Spatial Visualization through Cartographic Animation: Theory and Practice

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ABSTRACT

The creation of cartographic animations has been feasible since the early 1960's but has only recently become a practical alternative for the display of maps. A theoretical framework is emerging for this form of spatial visualization. The basic goal of cartographic animation is the depiction of change. The types of change can be categorized as temporal and non-temporal. Most cartographic animations depict change over time. Non-temporal cartographic animation are also possible. Examples include animations of data classification, data generalization, and a series of related variables from a single time period.

A number of tools are now available to assist in the production of cartographic animations. These tools can be classified as frame-based or cast-based animation. Frame-based animation combines a series of maps that are usually generated by another program. The maps are stored in a raster form and can be placed on the screen at up to 30–60 frames per second. In cast-based animation,

a script is used to make foreground objects move against a background. This form of animation does not require the creation of individual frames. Both methods of cartographic animation are examined for their utility in spatial visualization.

INTRODUCTION

Visualization is the creation of computer graphics images that display data for human interpretation, particularly of multidimensional scientific data. It has been interpreted broadly as a method of computing that incorporates data collection, organization, modeling and representation. Visualization is based on the human ability to impose order and identify patterns.

An outgrowth of statistical analysis, visualization is now used in a variety of disciplines. It has strongly influenced all forms of data analysis. For example, programs are available to graph a x, y and z variables (e.g., Abacus MacSpin). The programs use animation to ‘spin’ a three-dimensional graph depicting the data. The animation makes a cloud of points that exists in three-dimensions visible.

Cartographic visualization, sometimes called geographic visualization, is interpreted as the use of similar techniques for the display of maps. In discussing the possibilities of computer technology, MacEachren and Monmonier write:

> The computer facilitates direct depiction of movement and change, multiple views of the same data, user interaction with maps, realism (through three-

> dimensional stereo views and other techniques), false realism (through fractal generation of landscapes), and the mixing of maps with other graphics, text, and sound. Geographic visualization using our growing array of computer technology allows visual thinking/map interaction to proceed in real time with cartographic displays presented as quickly as an analyst can think of the need for them (1992, p. 197).

In part, the strong interest in visualization within cartography is a response to a data-base view of maps that emerged along with the growth of geographic information systems. Implicit within the data base view is the notion that all elements of a map can be decomposed and represented within a file on the computer. Further, once so encoded, all analysis can proceed with the data base without any need for graphical representation or human involvement. This view of maps can be termed a non-graphical cartography. Visualization reaffirms the importance of the graphical illustration in all aspects of analysis and interpretation. It recognizes that the human has special abilities to interpret graphical displays.

Important elements of the visualization interface are interactivity and animation. While GIS systems have stressed interaction, both with the graphic component of the map and the underlying data, they have not incorporated animation. In part this is due to hardware limitations and incompatibilities for the display of animations. However, the avoidance of animation is also related to a general fixation on the single map, a result of many centuries of experience with this representational form.

CARTOGRAPHIC ANIMATION

Animation may be defined as creating the illusion of movement or change by rapidly displaying a series of single frames, as with film or video (Roncarelli 1988). A common example would be the movement of a cartoon character. Movement can also be interpreted as the change in the perspective of the observer as the figure remains still.

The advantages and feasibility of cartographic animation were described by Norman Thrower as early as 1959 (Thrower 1959, 1961) who viewed its potential from the perspective of film. The computer was soon being used to create the individual frames (Cornwell and Robinson 1966). In the years since, there have been few examples of cartographic animations, due largely to the complexity of their creation and cartographers fixation on the printed map (Campbell and Egbert 1990; Karl 1992). Exceptions include cartographic animations to depict the growth of a city (Tobler 1970), traffic accidents (Moellering 1972, 1973a, 1973b), population growth in an urban region (Rase 1974) and three-dimensional cartographic objects (Moellering 1980a, 1980b).

Recent contributions in cartographic animation have attempted to formulate a conceptual foundation for the use of animation in cartography. Monmonier (1990) has proposed a scripting mechanism to direct the display of a map series and DiBiase et al., (1992) outline a series of dynamic variables for cartographic animation.

