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A Survey of Visualization Techniques and Tools for Environmental Data

Romal Bharatkumar Patel

Software Developer-Full Stack, SoundThinkg Inc., Fremont, USA
Email: patelromalusa@gmail.com

Abstract

In modern time, visualizing a collection of discrete values and data is frequently required in scientific investigation. Predicting the potential fluctuation of a parameter such as heat flux, stress, or weather patterns is difficult in the case of environmental data. Numerous new visualization techniques and technologies for analyzing large datasets are common in the field of software visualization. However, selecting the right tool to meet requirements of the users for visualizing large datasets remains difficult. This paper offers the results of a survey conducted on the techniques and tools currently used for environmental data visualization by past researchers and authors. It provides an overview of several popular visualization tools and a brief assessment of their capabilities to support research involving large datasets of environmental data. A classification system of visualization techniques is also tried to present, determined by the number of different factors that can be visualized. Emerging innovations in the development of related user interfaces, as well as a variety of new visualization tools and their appropriateness, are also addressed. Ultimately, several future research directions in data visualization are proposed.

Keywords

Data Visualization, Visualization Tools, Environmental Data

1. Introduction

Environmental research and weather science is becoming increasingly important all over the globe. In aims to investigate and understand the impact of changing climate on humans and the earth, an ever-increasing proportion of environmental and climate data is assessed, preserved, and analyzed.

Many organizations make ecologic data available online to aid research projects

on environmental issues all around the world. Citing some of them, the National Oceanic and Atmospheric Administration (NOAA), the Western Regional Climate Centre (WRCC), and the Nevada Climate Change Portal (NCCP) are examples of such organizations. Analyzing very massive data without any of the aid of visualization is a difficult and time-consuming task.

As graphical representations of data become more effective at communicating ideas, the demand for visualization is increasing in a variety of fields, including biz, tech, public schooling, sciences, sociology, biomedical science, climatology, geomorphological, accounting, and genetic variation. Visualization aids in the efficient discovery of hidden patterns in raw information. It helps the study to concentrate mostly on the conundrum and accomplish their goals extra speedily. There are many private sector visualization tools commercially available, but each one is built for a specific function (Ravi & Yan, 2013). It sometimes gets difficult for an analyst to select a tool from the vast array of tools currently offered.

The investigation introduced in this study was undertaken as part of the process of selecting visualization tools for the development of a visualization system for the NCCP. NCCP is a cyber-infrastructure hub and even a collection of precious assets for climate change research in Nevada. A 2012, NSF EPSCoR-funded project entailed multidisciplinary group efforts by academic researchers from UNR, UNLV, DRI, and other NSHE entities (UNR Valley Road Weather Station, 2012). The main objective of that portal is to quickly and effectively deliver climate data to researchers, the broader population, interested parties, and policy experts, and to diagrams reveal this data using visualization tools (Ravi & Yan, 2013).

Another of the undertakings prior to writing the code for the NCCP's visualization constituent was to select a set of visualization tools. The current survey was inspired by the need to determine the most suitable tools from a pool of existing visualization tools. Despite the fact that several frameworks have been proposed for visualization tools, it ends up taking a considerable time to select the right tool that fulfil the needs of end users.

The purpose of this survey paper is to assist environmental data researchers in quickly locating a visualization tool that meets their needs. When selecting the right software for their functions, studies should consider the capabilities, practical application, attributes, and boundaries of the techniques.

The recommended categorization of visualization toolkits aids scientists in locating the wanted software. The rest of the study is structured as to discuss the context as well as several conventional surveys of visualization tools; then it tries to present a new survey of visualization tools, categorizing them according to functionality, strong points, and boundaries. Following section proposes a brief taxonomy of visualization tool and discusses the top of the line in data visualization; and examines several areas for future research in data visualization as conclusion (Ravi et al., 2015).

2. Ease of Use

2.1. A Summary of Previous Surveys and Work

To that of the authors' knowledge, no complete and accurate surveys on visualization tools for climate data have been conducted. Nevertheless, a survey comparable to this was undertaken for biological network visualization tools. That survey examined graphical representations including certain Medusa, Cytoscape, BioLayout Express3D, ProViz, and Pajek. The visualization functionalities, performance, interoperability with certain other equipment, backed incoming data configurations, user-friendliness, and appropriateness of these techniques were evaluated.

