PERCEPTION OF TIME VARIABLES ON DYNAMIC MAPS

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Abstract. In recent years we have seen a variety of small dynamic maps in electronic media. The increasing use of the Internet and WWW has played a major role in the dis-semination of interactive map applications and animations. These applications often includes phenomena that have a temporal dimension. While the animation itself is well visualized, the information about the point of time may be “hidden away” in a corner of the presentation. This paper focuses on the visualization of the temporal dimension itself. Some proposed methods are tested on an audience.The methods that are based on per-ception of the “time information” by the peripheral sight seems promising.

Key words: Dynamic maps. Interactive maps. Temporal dimension. Visualisation.

1. Introduction

The increasing use of the Internet has opened a new category of small applications that handle geographic information and map data. These are mainly small applications which solve very spe-cific problems. Many users of the Internet have little or no skills in the field of geographic infor-mation systems. Consequently the applications must have a very simple user interface to make them easily understandable for non-professionals (Midtbø, 1997).

On an ordinary or "static" paper map, time has been an issue for hundreds of years (Vasiliev, 1997. In later years research has focused on spatio-temporal data models and management. In the visualization of these data, the temporal dimension has to be taken into consideration. Computer technology and dynamic maps open new methods for these presentations. This, and the fact that the World Wide Web paves the way for numerous small map applications which are accessed by people without any technical qualifications in the field of cartography and maps, results in a demand for easily perceptible presentations of the temporal dimension.

The methods that are explored in this paper are based on the assumption that a wide audience should understand the resulting map application. Equivalent methods can be used in more com-plex combinations when the presentations are for expert users (Krygier, 1994). Various authors have looked on how to visualize time-series data. Monmonier (1990) proposes the temporal brush, which is a kind of scroll-bar for the temporal dimension. Peterson (1999) discusses active legends for interactive cartographic animation, and states the importance of breaking loose from paper-based thinking. Temporal map legends are explored further in Kraak et al. (1997), where the legends are classified as embedded in the map display or are shown in a separate area. This paper uses the term temporal variable when the temporal dimension is illustrated, and the term main (or principal) phenomena for the objects that are the main theme of the map. The paper focuses on the situation where the temporal variable is presented simultaneously with the princi-pal phenomena. Some experiments, with animations including the temporal variable, are evalu-ated by a “test-panel”.

2. Time as a Variable on the Map

Time is a dimension that is difficult to define, because each person has his/her individual percep-tion of time. In the field of psychology there is of course a lot of literature on how people per-ceive time. Block (1990) writes that psychological time consists of three major aspects: **successio**n, **duration** and **temporal perspective.** These are the results of psychological studies of how a human perceives time. It will be a natural consequence to take this knowledge into con-sideration when time is illustrated on a dynamic map. Each human has his/her own temporal per-spective. Consequently it would be useful to know if individual humans have common reference systems in their perception of time. Variations caused by the Earth's position to the sun are of course major elements.

According to Bertin (1981) only one variable, in addition to the position, should be presented on a thematic map when the aim is to make a "seeing map", or in other words; keep the perception of the contents on a global level (Bjørke, 1997). On an interactive map, where a phenomena changes over time, it is essential to include a variable that shows the point of time for the present phenomena. Consequently the temporal variable has to be presented in parallel with the main phenomena we want to show.

Kraak et al. (1997) point out two major types of legends for temporal animation. The first is leg-ends in a separate display area, where they identify three sub-categories: analogue clock, slide bar and numerical. The second is embedded into the map display. They show background colour and sound as examples in this category and use the term "legends for temporal map". This term can be appropriate in the description of the first category. However, some of the methods that is evaluated in this paper show how the presentation of time is built together with the principal phe-nomena in a way that it can be discussed if it is a legend, or that it should be considered as kind of variable. The main issue is to harmonize the variables on the map in a such manner that the map reader perceives the information on the map, and simultaneously knows the point of time for the situation. The first bit of information must not drown the other - and vice a versa.

A paper map made for perception on a global level should mainly answer the question: "where is this phenomenon". In an animation we also want to answer the question: "what time is the phe-nomenon existing". Our aim is to maintain the perception on a global level. Keates (1982) describes the human eye/brain capacity in the perception process. The cones, which are sensitive to differences in wavelength (colours), are mainly centred around Foeva and have a "direct con-nection" to the brain. These photoreceptors cover a small sharp-sight area, while the second type, rods, cover the peripheral-sight area. The rods will respond to small changes in intensity (value), but are insensitive to differences in wavelength. In the light of this it can be concluded that leg-ends with changing colour in the periphery of the animation should be avoided. The use of changing legends or local animations in a separate display area will in most cases reduce the level of global perception. Ideally the change in time should be perceived without moving the glance away from the main phenomenon.

