A survey on visualization techniques to represent time-series data

Information Visualization (CSCI 628)

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Abstract

Visualizing the changes over time is an interesting topic and covered vastly in the visualization field. The time dimension can present intriguing patterns in the data including but not limited to cycles and polarization. In this survey, we intend to look at different visualization techniques that can be used to represent data in relation to time.

Introduction

Time-series data is vastly covered in different research fields to understand patterns, repetitions, and trends [11,14]. Many different visualization techniques like sequence chart, point chart, line chart, bar chart along with user interaction like zooming, brushing, linking presents a variety of options to represent time series data [14]. In this survey paper, we look at different representations of time-series data in scientific literature and also some visualizations that can be repurposed to represent time series in a meaningful way. We classified the documents by publication year and relevance of the research topic to time series in the “Classification” section. Then discussed the research articles in the “Literature Review” section. We discussed our findings and our opinions in the “Discussion” section and finally concluded the document with some discussion about possible future works in the “Conclusion” section.

Classification

We have reviewed 15 scientific literature between 1999 and 2021 and grouped those by the publication year and relevance to time series in table 1.

Table 1: Number of documents clustered by publication year and research area

Publication / Research topic	Time series data	Other research areas
1999 - 2005	2 [11,14]	1 [2]
2006 - 2010	1 [7]	1 [15]
2011 - 2015	1 [10]	3 [5,8,9]
2016 - 2021	4 [1,3,6,13]	2 [4,12]

Literature Review

Wijk and Selow [11] presented the method of clustering time-series data in a calendar view to reveal the patterns in human behavior. They also introduced interactive features to click on dates on the calendar to select specific dates and do further analysis. Although the paper did not consider high-dimensional time-series data, they presented an interesting visualization method for that period of time.

Weber et al. [14] proposed a spiral representation of time-series data which is useful to reveal patterns and compare the change over different time scales. They also proposed to present a larger dataset in helix and use brushing to select a segment of the data to display as a spiral. Their proposed spiral method (Figure 1) is a useful technique and several different extensions and iterations of the method are used in time-series visualization in present days.

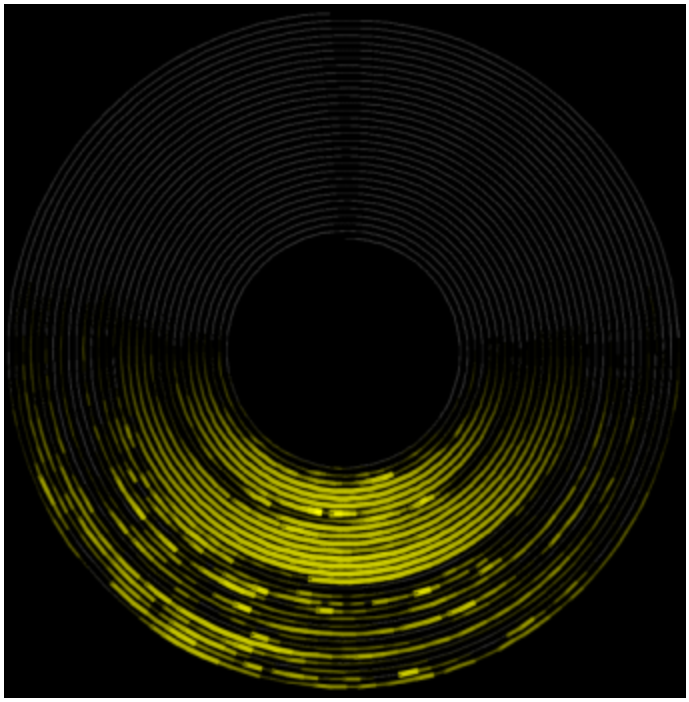

Figure 1: Visualizing time-series data in a spiral (Weber et al.)

Brandes and Wagner [2] proposed a tool to visually analyze social network data which shows the relation between nodes and the centrality using a network diagram. This is an interesting work for the time and a time dimension can easily fit into the network diagram to show the change over time in a network.

Herr et al. [7] investigated a technique to compare time series data using different bands in horizon graphs. They represented time-series data in a filled line graph and used bands to cut off the graph and overlaid on top of each other (Figure 2). They performed a survey of the visualization technique and asked the participants to estimate the values from the visualizations. They found that estimation error was high when 4 bands were used and the time to estimate increased with the number of bands.

