New Geographic Visualization Tool: A Multiple Source, Quality, and Media (MSQM) Maps

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Abstract

This paper continues the discussion of maps for the future. Current computer-based maps are inadequate to represent the geographic environment. Therefore, a new generation of maps needs to be designed. These new maps must be customized, highly interactive, and realistic. The status of our research is presented together with our effort in developing a prototype multiple source, quality, and media map.

1. Introduction

Current computer-based representational models of geographic data are limited to raster or vector, static, time-invariant data. The resulting *digital maps are inadequate to portray the geographic information as efficiently as possible or even as efficiently as their paper predecessors*. Specifically, vector maps are limited in their graphic representation and content; raster maps are limited in the information they carry.

Vector maps may have limited symbols or no symbols at all. For example, the U.S. Geological Survey DLG files (generated from the quadrangle series) are organized by categories (hydrography, roads, railroads, etc.) and carry only line representations. DLG files do not carry symbols or geographic names.

Raster maps generally portray the ground in a fashion similar to hardcopy maps, but only if the appropriate scanning resolution and the appropriate scale of display are used. Raster maps are very difficult to use in a computer environment if we want to do more than just look at them. The basic problem with current raster maps is that they carry very little explicit information. Explicit information is the type of information that is expressed directly without vagueness, implication, or ambiguity, leaving no questions with respect to its meaning or intent. It is the kind of information that computers can process. In the case of explicit information, a raster map carries only the location of each pixel and a value per pixel (usually associated with a color). But, in maps we are interested in cartographic objects and their relationships. Raster maps do not carry this type of information explicitly.

In this paper we continue our discussion of maps of the future (Ramirez, 1999) and present an alternative to traditional map representation, a Multiple Source, Quality, and Media (MSQM) Map, which is a prototype of a new visualization system. The development of this prototype system requires studying two basic issues: (1) what needs to be shown in a MSQM map; and (2) how do things need to be shown? To answer the first question we would need to consider what current maps show and what else should MSQM maps show based on the datasets collected today. The second question would be answered based on what current maps show and on what we want and need to see today in mission-specific geospatial visualization tools.

Current maps show the environment only from above. Our prototype system shows the environment not only from above but also as if the percipient were immersed in it. It also integrates geographic databases of different resolutions. Therefore, a user may start by displaying a portion of the Earth's surface 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 become 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.

The prototype system integrates horizontal and vertical vector data, horizontal and vertical raster data, 360^o panoramic views, audio, text, special effects, and intuitive to sophisticated quality information.

2. Current Status: What Needs To Be Shown in a Multi-Media Map?

What needs to be shown in a map is related to the purpose of the map. But, in general terms, a list of *what* needs to be shown in a multiple source, quality, and media map might look like this (Ramirez, 1999):

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 estimators.

Our goal in this research is to investigate general-purpose topographic maps. This research is focused on map scales from 1:10,000 to 1:100,000. We have completed the study of issues 1 to 4, and issue 10. A brief discussion of our findings is described next.

2.1 The Surface Being Represented

Traditional maps implicitly represent the ground surface by contour lines. Contour lines are a powerful way to convey relief information in analog planar maps. Contour lines and contour labels provide enough information to create in the map user’s mind a three-dimensional model of the ground surface. This model is the result of understanding the meaning of contour lines as the outline of the intersection of a set of parallel planes and the ground volume, and the contour labels as the corresponding ground elevations of some of those parallel planes.

Contour lines do not work so well in computer maps. The size of the display device and the scale of the display restrict their efficiency. Partial view of contour lines or lack of contour labels in a particular display may not convey a correct three-dimensional view of the ground surface in the map user’s mind. An excessive number of contour lines (perhaps contour lines that are too close together) and/or contour labels too small to be read may also generate an incorrect three-dimensional ground model in the map user’s mind. These two situations may be due to improper map scale display and/or to the size of the display device.

Another limitation of contour lines for computer maps is the fact that computers allow the simulation of three-dimensional views. In three-dimensional maps contour lines are a very poor way to show the ground surface. The fact that contour lines belong to parallel planes results in a discontinuous three-dimensional representation of the ground surface.