The animation of maps has been predominantly associated with the representation of change over time. Examples of temporal animations would include changes in per capita income, the increase in population density or the diffusion of a farming method such as irrigation. Cartographic animations are useful for other purposes as well, such as depicting the deformation caused by a map projection (Gersmehl 1990), a three-dimensional surface (Moellering 1980a, 1980b) or the classification of data (Peterson 1993). Such *non-temporal* uses of animation in cartography may evolve into the major application of the technique.

Non-Temporal Cartographic Animation

Other types of cartographic animation do not depict change through time. The maps in Figure 2 are individual frames from a generalization type of cartographic animation. The maps depicted in the animation change from two to six classes and show the effect of the number of data categories on a mapped distribution.

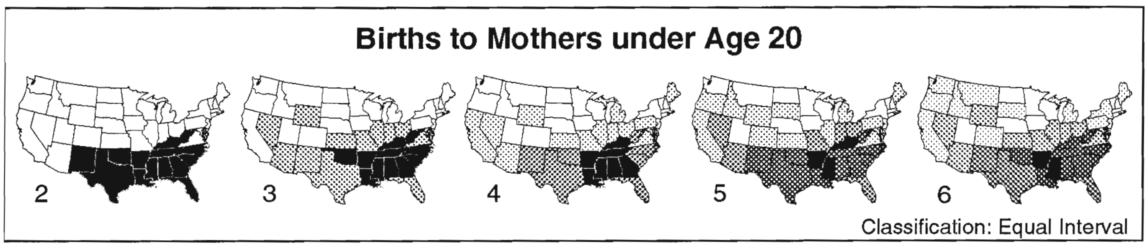

Figure 2 Selected frames of a generalization animation. The map at the far left with two classes is the most generalized depiction of the data. The remaining maps depict the data with decreasing levels of generalization - three, four, five and six classes respectively. The darker shadings indicate a higher percentage of births to mothers under age 20. (From *Interactive and Animated Cartography* 1995)

The effect of data classification can be observed with a classification animation. Here, each frame of the animation depicts a different classification scheme. A number of different statistical and non-statistical methods exist for classifying quantitative data (e.g., standard deviation, natural breaks; see Dent 1993). Figure 3 depicts the individual frames of a classification animation. The viewing of a classification animation can present the variety of classification options quickly and provide a less misleading view of the data than simply relying on one map.

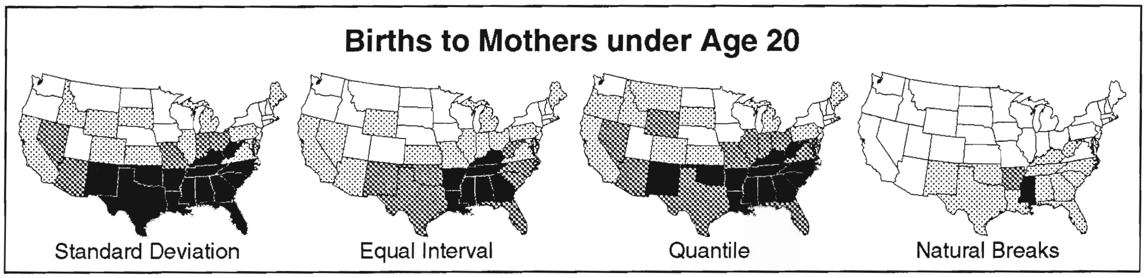

Figure 3 Selected frames of a classification animation. All maps depict the data using four classes with the darker shadings denoting states with a higher percentage of births to mothers under 20 years of age. (From *Interactive and Animated Cartography* 1995)

Another type of animation would be the depiction of a spatial trend. A spatial trend can be evident when examining a series of related variables. For example, the percentage of population in age groups (5-13, 19-24, 45-54 years of age, etc.) will usually show a clear regionalization in a city with the older populations closer to the center and younger populations nearer the periphery. An animation of age groups from younger to older depicts high values 'moving' from the periphery of a city to the center (see Figure 4). Variables such as income and housing valuation depict similar geographic trends.

