Classification and Application of Cartographic Animation

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The development of a definition and classification scheme for cartographic animation is now warranted, since focus on the visualization method increased during the 1990s. This article offers a comprehensive definition of animation, distinguishing between animation, slide shows, multimedia, and hypermedia. In addition, a classification system identifies and offers specific characteristics for four different methods or types of cartographic animation: time, areal, thematic, and process. **Key Words: animation, cartography, research tool, visualization.**

Introduction

With use of cartographic animation now widespread, different techniques and types of animation are being developed. The purpose of this article is to identify the different categories of animation and to briefly discuss their potential usefulness to cartography, as well as to other areas of geography.

The focus here is specifically animation, which will be defined now for clarification purposes. An animation may be, in simplest terms, any moving presentation—be it through film, video, or computer—that shows change over time, space, and/or attribute. Animations, which often run multiple frames per second, differ from computer "slide shows," which are simply a series of graphics presented concurrently, often employing transitions, such as fades or wipes, from frame to frame. The difference between the two is a matter of timescale. In animations, the viewer cannot detect the point at which one graphic in the series replaces the previous, while in slide shows, the viewer can identify the point at which graphics change. In other words, each individual *slide-show* graphic frame remains on the screen longer than does each *animation* graphic frame.

An animation often consists of thousands of slightly different individual frames and may include sound (narration, music, or sound effects), resulting in a *multimedia* animation. Multimedia animation may be incorporated into a *hypermedia* presentation, which allows users to explore data through the use of on-screen buttons (Krygier et al. 1997). In some cases, animation may be simultaneously multimedia and hypermedia, as is the case with some areal animations, or "fly-bys," discussed later. Often the distinction between multimedia and hypermedia is blurred and while these two are often used together in a presentation, they are different methods, serving different purposes (for further discussion of the distinction between these methods, see Krygier et al. 1997).

Background

Animation is now beginning to become widely used, not only by cartographers, but also by other geographers. Its popularity as a data-display method has grown since Campbell and Egbert in 1990 spoke of the lack of incorporation of animation into geography. In the thirty years before 1990, the field of geography was only speckled with papers, including those by Thrower (1959), who thought that popular animation had nearly arrived, and Tobler (1970), who first published the results of a computer animation in cartography (Campbell and Egbert 1990). Fortunately, since 1990, geography has witnessed the beginning of what could finally be the blossoming of animation, as more projects, papers, theses, and dissertations continue to be devoted to the subject.

Terminology has varied through this evolution of animation. The terms "cartographic animation," "map animation," "four-dimensional cartography," "dynamic mapping," and "spatio-temporal display" may all be used to describe "cartographic displays having a succession of maps pertaining to the same area whose content changes in relation to the independent variable—time" (Weber and Buttenfield 1993, 141).

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After years of experimenting with the uses of animation, this method seems to have proven valuable in geographic education, specifically in the development of educational supplements, including student exercises and instructor aids. Educational publishers offer CDs containing geographic applications—which include multimedia, hypermedia, and animation—as supplements to textbooks or as independent products.

Fortunately, the popular application of animation, multimedia, and hypermedia in geographic education is resulting in the continued development of design methods as well as of technology. As a result, several categories and uses of animation as *data display methods* have been developed and are identified below.

Categories of Animation

Both the earlier years of design and method experimentation and the current widespread development of educational materials have produced a plethora of animations and accompanying literature. The highest-order classification may be based on interactivity, which separates animations into two categories, *presentation* and *interactive*. Presentation animations allow the viewer little or no control over the progress of the product; the animation is only viewed. If it is seen through a computer, the viewer may be able to control the speed and may be able to pause the movement. One advantage of this method is that the graphics may be viewed in other ways, such as via video or film projector. Interactive animations—also known as hypermedia animations, as mentioned above—offer the viewer considerably more control over the course of the animation. The viewer may direct the animation in several ways—panning, zooming, and rotating—as well as engaging in discourse with the computer through inputting data or responding to questions. The following defined categories do not distinguish based on this factor; they rely on different bases for classification. As a result, animations falling into one or more of these categories may be either presentation *or* interactive, depending on how the author intends the final product to be used.

