Review of Temporal Visualization Technique on Greenhouse Gas Emissions

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Abstract

In this document, I have reviewed temporal visualization techniques applied to the topic of greenhouse gas emissions. These techniques are specifically designed to handle time-based data, or time-series data. I examined the process of constructing temporal visualizations to effectively display trends and patterns in emissions data over time, providing insights into long-term changes and seasonal variations.

Additionally, I evaluated the advantages and limitations of these visualization techniques, summarizing their industrial and academic impact.

I. Introduction

This technique displays data that changes over time, commonly referred to as temporal data [1]. Temporal visualization techniques are particularly effective for revealing trends, patterns, and variations within time-series data, such as greenhouse gas emissions (GHG). By illustrating the progression of data over time, these techniques can help users understand changes over time, making them essential tools for analyzing dynamic processes like emission patterns and climate trends. The common methods of visualizing temporal data (e.g. greenhouse gas emissions (GHG) over time) are line chart, stacked area chart, and stacked bar chart.

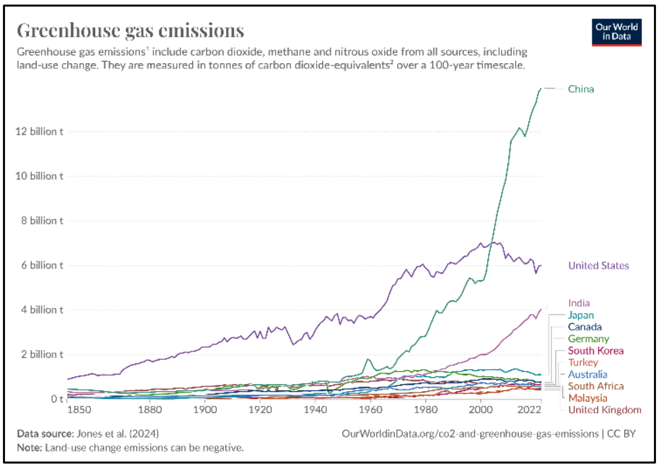

Figure 1: Line Chart [2]

A line chart connects individual data points to show data continuity, making it easy to understand and identify trends. Line chart is one of the most widely used temporal visualization techniques for representing time series data, particularly for monitoring trends over time [3]. In a line chart, time is typically represented on the x-axis, while the data collected over the years is displayed on the y-axis. Points are connected by lines, allowing viewers to easily observe trends, such as increases or decreases over time. Each line represents a different category and is color-coded to distinguish between them. In the context of greenhouse gas (GHG) emissions, line charts can effectively display emission trends for various countries, with each line representing a different country and color-coded for easy distinction.

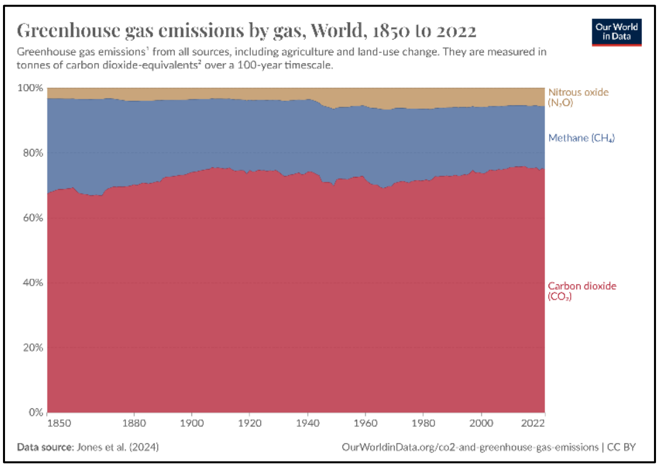

Figure 2: Stacked Area Chart [2]

A stacked area chart is an extension of a basic area chart, useful for comparing multiple variables that change over a time interval [4]. It consists of a series of areas stacked on top of each other, with each area representing a different variable or category, typically displayed in distinct colors for easy differentiation. In a stacked area chart, the x-axis usually represents time, showing intervals such as days, months, or years, while the y-axis represents the cumulative value of all categories combined. In the context of greenhouse gas emissions, a stacked area chart can effectively display the contributions of CO_2, CH_4, and N_2O over several years, illustrating both individual and overall emission trends to help stakeholders understand emission dynamics over time.