On computer graphics, sometimes, a set of grids or triangles is used for explicit representations of the ground surface. Grids or triangles are planar approximations of the surface of the Earth. If their size is small, the overall representation may be adequate from some distances. General problems with these representations are: they are locally uncorrelated; in general, they are two-dimensional; they are too coarse if you get closer; fine details, such as some break lines and points may be lost; imprecise (fuzzy) representation is not possible; and precise computations are difficult. Practically, at this point the use of dense grids and/or triangles provides the best alternative to surface representation. Ideally, we would like to have a three-dimensional representation of the surface of the object represented that overcomes all the problems mentioned above. But, no such representation is in place yet.

2.2 Finite Number of Objects

Objects to be represented are application dependent. We will consider two options for multi-purpose topographic maps. First option: objects are defined by the content of a default map. Second option: the map user selects the object classes (customized maps). For the first option, we follow traditional mapping standards in deciding what objects to show on a map. Specifically, we are using the U.S. Geological Survey Quadrangle Standards. For the second option, the user will select, from a list of object classes, those to be displayed at any given time. The only restriction in this case to the map content will be given by the data in the database. The list of object classes will reflect the content of the database. These objects may be represented as having volume, as static, or dynamic.

2.3 Interrelation Between the Objects and the Surface

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, it may also show size, area, and orientation relationships (for example, iconic representation of area features). They may be located on, over, or below the surface. Therefore, we would have multidimensional (considering time as a dimension) representations of these objects in their true size and relationship with respect to the surface.

2.4. Interrelation Among Objects

In this research, interrelations among objects also have two options. The first option is the default interrelations. Again, we decided to use traditional mapping interrelations. By default, only the relative location among objects will be shown. The second option is customized interrelations. In this case, the user will select, from a list of characteristics, those to be shown on the map. The list of characteristics may include, for example, size, distance, orientation, age, elevation, importance, etc. Again, the data content will be the only limitation to characteristics to be listed.

2.5 Quality Estimator

We believe each object representation (or at least, each class) must have a quality estimator. Quality estimators can be displayed under user control as tables or as graphic symbols.

3. Current Status: How Do Things Need To Be Shown?

In agreement with Ramirez (1999), a list of possibilities may look like this:

1. Realistic, iconic, symbolic, or indexical representation,
2. Any combination of the above,
3. Given ratio with respect to the actual size,
4. Different ratios,
5. Several spatial/temporal dimensions,
6. Statically and/or dynamically,
7. Incorporating other perception senses,
8. Incorporating natural elements and forces,
9. Crisp boundaries,
10. Fuzzy boundaries,
11. Crisp and fuzzy boundaries,
12. Specific characteristics (object class, geographic extent, etc.),
13. User’s immersion or as observer, and
14. Displaying quality information under user-control.

Our research on items 1 to 4 is described below.

3.1 Realistic, Iconic, Symbolic, or Indexical Representation

Map object representations will incorporate the traditional mapping signs (iconic, symbolic, and indexical). Iconic signs are those signs that resemble the object on the ground. For example, a closed polygon that looks similar to the outline of a building as seen from above. Symbolic signs are those that have no similarity to the shape of the object on the ground but that are used by convention. For example, horizontal control points are represented by equilateral triangles. Indexical signs are those representing locations (grid intersections, tic marks, etc.). Realistic signs will be added to the above signs. Realistic signs are those that look very much as the object from the ground. Photographic images are an example of two-dimensional realistic signs.

3.2 Any Combination of Object Representations

A combination of realistic, iconic, symbolic, and indexical representations is a departure from conventional mapping and has two major implications. One, we need to move from the traditional data model as given by Burrough (1996) into a more up-to-date data model. Two, a new database structure may be needed. We have developed an extended representation model (Ramirez, 2001) and a new database structure.

3.3 Representation at a Given Ratio with Respect to the Actual Size

Maps of the future would be displayed at any ratio (or scale). But, some kind of scale indicator and quality information always will complement the display. 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 is displayed at scales beyond what is appropriate. Sound and/or visual effects will be used to attract the attention of the user whenever warnings are needed.

