International Cartographic Association
Association Cartographique Internationale

A time-driven symbology for map visualization

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Keywords: Time-driven map, Spatiotemporal Cartography, COVID-19

Abstract:

The map visualization is a delicate mixture of science and art that conveys lots of geospatial information at a glance. As far as cartography is concerned, making sense of geospatial data is mostly set by color, size, pattern, and shape in a 2D context. In practice, mapping the multi-dimensional complex world into 2D or even 3D maps is facing some challenges. Cartographers often apply certain methods such as generalization, symbolizing, overlaying data layers to simplify these complexities. Available methods for geographic representation often answer the what and where questions about features. On the other hand, map users and analysts might be looking for answering when. In fact, enriching three spatial dimensions with the temporal dimension can make the generated maps more informative and synthetic. The hierarchical structure of granularities in time such as days, weeks, months, and seasons and also its natural cycles and re-occurrences, make time a crucial and distinct dimension. Accordingly, appropriate visual and analytical methods are required to explore and analyze spatiotemporal data (Aigner et al., 2011).

Regardless of spatial complexity, adding time dimension has difficulties. It is traditionally done by creating time frames of geographical space and representing it as a map. Therefore, to grasp the spatial changes of a phenomenon over time, it is necessary to follow these frames in order. Although this technique is simple, depending on the time period of studying a case and the time interval of each frame, it can lead to the production of large numbers of maps that make it tough to analyze them. To meet this challenge, some researches have been conducted. Keim et al. (1995) presented a space-efficient way of visualizing large amounts of multidimensional data. Using one pixel for presenting each data value, this technique proposed a pixel-based representation by a 'recursive pattern'. Tong et al. (2017) developed time-oriented cartographic treemaps. Cartographic treemaps provide users a space-efficient overview of the complex, multi-variate data coupled with the relative geospatial location to smooth the way of data exploratory tasks. Thakur et al. (2010) introduced a single view 3D pictorial representation to visually exploring and analyzing time-varying spatial data. This method was based on the standard space-time cube metaphor.

In the current work, a novel time-driven symbology technique has been introduced to assign temporal meaning to a geographical map. It allows visualization of spatiotemporal variation in a spatial feature property on a static map. In other words, this method provides a space-efficient way of visualizing spatial data in three different time intervals simultaneously on a static map. Therefore, instead of comparing three maps, one can study the dynamics of a particular phenomenon in three time periods in one map and with an overview. This can be a very useful tool in data exploratory or investigation in spatial analysis, modelling, and planning tasks. The most significance of this symbolizing approach is the combination of time and space in one map using colors. The main idea of this approach is derived from the nature of color space. A color can be specified as an RGB value in a three-elements RGB triplet, (r, g, b), that specifies the red, green, and blue components of a single color. A value between 0 and 255 for each component determines the intensity of them to specify a color. All possible colors through this formula are 256 x 256 x 256 = 16777216. Thus, rgb(0, 0, 255) indicates 'blue', because 'red' and 'green' are set to 0, and 'blue' is set to its maximum value. If all parameters are set to 0, producing color will be black. Moreover, rgb(255, 255, 255) results in white. Equal values for each component generate shades of gray. In cartography, color is a vital component to show spatial variation. It is very common to use different shades of one color to show the strength and weakness of a quantity throughout the map. Considering the mentioned properties of colors, proposing approach treats variations of intended property as this shading mechanism for each time period. Therefore, it encodes all possible quantitative values into the range of 0 to 255 for each time period and considers the results as an intensity value in a RGB color component. By putting these components together, the color that should be displayed on the map for each location is obtained. Since color has three RGB components, only three time intervals can be considered simultaneously. Thus, this method is very suitable for the investigation of seasonal changes. Regarding spatiotemporal variation of intended characteristic, the monthly values of each season generate specific colors. Therefore, symbolizing using these time-driven generated colors provides valuable information for the user concerning variation or trends during the examined time. In addition, this method is very space-efficient and avoids eye movements between same places on three distinct maps. As an example of this method, figure 1 indicates proposed map symbology method for COVID-19 confirmed cases during three months from

November 2020 to January 2021 in the United States. The data were obtained from the New York Times[1]. The important point is that in cartography, darker colors generally depict the intensity and high values of the characteristic. In coloring, as described so far, the opposite happens. Therefore, to bring this issue closer to the mental background and not to break the general rules of cartography, the values in the formula were subtracted from 255. Figure 1(a) indicates the proposed spatiotemporal map visualization of the data. Indeed, it contains information on three separate maps that are seamlessly integrated into one map by hashing them into colors. These three distinct maps of each month are shown in sub-figures (b) to (d). These three maps are colored based on their RGB values in the integrated map. Hence, the spatial distribution of COVID-19 cases in November, December, and January were encoded by red, green, and blue ramps respectively. Taking monthly maps into consideration, California, Texas, and Florida are the states with the highest number of coronavirus cases. In addition, California had the highest cases in January due to its darkest color. Regarding each map of January, November, and December cases as Red, Green, and Blue in RGB color components, the color encoded map was obtained (Figure 1(a)). The brighter and whiteish the color, the lower cases in that state during three months. Figure 1(a) shows that the distribution of COVID-19 confirmed cases is almost homogeneous in the central part of the contiguous united states. The brownish color in California and Texas depicts an intensity of blue color, followed by more cases in January. Therefore, it is seen that according to the new method, in addition to spatial dimensions, the time dimension can be added to a static map, which is very space-efficient and helps users to identify the spatial-temporal trend of a phenomenon in a map.

