Maps for the Future: A Discussion

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Abstract

Generation of digital cartographic products is labor-intensive, costly, and difficult to standardize. But, demand for them is increasing due to the wider acceptance of Geographic Information System (GIS) technology. It is becoming evident that traditional computer-based maps are inadequate to portray this geographic information as efficiently as possible.

It is highly desirable to develop cartographic solutions with a high degree of automation and alternative means of visualization. Image understanding (computer-assisted annotation) combined with cartographic methods provides the opportunity to increase the level of automatic information extraction from ground images. This, in turn, will increase the need for better visualization alternatives.

We believe that future maps must be highly adaptive, interactive, and realistic, and that these future maps will support better decision-making. The goal of this paper is to explore the idea of "maps for the future." It is obvious that different types of maps are needed to improve the display and analysis of geographic data, that there is no longer the need for massive printing of maps, and that it makes more sense to produce maps on demand. We will explore new visualization alternatives for geographic data such as incorporation of movement (dynamic objects) combined with still objects, incorporation of sound and other multimedia effects, and multi-dimensional representations (including volumetric and time representations).

Introduction

Generation of digital cartographic products such as maps is still labor-intensive, costly, and difficult to standardize. But, the demand for digital cartographic products is increasing due to the wider acceptance of Geographic Information System (GIS) technology. The information in digital cartographic products as generated today is significantly different from hardcopy cartographic products. Those differences go to the heart of what is a map. Also, it is becoming evident that current digital maps are inadequate to portray geographic information as efficiently as possible. We believe that current visualization of geographic data on computers is no more (and perhaps less) efficient than paper maps and, therefore, it does not serve the needs of the GIS community well.

Limitation of Current Digital Maps

Let us study these assertions. *Generation of digital maps is labor intensive and costly.* Let us concentrate our attention on general-purpose topographic maps such as the 7.5-minute series of the U.S. Geological Survey (USGS), as an example, and let us assume that all the geographic data necessary for the production of a map series of general-purpose topographic maps has been collected. Let us use [Ramirez, 1991] cartographic components to describe a map of this map series:

Any general-purpose topographic map has some or all of the components described below.

-*Cartographic projection* is the component that identifies the map projection used in the map.

-*Contour interval specification* is the component that carries the prescribed elevation difference between successive contour lines for a specific map sheet.

-*Credit and notes* is the map component which includes information such as: map disclaimers, warnings, publisher's name, copyright's owner, map sheet number, number of copies printed, publication date, production method, revision date, and so forth.

-*Direction arrow* is the component that indicates on a map the primary reference direction relative to the earth or any celestial body (for example, the direction of true North).

-The *heading* component is taken here following [Bertin, 1983]. It is composed of the title block and the legend. The *title block* carries information that identifies the represented area and the map producer. The *legend* is the link between the cartographic language and the natural language of the map producer. It is equivalent to a bilingual dictionary. It uses graphic signs and natural language (the language of the producer) to define the equivalencies between the components of both languages.

-The *positional diagram* is the map component that shows the position of a map sheet with respect to the whole area of interest.

-The *positional reference frame* is the component that connects the terrain to the displayed area on a map.

-The *quality of data sources* provides the basic information from which the quality of a map can be evaluated.

-*Representational signs* are those signs located in the *display area*, which is the area delimited by the positional reference frame of a map. Three kinds of representational signs are found: graphic, natural language and numerical language signs.

-*Scale representation*, in very simple terms, is the reduction ratio from the surface represented to the map representation. It can be expressed graphically or numerically.

-*Surface of reference* is the surface used as the datum for coordinate computation.

Some of these components, such as cartographic projection, direction arrow, legend (as part of the heading), scale representation, and surface of reference are constant for all the maps of a map series. Generally, their insertion in a digital map as symbols (or equivalent concepts) is cost-efficient.

The other map components change from map to map. Out of these other components, representational signs in the display area is the one component least subject to automation. All the problems related to cartographic generalization affect their visual representation and location. For example, symbol type (point, line, area), symbol characteristics (size, value, pattern, color, orientation, and shape), minimum size (which allows for distinguishing an object), exaggeration (to allow differentiation of objects), simplification and smoothing (to decrease the complexity of lines and areas in agreement with the scale of representation), integration of relief representation and planimetric objects, etc., need to be resolved as part of the visual representation and location of objects in the display area. This requires a “global” approach to generalization, where the interaction and effects of the representation of the different ground objects are dealt with at once. We do not have a solution for this yet. The visual representation and location of ground objects in the display area of a map is basically a manual-labor intensive operation similar to the one used in hardcopy maps and one that we do not yet know how to automate. In general, this representation is different from map to map. This has made the production of maps –hardcopy or digital –very costly.

