Interactive Information Visualization of Trend Information

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Abstract

This paper proposes the visualization cube as a reference model for spatiotemporal trend information. The interactive visualization system for earthquake trend information was proposed at MuST in NTCIR-6 workshop, which defines earthquake trend information as spatiotemporal information and designs the interaction between different views so that temporal and spatial trend information can be effectively combined. By extending the functionality of the system, this paper proposes the concept of visualization cube, which defines the data structure of spatiotemporal trend information, type of views, and interactive operations for generating views. The interactive operations for generating various views include drill down/up, comparison, spin, and transition. The interactive information visualization system for spatiotemporal trend information is also developed based on the concept of visualization cube. The system was used in actual classes of an elementary school, of which the result shows the system has enough usability for 5th-grade elementary school children to perform exploratory data analysis. It is expected the visualization cube contributes to the improvement of the visualization platform that is developed by MuST workshop.

Keywords: Interactive Information Visualization, Trend Information, OLAP

1. Introduction

A trend generally means a general direction in which a situation is changing / developing. The MuST workshop [4] extends the general meaning and defines trend information as a kind of summarization of temporal statistical data, obtained through synthesis rather than simple enumeration. Most of trend information in MuST corpus such as trend of gasoline price and home run race are represented as time series of statistical values. This kind of trend information is called *temporal trend information* [9]. On the other hand, the MuST corpus also contains different type of trend information, such as typhoon and earthquakes. That is, the trend of these events is observed both temporally and spatially. This type of trend information is called *spatiotemporal trend information*.

The interactive visualization system for earthquake trend information was proposed at MuST in NTCIR-6 workshop, which is designed for treating spatiotemporal information by defining the interaction between different views so that temporal and spatial trend information can be effectively combined.

As a free subtask of MuST in NTCIR-7 workshop, this paper proposes the concept of visualization cube as a reference model for spatiotemporal trend information, by extending the functionality of the system developed in NTCIR-6 workshop. The visualization cube defines the data structure of spatiotemporal trend information, type of views, and interactive operations for generating views. The interactive operations for generating various views include drill down/up, comparison, spin, and transition. The interactive information visualization system for spatiotemporal trend information is also developed based on the concept of visualization cube. The system was used in actual class of an elementary school, of which the result shows the system has enough usability for 5th-grade elementary school children to perform exploratory data analysis.

The paper is organized as follows. Section 2 describes interactive visualization system for earthquake trend information as a related work, and the concept of visualization cube is proposed in Section 3. Section 4 proposes the interactive visualization system based on the concept of visualization cube.

2. Visualization of earthquake trend information

Takama et al. have proposed an interactive visualization system for earthquake trend information extracted from tagged corpus [8, 9]. The tagged corpus used in the system is provided by MuST in NTCIR-6 workshop [4]. This section briefly summarizes the system.

2.1. Trend information in news articles

The system classifies the trend information that can be extracted from regular articles about earthquakes into the following categories.

(A) Trend information contained in a single article.
(B) Trend information obtained by summarizing multiple articles.
  (B-1) Temporal trend information
  (B-2) Spatial trend information
  (B-3) Spatiotemporal trend information

Trend information of type (A) is the relation between hypocenter and corresponding seismic intensities observed at several observation points, which are usually contained in the same article. It can be classified into spatial trend information, and be also a basis for obtaining trend information of type (B). Trend information of type (B) is further divided into 3 types according to the way of summarization. For example, when we want to know how often earthquakes happened during a specified time period, temporal trend information (B-1) showing the frequency and interval of earthquakes could be useful. When we want to know all the earthquakes occurred in specified area within 5 years, generating temporal trend information focusing on that would be suitable. On the other hand, spatial trend information (B-2) would be useful for seeing the spatial relation between different earthquakes. One of examples of such case is when we want to know where earthquakes happened within last year.

Trend information of type (B-3) contains trend information both spatially and temporally. Let us consider the case when we want to know the area in which earthquakes frequently happened in recent years. In such a case, frequency of earthquakes (temporal trend information) for each area would be summarized, and then comparison of the area-wise temporal trend would be performed by considering spatial relation among areas. Furthermore, swarm earthquakes, which are occurred in the neighborhood within relatively short time period, can also be classified into spatiotemporal trend information.

