used. Sound and/or visual effects will be used to attract the attention of the reader whenever warnings are needed. The new tools will compute an "optimal" scale to display the information. This optimal scale will be computed based on a set of parameters set by the user.

Geographic datasets of higher resolution are collected for some areas of the world. This trend will continue for the foreseeable future. Therefore, beyond national coverage (such as the 1:24,000 DLG scale for the United States of America), there are (and will be) areas of nations covered with more precise datasets. New visualization tools must be able to display all these datasets in an integrated fashion. We foresee the maps of the future displaying different views of the ground simultaneously and under user-control. Each view may be at a different scale and will have the appropriate scale and quality information, or will show all data as a single integrated representation with appropriate quality information.

One of the major limitations of current maps is the fact that they display a multi-dimensional environment in a two-dimensional media. Isograms (or isolines) have been used on hardcopy maps to represent a third dimension very successfully. But, they are not so efficient when used in digital maps. A major need for the maps of the future is the capability to display a multi-dimensional space in a more realistic fashion. Two emerging techniques today are holography and virtual reality. We expect that new visualization tools will use these or alternative technologies to achieve the goal of realistic multi-dimensional environment representation.

Another major limitation of current maps is the fact that they display the environment for a particular moment in time. This is a major limitation because of the dynamic nature of the Earth and phenomena related to the Earth. 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. Computer animation is one of the technologies that provide such a capability.

We perceive the environment through our five senses, but current maps only use our sight to perceive the geographic information. Future maps should incorporate the use of other senses. Hearing is one sense that can be incorporated easily. For example, we can use sound to bring the attention of the map reader toward a particular object on the map, or to warn him/her of the improper use of the information. Incorporation of additional senses to perceive map information will be a major part of the new visualization tools.
Natural elements and forces, such as the position of the sun, time of day, location and extension of shadows, clouds, rain, winds, and tidal stays are a fundamental part of how we perceive the environment. In the two-dimensional world of current static maps, this information, generally, is not shown. New visualization tools must have the capability of showing this information under user-control. Natural disasters, such as earthquakes, flooding, landslides, forest fires, and tornadoes and their possible effects should be available through simulation techniques and displayed on new maps upon user request.

We live in an uncertain world. Not only do we not know what will happen in the next moment of time, but also we do not know the precise definition of our environment. Questions of where is the precise location of an edge of a road, a coastline, of a forest, are just some examples of how uncertain the world we live is. In current maps we represent, in general, uncertain situations by crisp representations. Line segments that define precisely their location and extension represent edges of roads, coastlines, and forests. Of course, this is an idealization of what we are representing. An alternative to this crisp representation could be based on fuzzy logic. As indicated by Sasikala et. al. (1999), “fuzzy logic can be described as a logic of approximate reasoning. It provides strict mathematical framework in which vague, conceptual phenomena can be precisely and rigorously studied.” Fuzzy representation of ground objects will provide a closer representation of the world than the one we use today in mapping. New visualization tools must be able to show fuzzy and/or crisp objects with the corresponding quality estimators.

Current digital maps allow the selective display of information based on how data is organized by classes (called layers, levels, or coverage in current mapping systems). This capability should be maintained and expanded in the new visualization tools. For example, selected objects of a class may be turned off under user control or selecting a particular characteristic of objects (for example, size) could generate a new class of objects in a transparent fashion. Also, objects of different classes should be combined together in a single class without interfering with each other. For example, contours and buildings could be combined together and displayed without pieces of contours running inside buildings. This requires the capability to make transparent any of the segments of objects portrayed on a map.

Current maps show the environment from above. New visualization tools must be able to show the environment not only from above, but also as if the reader were immersed in it. As indicated earlier, we expect new maps to be based on geographic databases of different resolution. Therefore, a user may start by displaying a map as if he/she were outside the area displayed. Then, the user may select an area to be displayed in greater detail and at a particular point, he/she may want to get immersed in the representation. When this happens, the user will be able to see him/herself surrounded by the ground objects and able to walk though them. An example of this kind of application is the designing of a golf course. The user may start by having an eagle’s eye view of the area of interest. Then he/she proceeds with the design of the golf course. At this point, the user may want to get immersed in the design to observe in greater detail how a golfer will view a particular hole.