A review of the literature reveals several categories of animation, identified here as *time-series*, *areal*, *thematic*, and *process* animation. Some differences between these categories are distinct, and some are subtle. Usually, the literature fails to identify an animation as being of a particular type or to place it into a distinct category, probably because a comprehensive categorization system for animation does not yet exist. This article offers a categorization scheme for animation and highlights ways in which animation may be used most effectively for representing dynamic data.

The categorization scheme is based on three criteria: time, variable, and space. The dynamic or static quality of each criterion provides the classification basis. Time is considered to be dynamic if the dataset includes temporally varying observations—in other words, if the data include observations that change over time. Time is considered static if the dataset is temporally unchanging—in other words, if observations are made at a single moment or at least recorded as a single moment. Variables are considered dynamic if their quality or quantity changes; as discussed further below, these changes may or may not take place over time. Conversely, variables may be labeled static if they and the symbols representing them do not change. The space may also be identified as either static or dynamic, depending on whether the base map itself is held constant or allowed to change through either viewer or animation control.

The discussion below will further elaborate on the characteristics of time, variable, and space as well as their static or dynamic nature. This discussion will allow a reader to identify different types of cartographic animation that may be created based on specific characteristics of their spatial data. The reader may apply a decision-tree diagram, such as that in Figure 1, to assist them in selecting an appropriate animation method. To use the decision tree, the reader must first identify the dynamic or static nature of time, variable, and space characteristics in the dataset they wish to visualize. The classification scheme is designed to allow creators and users of animation to choose a specific type of animation that best visualizes their unique data. Included in the discussion of each category is a three-axis graphic, which provides a graphic representation of the combination of criteria comprising the specific category. The three axes in each diagram represent space, time, and variable. The shading or absence thereof indicates the

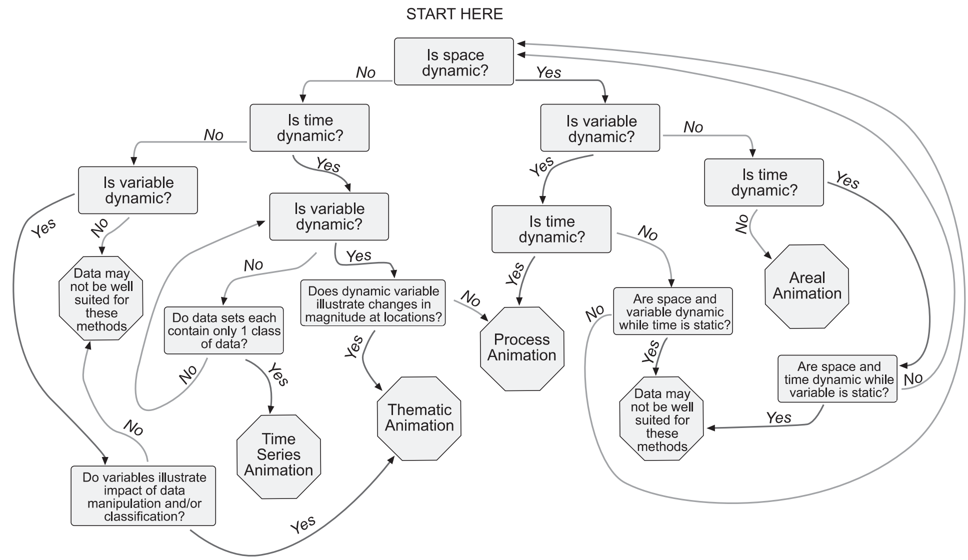

Figure 1 *Decision-tree diagram.*

static or dynamic nature of each variable. The axes do not represent numerical values of the criteria; instead, they show the potential for change of the criteria. For this reason, the diagrams are not drawn as cubes, which may give the visual impression of finite axes. Rather, the open-ended axes of the diagrams included here indicate the change potential, which is theoretically infinite.

Time-Series Animation

Animating time, "where the map is held still and the action played out upon it" (Dorling 1992, 218), has been one of the most popular forms of animation. Change over time normally may be shown in a time-series animation, in which time is dynamic (it changes), the subject or variable remains static (no change in the variable quality), and the location (base map) is static. Figure 2 provides a graphic cube representation of these criteria.

Characteristics of Time-Series Animation

Time-series animations portray data that maintain three distinct characteristics: dynamic time, static variable, and static space. These characteristics are presented in Figure 2 and discussed more fully below.

