# CARTOGRAPHIC ANIMATION AND LEGENDS FOR TEMPORAL MAPS: EXPLORATION AND OR INTERACTION

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## Abstract

Temporal cartographic animations are increasingly common. For users to understand a temporal animation, they must not only apply an appropriate spatial knowledge schema that allows them to interpret relative geographic location, they must also apply an appropriate temporal schema that allows them to interpret meaning inherent in the sequence and pacing of the animation. Similar to static maps, then, the animated maps should be accompanied by a legend that prompts an appropriate schema. However, with animation, the legends function, not only as an interpretation devices but also as a navigation tools. This paper describes potential legends for temporal animation and argues that choices among them should be made with regard to the nature of the temporal data. A test is proposed to assess the viability of the different legends.

## Introduction

In today's world of spatial data handling, visualization requires an interactive and dynamic environment. The cartographic animation plays a prominent role here, and can be used not just to tell a story or explain a process, it can also reveal patterns or relations which would not be clear by looking at static maps. The cartographic animation is often categorised into temporal and non-temporal forms. The last is used to explain spatial relations by presenting individual map images in a logical sequence. The temporal animation is used to display world time in a temporal sequence, especially to display and explore the increasing varieties of spatio-temporal data sets becoming available. Temporal animation has some interesting advantages over traditional static temporal maps or map series. In particular, it offers scientists the opportunity to deal with real world processes as a whole.

This paper presents a conceptual approach to possible legends for temporal cartographic animations. The approach focuses on matching legend styles to the context for map use. Specifically, we argue that there are different aspects of spatio-temporal data that use of visualization might be focused upon and corresponding differences in kinds of spatio-temporal queries that visualization interfaces in general, and map legends in particular, must support. Legends for temporal maps serve a variety of roles (as they do for non-temporal maps). Among these roles is to suggest an appropriate knowledge schema for interpreting information presented. For animated temporal maps, legends can also become a vehicle for dynamic control of the animation. As such, they suggest schemata for framing spatio-temporal queries (and may also discourage use of alternative schemata).

The approach to legends for spatio-temporal maps that we develop leads to a variety of questions that call for empirical research. The paper concludes, therefore, with a proposal for a usability experiment designed to assess the general approach to temporal legends developed.

## Spatial data and temporal animations

Cartographic animation is about change, change of spatial data’s components. Animations can depict change in space (position), in place (attribute), or in time. Their real power, of course, is to show the interrelations among these three components ( see figure 1).

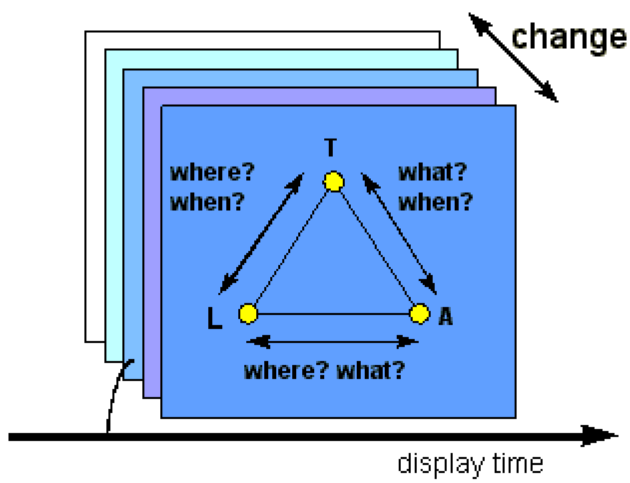


*Figure 1. Interrelation between spatial data’s components and the animation frames.*

Temporal animations show change of spatial patterns in time. In these animation, a direct relation between display time and world time exists, and a transition between individual frames implies change in the spatial data’s locational and/or attribute component. Display time can be described as "representational-time", as refers to the moment a viewer of an animation actually sees the images. World time is "real-world"-time (time units can be seconds, weeks, years, etc.), referring to an event that take place. Examples of temporal animations are those of the Dutch coastline from Roman times until today, boundary changes in Europe since the second World War, or the changes of yesterday's weather. Temporal animation can also deal with time aggregates, such as the display of weekly or monthly cycles.

Animations cab have a narrative character. They often tell a story (Monmonier, 1990). The flow of the story can be influenced by application of the dynamic variables (MacEachren, 1995. Most prominent of these variables are duration and order, which have a strong impact on the animation's narrative character. They define the time an individual frame is visible, as well as the order of the frames. In case of a temporal cartographic animation order presents the viewer the link to world time.

