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Combining Space-time Cube and Dashboard for Visual Analytics: A Case Study with Bibliographic Data

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Abstract:

Understand regional natural, cultural, or economical environments are the prerequisites for regional planning and decision making (Hägerstrand, 1970). It often requires people to understand spatial and temporal information through (big)geodata. Space-time cube is a visualization method that utilizes 3D space to show spatial information on a map horizontally and show temporal information vertically (Kraak, 2003). They are applied as effective visualization methods to highlight temporal patterns in space (Zuo et al., 2022b, Keler et al., 2023). Visual tools are needed to help people learn the overview of the environments and enable people to analyze them in different level of details.

Integrating the representing space, time, and hierarchical information in an at-a-glance view can help people to gain an overview and then explore the details. However, the visual interfaces are often too informative to read. Integrating a dashboard design could sort the information for readers and highlight important key information. This paper applies the combination of spatiotemporal cubes and dashboard design in the case study of spatiotemporal data to achieve visual analytics. Specifically, previous studies suggested that dashboards facilitate visual analytics by logically arranged visualizations (Zuo et al., 2022a, Zuo, 2022). First, the spatial, temporal, and hierarchical data structure is presented by the 3D space-time cube (STC) design. Then a dashboard layout is designed to guide users to read from an overview to details.

We chose bibliographic data in our case study as test data, which has rich spatial, temporal, and topic information. It is collected from the ACM Digital Library[1]. The collected data includes title, author, affiliation, published time, and index terms (ACM classification system). It has 23,385 items, covering articles with Chinese affiliations from 2017 to 2020. We developed a visual interface to represent the distribution of spatial, temporal, and topic in the collected articles. The interface design combined the space-time cube method and dashboard design method to help users identify the data patterns. For instance, the temporal trend in the number of articles in all the covered regions, the proportion of articles in various research domains, and the portfolios of research topics in different regions. The data is preprocessed by converting addresses to coordinates, aggregating the number of publications by keywords in the ACM hierarchical keyword system [2], and aggregating the publications according to geographic regions and time.

We designed the visual interface with consideration of the visualization method selection, layout, and interactions. Figure 1 shows the interface design in three images: (a) layout design, (b) interaction design, and (C) interface design. The layout uses a space-time cube as the main interface in Panel A, and users can zoom, rotate, and click the scene to explore the differences of the symbols. Panel B is static information, including the title and legend for users to interpret the symbols. Panel C provides data filters of selected regions and times. Panels D, E, and F show detailed information about a chosen symbol from Panel A. The interaction design shows how the visualizations are linked between panels, and the main interactions users can do are clicking a symbol in Panel A and selecting in Panel C. The interface is mainly composed of four visualization methods: a space-time cube to show the spatiotemporal distribution of aggregated research topics in Panel A, a single symbol to show the overview of the proportion of the research topics in multiple years in Panel D, a donut chart to show the overview of one selected year in Panel E, and a bar chart to show the number of articles in a selected research domain.

The evaluation of the interface is in two phases, 1) evaluating the understandability and engagement of the combination of STC and dashboard, 2) evaluating the influence of dashboard layout on the effectiveness. In the first phase, we recruited seven participants (between 24 to 36 years old) to complete four benchmark tasks, including analyzing multiple variables, temporal dynamics, spatial clusters, and spatiotemporal patterns. The participants were then asked to fill out a survey regarding understandability and engagement. The preliminary results show that the interface can help users to perceive the information, but understanding spatiotemporal semantic information all at once is still challenging. The second stage has not completed. We plan to use think-aloud method to reveal the roles of visual elements during visually analyze.

Integrating space-time cube in dashboard layout design helps users understand complex information from various perspectives. Additionally, interactivity is a crucial component of visual analytics. Users can adjust the time range and spatial area through controls such as sliders, filters, and search boxes, which, when combined with the spatiotemporal cube's display of data, stimulate user engagement and enhance the ease of information retrieval. The hierarchical data

[1] https://dl.acm.org/
[2] https://dl.acm.org/ccs

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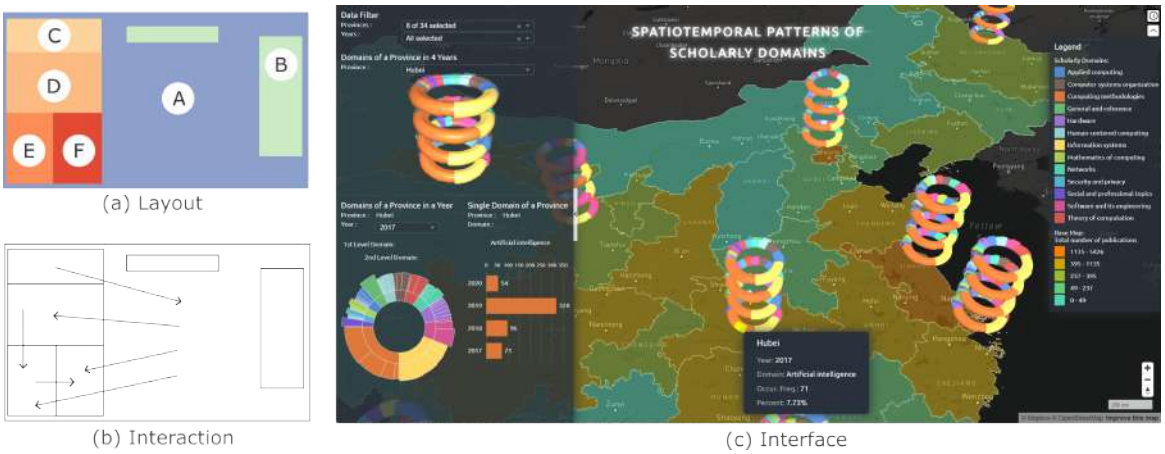

Figure 1. The interface design of the space-time cube in a dashboard.

structure is repeated appearing in multiple visualizations, so that users are visually guided to view the patterns from different perspectives. This approach to visual analytics aims to reduce the difficulty of understanding complex information, broaden the diversity of users, and accommodate both experts and non-experts in their interpretation and understanding of the information. The next step of this research is to explore the reading strategy of users and find out the reasons for choosing certain strategies. The results will be useful for formulating design suggestions.

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