Dynamic Time The most important characteristic of a time-series animation may be the depiction of change over time. In this categorization, a variable's changing location *over time* is highlighted; the variable appears or disappears at varying locations through time. For example, the geographic extent of a bark-beetle infestation may be visualized by creating dozens of different maps (using the same base map), each representing infestation locations over twenty years. In this example, data may be represented per day, week, month, or year. For

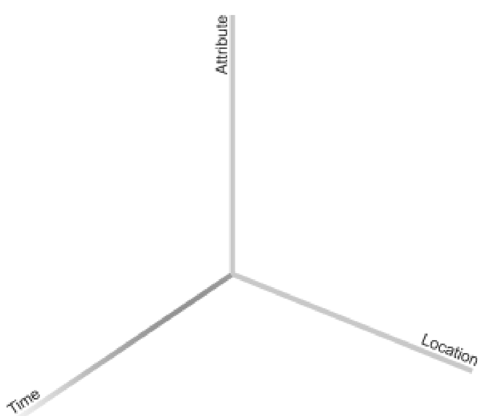

Figure 2 *Time-series animation criteria axes.*

time-series animations, the time scale is not restricted; change may be measured and visualized over seconds or over centuries.

Static Variable For the purposes of the classification scheme presented in this article, a variable may be considered static if the quality of the variable, represented by the variable's symbol on a map, does not change. For example, consider the bark-beetle infestation. If the data include locations for specific trees that were attacked over the course of many years, the cartographer could symbolize each tree infestation with a single symbol. The final animation could show symbols appearing as trees are infested, or tree symbols could be shown disappearing from the map as each tree dies from the beetle attack. Similar to a dot-density map, the static quality of this variable is represented with a constant (unchanging) symbol. Although attribute symbol quality does not change, the animation may portray data pattern or density changes. In other words, density patterns may be visually perceived, even though the attribute's symbol remains static.

In time-series animations, the *existence* of a variable is documented through discrete change at varying locations, rather than *differences in quantity*, which could be represented by changing symbols. If a researcher wishes to illustrate quantity differences, this goal could be accomplished through the use of different symbols representing different quantities of an attribute at varying locations. These quantity differences can be portrayed by creating a thematic animation (discussed below), rather than through a time-series animation. But, while time-series animation data are static, they may be measured and represented as point, line, or area data.

Finally, while a symbol may be used to represent an attribute and while that symbol remains static, it does not necessarily have to be qualitative (nominal). A single symbol may be used to represent a quantitative amount of a variable (say, one dot representing five trees infested by the bark beetle). However, the value of the symbol in a time-series animation will not change, as this would represent dynamic attribute symbolization.

Static Space Although a variable's appearance or disappearance in geographic areas is depicted, and therefore space as it relates to the *location of a given phenomenon* may change through time, usually the whole map area is held constant: the base map itself does not change. Therefore, time-series animations are considered to maintain fixed space. However, two time-series animations may be included together in a single presentation. For example, if the bark-beetle data include precise data for a small geographic area, then a large-scale animated map could be created, as described above. But, in this example, a single, unchanging base map on which the bark-beetle symbols appear and/or disappear is maintained. Assume that statewide data that show which counties are inundated by the bark beetle are also included. The state-level data could be represented by coloring each county as it initially becomes infested. The state map—a relatively small-scale map—which represents area data (county) with area symbols (colored enumeration units) could follow the first large-scale map, which visualizes individual, tree-level data (point symbols representing point data). But, again, this presentation would include two separate time-series animations presented consecutively.

Design Considerations and Applications of Time-Series Animation

Because a time-series animation visualizes a given phenomenon changing locations through time—a characteristic intrinsic to the categorization of time series—a main focus of the presentation is time. As a result, time changes can ideally be represented as occurring at a constant rate, as much as the original data will allow. For example, in a one-hundred-year timetable, a map (animation frame) may be created to represent change for each successive year, instead of several frames showing change sporadically (at two-year, then one-year, and then three-year intervals). However, maps are created for a specific purpose, and therefore the intended communication goal will influence the visualization of the data.