For the user of a cartographic animation it is important to have tools available which allow for interaction while viewing the animation (Monmonier & Gluck, 1994). Seeing the animation play will in most cases leave the user with many questions of what he/she has seen. Just a re-play is not sufficient to answers questions like 'What was the weather in the north-west at noon?', or 'On which side of the city did the tornado strike'. Most general software to view animations already offer facilities such as 'pause', to look at a particular frame, and '(fast-) forward' and '(fast-) backward', to go to a particular frame. Dynamic temporal legends, as will be explained in more detail below, can add significantly to a users ability to interact with the animation.

Temporally dynamic maps, as described above, can be classified on the basis of the structure of the temporal data being viewed. One such characteristic of data is whether the information is linear or cyclic in structure. This is both a philosophical and pragmatic distinction. Information of a linear temporal structure changes steadily or chaotically, as observed. Information of a cyclic nature, on the other hand, is related to perceived temporal patterns. Weather forecast maps, like those seen on television, provide examples of both types of data. On a synoptic (continental spatial and week-long temporal) scale, features such as air masses, warm and cold fronts, and upper-air winds change and progress in linear time: such parameters as speed and intensity of these large-scale features would show no regular periodicity (more technically, no peaks in their frequency spectra). However, other important features such as temperature patterns, fog areas, and surface winds have very periodic (most often diurnal) patterns. What are the most effective ways of portraying the temporal variable of these different types of phenomena? Might we find conclusive evidence that one type of legend is more appropriate for cyclical than linear phenomena?

Another characteristic of spatio-temporal data that might have an impact on the optimisation of the legend is the phenomenon's temporal regularity. This is analogous to the cartographic problem of finding ways to represent irregularly distributed spatial data (e.g. point observations) of continuous phenomena. In animation, it may be important to make the viewer aware of the fact that the information presented occurred or was collected at irregular time intervals. In the examination of certain types of spatio-temporal phenomena, a researcher might vary the temporal detail through the animation. For example, pollution measurements of a water body might be taken twice monthly during the summer months, but only once monthly during the winter. In medical applications, temporal frequency might go up during a certain critical event, like an outbreak of measles in a community. Thus, an indication of the real world location in time must be complemented by an indication of the animation's (potentially variable) real-world temporal frequency. It is perhaps this type of situation in which a sonic legends (or a sonic supplement to a visual legend) have the greatest advantage (Krygier, 1994).

In data exploration tasks, it may be useful for the viewer to observe an animation of spatio-temporal information in non-temporal as well as temporal order, an analysis method that DiBiase, et al. (1992) term re-expression. Order is considered by MacEachren (1995) to be one of six fundamental dynamic variables for animated maps; placing a time series in a non-temporal order can reveal trends that are otherwise hidden. For example, by placing monthly frames of an animation in order of model prediction variance (rather than in chronological order), DiBiase, et al. (1992) showed that the most significant variation in model prediction variance occurred in the spring

months (during the planting season). This important aspect of the model's output would have been missed if the order had not been transformed. We hypothesize that, for this type of exploratory analysis, some temporal legends will afford greater clarity than others. This hypothesis is based on an assumption that different styles of temporal legends will differ in their ability to help analysts adapt a knowledge schema developed for understanding change (in location or attributes) across time to one that deals with change (in location or time) across an attribute sequence.

## Legend types

Animated maps need a legend, just as any other map. Part of this legend has to explain the meaning of the map symbols used in each individual frame. However, the part of the legend that explains the animation's temporal component can have a dual function: it tells the time and lets you travel time (figure 2). The first function links display time to world time. The second function allows the user, within the limits of the time-scale, to manipulate various aspects of time, including: moving to a particular point in time, specifying a period in time across which information is aggregated, or selecting the temporal resolution at which information will be examined.

The combination of legend as an interpretation device and an interface control tool allows the user to answer questions related to the existence of an entity (if?), the temporal location (when?), time intervals (how long?), temporal texture (how often), rate of change (how fast?), and its sequence (what order?) (MacEachren, 1995). These kinds of queries range from binary choices (if something exists at a particular time or not) through queries of information at the ratio level (the speed of an object through space) - see figure 3).

The choice of a legend form depends on the nature of the spatio-temporal phenomena displayed by the animation, the nature of the temporal queries that users are expected to make, and the knowledge schema concerning spatio-temporal entities that we are trying to prompt (e.g., time as a line versus a cycle, space-time as a volume versus space as a volume with time as an attribute of that volume).