One Aigner, conducted a comparative analysis of metadata visualization tools (Shakeel et al., 2022). Series of images, Xmdv Tool, Spotfire, and ILOG Exploration were evaluated in comparison, basic user activities including one or multiple parameters and innovative types of work especially in complex dilemmas were trailed, the tools' functionalities were categorized, and a sequence asserting the advantages offered by every tool was offered up. Input and output binary formats and presentation of higher datasets are among the suggested enhancements to the investigated visualization tools.

Coming next, Mozzafari and Seffah momentarily performed a comprehensive visualization tool for field and weather data such as IBM Data Navigator, OceanShare, ImmerseDesk, CAVE, and Infinity Wall. This software was discovered to be beneficial for assimilating large datasets but to be any less simple and straightforward and incapable of linking multidimensional data. The study focused on a software suite that provides involvement and visualization services. The operations include acquiring glimpse into solitary data employing visualizations, linking visualized data using different techniques, and uncovering concealed patterns in large data points.

According to previous research, there have been numerous challenges that visualization tactics face. In the upcoming sections, this paper will look at a few conventional visualization tools (Ravi et al., 2015).

2.2. Visualization Tool Survey and Exploration

Below are some of the existing equipment for visualizing environmental data for review of this study. These tools are typically used mostly for specialized tasks. The study provides for a comprehensive description of each tool's functionalities, practical application, attributes, and barriers.

1) ArcGIS

ArcGIS is a software on internet that allows users to quickly create maps by using geographic knowledge. It is a proprietary software made available by the Environmental Systems Research Institute (ESRI), the world leader in Geographic Information Systems (GIS).

Features

ArcGIS comes in a multitude of editions. Locations, statistics, as well as soft-

ware solutions can be accessed by end users via desktops and laptops, smart phones, ipads, and the browser. By using ArcGIS API for JavaScript, Flex, Visual studio, and SharePoint, website designers can create applications that run on various channels. The geo-positioning functionality of the device allows people to share data, maps, and implementations. The windows version of ArcGIS includes predefined frameworks that streamlines the establishment of maps that can be made available to the public (shown in the below picture). The ArcGIS recompilation SDK for Windows mobile, smart device, and tablet devices is now readily accessible. The ArcGIS online service provides users with a fully prepared software configuration with rich original material.

Best attributes

a) ArcGIS has a clean UI and is simple to use.

b) High resolution mapping of any complex data can be generated pretty fast by using standardization for windows/Mac users and the users are not needed to worry for any installation of ArcGIS online software.

c) It supports various kinds of inputs.

Cons

a) ArcGIS is costly to run, and that there are extra expenses for software updates.

b) The clip spatial analysis tool is slow and frequently generates erroneous results. B. AVS/Express.

AVS/Express facilitates object-oriented functioning and therefore is primarily used by software engineers as well as non-programmers for visualization.

Features

AVS/Express is compatible with a variety of operating systems and provides a wide range of 2D and 3D visualization tools. Furthermore, multi-gigabyte types of data can be visualized. The tool's intra, as well as inter-platform GUI system and connectivity leads to rapid web applications. AVS/Express has a catalogue of 900 configurations that can be used to perform complex visualization and information management tasks. The tool's massively parallel programs enable computing services out all over cache coherency, resulting in extremely high-performance computing. The tool's multi-channel output allows visualizations to be displayed across large channels.

Best Attributes

- Systems from programming languages like java, C, C++, and FORTRAN are easily integrated.
- Ranges to the really massive amounts of data that are even more complex.

Cons

- It relies on secondary storage to transfer performance to end user, which can outcome in slow performance at key moments.
- Because it claims to support multiple systems, the level of standard customization options and control mechanisms currently offered is pretty limited.

3) GrADS

Grid Analysis and Display System (GrADS) is a content exploitation and visu-

alization tool for Planet's surface scientific information in a 5-dimensional arena.

Features

GrADS executes functions using FORTRAN-like control manifestations and includes a wealth of built-in operations. Users can also add the outside processes printed in any computer language, and the production visuals can be stored as pictures or PostScript.

Best attributes

- This toolkit is free and open source.
- It acepts a number of data formats as input.

Cons

- There is only a web browser option.
- Users must learn instructions in way to garner and govern the graphics, which may make this same tool less enjoyable.

4) Integrated Data Viewer (IDV)

IDV is a Java-based programming model for earth science data analysis and visualization.

Features

IDV is available on a variety of portals. To work well with IDV foundation, Java and Java3D are required. Besides earth science application fields, its new feature can be customized to carry out specific tasks. IDV has labels for the distance measurement axes and can showcase multiple data types at the very same time.