The information in digital cartographic products as generated today is significantly different from hardcopy cartographic products. In the digital environment the scale representation, for example, does not convey the same information as in hardcopy maps. In a very simple fashion, scale representation can be defined as “the ratio of a distance on the map to a distance on the ground.” From the viewpoint of visualization, on hardcopy maps, the distance between two points is constant, and therefore, the map scale is invariant between those two points. On digital maps the distance between two points depends on the zooming (or magnification) factor used at a particular moment. From this viewpoint, the map scale is variable between any two points in a digital map. This greatly changes the perception of the implicit information carried by a map. Implicit information is that which can be understood from the map representation although it is specifically unexpressed. An example of implicit information is how far apart are two objects on the ground. Of course, if this distance is computed from the coordinate values in the geographic database this distance is constant regardless of the graphic representation on the screen.

The concept of scale in turn impacts the concept of quality of the data sources component. Many maps provide minimum information about their quality. For example, the USGS 7.5-minute quadrangle series contains only the following statement, “this map complies with national map accuracy standards.” Accuracy standards are scale dependent. For example, the National Map Accuracy Standard (NMAS) 1947 [American Society of Photogrammetry, 1980] states, “For maps on a publication scale of 1:20,000 or smaller, no more that 10 percent of the points tested shall be in error by no more than 1/50 inch, measured on the publication scale.” Therefore, for maps at scale 1:24,000 the maximum positional error allowed is of 40’. The Geospatial Positional Accuracy Standards Part 3: National Standard for Spatial Data Accuracy (NSSDA) [Federal Geographic Data Commission, 1998] states, “The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. RMSE is the square root of the average of the set of square differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points.” This standard “does not define threshold accuracy values. Agencies are encouraged to establish thresholds for their product specifications and applications and for contracting purpose.” Therefore, it is expected that agencies will set accuracy thresholds per map scale. In the case of hardcopy maps, the effort and cost of making a larger scale map from a smaller scale map is so much, that in general, this is not done. In the digital environment, there is no major difference in effort and cost in generating maps almost at any scale from the same geographic database. As a matter of fact, many casual users of digital maps may not be aware of the quality limitations and proceed to generate and use maps at scales beyond what is appropriate. Therefore, generation and uses of maps (digital and hardcopy) in scales beyond what is allowed, is a potential danger in digital mapping.

Current digital maps are inadequate to portray the geographic information as efficiently as possible. Digital maps can be classified as vector or raster maps. Vector maps, in general, are limited in their graphic representation. For example, the Digital Line Graph (DLG) maps of the USGS use a very limited number of visual variables. Figure 1 shows a piece of the 7.5-minute quadrangle and the equivalent area taken from DLG files. On the other hand, vector files carry connectivity relationships, and in many cases topologic and attribute information. In the case of the DLG, lines provide connectivity among points. Nodes and areas are special cases of lines. As indicated by [U.S. Geological Survey, 1990], “The DLG-3 concept is based on graph theory in which a two-dimensional diagram is expressed as a set of nodes (topologically significant points), lines, and areas in a manner that explicitly express logical relationships.” Besides the positional and topological information, DLG data also carries explicitly encoded attributes. Each attribute code identifies the major category to which a cartographic object belongs (roads, hydrography, boundaries, etc.). Each attribute code has a major code and a minor code. For example, the major code 170 identifies the category Transportation, and the minor code 0202 identifies a primary route, class 1, divided, lanes separated.

Figure 1. Portion of a 7.5-minute quadrangle and corresponding DLG.

Raster maps generally portray the ground in a similar fashion to hardcopy maps if the appropriate scanning resolution is used. On the other hand, they 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. 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 explicitly do not carry this type of information. Scanning a small part of the hardcopy map for the 7.5-minute quadrangle for Springfield, Ohio generated the left part of Figure 1. The scale of this portion of the map was changed in Figure 1 creating again the same kind of problems mentioned for vector maps.

Therefore, neither digital vector nor raster maps have, by themselves, a set of equivalent attributes to what hardcopy maps have, that allows the efficient portrayal of geographic information. Vector maps lack the graphic quality of paper maps and raster maps lack the wholeness of hardcopy maps.