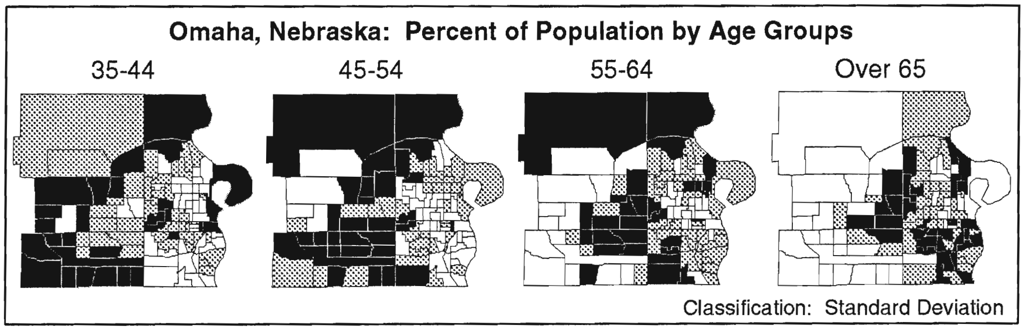

Figure 4 Selected frames of a spatial trend animation. The objective of this type of animation is to show a spatial trend of a series of related variables. Omaha, Nebraska developed along the Missouri river which delimits the city on the east. The older parts of the city correspond to the smaller census tracts in the middle, eastern part of the city. The newer parts of the city (where the younger people live) are more to the west and north. (From *Interactive and Animated Cartography* 1995)

A number of different types of non-temporal animations are possible with maps. Probably the most widely used is the 'fly-through.' Moellering (1980a, 1980b) showed how an animation could be made of a three-dimensional object by moving around it in time. The technique has been expanded by combining a digital image of the earth and an elevation model. A large number of oblique views are then constructed to simulate flying through a terrain. The method was demonstrated in *LA: The Movie* created by the Jet Propulsion Laboratory. Individual frames of the movie are shown in Figure 5.

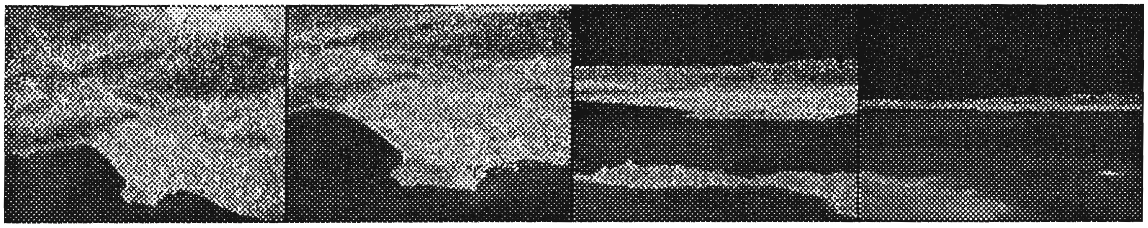

Figure 5 Four frames from a production by the Jet Propulsion Laboratory called LA: The Movie. The fly-through animation was created by combining satellite imagery with digital terrain elevation data.

Given the number of different applications, cartographic animation may best be defined as the depiction of *change* through the presentation of a series of maps in quick succession. The growth of a city or the flow of a jet stream show change in position. *Temporal animations* depict change through time. *Non-temporal animations* shows change that is caused by factors other than time.

Animation Variables

A review of the different animation variables help to show the potential application of animation in cartography. The variables of animation include graphical manipulations and sound. Sound can be used to accentuate an animation. For example, a change in pitch could accompany a ‘cartographic zoom’ with the pitch getting higher as one zooms in. The graphical variables of animation include (after Hayward, p. 9):

1) *Size* – The size of an area on a map may be changed to show changes in value. For example, the sizes of countries are made proportionally larger or smaller to

depict the amount of oil or coal reserves. An animation can be used to transform the map of oil reserves into the map of coal reserves to show the differences in location of the reserves.

2) *Shape* – An area on a map can be made to change in shape. The shape (and size) of Greenland varies as a result of the influence of a map projection. An animation can be used to blend between the two shapes to accentuate the effect of the different projections.