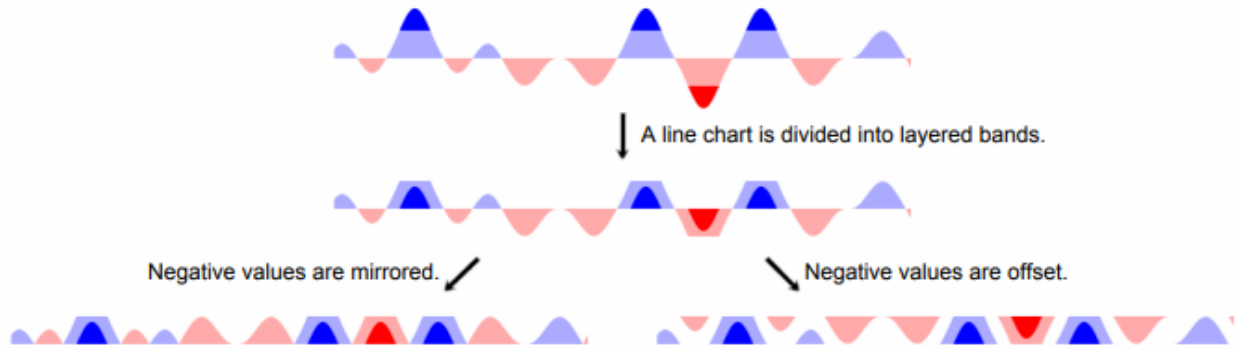

Figure 2: Processing of building horizon graph with two bands (Herr et al.)

Yu et al. [15] proposed a method of touch-based exploration for 3D data. The exploration method can be very useful for medical imaging representation. This method can be repurposed to represent an overview and further explore time-series data.

Chuang et al. [5] proposed a tool - "Termite" to visually represent topic models. The tabular format (Figure 3) used by the authors helps identify significant terms in a topic. The same visualization technique can be informative if one of the dimensions is repurposed to represent time.

Keahey [8] presented different visualization techniques to show large data sets which are useful to convey a message without focusing too much on the fine-grain details. Time-series data often become huge [11] and require clustered representation in the visualization. The use of radar charts and calendar heatmaps can be interesting ways to represent time-based data while giving an overview to the readers.

Perin et al. [10] proposed an interactive horizon graph (IHG) technique to compare multiple time-series data using pan and zoom feature on top of the horizon graph technique. The user study performed by the authors showed that the proposed method

performed much better than the existing reduced line chart (RLC) or horizon graph (HG) techniques.