3.4 Representation at Different Ratios

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, there are (and will be) areas of nations covered with more precise datasets. Maps of the future must be able to display all these datasets in an integrated fashion. This is what we meant in talking about representing maps and their objects at different ratios (or scale). We foresee the maps of the future displaying different views of the ground simultaneously, or under user-control. Each view may be at a different scale and will have the appropriate scale and quality information.

4. The Prototype System

Our prototype system combines horizontal digital vector datasets and raster images of the ground with vertical vector datasets and raster images, panoramic views, sounds, and special effects. The goal of this approach is to create a realistic multi-dimensional visualization of the ground. In this environment, 360^o panoramic views will allow the user to navigate through different levels of detail by pointing to and clicking on those objects that he or she wants to examine in greater detail.

A small prototype pilot project incorporating some of the above datasets is being conducted in Upper Arlington, Ohio. The City of Upper Arlington is part of Greater Columbus.

For the Upper Arlington Pilot Project (UAPP) we are integrating the following geographic datasets:

(1) Vector digital data, specifically the dataset generated by the Franklin County Auditor's Office at the scale of 1:2,400,
(2) Vector digital data at scales 1:24,000 and 1:100,000 from the U.S. Geological Survey DLG files.
(3) Horizontal digital images, digital orthophoto quarter-quadrangle (DOQQ) at the scale of 1:12,000 generated by the US Geological Survey and the State of Ohio.
(4) Horizontal digital images, from IKONOS, 4-meter resolution.
(5) Horizontal digital images from LANDSAT 7, 30-meter resolution.
(6) Vertical digital images generated by the GPSVan™ along some of the streets,
(7) 360^o panoramic views of selected locations.

We are working on integrating these datasets and adding sound and special effects in order to produce a MSQM map. The approach to be followed is described in the next sections.

4.1 Vector Horizontal Data

From the Franklin County Auditor's database we have extracted the area of the City of Upper Arlington. This includes streets, street names, building outlines, lot outlines, and names of landmarks. The part of Upper Arlington used in the pilot project is shown in Figure 1, outlined by the thick black line.

DLG data for roads, hydrography, and boundaries at scales 1:24,000 and 1:100,000 were extracted for the pilot project area. All vector data were converted into the CFMDBF database. Currently, the CFMDBF vector database contains data at three different scales: 1:2,400, 1:24,000, and 1:100,000. Geo-referenced geographic names are also stored in CFMDBF.