Best attributes

- It is freely available.
- High-quality 3D visualizations are provided.
- It is capable of plotting data from remote servers.
- Endorses a variety of data types.

Cons

It necessitates a large amount of RAM, which might lead to lagging of function for huge datasets.

3. A Simple Taxonomy of Visualization Tools

Some many considerations can be used to categorize current sustainability data visualization approaches. Many investigators have developed a classification system for visualization tools. Schneiderman, for instance, labelled visualization strategies based on statistical sorts and offer enhanced. 1D, 2D, 3D, multi-faceted, transcendental, tree, and network types of data are examples of specific data kinds. Schneiderman suggested the following client requests when categorizing the methods: outline, zoom, sensor, specific information, make reference, genealogy, and capture. Keim categorized the approaches according to attribute data and interaction/distortion mechanisms. Excluding the algorithms/software, his data types were parallel to what is used Schneiderman. For characterization, connectivity approaches such as level of quality, reflection, windowing, zoom,

misinterpretation, and web address exfoliate were generally regarded. Silva categories the methods that are based on visualization and engagement capabilities, Muller categories them as active or passive, Chi categories them predicated on visualization mechanisms, and Tory categories them depending on the types of the data models used. While these classification systems are broader, we suggested a classification scheme of visualization methods related to the data varieties used to demonstrate weather parameters in this paper. The most common types of environmental publicly available information are: one-dimensional, including temperature and pressure and meteorological parameters; two-dimensional, which contribute from a mixture of the two data points, such as moisture levels; three-dimensional, which constitute a set of three data points; multi-dimensional, which incorporate a perfect blend of more than three factors; and belatedly, rainfall patterns text data found in paperwork or news.

1) In One-Dimensional Structures the data values in a one-dimensional data set directly correlate to one variable, and that each data item has only each worth. Scatter plots and standard distribution patterns are two examples of one-dimensional data visualizations.

2) Data in two dimensions matches up to two variables. Visualization makes it simple to discover the correlation between two variables. Sequence diagrams, changeable comparison using visualizing, bar charts, area charts, data tables, maps, scatter diagrams, and live feed line and arrow visualizations are examples of 2D weather data visualizations.

3) In Three-Dimensional Forms the three-dimensional space, sample data have three characteristics. In relation to the two-dimensional data, the visual representation of the three factors demonstrates complexity and motion. Isosurface tools, such as those introduced in and, straightforward tonnage providing, slicing methodologies, 3D bar charts, and plausible mockups are examples of methods for expressing three-dimensional data.

4) In Multi-Dimensional Data Attributes the number of data character traits in multi-dimensional arena runs the gamut from four to hundreds. Numerous approaches are useful to fully comprehend the correlations between different data points. Multivariate data visualization approaches are based on bimodal distribution mappings, complementary coordinates, star waypoints, locations, and autoglyphs.

4. Discussion

Upon surveying four visualization tools, it is clear that neither of them totally meet the requirements of the consumers. To really get the intended results for climate scientists, subscribers must toggle between tools. Although most data (particularly in the fields of weather forecasting, environmental studies, and meteorology) is conveniently and publicly available for the study via the Internet, dealing with big amounts of information is complicated when such data is in variety of formats. Furthermore, only a few visualization tools have their reposito-

ry standalone executable, allowing visualization teams to better incorporate their concepts by not possessing to start again from scratch. With the application of high workstation display technology, 3D/4D techniques are now the primary focus of visualization. The advantages of these methodologies, which change the current 1D/2D tools that have been used for over several decades, should be researched a little farther. In addition, customer interaction with visualizations is now becoming highly complicated. Subscribers, for illustration, can investigate several more official details in the visualization by wheeling the pointer over that, or they can start changing the visualization through using operations such as magnification in, zoom out, moving in the opposite direction, or charts by choosing a particular multiple views—Google, for instance, offers all of these capabilities in its visualizations.

5. Conclusion

As of now, the hurdles for data visualization design team encompass developing software that: operated on a wide range of technologies, such as desktops and laptops, mobiles, display window frames, and touchscreens; sources of international operating systems (windows, Mac, as well as UNIX); provide a few visualization options and functionality so that subscribers do not require extra tools; offer multiple communication and visualization techniques; and provide amazing graphics with animation. Because the established visualizations are so important in this stage, it is also critical to check whether there are any incomplete data characteristics from damaged equipment and even if the obtained information is analyzed. A standard input format would also be beneficial for the visualization tools. In the long term, we hope to see a comprehensive visualization system for the NCCP that takes into account the functionality listed above.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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