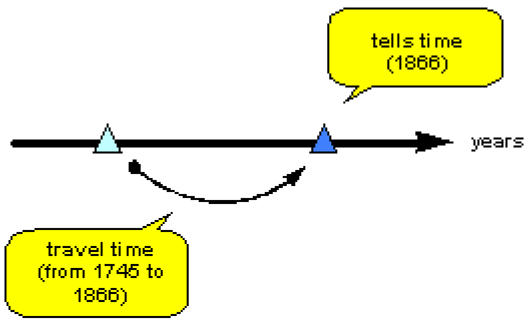


*Figure 2. The two main functions of the legend of a temporal animation illustrated in a linear time-model.*

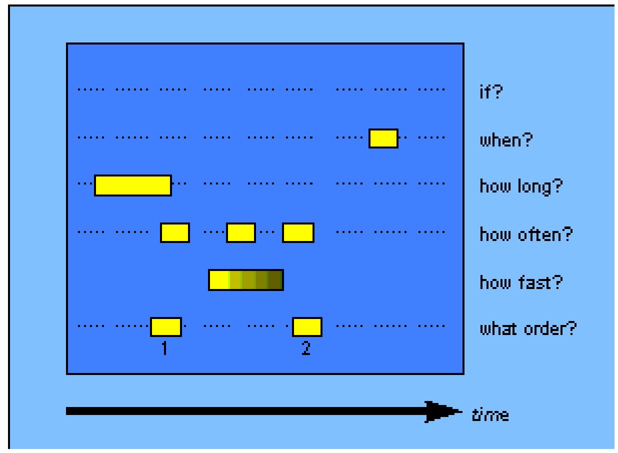


*Figure 3. The type of queries to answer when the animation's legend properly combines the 'tell time' and 'travel time' functions.*

For temporal animation, two major legend types can be distinguished. In a direct transfer from static maps, the legend can appear in a visually separate display area (window). The dynamic nature of animation, however, also allows for legends that are visually or sonically embedded directly into the map display (see figure 4).

With legends in windows, three sub-categories can be identified: an analogue clock in which location in time is represented by the orientation of a dial or hands, a slide bar in which location in time is represented by a marker on a line that depicts the time span of the animation, or through numbers that represent time in discrete units.

Indication of time by numbers is precise but the user has no idea of the total time scale or position within a cycle and interaction is difficult. In addition, numerical legends will probably distract viewers from the main display more than any other legend type. However, numbers might be suitable in combination with either a bar or a clock.

A round clock or clock-like legend is very suitable to explaining cyclic time, such as the day and the seasons. Legends modelled on clocks, as with real clocks, will generally depict one cycle of time that may be repeated many times across the time span of an animation. Thus location within the temporal cycle is clearly depicted, but location in the full time span may not be.

The slide bar is suitable to explaining linear time, such as the progress of an oil spill as it spreads and shifts location over time. The full temporal scale is visible and it can be easily interacted with. Repeated cycles are less easily shown. For both the clock and slide bar, the notion of past, present and future can be depicted. Past is signified by filling/colouring the area which has past, present is represented by a sign-vehicle indicating the boundary between past and present, and future is represented by the unfilled area. When the present is a time aggregate rather than an instance in time, the width of the boundary between past and future can depict the time period across which aggregation takes place. All three visually separate legend types are likely to be distracting since the user has to look at two 'views'.

Embedding the legend visually or sonically within the map has the potential to avoid the problem of dividing a user's attention between two competing views. Visually, the notion of time can be represented through periodic changes to the background or map symbols (e.g., the screen dims slightly at "night" and brightens during the "day"). As with numbers, sound might work in combination with the clock or slide bar. Narrative sound can be used to signal "dates" in time. To represent the passing of time, however, more abstract sonic sign-vehicles are more useful (e.g., a repeated tone the frequency of which indicates how rapidly time is advancing in that portion of the animation). Sound can "tell" the time, but control of time through sonic input is quite difficult to realise (although spoken controls are increasingly possible as voice recognition software becomes more widely available).