**OUR PROTOTYPE MULTIMEDIA VISUALIZATION SYSTEM**

There are different alternatives to the integrated visual display of geospatial multi-media information. At the Ohio State University Center for Mapping we are developing a prototype geospatial visualization system. Our conceptual approach is as follows. We believe that a “Windows” approach is cost-efficient and provides a large number of options to display the different data sets. In our conception of the multi-media visualization system, we have several windows that could be displayed simultaneously or that can be displayed one by one. Each window allows the display of a different data set or the display of the same data set at different resolutions, or any combination of the previous two options. For example, vector horizontal data could be displayed in a window, raster horizontal images of the same area could be shown in another window, raster vertical images (such as mobile technology images) of the same area could be shown in another window; a 360° panoramic view (such as a QuickTime view) of the same area could be displayed in another window, and a three-dimensional terrestrial laser scanning model of the same area could be shown in another window. Or, for example, the vector vertical data (profiles) could be shown for the same area at three different resolutions and the horizontal raster data for the same area could be shown at two different resolutions. **Figure 1 shows an artist rendition of the prototype system. At the lower right corner we can see five windows showing vector data, raster images in two windows, elevation data in the other window, and a virtual reality display.**

All windows are synchronized in such a way that any operation applied to one of them, such as panning, zooming, or rotation, are applied automatically to all the other windows, except if the user specifies otherwise. Synchronization will be done based on a common geospatial reference frame used to display each data set. For example if the user is displaying the vector horizontal data in a window and the raster horizontal window in another window and he starts panning the data in the vector horizontal window, then the system automatically will pan the raster horizontal window to keep both displays completely synchronized.
Our final prototype system will display vector horizontal information (roads, buildings, water streams as seen in conventional hard-copy and digital maps), vector vertical information (profiles, DTMUs, TINs, and contours) raster horizontal (space and aerial images of the surface of the Earth obtained with different sensors), raster vertical (mobile mapping images), 360° panoramic views (QuickTime type of views), digital video, three-dimensional laser models, virtual reality, and textual information. The upper part of Figure 1 shows examples of these data sources. The prototype system will also have an audio component that will allow listening to the content of textual information.

Display of vector horizontal information is mostly done similarly to how that information is displayed today in digital mapping and Geographic Information Systems (GIS). We use iconic, symbolic, indexical representations of ground objects as in conventional mapping, plus realistic representation provided by photo images of ground objects. Figure 2 shows examples of these representations.
Vector vertical information is selected by the user and results in terrain profiles, digital elevation, triangular irregular network, or contours. Examples of these data information types are shown in Figure 3.

![Vector Vertical Information](image)

**Figure 3. Vector Vertical Information**

Raster horizontal information is provided by space and/or airborne images of the surface of the Earth at the same or at different pixel resolutions. Our goal is to display the data ( raster and vector) at a given scale in an integrated fashion. This means, for example, that data of lower resolution for an area may be displayed first. Then, later on, if the user wants a more detailed display, the visualization system goes to a better resolution (different data sources) for the area of interest. This is done in a fashion transparent to the user. Figure 4 shows this capability. The views to the left are the Landsat image (30 m pixel resolution) ( upper view) and the lower view is a digital orthophoto quarter-quadrangle (1 m resolution) for a part of the area covered by the Landsat image. The right views are vector data. The upper view is Census data for the area covered by the Landsat image to the left. The lower right view is vector data from the Franklin County Auditor’s Office.

![Raster and Vector Horizontal Data Having Different Resolutions](image)

**Figure 4. Raster and Vector Horizontal Data Having Different Resolutions**

Raster vertical images are photos taken perpendicular to the surface of the Earth. Examples of these photos are those acquired with a terrestrial or aquatic mobile mapping system, and those pictures taken with digital cameras interfaced with a Global Positioning System (GPS) receiver from the ground. Figure 5 is an example of vertical photos obtained from a mobile mapping platform.

![Raster Vertical Images from a Mobile Mapping System](image)

**Figure 5. Raster Vertical Images from a Mobile Mapping System**
360° panoramic views are the types of images generated by Apple QuickTime software and similar products that generate a circular view of the environment with respect to a fixed location. They are generated from a set of consecutive overlapped vertical photos taken from a central location and projected onto a cylinder and stitched together to provide a continuous view around a central point. We have developed a solution to georeference panoramic views. Figure 6 shows 17 consecutive images used to generate a panoramic view. To generate the 360° panoramic view, the two strips shown in Figure 6 need to be joined by their ends, marked with the red tags, and after that the two ends of the resulting strip need to be connected together to generate the circumference of a circle. The user needs to be located at the center of the circle to appreciate the full effect.

Figure 6. Stitched Images Used in Creating a Panoramic View

We have two options for video. The first option allows creating your own video from still images. The second option allows you to import a digital video into the prototype system. Our system supports AVI, MPEG, MP3, FLV, JPEG, PNG, BMP, SGI, WAV, OGG and many other formats. Figure 7 illustrates two steps in the creation of a digital video.

Figure 7. Example of Two Steps of Digital Video Creation

Three-dimensional laser models are generated from aerial and/or terrestrial laser scanners. A laser scanner is based on a laser-base scanning head that sends and records thousands of laser pulses that bounce off a surface we want to survey. The results are thousands of three-dimensional points describing the surface. Modeled surface precision of ±2 mm is possible. Figure 8 shows a terrain model generated from laser scanner data.