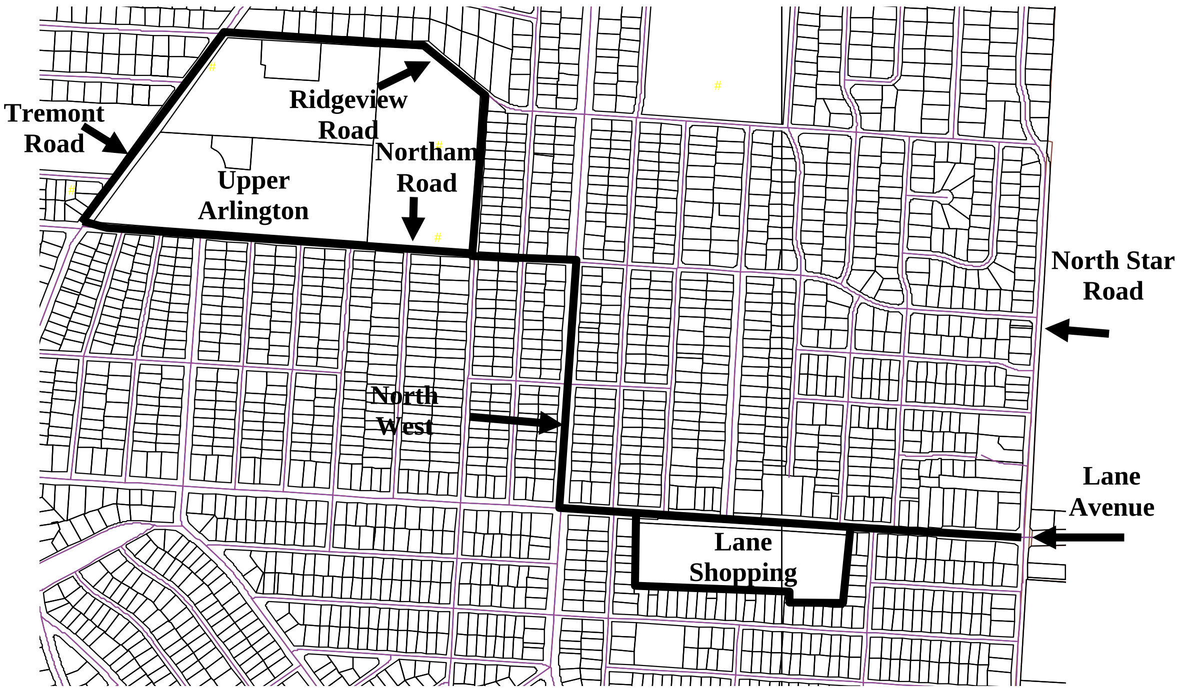

Figure 1. Pilot project area
(From the Franklin County Auditor Database)

Figure 2. Upper Arlington extracted from DOQQs O4008364.SWS and O4008364.SES

4.2 Horizontal Digital Images

Rectified images of 1-meter, 4-meter, and 30-meter resolutions for the pilot project area were extracted from DOQQ, IKONOS, and LANDSAT 7 images, respectively. Every pixel of these images was geo-referenced. Geo-referenced information was stored in CFMDFB.

4.3 Vertical Digital Images

Mobile mapping technology was pioneered at The Ohio State University Center for Mapping. This technology allows the collection of positional information and digital images at highway speed. Images from this technology provide a vertical view of streets and their features. These images show the streets and their objects as an observer walking or driving a car sees them.

Digital cameras can be mounted to look in front, to look behind, and/or to look to the sides of the vehicle. The images used in this prototype project were provided to us by TRANSMAP Inc. Figure 4-a shows a image obtained from the camera looking forward from the front of the vehicle. Figure 4-b shows an image taking with a camera looking to the right side of the vehicle.

(a) (b)

Figure 3. Mobile Mapping Images

Every pixel of these images was geo-referenced. Geo-referenced information was stored in CFMDFB.

4.4 360^o Panoramic Views

The panoramic views are views of selected sites along the pilot project area. A total of 75 sites are included in the pilot project plus 27 sites inside Lane Shopping Center. The panoramic view for each site is generated from a set of overlapped images. These images are stitched together into a circular view, with the observer in the center of the circle. An average of fifteen digital photos were used to generate each panoramic view. Apple developed this technology. Apple QuickTime was used to generate our earlier views on a Mac OS-based computer. Later on, we used Cannon Photo Gold’s Spin Panorama, complemented with our own software to create these views.

Figure 4. Images used to generate a 360^o panoramic view

Figure 5 shows the overlapped images for one of these sites. Every pixel of these images was also geo-referenced. Geo-referenced information was stored in CFMDFB.

4.5 Sound and Special Effects

In this pilot project sound is used as an alternative to labels for streets and landmarks. For example, you could listen to the names of main roads and secondary roads, as well as the name of schools and shopping centers. Special effects are limited to flashing lights used to focus attention to query results. For example, this effect could be used to highlight all schools in the pilot project area.

5. An Overview of the UAPP Integrated Data

Figure 7 shows in schematic fashion the different data sets and how they are integrated.

