VISUAL ANALYSIS OF TIME AND LOCATION DEPENDENT DATA ON THE MAPS

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ABSTRACT

Advances in satellite end map technology have provided various opportunities such as analysis and interpretation of time and location dependent data. In this study, graphical tools enabling analysis and visualization of this kind of data (temperature values in the last five years for Turkey) on the map have been plotted via texture mapping technique.

KEYWORDS

Time series data; visual data analysis; texture mapping; information visualization.

1 INTRODUCTION

Data are numerical or non-numerical set of research results obtained from various observations by a researcher. Data analysis is the process of collecting, modeling and transforming to another form. Application of statistical methods and techniques in data analysis was a very time consuming process in a period when the computers and software were not in our lives. Today, with the widespread use of computer, the innovations occurring in this area allow the process of data analysis to be made easier.

Numerical analysis of time and location dependent data (temperature, pressure, altitude, etc.) is very difficult. However, how characteristics of these values change depending on the time with the visual effects can be more easily understood and interpreted. Pictures make many things cannot be expressed in numbers understandable to everyone.

Time series graphs are vital importance in different applications of statistics. When recording values of the same variable over an extended period of time, sometimes it is difficult to discern any trend or pattern (the weather, business models, populations etc.) [1]. However, once the same data points are displayed graphically, some features jump out. Time series graphs make trends and patterns easy to spot. These trends and patterns are important as they can be used to project into the future [2]. Analysis of time series data and visualization of them are quite broad subjects. Up till now, various studies have performed for different purposes in different domains.

In this study, we propose an architectural framework composed of services and interactive graphical tools enabling analysis and visualization of spatiotemporal data. The word spatiotemporal conveys the meaning of space and time together. A space on a geographical map may be a location or particular area. Since the space and time together can make more meaningful interpretations, we extend time-value concept by combining it with a geographical map.
The visualization is achieved by means of embeddings of 3-D icons into the map images to represent spatiotemporal datasets. This approach enables integration of time and space dependent attributes through the visualization on maps. This also enables emphasizing the patterns by developing and underlying the linear temporal dependencies. To realize that, texture mapping concept [3] and space time cube metaphor are used. The effectiveness of the proposed system is proven at the end of paper over a test case scenario. In the scenario we use temperature values for Turkey and analyze them on Turkey’s satellite map.

The remaining of the article is organized as follows: Section 2 presents some works related visual analysis of time and location dependent data. In Section 3, architecture is proposed broadly. Section 4 presents application that plotting average temperature value provides’. Section 5 draws a conclusion and suggests some future enhancements.

2 LITERATURE REVIEW:
SPATIAL DATA ANALYSIS ON MAPS

The analysis of time-varying data is an essential subject in the fields of science, engineering, business, and etc. Some visualization methods have been developed for analyzing time series data [4]. Aigner et al. [5] give a survey of time dependent data visualization.

A conventional approach to visualize time varying data is standard space time cube (STC). STC method [6] displays evolutions and positions of object locations. Thakur and Hanson [7] have developed a pictorial representation that is based on the standard STC metaphor and provides in a single display the overview and details of a large number of time-varying quantities.

Another well known technique dealing with time series data is visual exploration of the spatial distribution of temporal behaviors. Gennady and Natalia [8] concentrate on the exploration of changes of thematic properties of spatial objects. Their objective is to find suitable approaches and suggest tools for analyzing multiple spatially distributed time series. Also, they designed and implemented techniques for the investigation of trajectories of moving objects [9] and spatio-temporal distribution of point events [10].

Tominski et al. [11] describe an approach for visualizing spatio-temporal data on maps by embeddings of 3D icons into a map display for representing spatio-temporal data, and an integrating of event-based methods for reducing the amount of information to be represented. Their approach is capable of visualizing multiple time dependent attributes on maps.

In our previous publication, we suggested an approach [12] that time-series data is plotted and displayed as line and bar graphs. When the user wants to plot graph, he/she enters time series data according to the format and sends them Web service by means of proxy class. Image file is created with respect to sending information and sent back to the user. The user can enter time series through interface or perform the drawing for the values registered in the file.
In this study, we propose an architectural framework composed of services and interactive graphical tools enabling analysis and visualization of spatiotemporal data (temperature values in the last five years for Turkey) via texture mapping technique.