Figure 8. A Terrain Model Generated from Laser Scanning Data

As indicated by Bidoshi (2002), computer hardware and software have reached a point where simulation of the complexity of the real world is possible. Virtual reality allows us to do that. Based on hardware and human-computer interfaces, Fairban and Parsley (1996) classify virtual reality as:
- Full or Immersive Virtual Reality requires the participant to be subject to stimuli affecting many senses including vision, hearing, balance, and touch. These systems require head-mounted equipment, tactile gloves and moving platforms.
- Transparent Virtual Reality uses the real world as a backdrop, seen through the device presenting the spatial information. Flight simulations for military pilots are examples of these systems.
- Projection Virtual Reality can be a multi-participant experience involving the presentation of large-scale graphical displays. Planetarium-like situations are an example.
- Desktop Virtual Reality is a Virtual Reality system in a desktop computer. User navigates as if he/she is within the scene in the computer. It is the most commonly used VR system, due to the fact that it can be presented on standard computer monitors.

We propose to use Desktop Virtual Reality as part of our prototype visualization system. We propose to use dynamic visualization to display our environment and real world phenomena, such as clouds, rain, and object movement. We propose to incorporate augmented reality capabilities (the combination of reality with non-existing objects) as a means of manipulating the environment. Virtual reality will be used to display text and non-spatial data. This will be accomplished by designing a set of “cabinets” where the user can access these data. The user will be able to see the environment from outside or could be immersed in it. Figure 9 is an example of our conception of virtual reality in our prototype visualization system.

![Figure 9. An Example of Virtual Reality](image)

One convenient and easy entry point for the majority of individuals to access and interact with geographic areas of interest is through the use of common geographic place names. This can take two forms: (1) querying spatial databases for information, and (2) while viewing a screen display, querying the display for the name of a visible feature. The goal of this step is to integrate files of geographic place names with multi-media data sources to enable the user to interact with spatial databases using geographic place names.

![Figure 10. Audio Interface](image)
This capability is nested within the proof-of-concept visualization system. Figure 10 shows the audio interface incorporated into our system. We have developed two alternatives for incorporating geographic place names on digital maps and images: (a) use of audio to relate the names of geographic features to the user, and (b) the use of text characters displayed under user command to show geographic place names. The user would be able to select whether s/he would like the place name spoken or written on the screen.

In the context of our research, the placement of geographic names on digital maps and images is different from the placement of geographic names on hard-copy maps. There are several issues we have researched, such as name placement for point, line, and area features, orientation and size of text, location of text with respect to geographic features, and the maximum number of names to be kept when multiple names are displayed. These issues were studied in the context of computer screens (generally, a specific computer will have a computer screen of a specific size). Therefore, a given digital map or image could be displayed at different scales in two adjacent computers having screens of different size. If the same geographic area is displayed on both screens, it may be possible that geographic names may need to be shown differently.

The basic idea in our approach is to place geographic names as an independent layer. This means that even though names are anchored by position of the object they identify, we can manipulate them independently of those objects. This allows us to keep their size constant (and readable) when the objects they identify are zooming out. Also, our approach allows names to follow the objects they identify (if you pan the screen, and there is and object from the previous screen in the new one, and that object had its geographic name displayed, the geographic name will follow the object and it will be displayed in the new screen).

In this research we have incorporated audio (to present geographic names) to digital maps and images. Audio is used as a surrogate for conventional geographic name text. We believe that audio can provide the same information as text without the drawbacks associated with text (scale-dependency, information loss, etc.). As indicated by [http://www.nyu.edu/atg/library/papers/internet.adios](http://www.nyu.edu/atg/library/papers/internet.adios): "A number of studies have shown how audio contributes to the human-computer interaction process to provide a richer, more robust environment than with mere graphic feedback."

The final component of our system is the quality information. This component displays graphic and tabular information of the geospatial data. Besides the traditional quality information for points, we have researched the development of metrics to measure the positional accuracy of linear features. Linear features are more complex than cartographic points and are major components of spatial databases. Generally, there are more linear features than cartographic points in most general-purpose topographic maps.

![Figure 11. Linear Quality Measures](image-url)
Four quality measures (Figure 11) have been developed and are implemented in our prototype system Ramirez and Ali, 2003): Bias Factor, Distortion Factor, Fuzziness Factor, and Generalization Factor. The Bias Factor compares the relative location of a linear feature that is less precise to another similar feature that is more precise by super-imposing them and comparing the number and lengths of sub-segments of the less precise feature that fall to the right of the more precise feature with those that fall to the left of the more precise feature. The distortion factor compares the standardized parameterization of two linear features of the same region of the Earth using the equivalent standardized locations. Fuzziness is the factor related to the definition and identification of the end points of two linear features to be compared. The generalization factor compares the lengths of two equivalent linear features.

CONCLUSIONS

We have presented the theoretical concepts of a geospatial multi-media visualization system. We have also described the different components of the prototype system. All these components, with the exception of the virtual reality modulus are implemented. We have used ESRI software as the basic drafting platform and two shareware products, ReadPlease Plus (audio) and VideoMach 3.3.0 (video), together with our own software to implement the prototype system. In general, the integration of the different software components has been accomplished without major difficulties.

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REFERENCES