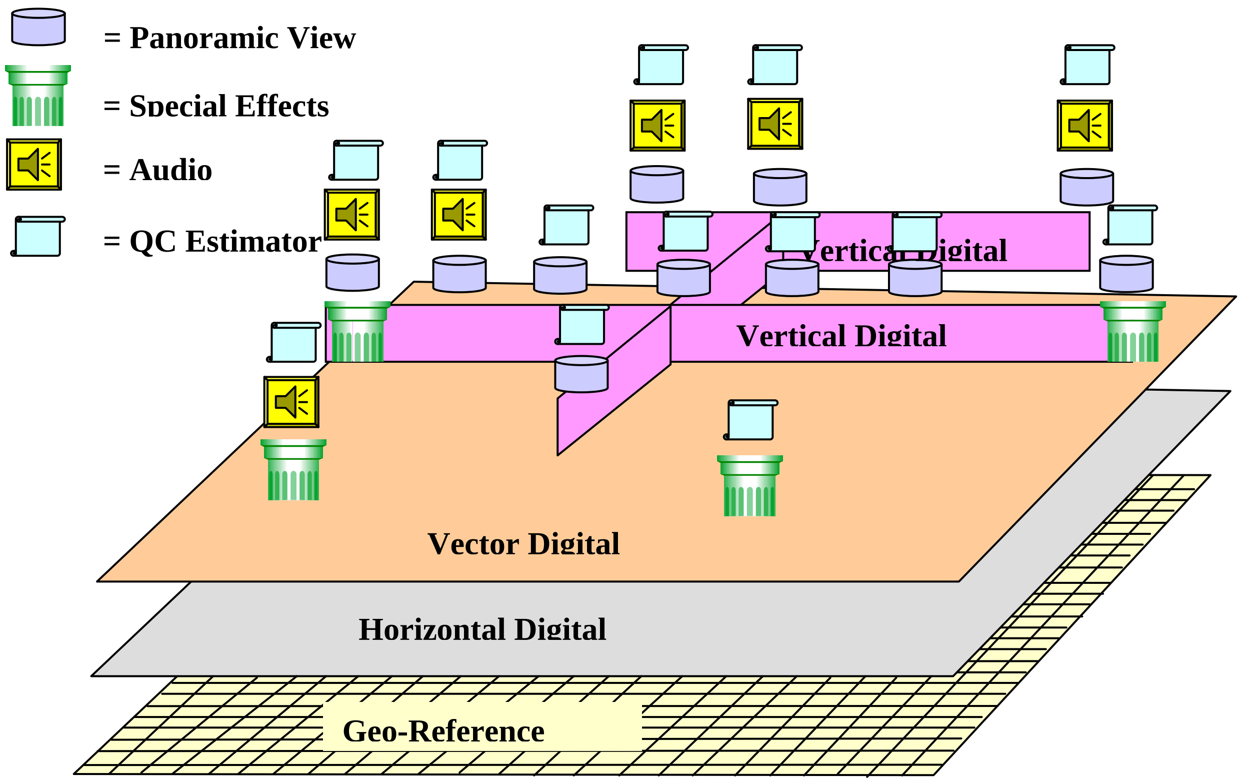

Figure 5. Schematic Representation of Pilot Project Datasets

All datasets are geo-referenced to a universal coordinate system, and this is the key to retrieving all pertinent information. Coordinates in this universal coordinate system are assigned to each pixel of each raster image (including 360^o panoramic view) and to each node of the vector data.

This integration allows access to all the pertinent information contained in the database by choosing any location of the multi-media display. As an example, if you select on the vector representation, the corner of Lane Avenue and Northwest Boulevard, you will automatically be able to see the corresponding portion of the digital orthophoto quarter-quadrangle, IKONOS, and LANDSAT 7; the images from the GPSVan™, the 360^o panoramic view, and simultaneously, if you wish, you will be able to listen to the name of the intersecting streets.

A user interface facilitates the selection of location by the user and the display (in different windows) of the different pieces of information.

6. Status of the UAPP

All datasets have been extracted and incorporated in CFMDBF. Capabilities to display streets and landmark names are being implemented as well as audio.

All 360^o panoramic views have been generated and they are being geo-referenced. Software to handle geo-referenced panoramic views is in place. A user interface to display the different datasets in a synchronized fashion is in place.

7. Conclusions

We continue developing the concept of maps for the future. We have developed portions of the conceptual framework described by Ramirez (1999), and we are implementing a prototype multiple source, quality, and media (MSQM) map. We have in place an extended representation model for geospatial information, a new database structure, and we are conducting research in audio in mapping, and data mining of images. All of this work will be integrated into what we envision to be the maps of the future.

References

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