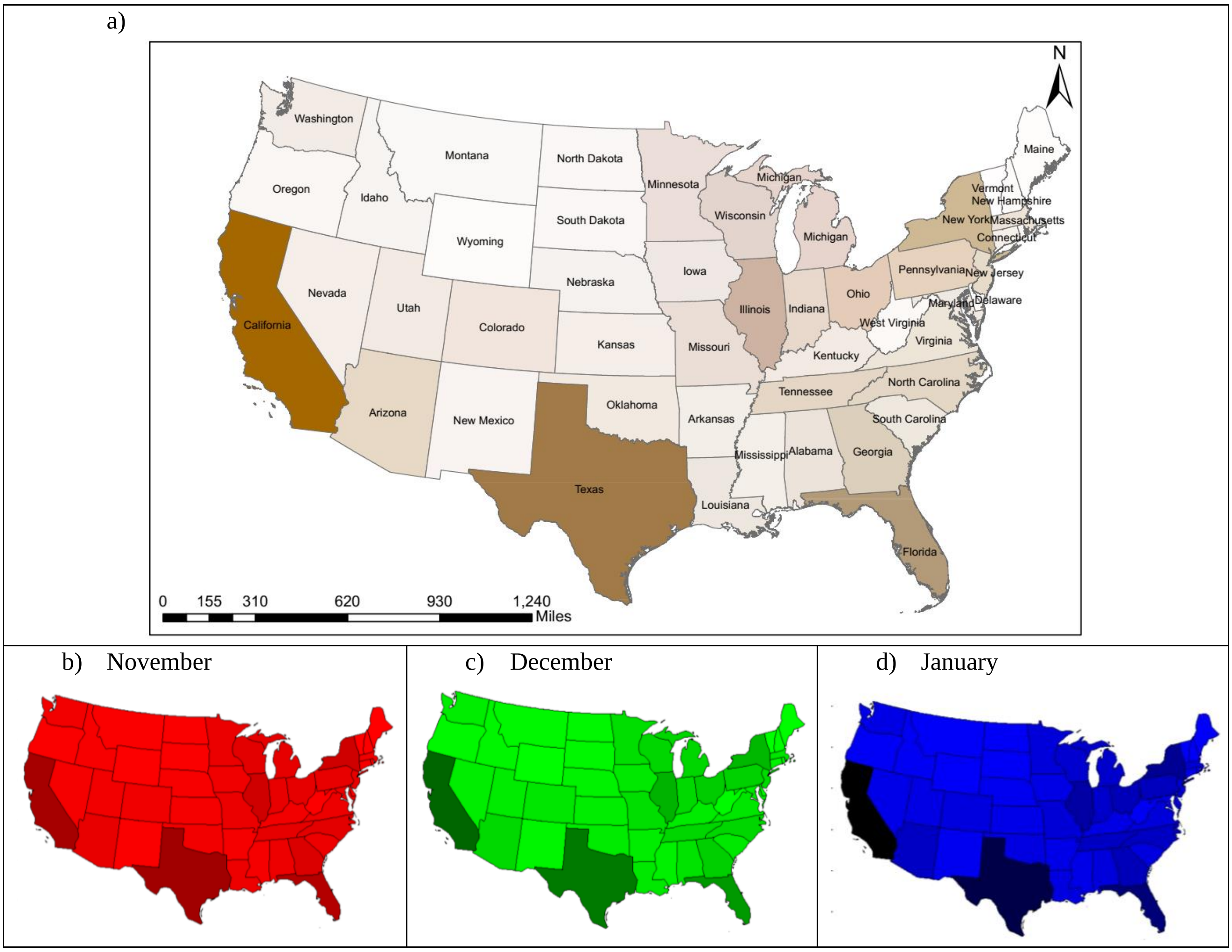

Figure 1. COVID-19 confirmed cases in the U.S. states during three months from November 2020 to January 2021. a) Proposed time-driven visualization for confirmed cases during three mentioned months. b) Confirmed cases in November 2020. c) Confirmed cases in December 2020. d) Confirmed cases in January 2021.

[1] https://github.com/nytimes/covid-19-data