3) *Position* – A dot is moved across the map to show change in location. For example, the center of population for the United States has moved consistently to the west, and more recently to the south. An animation can be used to depict this movement through time.

4) *Speed* – The speed of movement varies to accentuate the rate of change as, for example, with an animation that depicts the movement in the center of population for the United States.

5) *Viewpoint* – A change in the angle of view, could be used to accentuate a particular part of the map as part of an animation. An animation of population change in the United States may use a viewing angle that focuses attention on the western and southern states where significant increases in population have occurred.

6) *Distance* – A change in the proximity of the viewer to the scene, as in the case of a perspective view. In cartography, the distance variable may be interpreted as a change in scale.

7) *Scene* – The use of the visual effects of fade, mix and wipe to indicate a transition in an animation from one subject to another.

8) *Texture, Pattern, Shading, Color* – Graphic variables

Reordering: The order of scenes in a time-series animation is usually from beginning to end. Reordering involves the presentation of the scenes in a different order, usually according to an attribute. DiBiase, et. al. (1992), give the example of depicting earthquake events. A typical time-series animation would depict earthquake events through time. Another approach would be to order the frames by the number of deaths caused by the earthquake. In this way, an emphasis is placed on a measure of earthquake severity.

Pacing: Pacing refers to varying the duration of scenes. Once again, using the earthquake example, DiBiase, et.al. (1992), propose that the duration of the scene be proportional to the magnitude of the earthquake or the number of deaths.

CREATING A CARTOGRAPHIC ANIMATION

Animations were at one time created manually, a frame at a time and transferred onto film. The techniques that have been developed for computer animation go well beyond those of film animation.

Gersmehl (1990) distinguishes between seven types of computer animation that are applicable to cartography. These seven can be grouped into two categories: frame-based animation and cast-based animation. The two differ in how the animation is created. In frame-based animation, the individual frames do not share common elements. Types of frame-based animation include the flip-book and the slide-show. With cast-based animation, foreground objects can be made to move against a background. The more sophisticated approaches to cast-based animation allow background and foreground objects to move simultaneously. Examples of the cast-based approach include the sprite, stage-and-play, color cycling, metamorphosis (polymorphic tweening) and model-and-camera.

<u>Frame-based Animation</u>

The frame-based approach to animation is the simplest form of animation. The individual frames can be created by a graphics, mapping, or GIS program. Many frames are required for even a few seconds of animation. The illusion of movement or change is created by displaying the frames quickly.

A number of programs are available to assemble, store and display this type of animation. The first type, presentation programs (e.g, PowerPoint (Microsoft), Persuasion (Aldus) and Freelance Graphics (Lotus)), are designed for the display of text and graphics as part of a presentation but can also display a series of individual frames at animation rates. Card or page-based multimedia authoring programs like HyperCard can be made to display a series of frames quickly. The advantage of these programs is that they are designed for interactive use. The user can interactively select an animation and also control the speed of display. Some image processing programs can be used for animation. With NCSA Image, a public domain image processing and analysis program, animations are created by specifying an animation option and then opening a series of images. The program animates a stack by repeatedly displaying its slices (frames) in sequence. Finally, programs for editing digital movies (e.g., Adobe Premiere) can combine graphic files, still images, audio and video sequences for the creation of animations.

Cast-based Animation

Cast-based animation is based on the concept of the 'cel.' This form of animation is related to conventional film animation and the use of multiple transparent sheets to form a complete frame. A cel is an individual layer of a frame of animation and a frame can be composed of many layers. A frame of an animation can consist of a background cel (a landscape) and a series of foreground cels containing an object that can be made to move on the background.

There are four types of two-dimensional cast-based animation: *sprite*, *stage and play*, *color cycling* and *metamorphosis*. The *sprite* and *stage and play* are implementations of this foreground/background, cell-based concept in animation. The sprite is simply an object that moves against a static background. *Sprite* animation is commonly used in video games like PacMan. The *stage and play* type of animation is a more complex form of the sprite. Here, the foreground object or actor can change in appearance or in its speed of movement. The background can also change simultaneously with changes in the foreground. More sophisticated video games (e.g., car racing) implement this type of animation.