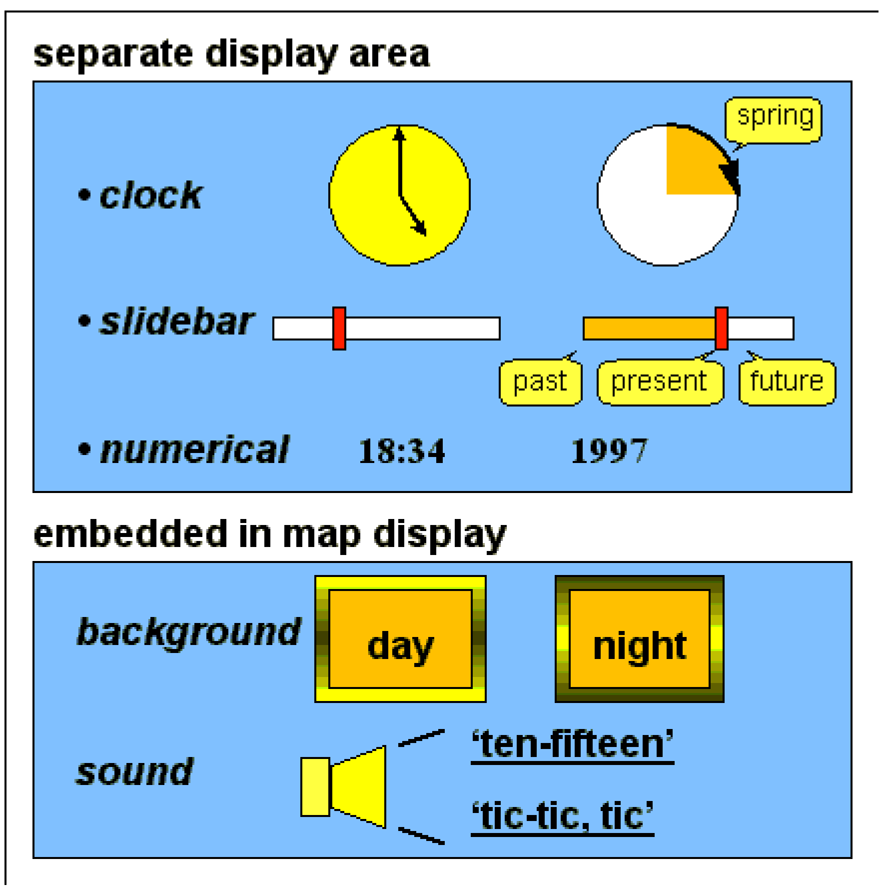


*Figure 4. Classification of potential temporal map legends.*

This context-driven conceptual approach to dynamic map legend design remains untested. The next step in our research is to assess its viability by employing a task-based human-subjects approach in which performance in dynamic map interpretation using alternative legend designs will be compared. The theoretical underpinning of the logistics of such an experiment are not trivial. Here, we offer some ideas for an empirical assessment of these and related topics.

In a review of cartographic design experiments, Petchenik (1983) calls for, among other considerations, "naturalistic" design research in which the subjects tested are shown real-world examples of the maps under assessment, rather than "test" maps which isolate the variable to be studied in some artificial or forced way.

This is particularly important in our research, where the goal is to inform the design of maps for exploratory visualization purposes, where context is so essential. Our choice of phenomena (as well as different legend designs) to be presented to subjects, therefore, is a key consideration. Dynamic map applications shown in the experiment will be chosen to be particularly illustrative of the contextual applications of structure, regularity, and order, as explained above. For example, test animations may show meteorological model output (regular temporally, with both linear and cyclic phenomena), historical land-use data (irregular temporally), and the Mexican climate model output described above (in non-chronological order).

Another important consideration in map design research is the identification of the experience of the subjects with the maps tested. Distinguishing between "experts" and "novices" might reveal important differences in design according to the maps' potential uses. Because we will have difficulty (for this experiment) finding a significant number of experts in cartographic animation, we may choose as one of our test maps a weather forecast map (very much like those on television) a map type for which otherwise novice subjects have some expertise because of their familiarity with this

type of presentation. For other less familiar applications, most subjects will be considered novice users of cartographic animations.

It is proper to assess the efficacy of the temporal legend not only according to the potential application, but also according to the task at hand. In an experiment by DeLucia and Hiller (1982), which focused on the role of legends in understanding static maps, questions were asked which led subjects to not only acquire data from the map but also visualize the environment on the map. Their experiment showed that a "natural legend", which showed (in their specific case) hypsometric terrain shading on schematic mountain, rather than in the "standard" legend boxes, enhanced subjects' ability to visualize the landscape, but did not aid in more specific data acquisition. MacEachren (1995) suggests that this experiment demonstrates that maps in general -- and legends in particular -- prompt users to see, organise, interpret, and interrogate the information presented through the use of schemata, cognitive methods of distinguishing between graphical stimuli. Specifying terrain using a symbolic pictorial representation prompted appropriate schemata for map interpretation in DeLucia and Hiller's subjects. With carefully chosen questions, similar analysis might be possible with symbolic pictorial representations of time (like clocks or timelines).

Although our goal is to evaluate representative legend styles from the typology outlined above, it is possible that for certain animated map applications, a legend is not only redundant and unnecessary but perhaps distracting and confusing, a pitfall described by Campbell and Egbert (1990). Thus, map use with and without temporal legends should be compared as part of our investigation.

## Conclusion

An experiment to investigate optimal temporal legend design is presently being planned and constructed. It is designed to fit into the conceptual framework of temporal animations described herein. We will assess different legend forms in different use context in an effort to develop guidelines for appropriate matches between legend style and intended use (and users).

The above description of the proposed experiment serves to demonstrate that the investigation of this type of map design question must be carefully and deliberately considered. This experiment proposal thus serves not only as a specific outline of our upcoming test, but also as a guide for conducting empirical research on similar questions.

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