Time-series animations portray the chronological and *spatial* change of phenomena and thus are intrinsically *geographic*, because they provide a method for illustrating dynamic geographic data (chronologically changing spatial data). This method has utility in several areas of geography; a few specific examples are presented here. Medical geographers can use time-series animation to display the appearance of a disease in specific areas through time (point or area data). Population geographers may employ this method to visualize the migration sources of U.S. immigrants through time (usually area data, such as countries or provinces). Military geographers may use this method to illustrate changing political borders resulting from military campaigns (line data). Finally, as in the example discussed above, biogeographers can visualize disease, infestation, and animal-migration data.

Areal Animation

Areal animations "emphasize the existence of a phenomenon at a particular location" (DiBiase et al. 1992, 206). Unlike time-series animation, where the animation is shown from a constant viewpoint (static base map), the viewpoint in an areal animation is dynamic (the base map is not static), while time remains fixed.

DiBiase and colleagues (1992) identify this location change as visualizing change through space. Currently, one of the most popular ways to achieve an areal animation is by using a "fly-by." DiBiase and colleagues (1997, 207) define a "fly-by" as "a sequence of views of a static surface or volume in which the viewpoint of the observer changes gradually." Fly-bys can be either presentation or interactive animations. Using a presentation fly-by animation, the viewer may observe a rotating earth, for example, where the only control the viewer has over the course of the animation is in starting or stopping the rotation or through adjusting the speed at which the rotation is viewed. Using an interactive fly-by animation, such as one that shows terrain, the viewer can control the geographic position from which the animation is viewed—they can view a mountain range, for example, from a northwest position at a 100-foot altitude and then move to a southeast position at a 1,000-foot altitude.

Another common example of an areal animation is the increasingly common interactive Internet street map. Many of these maps allow the viewer to input a general geographic area, such as a city or state, but some allow increased specificity by permitting the input of a specific address. Once the map is displayed, the viewer can change scale, pan, and sometimes rotate.

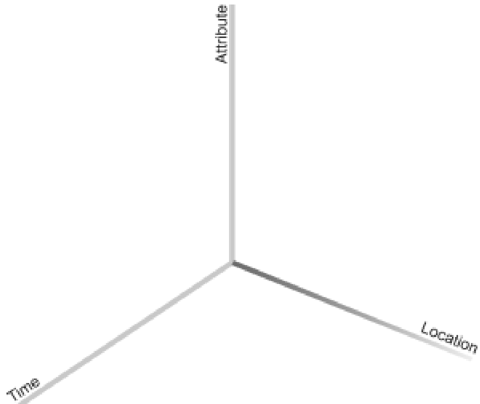

Figure 3 *Areal animation criteria axes.*

Characteristics of Areal Animation

Three characteristics may be observed in areal animations: static time, static variable, and dynamic space. Figure 3 provides a graphic illustration of these characteristics, which are discussed more fully below.

Static Time An areal animation may be considered to be a "snapshot" in time. Time is static. Therefore, areal animations as classified here would not show change over time. Instead, if a geographer wishes to visualize terrain or other areal changes over time (continental drift or creation of mountains, for example), they may choose to visualize the data through a process animation, discussed below, which may be used to visualize dynamic time and dynamic space.

Static Variable While an areal animation can—and most likely will—include many variables, these variables are fixed (unchanging). Because areal animations do not show change through time, specific observations—and therefore each unique symbol representing these observations—remain static on the base map. As a result, variables are shown with neither discrete nor continuous change. However, several unchanging symbols may be included in the animation. For example, a fly-by of a mountain range could include symbols representing several variables, including elevation, biological data, and cultural phenomena (roads, buildings, and so on). Also, while the variables are static, areal animations may represent qualitative or quantitative data. Because the objective of many landscape fly-bys is to visualize terrain differences, the visual difference between the top of the mountains and the bottom of the valleys, for example, illustrates elevation differences, which are quantitative data. One can also imagine a map in which states are classified qualitatively according to the predominant crop grown (e.g., corn, wheat, oranges), on which a viewer can pan or change to larger scale to see the same data differentiated by county. Both examples animate data that are distinguished as qualitative or quantitative, but both may be classified as areal animations.