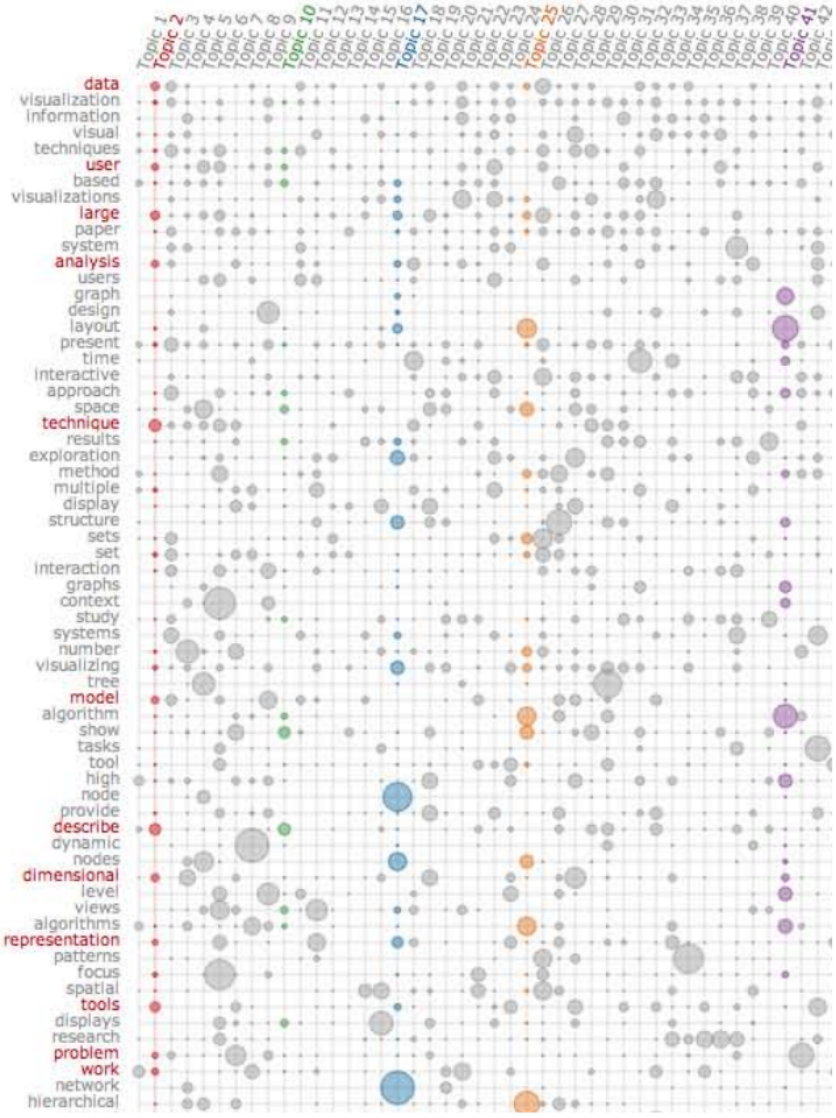

Figure 3: Terms ordered by frequency (Chuang et al.)

Time-series data can cover a long period of time and even with animation, can sometimes become difficult to understand for untrained users. The tool “Visjockey” by

Kwon et al. [9] proposes a method to add a connection between the text and the visualization making it easier for the viewers to understand the intent of the author.

Fulda et al. [6] proposed a browser-based tool called "TimeLineCurator" to generate a timeline from unstructured text using NLP. This tool is especially helpful for time-based data extraction from unstructured texts like blogs, news, and other media.

Bach et al. [1] presented “Time Curves” to represent an overview of time-series data and clustering similar events together. Although there are some limitations like the direction of the line does not represent temporal evaluation, their approach is useful in representing multi-dimensional time-series data, and identifying similarities or outliers among the events.

Wang et al. [12] proposed “Topic Panorama” a visual topic analysis approach to analyze and understand the use of similar topics over multiple sources. In their proposed approach they displayed the topics a network graph within a radial visualization of the sources. The change of topic over time is also displayed in a different view. The interactive radial display is the most interesting which can show the relation of topics along with uncertainty.

Brehmer et al. [3] discussed the design choices for temporal data to use a storytelling approach, which can better convey the message to the users from different narratives. They proposed 14 design choices in 3 dimensions and presented different visualization approaches by combining those.

Wang et al. [13] proposed a visual analysis tool - “ConceptExplorer” to analyze the concept drift using the time series data from different sources. Their tool lets users

choose a segment of the timeline for analysis and compares concepts in a correlation matrix.

Carvalho et al. [4] chronicled the progress in Covid-19 research in the first 12 months from the outbreak of Sars-Cov-2. Their work summarizes the significant achievement of scientists and researchers in a short period of time while also outlining the gaps in research. They used a very basic timeline visualization in their paper which shows that a bare minimum visualization can be enough to convey the message.

Discussion

In this survey, we have reviewed several techniques to visualize the time dimension in a dataset and also the progress of time-series visualization in the last two decades. We have seen different approaches to visualize time-series data efficiently. We also deviated a little towards some non-time-series research to see interesting visualizations that can be incorporated in the time-series visualization. With the increased volume of data and progress of NLP, time-series visualization techniques have also evolved. We also noticed some approaches like spiral representation, although with some improvements, are still a prominent form of timeline visualization.

Conclusion

Visualizing data in relation to time is widely used in different research areas and many interesting methods along with interaction and animation have emerged. Although it is a widely researched topic, there are still works to be done. Time-series data usually are large and visualizing them meaningfully demands larger space and user interaction. The

increased use of small-screen devices presents new challenges in the field. High-dimensional time-series data also have more research to be done.

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