3 BACKGROUND

This section explains the concepts related to the domain. We give information on spatial reference systems (section 3.1) and texture mapping (section 3.2), and their functions in the proposed framework.

3.1 Spatial Reference System

Spatial Reference Systems (SRS) are also called Coordinate Reference Systems (CRS). SRS define the mathematical formulas to calculate or transform locations of geographically referenced objects. Every geographic (or spatial) data is defined with a reference system. SRS enable integration of geographic datasets in the same framework such as a map. SRS also help us to see if the two datasets from disparate resources are interoperable or compatible. If they are compatible (i.e. in the same SRS) then, the analysts can perform integrated analytical operations. There are two-general classes of coordinate systems. One is geographic coordinate systems and another is projected coordinate systems. Geographic coordinate system is global coordinate system and defined with latitude and longitudes. On the other hand, projected coordinate systems use projection models-formulas to map earth’s spherical surface onto a 2-D Cartesian coordinate plane.

To integrate a dataset to the system as an overlay layer, its coordinate system needs to be known and has the same coordinate system as the base map on which it is going to be plotted. World coordinates values of data held in database are pre-calculated in accordance with the specific spatial reference system (SRS). SRS of the satellite image that will be used must be the same as SRS of spatiotemporal data to be overlaid. Otherwise, the various conversion algorithms should be applied to have them in the same SRS.

3.2 Texture Mapping

Texture mapping is a rendering technique aiming at making 3-D objects to be visualized more realistic and more complex. Texture mapping is defined as projecting 2-D image patterns onto the surfaces of solid-objects. Texture mapping is well-known and widely used technique in implementation of open source 3-D object rendering. OpenGL is an open source application programming interface (API) for developing 2-D and 3-D computer graphics. It is cross-platform and cross-language standard specification.

Texture mapping basically does mapping of a 2-D image to a 3-D surface. A texture is just a bitmap image. Pixels of the texture are called texels. Suppose this texture has 256x256 RGB values. Then, this texture has 256x256 texels and each texel is an RGB triplet. Texel coordinates are in 2D, in the range [0,1]. In order to map a 2D image to a piece of geometry, we consider two functions: A mapping function which takes 3D points to (u, v) coordinates: f(x, y, z) returns (u, v). A sampling/lookup function which takes (u, v) coordinates and returns a color: g(u, v) returns (r, g, b, a).
At the core of the texture there is an image. In our case this is satellite map image. This is an array of color values. OpenGL enables plotting and overlaying 3-D icons on satellite map images by providing a rich set of API on texture mapping [13].

4 ARCHITECTURE

We present a visualization technique that addresses some of the challenges involved in visually exploring and analyzing the distributions of geo-spatial time-varying data. The proposed architecture is illustrated in Figure 1. We have developed a pictorial representation that is based on the standard STC metaphor and provides in a single display the overview and details of a large number of time-varying quantities. Our approach involves three-dimensional graphical widgets that intuitively represent profiles of the time-varying quantities and can be plotted on a geographic map to expose interesting spatiotemporal distributions of the data. To integrate and interoperate the spatially referenced map images and spatiotemporal data, they need to be in the same SRS system as mentioned in Section 3.1. Spatiotemporal datasets are integrated to the system by using OpenGL’s texture mapping approach and plotted on satellite map images (see Section 3.2).

The proposed framework is based on the STC metaphor used to display the positions and evolutions of locations of objects as a function of time. The STC approach consists of a 3D plot in which the spatial component (e.g., a geographic map) is plotted in the X-Y plane and the temporal domain is represented on the vertical axis. X-Y plane is decorated with satellite map images by using texture mapping approach.

![Figure 1. The prototype system architecture](image)

Spatial datasets in database are represented as cylindrical 3D icons with varying colors and width. Colors and width represent the quantities of non-spatial attributes of the data. Spatial attributes define the location of the icons. Our method involves a straightforward construction in which cylindrical disks, one for each time step, are stacked along a vertical temporal axis. The size (diameter) of the disk at each time step is scaled according to normalized data values and based on a pre-determined maximum disk size. The thickness of the disk is usually set to some constant value, though a user can interactively adjust the maximum width and thickness of the glyphs. Finally, we use the colors of the disks to encode data values and statistical quantities. In the next step, the 3D icons representing the time varying quantities are generated for each of the geographic regions in the data set; each icon is positioned at the corresponding region’s centroid on a
geographic map in the X-Y “ground” plane of the space-time cube.