Dynamic Space The most important characteristic of an areal animation is the illustration of spatial variation. While space (base map) remains fixed in a time-series animation, constant spatial variation is what distinguishes areal from other types of animation. Specifically, an areal animation may illustrate changing spatial viewpoints. Panning, zooming, rotating, and angle perspective are some of the techniques that may be used to create a dynamic space. A viewer may adjust map scale through zooming in and out, or they may adjust perspective by entering a specific viewing angle (above ground level, for example). In addition, north-east-south-west viewpoints may be changed through rotation or panning through the base map.

Applications of Areal Animation

Currently, most areal animations display landscapes or landforms. Therefore, the seemingly obvious beneficiaries may be geomorphologists. However, other geographers will find this method useful for displaying spatial relationships or patterns between different locations. While maintaining fixed time, terrain fly-bys usually only show landscape changes, but it is the inclusion of the other variables that makes this method appealing to other geographers as well. For example, one may look at socioeconomic trends among the states: as location varies, differences in a variable such as population may be observed. These changes may be achieved by using color, shading, or prisms to represent numeric values or nominal categories as they differ spatially at a single given time. Areal animations allow the viewer to spatially explore the geographic data and identify patterns, similarities, or differences between areas. For example, imagine a map of the United States constructed so that three-dimensional prisms represent the populations of each state for a given year, with higher prisms symbolizing higher values. The population would appear as clusters of skyscrapers in the Northeast and on the West Coast, while the comparatively sparsely populated middle of the country would contain only an occasional midrise. The animation viewer would be able to "fly" through the United States, gaining a dramatic and unique view of U.S. population distribution.

Thematic Animation

In thematic animations, location is held constant (static space) and time and variables may change their values or attributes (dynamic time and variable). The emphasis in a thematic animation is attribute, which is highlighted at a particular location and, over time, differentiated by value or nominal classes.

Several methods of thematic mapping can be applied to visualize spatial data, creating static thematic maps. It follows that some of these methods can also be applied to create animated thematic maps. For example, an animation that uses graduated color symbols (choropleth) or graduated point symbols to illustrate the magnitude in difference through time at different locations would be classified as a thematic animation. However, as mentioned in the time-series discussion, an animation that uses dots (similar to a static dot-density map) or unchanging solid-area (choropleth) symbols to show the appearance and/or disappearance of an attribute at different locations through time would be better classified as a time-series animation. Therefore, use of a traditional, static thematic method in an animation does not automatically classify it as a thematic animation.

Graduated symbols or choropleth mapping methods may be used, but animations employing other thematic methods may belong in other categories. For example, an animation based on a series of dot-density maps would perhaps be better classified as a time-series animation, since the variable's attributes are maintained (one dot size and color), time varies, location (base map) remains static, and the dots appear and disappear at different locations over time. Choropleth maps may be used in either time-series or thematic animations, the main difference being that in a time-series animation, the symbols used to represent a variable do not change: they are presented as one class of data (recall, however, that the class may represent either qualitative or quantitative data). A thematic animation, though, will include several categories of data, which may also be qualitative or quantitative. These characteristics are discussed in more detail later.

Peterson (1993) identifies four ways in which animation may be used, all of which may be classified as thematic animations. *Classification* animation is used to show and compare the different methods of classification. *Generalization* animation shows the different levels of data generalization as the number of classes change for the same data on a given map. *Geographic trend* can be observed when viewing a shifting of values shown in a choropleth animation depicting changing land values, for example. Finally, animation is used in *comparing distributions* within a series of maps.

Characteristics of Thematic Animation

The matic animations share the following three characteristics: static or dynamic time, dynamic variable, and static space. Figure 4 illustrates the time, variable, and space characteristics that define an animation as thematic.

Static or Dynamic Time Recall that in a time-series animation, time is dynamic, and in an areal animation, time is static. In the case of a thematic animation, time can be either static or dynamic, depending on the specific nature of the animation. Borrowing from Peterson's (1993) classification, animations can be used to compare and contrast different methods of classification, as well as different levels of generalization within a single classification. Datasets can be classified using several different systematic and acceptable methods. However, in most cases, the resulting classification will differ by class number, individual class ranges, and class members. Moreover, not only do different classification methods result in different maps, but different calculations using the same classification methods can also result in different maps. For example, when using equal intervals, one can choose different intervals for different classifications. Also, when employing the quantile method, quartiles or quintiles would most likely result in different classes and would then map differently. Different breaks can be chosen if using the natural-breaks method, and user preferences abound when using the arbitrary method. Therefore, one could choose a single dataset (fixed in time and space) and complete a myriad of classifications that might all be visualized through a thematic animation.