Color cycling makes use of the way colors are represented on the screen of the computer. With this technique, a path is defined and broken-up into small segments. Each segment is given a slightly different color. Then the colors are shifted down each segment in the path to give the impression of movement. This quick change in color along a path is used to simulate movement, as is commonly done with the representation of the jet stream on television weather maps (Figure 6a).

Metamorphosis, also called polymorphic tweening, is the procedure used to change one shape into another (Figure 6b). For example, one could have a graphic object of a fish and another of a bird. One would then tell the software to transform the fish into the bird and it would calculate the 'in between' frames to make it appear as if the transformation were taking place. This can be combined with the sprite operation to show the fish jumping out of a lake, transforming into a bird and flying into the air.

Full-featured animation programs implement all or nearly all of the animation techniques previously described. The programs integrate a combined graphics-editing and scripting environment. Examples of programs in this category include: MacroMedia Director for the Macintosh and AutoDesk Animator/ Animator Pro for DOS.

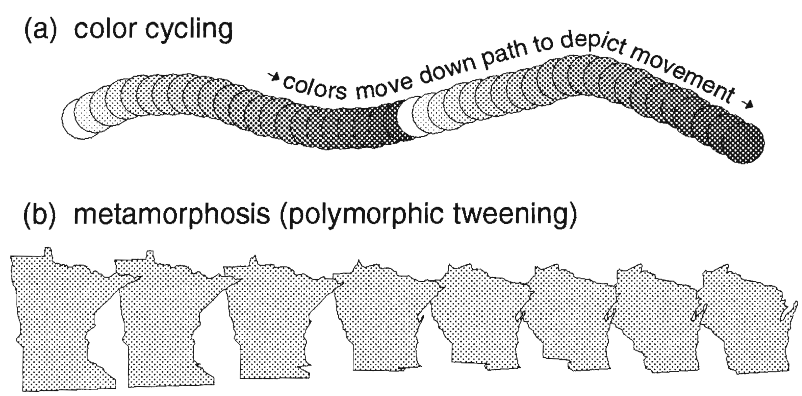

Figure 6 Two types of computer animation. Color cycling (a) simulates movement along a path by changing colors in zones along the path. Metamorphosis or polymorphic tweening (b) derives in-between frames between two given shapes. In the example shown here the outline for the state of Minnesota is converted into that of Wisconsin. (From *Interactive and Animated Cartography*

1995)

CONCLUSION

Visualization is a mental process. It is dependent upon the recognition of patterns in both static and dynamic displays. An individual map depicts a static pattern. Animation presents patterns over time. The time element may be used to display patterns that are temporal or non-temporal in origin.

Animation is an important technique in our use and understanding of spatial data. Cartographic animation demonstrates that individual maps are only a snap-shot in time. One should ask: What was before? What will come after? What trends would be evident if the time element could be viewed as an animation? The individual map is a snap-shot not only in time but also in terms of the data. What non-temporal trends would be evident if a map were viewed along with other related data sets (e.g., age distribution in a city)? Finally, the individual map is a snap-shot in the choice of the representational forms that were used to depict the world. The use of different symbols or data classifications can also constitute an animation.

A variety of techniques are associated with computer animation. The simplest form is frame-based animation that displays a series of frames in rapid succession. Programs for creating interactive presentations, multimedia integration, and image processing may all be used to assemble such an animation. This is the most feasible approach for creating a cartographic animation if another program is available to create the individual maps. Additional animation procedures are associated with cast-based animation, including: *the sprite*, *stage and play*, *color cycling* and *metamorphosis*. These techniques can be used to interactively create a cartographic animation with a base-map, although the process can be time-consuming.

Computers programs for data-driven cartographic animation are not yet widely available. A program has been developed for the interactive animation of choropleth maps (MacChoro for Apple Macintosh). The program demonstrates that a frame-based type animation can be added to an existing program for computer mapping. Frame-based procedures could be integrated within GIS programs and this would significantly increase the accessibility to this form of spatial visualization.

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