In Midtbø (2000) methods for the presentation of the temporal dimension are classified as *active legends outside the main presentatio*n, as *active legends within the main presentatio*n, *as an over-all animation* and as *imparted by soun*d.

This classification is somewath different from Kraak et al. (1997). To keep the global level of perception, both the presentation of time variables and the presentation of the main phenomena should be based on the visual variables of Bertin (1981) (location, size, value, texture, colour, orientation, shape). In such an interactive map animation, it is important to choose visual varia-bles in a way that they do not confuse the map reader. Consequently the visual variable for the temporal dimension has to be distinct from the visual variable for the main phenomena. It will for example be very confusing to let a growing bar represent change in time, while change in the main phenomena is represented by growing/shrinking bars.

3. The Evaluated Methods

In Midtbø (2000) several methods within each class are presented. This paper discusses some of the proposed methods in the light of some experiments. From the category *active legends outside the main presentatio*n, which includes methods as local animation, text-string and alternating icons, the two first methods are chosen for further evaluation.

- **Local animation:** Several local animations can be constructed on the basis of Bertin's (1981) visual variables. However, since suc- cession is an important factor in the human perception of time, a consequence is to choose variables with ordering qualities. The duration of events and intervals between events may be pointed out by selective varia-bles. The analogue clock falls into this cate-gory. In our example a growing bar is used to indicate the point of time (Figure 1). The growing bar involves both the variable size and the variable location.

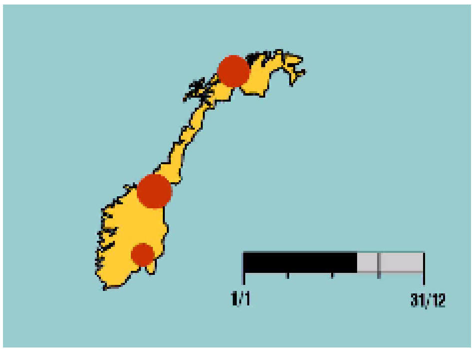

Figure 1: The growing bar

- **Text-string:** Point of time is represented by a number, word or text string that changes when the point of time changes. A digital clock repre-senting 24 hours, or the name of the months rep-resenting a year are typical examples. This method is definitely the most used method for presentation of the temporal variable. In most small dynamic maps on the Internet, where time is a variable, the point of time is visualized as a

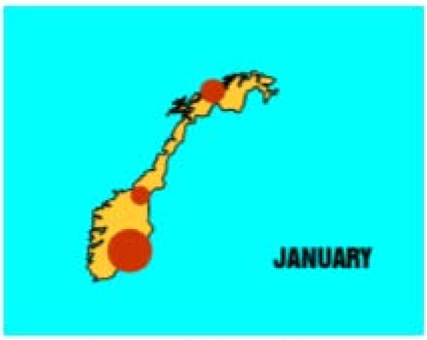

Figure 2: Text-string

date, month, digital clock etc. Often printed by a small font and "hidden" in a corner of the pres-entation. In our experiments both small and large fronts where tested.

On a thematic paper map, with a global level of perception, the user gets an immediate impres-sion of the map before he/she studies the legend (MacEachren, 1995). On an interactive map, or map animation, the temporal variable changes during the presentation. It is a matter of course that the variable is self-explaining and easily understandable for the map reader. However, when the temporal variable is presented in a separate area outside the main presentation, and both the temporal variable and the main phenomena change, it may be difficult to keep the perception on a global level. To make this possible, the temporal variable has to be perceived by the peripheral-sight. As a consequence of this, colours in the temporal variable will make a poor contribution to the comprehension of an active legend outside the main presentation

When the entire map is in focus the active legend should have a central location, and when a cer-tain area is investigated the legend should be close to this. To improve the simultaneous compre-hension of the temporal variable and the main phenomena, the active legend can be located in closer connection to the main presentation. In the category active legends within the main pres-entation, Midtbø (2000) proposes methods as movable legends, multiple legends and incorpo-rated legends. This paper examines another method in this category; an enclosing legend.