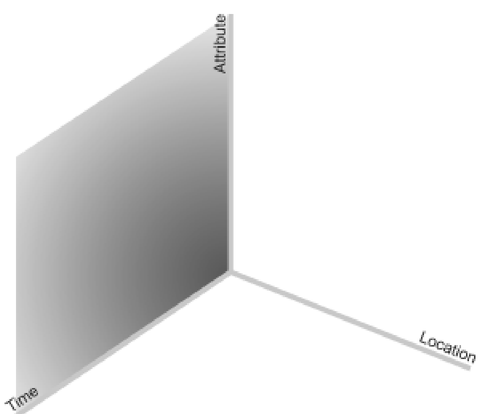

Figure 4 *Thematic animation criteria axes.*

Dynamic Variables One of the most significant characteristics of thematic animations is the dynamic variable. The symbol assigned to a specific value or class and represented at a given location on the base map may change its quality through time. Consider the population example discussed above. A single state could change hue values several times as the animation progresses due to population fluctuations over time. Thus, the symbol represented at a specific location will physically change. The change may be observed as discrete or continuous change—for example, a discrete jump in an enumeration unit on a choropleth map from light blue to dark blue, or the continuous growth of a graduated symbol. Contrast this characteristic with the static variable utilized in a time-series animation. In that case, a symbol may discretely appear or disappear in given area (presumably as the data in that given location changes), but the quality of the symbol itself does not change. Although *static* thematic maps may represent quantitative or qualitative data, thematic animations may represent quantitative data. The dynamic symbols in a thematic animation represent differences in magnitude at given locations (point, line, or area). Qualitative data may be better represented through a time-series animation.

Static Space Like time-series animations, thematic animations maintain a fixed base map; zooming and panning around the base map are not characteristics of this method. Therefore, while data may vary from location to location, the overall base map itself is static. However, as can be accomplished when employing a time-series animation, two thematic animations with two different base maps can be shown consecutively, or even concurrently. For example, a dataset that maintains population data per state for each year between 1,600 and 1,999 could be animated, resulting in thematic animations. An animated choropleth map could be created by systematically classifying the data for each year and assigning different values of a hue to each class. Because of the settlement patterns of the United States, two animations using two different base maps may be appropriate. A base map of the eastern seaboard could be used for about the first 200 years (resulting in a 200-frame animation, for example), followed by another animation in which the base map includes the entire 50 states (300 additional frames, with one frame representing each year of data). The resulting animations would most likely show states changing hue values as their individual classification changes. Again, though, the resulting product would contain two different thematic animations shown consecutively—although, depending on the dataset and mapping purpose, two animations could also be shown concurrently, essentially resulting in a split-screen.

Applications of Thematic Animation

Thematic animation would be useful for cartographers and other geographers who wish to represent temporal and variable changes in a particular location, such as the changing predominant economic bases of U.S. cities. In this example, the location is constant (one city); time varies (chronological change); and the variable changes (varying economic bases such as agriculture, manufacturing, or service). Because this method provides a platform for displaying dynamic geographic data, it has the unique ability to dramatize and highlight geographic trends and demonstrate the effects of spatial autocorrelation, a subject of study that is uniquely geographic. A similar animation could highlight the changing influence of a single component of economic base, such as the service industry, in several cities over time. In this example, a graduated symbol could be used to represent the changing percentage of service as part of the economy through a given period of time.

Process Animation

Process animation takes a unique perspective. Although some animations—even some of the examples mentioned above—may not differ dramatically from a series of static maps, process animation offers two important attributes that static representations do not: motion and trajectory. Motion is defined by *Webster's Desk Dictionary* as "the action or process of moving or changing place or position," while trajectory has been defined as "the direction of travel of a moving object" (Reiber 1991, 318). Therefore, by creating an animation that emphasizes both motion and trajectory, the viewer will be able to visualize a phenomenon that cannot be visualized in static maps, "the continuous evolution of [a] process" (Epstein 1990, 54).