Current visualization of geographic data on computers is no more (and perhaps less) efficient than paper maps. In the previous paragraph we pointed out some of the limitations of digital maps from the viewpoint of visualization. A close look at hardcopy and digital maps shows several additional limitations of digital maps. For example, the limited size of the display media for digital maps greatly restricts the flow of information from the map to the percipient (the map user). Let us use the 7.5-minute quadrangle map to illustrate this point. 7.5-minute quadrangle maps are published on sheets 21.5" by 27" (54.61 cm by 68.58 cm). Usually, lines in these maps have been drawn with a minimum width of 0.1 millimeter. Computer monitors are made with different sizes and resolutions. For example 19" and 21" monitors are made with a dot pitch between 0.22 and 0.28 millimeters. Larger screens (33", 37", 42", etc.) have a dot pitch from 0.83 to 0.96 millimeters. Therefore, there is no real gain from the viewpoint of image resolution in using monitors over 21". As indicated by [Spiess, 1995] "Minimal dimensions are rather coarse on a screen in comparison to a paper map with line widths of 0.1 mm. A pixel on a 19" monitor (385 x 287 mm) with 1184 x 884 pixel resolution measures 0.28 mm. This causes ragged lines, an effect that to some extent may be mitigated by the aliasing technique. Furthermore, the color contrast that can be established for images on a display, is often not as strong as on paper. In a number of tests it has been shown that for clear identification of a topographic pixel map on such a display, the paper map has to be enlarged at 250 per cent. In other words on such a display we work only with sections of 12 x 10 cm, spread over the whole screen, of any scanned map." Therefore, with the current status of technology, we are limited in general to viewing on any computer monitor only a small portion of a map, with equivalent resolution to a hardcopy map. In the case of the 7.5-minute quadrangles we are able to see less than 25% of the whole map at any one time.

In many cases, practitioners use computer systems with two monitors. On one screen, the whole map is shown all the time, and on the second monitor a small area of the map is displayed, the area where the operator will be working. This approach eliminates the constant zoom in and out on the monitor, and provides an easy way to reference the working area with the whole map. But, on the other hand, it does little to improve the perception of the implicit and explicit information. As an alternative, most practitioners use a hardcopy map for orientation and perception of the information, and the digital map display is used only to modify and query the map.

The examples presented above show some of the limitations of current geographic data visualization techniques. We believe these limitations are the result of the original goal of cartographers of replicating manual cartographic methods on computers. Very little attention was paid to the different nature of the new media, especially early on, when computers were seen as processing machines more than as interactive machines. Cartographers saw digital plotters as the natural output device for mapping products, and, therefore, there was no reason to be concerned with computer visualization. Today, the situation is different. Computers are interactive machines that we use to visualize, query, and analyze. They are used by an increasing number of people, and with the decreasing cost of computers and their increasing capabilities this number will continue growing. Also, the incredible growth of GIS has multiplyed the demand for geographic data. It is becoming obvious then that the major bottleneck in mapping and GIS is the visualization of geographic data. In the next section we will discuss our vision of maps for the future.

Maps for the Future

It is becoming highly desirable to develop cartographic solutions with a high degree of automation and alternative means of visualization. Image understanding (computer-assisted annotation) and prediction methods, combined with cartographic methods, provide the opportunity to increase the level of automatic information extraction from ground images. The outcome will be up-to-date geographic datasets. Up-to-date geographic datasets are fundamental for GIS. GIS queries, usually, are related to the present time. Therefore, a current representation of the environment is required to generate appropriate answers to these queries. This will increase the need for better visualization alternatives. We believe that future maps must be current, but also highly adaptive, interactive, and realistic. These maps will incorporate movement (dynamic objects) combined with static objects, sound and other multimedia effects, and multi-dimensional representations (including volumetric and time representations). Also, these maps will support "augmented reality" that combines natural images with computer-generated objects. This will allow us to investigate the combination of mapping and image data with computer generated objects that currently do not exist on the ground (and further, to forecast the effects those objects might have on their environment). This will be done dynamically, in 3-D, and so forth. This "virtual environment" may prove to be of great value for data analysis and decision-support systems. In this framework there is no longer the need for massive printing of maps, and it will make more sense to produce hardcopy maps on demand.

Data Updating and New Maps

Current geographic data is fundamental for GIS. Current or up-to-date geographic data describe the environment as it is today. Current data must be used in new maps. The most cost-efficient way to generate up-to-date data is by map revision. Map revision uses all unchanged data for an area and only deals with the changes on the ground. At the Center for Mapping we have studied the map revision problem and developed a cost-efficient solution. This solution is discussed in great detail in [Ramirez, 1998] and combines image understanding, Bayesian networks, conflation, and geographic data revision theory. The discussion of map revision goes beyond the scope of this paper but we want to stress here the importance of current data for new maps.

New, Highly Adaptive, Interactive, and Realistic Maps

Maps graphically represent some geographically referenced information. We use maps to learn new facts from explicit information, learn new facts from implicit information, and to confirm previous knowledge. Maps are still the most efficient way to show the terrain surface, its features, and phenomena and events that are geographically located. Most current maps contain an explicit representation of the outline of ground features, events, and phenomena, and an implicit representation of the relief. If a map is well designed, understanding of all this information is self-evident.

Limitations in digital maps and the need of better ways to visualize geographically referenced information and queries create the opportunity to re-consider our ideas of what is a map. If we imagined for an instant that there were no maps today and that we were chartered with the task to create a means to visualize the environment, what kind of products would we create?