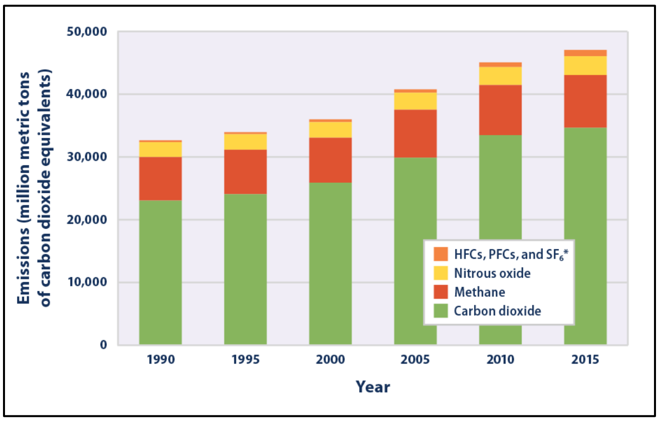

Figure 3: Stacked Bar Chart [5]

A stacked bar chart is a type of bar chart that illustrates the total of different categories while simultaneously breaking down how each part contributes to that total [4]. Each bar represents a main category, and the segments stacked within each bar represent subcategories. This design allows for easy visualization of both the overall amount and the individual contributions of each part. The x-axis typically shows the timeline, while the y-axis represents the total value, such as emissions in metric tons. This method helps users easily compare totals across categories and analyze the contributions of each subcategory over time.

II. PROCESS FLOW OF TEMPORAL VISUALIZATION TECHNIQUE

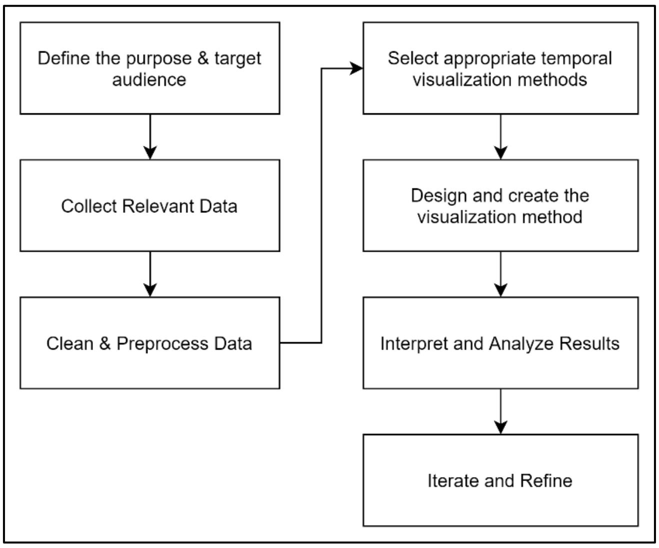

Figure 4: Flow of Temporal Visualization Technique

A. *Define the Purpose and Target Audience*

Define the specific objectives of the temporal visualization [6], such as highlighting trends, identifying patterns, or comparing categories over time. Determine the intended audience (e.g., researchers, general public) to align visualization complexity, style, and detail level with their needs and understanding. For, a temporal visualization can highlight yearly greenhouse gas emissions for different countries, with each represented by a distinct line color to help the general public easily understand and compare emission trends over time.

B. *Collect Relevant Data*

Gather temporal data from reliable sources, such as World Bank Open Data and Our World in Data, focusing on time-based elements (e.g., date, month, year) and key variables (e.g., emissions by gas type or region). Ensure data accuracy, completeness, and alignment with the visualization objectives.