- **Enclosing legend:** The active legend encloses the complete map presentation, or, from another point of view, the map is built-in the active legend. This method is particu-larly well suited for visualization of natural time cycles, like a year, a day etc. In Figure 3 the method is shown by "a satellite" that moves around the map according to the point of time it represents. In other words, the temporal dimension is represented by the visual variable *location.* It is important to design this kind of legend in a way that keeps the map presentation in focus, while the legend is perceived by the peripheral-sight. In Figure 3 the intensity of the dark satellite is perceived by peripheral-sight, while location of the satellite gives information on the point of tim**e.**

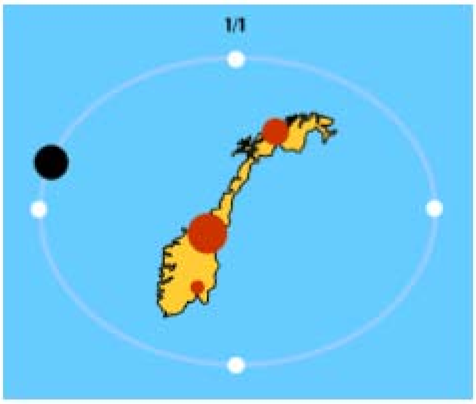

Figure 3: Satellite indicator

The visualization of temporal change can be included more directly in the main presentation, as opposed to the local methods where one or several active legends represent the temporal varia-ble. The aim is still to make a presentation that gives a good comprehension of the temporal change, simultaneously with an immediate impression of the principal phenomena. Again it is relevant to use Bertin's variables as a basis for overall animations, and again visual variables that include ordered and selective properties are important elements in the attempt to connect the vis-ualization to human perception of time. Above all; value, size and location meet these require-ments. Midtbø (2000) proposes the methods: alternating value, "the growing map" and "the gliding map" as examples on the temporal dimension visualized by overall animation. The last of these methods are involved in the experiments described in this paper.

- **"The gliding map":** By this method the location of the map itself in the display area denotes the point of time. When using a local animation, the eyes have to shift between the main presentation and the active legend during the animation. By using a "gliding map", the map itself is inte-grated in the description of the temporal dimension. In Figure 4 the map moves along the line, and the situation on the map corresponds to the present time along the line. The intention is that the eye will focus on the map itself all the way, while the loca-tion in the display is perceived by peripheral sight. As stated earlier in this paper, in some cases time will be described by repeating cycles due to natural phenomena and the calen-dar made by humans. For example may a phenomenon that changes during a year be pre-sented in a map that moves along a circle. In our experiments both maps that moves along a line and maps that moves along a circle are evaluated.

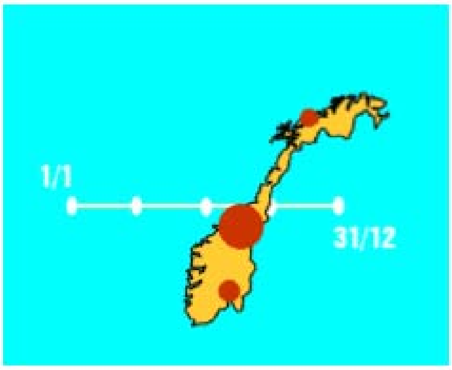

Figure 4: Gliding map along a line

4. The Experiments

The four methods described in Section 3 were involved in some small experiments. The objec-tive of the experiments was to get some indication on how well the temporal dimension could be perceived by an audience. A number of animations were made based on these methods. All of the animations show a map over an imagined phenomenon that changes through a year. The maps were made as animations without the opportunity of any interactive operations. The intention was to give the test persons a limited view of the situation to see if they could catch the informa-tion on the temporal variable. All the animations were made in Corel R.A.V.E., and presented to the test audience by Macromedia Flash files (.swf) through HTML and a web browser.

The animations were presented for 19 students in an auditory. In advance they had got a ques-tionnaire where they for each animation should indicate the point of time for a specific occur-rence in the map. They should indicate the month and the quarter of the year of the occurrence.

First a series of animations where the dynamic variable; *display date* (MacEachren 1995) was used to represent the principal phenomenon. The object, which in fact was a circle, popped up and was visible in "one month" of the animation. The *gliding map along a line*, *the growing bar*, *the text-string (large font)* and *the "satellite indicator"* were each presented in different speed. Slow speed (approx. 3 seconds), medium speed (approx. 2 seconds) and fast speed (approx. 1 second). The audience was told that the animation could start "any time in the year" and end up "one year later". The animations can be studied on *http://www.geomatikk.ntnu.no/prosjekt/tem-pvisual/pop.html*. The assumption was that legends outside the main presentation would be less perceivable at fast speed. That is because these methods require more eye movement

Because only 19 person where involved in the test, it may be inexpedient to use advanced statis-tical analysis on the result. However, to get some indication on the perception of the temporal variable a simple calculation of points was accomplished. The choice of the exact month was weighted 1.0, the neighbouring next and previous months where weighted 0.8, then 0.6 etc. A miss on five months or more gave no contribution. Neither did the “no idea” option witch was available in addition to the twelve months. Table 1 shows the results from the experiment.