This requires researching two topics, (1) what needs to be shown? (2) How do things need to be shown? The answers to these questions will provide the framework for the maps of the future!

What Needs To Be Shown?

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

(1) The surface being represented,
(2) A finite number of objects on that surface (depending on the application),
(3) Interrelations among 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 phenomenon, and
(9) Any combination of the above.

A fundamental part of any geographically 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. On computer graphics, sometimes, a set of grids or triangles is used for explicit representations 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 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. 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 is 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, it may also show size, area, and orientation relationships (for example, iconic representation of area features). New maps 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 maps 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, direction, etc.

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 on the new maps are those that differ from surrounding map objects by their size, visual attributes, or by any other means of making them different from the other objects in order to attract the attention of the map percipient.

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 concepts from very profound, 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 maps. "Augmented" objects are virtual (non-existing) objects 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.

"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 to part of the original object. The actual map representation would be modified automatically to reflect what would happen if such objects exist. These objects would be removed and placed on the graphic representation under user control.

Thematic maps show derived phenomena of all kinds. We expect the maps of the future to continue doing so but extending this capability to incorporate the additional characteristics described in the previous paragraphs.

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

How Do Things Need To Be Shown?

Let us focus our attention toward the second question posed at the beginning of this section, *How do things need to be shown?* We believe it is possible to represent a map and its object as follows:

(1) By realistic, iconic, symbolic, or indexical representation,
(2) By any combination of the above,
(3) At a given ratio with respect to the actual size,
(4) At different ratios,
(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, etc.),
(13) User's immersion or as observer, and
(14) Displaying 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 obtain *Symbolic or conventional* representation. Those signs that represent locations obtain *indexical* representation. As with current maps, the maps of the future must be able to use any combination of the four representations mentioned above.

Maps of the future 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 is displayed at scales beyond what is appropriate. Sound and/or visual effects will be used to attract the attention of the percipient whenever warnings are needed.

Geographic datasets of higher resolution are collected for some areas of the world. This trend will continue for a 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 by 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.

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 the maps of the future to 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 maps must be able to display dynamic changes on a background of static objects. Computer animation is one of the technologies that provides 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 percipient 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 new maps.

Natural elements and forces, such as the position of the sun, time of day, location and extension of shadows, clouds, rain, winds, etc. 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. Maps of the future must have the capability of showing this information under user-control. Natural disasters, such as earthquakes, flooding, landslides, forest fires, tornadoes, etc. and their possible effects should be available and displayed on new maps. Also, the weather conditions must be available and displayed under user request.

We live in an uncertain world. Not only do we not know what would happen in the next moment of time, but also we do not know the precise definition of our environment. Questions such as where is the precise location of an edge of a road, a coastline, a forest, etc., are just examples of how uncertain is the world we live. In current maps we represent, in general, uncertain situations by crisp representations. Edges of roads, coast lines, and forests are represented by line segments that define precisely their location and extension. 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 [Ganesan, 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 maps 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, coverage, etc., in current mapping systems). This capability should be maintained and expanded in the new maps. 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 (at least the user requests that). This requires the capability of map objects to make any of their segments transparent.

Current maps show the environment from above. New maps must be able to show the environment not only from above but also as if the percipient 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.

As discussed earlier, the information about the quality of the geographic data is in some way lost in digital maps. Also, it was indicated that even in hardcopy maps this information is limited. New maps must incorporate quality information in a more rigorous way and it must be mandatory. Quality information must be provided at the ground object level and must go beyond positional accuracy.

Conclusions

We have presented a discussion on the idea of maps for the future. This discussion is by no means exhaustive and should be considered only a preliminary step in the conception of new maps. As a result of this discussion we have identified a set of fundamental research topics. For example, what technology (or technologies) should be used to display multi-dimensional maps? What kind of geographic model should be used? What kind of primitives should be used to build complex objects? How should the ground surface be represented? How should volumetric features be represented? How should static and dynamic features be integrated? How should geographic data quality be evaluated and represented? How should fuzzy logic be extended to fuzzy mapping? Also, we have identified a set of practical problems. For example, with the current state-of-the-art technology what kind of new maps are possible today? What is cost-efficient? What kind of interfaces are required? How can existing data be used as part of the new maps? How current must "current" data be? We believe that the research of these and similar topics is a major step in our understanding of what kind of new maps are possible.

Even if the reader completely disagrees with our concept of future maps, we hope the ideas presented here show the need to start a discussion of how future maps should be. Such a discussion is necessary to conceive better ways to display cartographic information. A high level discussion may create the framework from which specific research projects can be undertaken by different organizations and individuals. Cooperative research among organizations and individuals may eliminate duplications and result in a faster outcome. If this happens, we feel this paper has accomplished its mission.

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