Motion and trajectory in animation are used very effectively in fields in which the viewer must understand a specific continuous action or be able to visualize objects as they appear in real life. For instance, in engineering, "where . . . rotation or portrayal of three-dimensional objects are involved and required, the use of animated graphics . . . has been found to be appropriate and is recommended" (Asoodeh and Clark 1993, 33). For example, an animation illustrating an offshore oil spill would be considered a process animation if the animation showed the continuous flow of spill, the speed, and the shape changes. This animation would show the constant movement and the process that the spill experiences from the initial point of spillage to when the oil eventually settles or is removed. A process animation such as the above example of the oil spill illustrates at least two dynamic characteristics—time (from moment of spillage through time to the settlement or cleanup) and attribute (the oil is the variable and is represented by a symbol that constantly changes size, shape, motion, and trajectory) —while space may be dynamic or static in this case.

Characteristics of Process Animation

The previous classifications include a combination of static and dynamic characteristics. In fact, in identifying the characteristics of the time-series, areal, and thematic classifications, the dynamic nature of one of the characteristics defines the classification to some extent. For example, with time-series animation, the significant consideration is that time is dynamic, while space and attribute are static. Space is dynamic (while time and attribute are static) with the areal animation. Attribute is dynamic, space is static, and time is either dynamic or static (depending on the specific dataset or purpose) in a thematic animation. With process animation, all three criteria may be dynamic, with none of the three more significant than others in defining this category of animation. Figure 5 illustrates the dynamic nature of all three characteristics.

Dynamic Time A process animation visualizes processes or concepts occurring and/or changing over *time*. As a result, according to the classification structure identified in this article, dynamic time is a characteristic of process animation. The time may be measured as part of a spatial database (population migration over time, for example) in which time data are recorded for phenomena. Or time may be part of a developed theory that is illustrated through a process animation. For example, while continental drift is a generally accepted theory, specific data were not recorded at given times as the process occurred; thus, a compiled dataset that includes dynamic time is not represented. As a result, process animation would not necessarily be employed to visualize the dataset; rather, it would be employed to visualize a theoretical process (in which time is a factor in the theory development).

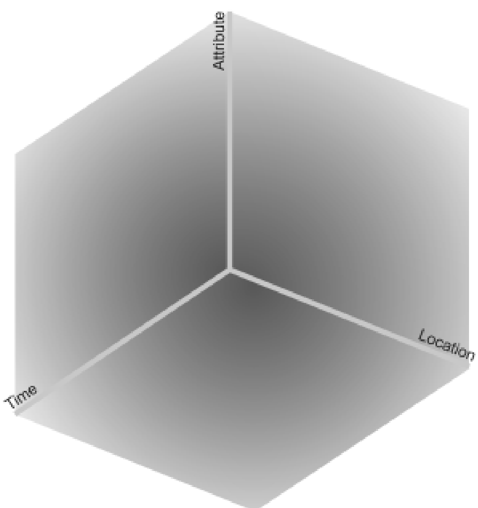

Figure 5 *Process animation criteria axes.*

Dynamic Variable As discussed above, a variable is dynamic when the symbol designed to represent an attribute changes its quality through time. With process animations, the variable exhibits continuous (though not necessarily constant) change. Consider the example of the oil spill. The symbol representing the process of the oil spill (the oil moving through and over the water) changes as the motion and trajectory of the spreading oil changes. Or imagine spilling a glass of water onto a blue and white tile floor. The water may flow over the tiles as a single puddle or may separate into different puddles, depending on the obstacles encountered over the course of movement. The number of variables should not necessarily factor into the classification. A single (albeit changing and dynamic) variable may be included in a process animation, or the symbols of several different variables (again dynamic) may represent different data. In addition, the variable data may be qualitative or quantitative. However, in the case of a process animation, the variable does not change to represent differences in magnitude at a given location (a growing graduated symbol or changing value of a hue), as would be seen in a thematic animation. Instead, the dynamic nature of the variable shows change, spread, or trajectory of a process.

Dynamic or Static Space In a process animation, space may be static or dynamic. The base map may be fixed while the action of the process is represented on it. Alternatively, the viewer may be granted control over zooming or panning around the map as the process plays out on the base map. The cartographer may also create the animation as a presentation animation and control the panning, providing base-map-shifting as the process changes course or the action intensifies from location to location.