C. *Clean and Preprocess Data*

After gathering the data, it is required to pre-process the data by handling missing values, standardizing formats, and organizing data to ensure accuracy and consistency for visualization [7].

D. *Select appropriate temporal visualization methods*

Choose the most appropriate visualization method (e.g., line chart, stacked area chart, stacked bar chart) based on the data characteristics and the intended purpose [8].

E. *Design and create the visualization method*

Set up the visualization with time intervals on the X-axis (e.g., years, months) and data values on the Y-axis (e.g., emissions in metric tons). Use distinct colors and styles for different categories or subcategories to enhance readability, and add labels, legends and titles to provide context. Utilize visualization tools or programming libraries (e.g., Tableau, Matplotlib, D3.js) to create a clear, accurate, and visually appealing display of the data [9].

F. *Interpret and Analyze Results*

Review the created visualization (e.g., line charts, area charts, or bar charts), to identify trends, patterns, and any unusual data points [10]. Analyze how the data changes over time and note any significant increases, decreases, or unexpected results. After this review, write a report that summarizes the main findings, highlighting the key trends and what the data highlighted.

G. *Iterate and Refine*

Gather feedback from stakeholders or users. make enhancements and adjustments based on the feedback given to improve the clarity and effectiveness of the visualization. Additionally, update the visualization as new data becomes available or as objectives evolve to ensure it remains relevant and informative.

III. ADVANTAGES & LIMITATIONS

A. *Line Chart*

The advantages of using line charts are that line charts are effective for displaying trends over time and allow for the comparison of multiple data series on a single graph, clearly visualizing data points and intervals [11]. For example, the line chart illustrates total greenhouse gas emissions by different countries over the years, with each country represented by a unique color to distinguish their respective emission trends.

The limitations of using line charts are that line charts are not suitable for showing part-to-whole relationships [11]. For example, the line chart is not suitable for showing how different types of greenhouse gases (e.g. CO_2, CH_4, and N_2O) contribute to total emissions over the years compared to stacked area chart.

B. *Stacked Area Chart*

The advantages of using stacked area charts include the ability to easily compare multiple categories and to illustrate how the total value changes over time [12]. For instance, stacked area charts effectively show part-to-whole relationships, demonstrating how different types of greenhouse gases (e.g. CO_2, CH_4, and N_2O) contribute to total emissions over the years, with each area represented in a different color for clear distinction.

The limitations of using stacked area charts include the potential for visual clutter and their ineffectiveness for non-cumulative data. When the data lacks a cumulative nature, such as non-numeric or non-sequential categories, a line chart may be a better choice. Additionally, if there are many overlapping area series or densely packed areas, the chart can become cluttered, making it difficult to interpret individual patterns.

C. Stacked Bar Chart

The advantages of using stacked bar charts include the ability to easily compare multiple categories and visualize each category's total [12], making them useful for representing cumulative data over time. For instance, stacked bar charts can effectively display the emissions of different types of greenhouse gases (e.g. CO_2, CH_4, and N_2O) over the years.

The limitation of stacked bar charts is that it's difficult to accurately compare segment values across different bars, as only the bottom segment is aligned along a common baseline. This lack of alignment makes it challenging to compare and analyze individual contributions within each category. For example, in a stacked bar chart, it can be challenging to identify the value of N_2O contributions over the years, as segments are not aligned to a common baseline, making comparisons across bars difficult.

IV. Impact Proposition of the Temporal Visualization Technique in Industry and Academic

Temporal visualization is essential for analyzing time-based data in both industry and academic. In the business sector, it enhances decision-making by revealing trends and patterns that inform strategic planning. In academic, visualizing temporal data during assessments helps teachers monitor student engagement and performance, identifying areas of misunderstanding and difficulty [13]. Research shows that these visualizations can improve educators' awareness of student behavior, enabling more tailored support [13]. Overall, temporal visualizations facilitate a deeper understanding of complex data, aiding analysts and educators in making informed, data-driven decisions.

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