	Text-string	Growing bar	Satellite	Gliding map
Slow	16.6	15.2	14.8	(16.3)
Medium	12.6	15.4	16.6	(12.9)
Fast	7.8	11.6	14.4	(15.4)

Table 1: Results from the test

We can read from the table that the text-string has got the best score at slow speed. That is partly because the eye is able “to follow” the text at this speed, but also because the text-string gives an exact statement of the point of time. In the other methods the exact point of time had to be inter-polated from the graphics. Information given in the text-string become less perceivable when the animation moves fast. The same tendency appears for the growing bar, while the satellite indica-tor seems to better suited at fast speed. The results for the gliding map is not quite comparable to the others, because this animation was a little bit slower than the other ones (heavy animation –slow computer).

In the first series of animation the display date variable was used for the principal phenomenon. That makes it possible for the audience to focus on the legend, while the pop-up circle was per-ceived trough the peripheral sight. To avoid this another series of animation involved the dynamic variable; *rate of change*. Three different cites on the map were represented by a growing/shrinking circle. The audience was asked to study one of the cites and note when the circle reached its maximum (or minimum). The animations can be studied at http://www.geoma-tikk.ntnu.no/prosjekt/tempvisual/size.html.

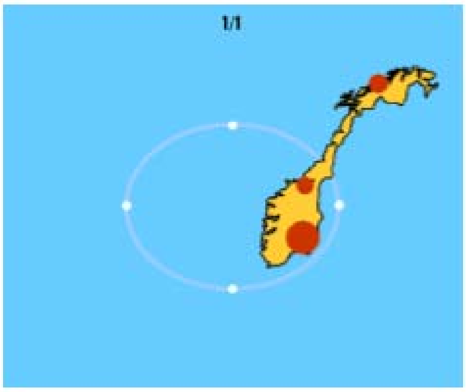

Figure 5: Gliding map along a circle

The results from the second series of animation showed no distinct difference from the first series. Our assumption were that the legends outside the presentation would be less perceivable when the eyes were forced to focus on the main phenome-non. The result gave no indication on this. How-ever, some interesting observations were made concerning the gliding map. Some of the anima-tions included a gliding map along a circle. The animate map covered Norway, and one site in the north, one in the middle and one in the south was visible at the map (Figure 5). The test results for this method gave the lowest score of the experi-ment. But Norway is a long country, and when the centroid of the map was gliding along the circle, the cites in north and south were closer to another part of the circle. The test result indicated clearly that it was the position of the cite relatively to the circle that was important when the point of time was stated, not the position of the map itself. Another map where the cite of interest followed the circle more closely gave much better results for the gliding map.

These small experiments give a weak indication that a large, and maybe enclosing legend can be well suited for the representation of the temporal variable. This legend will be perceived by the peripheral sight. However, more extensive experiments need to be carried out to make a final conclusion. In further experiments it would also be interesting to study how various kinds of sound variables could represent the temporal dimension.

6. Conclusions

Methods for presentation of dynamic, interactive maps in an electronic media are still at an early stage. However, the increasing use of small map applications, especially on the Web, has acceler-ated developments. When presenting phenomena that change over time in a dynamic map, a rational visualization of the temporal dimension is essential. Preferably it should be visualized in a way that is in accordance with the general human perception of time. The temporal dimension will somehow act as an extra variable in addition to the visual varia-ble(s) of the main phenomenon. The choice of variables has to be handled carefully. The varia-bles must be in accordance with the presented phenomena, and the temporal variable has to be distinct from the variable of the main phenomenon.

The experiments described in this paper indicate that an enclosing or dominating legend may be well suited for the time representation. This legend can be accompanied by a text-string to give an exact point of time when the animation is halted by an interactive user. The "satellite indica-tor" in our examples is based on representation of the point of time by the visual variable *loca-tio*n. If the main phenomenon includes moving objects, it may be wise to use an active legend for the temporal dimension that is *not* based on *location.*

It is important to design the legend for the temporal dimension in a way that makes a clear con-trast to the background. A poor contrast makes it difficult for the peripheral sight to distinguish the legend.

When using the method of "the gliding map" it will be important to keep the map itself rather small compared to the line or circle it moves along. Otherwise different cites on the map will appear as they exist at different points of time.

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