Our approach involves event-based interactive tools for capturing the query parameters through mouse and keyboard events. Screen coordinates and real world SRS coordinates are matched with pre-defined algorithms. The system transforms SRS coordinates to screen coordinates and vice versa. SRS coordinates and screen coordinates are called world coordinates and view-coordinates, respectively.

Spatiotemporal datasets are kept in databases with their geometric (point, line, line-string, polygon etc.) and non-geometric (time and others) attributes (see Figure 1). Geometric attributes are also called spatial attributes. They are defined with set of x,y points. X is called latitude and y is called longitude. Geographic attributes define the shape and the location of the data and non-geographic attributes define all the other attributes. In 2-D screen, locations are defined with X-Y coordinate values. These are calculated based on both real world and display-screen coordinates.

Although 3-D visualization of spatiotemporal data has proven to be effective in data analysis and pattern recognition, plotting 3-D icons on a specific area might end up with some problems compared to 2-D representations. 3-D visualizations have some challenging problems affecting the readability. One of these problems is occlusion resulting from overlapping icons. Another set of problems come from data’s density and distribution characteristics. Plotting of dense data with 3-D icons might cause over-plotting and occlusion. There might be some other problems coming from user interaction with the view screen. There are some common behaviors in users’ interaction with the 3-D view-screen, such as rotation, scaling and translation. Combinations of those behaviors might require complex coordinate transformations and might cause visual inconsistencies when the system is not programmed with great care. These issues need to be considered during the design and development stages.

4.1 A Use Case Scenario

As a use case scenario, we have applied the proposed framework on visualization and comparison of temperature values, which are time and location dependent data. Temperature values belong to Turkey’s provinces and provided by yearly basis.

Temperature datasets are spatiotemporal and they have spatial and non-spatial attributes (see Figure 1). Location values (x,y) are considered as spatial and temperature values are considered as non-spatial. Non-spatial attributes show average temperature values at the specified locations over the specified time intervals. Each temperature data is positioned on the map as a 3-D cylindrical icon and its location is defined on the map by using spatial attributes (x-y axis). Cylindrical icons are aligned with z-axis of 3-D presentation space. Temperature values are grouped and represented with different colors according to the changing values of non-spatial attributes of the data (Figure 2). For example, the temperatures between 0 and 5 are the first group and represented with the color blue. Similarly, the highest temperature values are represented with
the color red in the group 45-50. Sample color scales are shown at the top-right corners of the figures in Figure 3 and 4.

In the use case scenario, temperature data of provinces are recorded in the database as relational tables. Temperature data for the predetermined provinces are shown on the map with piled cylinders in which each cylinder shows different year’s average temperature value. (see Figure 3). When the user selects any specific province on the map (just by clicking on), he/she gets a result similar to Figure 4. The bar graph in Figure 4 shows temperature ranges by years. Each temperature range is painted in different colors. Information for what color represents what temperature value is given in color scale located at top-right corner of the user interface. Figure 5 illustrates more detailed 3-D bar graphs which can be obtained through user interface tools.

Turkey’s map image, which is going to be overlaid with spatiotemporal data icons, is obtained from a third party system. The LandSat-7 images used in this study were captured by LandSat-7 satellite. LandSat-7 data products are available from the USGS (U.S. Geological Survey) Centre for Earth Resources Observation and Science (EROS). Images were obtained from online web site (http://glovis.usgs.gov/). The web site offers satellite images of different locations and at different time intervals for registered users.

5 CONCLUSION AND FUTURE WORKS

Data analysis is used in many areas and individuals, institutions, and companies. Data analysis has become much easier with the advancing technologies. Visualization enables us to show the amount of data, make comparisons...
between data, and show changes between the data. In this sense, we have developed an event-based interactive visualization tools for analyzing spatiotemporal datasets.

The proposed framework is based on texture mapping with open source 2-D/3-D OpenGL libraries and Java technologies. Third party data and services can easily be integrated to the system to get more specific analysis and results.

Currently, in the system, still map images in pre-defined bounding boxes (window) are provided and the data falling in the same bounding boxes are plotted and displayed. In the future, we plan to integrate standard Web Map Services (WMS) [14] and Google Maps into the system. This will enable any data from any location to be plotted and analyzed easily without any constraints.

Moreover, user interfaces can be improved with some additional tools for statistical analyses such as calculating mean value, standard deviation and variance.

6 REFERENCES