Construction and Application of Process Animation

This type of animation, which emphasizes movement, is very different than previously discussed applications. Relative to the other three animation methods, process animations, which visualize motion and trajectory, may be considerably more complicated to construct, even given improving and more user-friendly animation software. Constructing this type of animation often involves combining characteristics of area, variable, and time. Since movement is an intrinsic factor in process animation, the base map may be constantly changing, as in an areal animation. In addition, this areal change is compounded by chronological change—which is the key factor in time-series animation—to produce areal change through time.

Geographers can use process animation to help explain continental drift, stream meandering, or any other spatial phenomena in which depicting movement over time is an intrinsic part of understanding the phenomena. Process animations may be considered to represent reality more closely or to be more like a film when viewed. Using process animation could represent an accurate interpretation of the behavior of the attribute; the viewer might be able to visualize the entire spread of a phenomenon or a theory or process.

Conclusion

The classification system discussed above offers a possible method for determining an appropriate animation that may be used to visualize a given dataset or theory. To apply the classification system and to work through the decision-tree diagram, a geographer should, ideally, possess a clear and complete understanding of a dataset's characteristics. Before implementing the decision-tree diagram, the geographer should consider the dynamic and/or static nature of time, variable, and space in their dataset. The summary chart in Figure 6 provides a succinct view of the data characteristics of each method.

Animation Method	Characteristics					
	Time		Variable		Space	
	Dynamic	Static	Dynamic	Static	Dynamic	Static
Time-Series	X			X		X
Areal		X		X	X	
Thematic	X	X	X			X
Process	X		X		X	

Figure 6 *Summary chart.*

An effective animation is a useful animation. This data display offers geographers an alternative to traditional display and research methods. Although animation is presently used by many geographers as a way to enhance still images, it can be used for so much more than merely enhancing these images. "The appealing feature of [animation] . . . is not only the capability of showing surfaces from different viewing points but also the ability to show change through time in a way that is more powerful than the creation of a series of static maps" (Moellering 1980, 67).

Animation may continue to gain popularity as a display tool for geographic data, which will further the development of improved technology and design techniques. Just as geographers realized the research potential of geographic information systems and remote sensing, the desire to keep current technical research as part of our science will provide the impetus for geographers to continue to explore technological research methods. This movement may allow researchers to realize the possibilities of animation and take a leading role of incorporating it as a bona fide scientific research method. For example, a geomorphologist may wish to test their new theory of landform development. Since many landforms develop over the course of thousands or millions of years, it may not be possible to view the entire theory at work through field observation. Instead, an animation illustrating the theory may allow the geomorphologist to ascertain the theory's strengths and weaknesses, leading to modification and improvement in the geomorphic theory. While it may still not be possible to observe the theory in the field, the animation may allow the scientist to "see" a simulation of the theory in action and determine which specific parts of the theory may or may not actually work.

This method may also be used to search for theories, rather than test existing theories. For example, an urban geographer studying the intraurban migration of various socioeconomic groups may create a time-series or a thematic animation for a given time frame. The resulting animation might lead the geographer to discover socioeconomic migration-pattern variations that were previously undetectable through viewing static maps or data tables. Cartographers can use animation as a tool for searching out the most effective map design before production (Lavin, Rossum, and Slade 1998). Or animation can provide a visual first look at remote-sensing imagery, possibly allowing a scientist to see patterns or change that may be difficult to discern from static images (Harrower 2001).

Finally, animation has become such a popular spatial-data display method that GIS and remote-sensing software packages are offering the capabilities of animation creation. However, funneling a mass of different datasets through the same default animation commands may not necessarily result in the ideal animation being created in each instance. Even if the classification scheme presented above is not the one employed to select an appropriate animation method, determining the characteristics of the dataset as well as the mapping purpose will aid in developing the animation that most effectively represents the data or theory. The categorization presented above allows geographers to identify an appropriate type of animation based on the characteristics of their datasets. An animation is most likely created to represent data. Just as a cartographer selects the most appropriate thematic-mapping method based on the spatial data to be mapped, the geographer should ideally be familiar with their dataset and know their mapping purpose before selecting an animation method. ■

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