2.2. System architecture

Figure 1 shows the system architecture of interactive visualization system for earthquake trend information, which consists of trend information extraction module, article database, earthquake information database, municipality database, trend information visualization module, and visualization interface. The processing of the system is divided into offline processing and online processing. In offline processing, information extraction module accesses to article database that stores tagged corpus and extracts information about each earthquake, which are stored in earthquake information database. The seismic information database search system[1] is used to complement deficient data. The municipality database stores the latitudes and longitudes of municipalities in Japan, which is used for mapping seismic observation points onto the map of Japan.

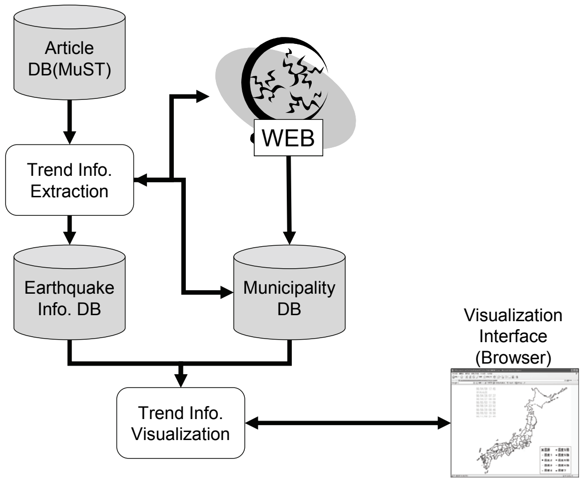

Figure 1. System architecture of interactive visualization system for earthquake trend information

In online processing, trend information visualization module generates visualization result required by a user from earthquake information database and municipality database. The visualization result is sent to a Web browser. The system visualizes the following information.

Visualization of spatial trend information with map of Japan: The location of hypocenter and corresponding seismicity of earthquakes that were occurred during the specified period are displayed on the map of Japan. Visualizing not only a single earthquake, but also multiple earthquakes on the same map can treat both of (A) and (B-2) type trend information as defined in Sec. 2.1.

Visualization of temporal trend information with line chart: The frequency (number of occurrences) of earthquakes that were occurred with a specified area, during a specified period is visualized with line chart.

Visualization of swarm earthquakes: As information about swarm earthquakes includes both of temporal and spatial trend information, the combination of spatial and temporal visualization is employed. That is, seismicity of swarm earthquakes in terms of spatial trend information is displayed with map of

[1] http://www.seisvol.kishou.go.jp/eq/shindo_db/shindo_index.html

Japan, while temporal trend information is displayed with a bar chart, of which date of earthquake occurrence and magnitude are mapped to horizontal and vertical axis, respectively.

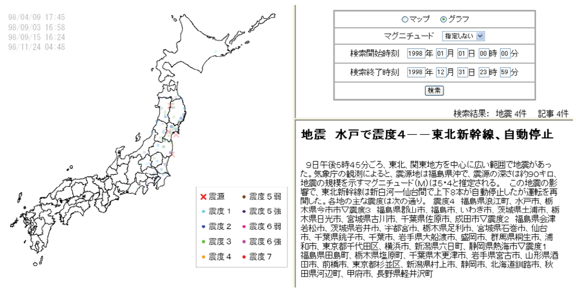

Figure 2. Screenshot of interface

A prototype system is implemented as JSP (Java-Server Pages), which is accessible from an ordinary Web browser. Figure 2 shows the screenshot of the interface. The left side of the interface displays spatial trend information with map of Japan, a query form is located at upper-right part, and corresponding news article is displayed at lower-right part.

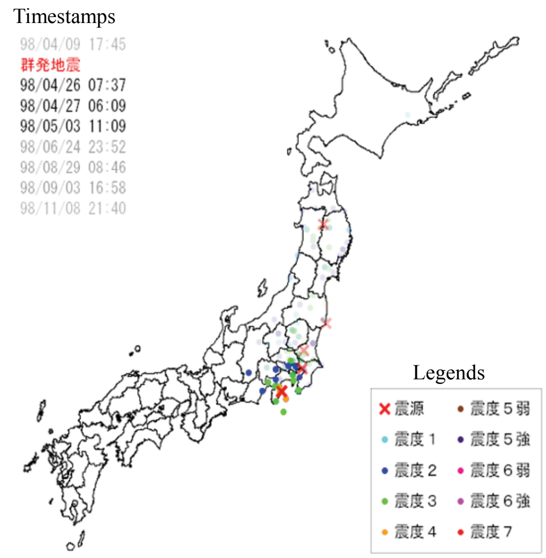

Figure 3. Visualization of spatial trend information with map of Japan

Selecting "map" in query form displays the retrieved result with using map of Japan, as shown in Fig. 3. The map is generated with SVG (Scalable Vector Graphics), in which seismic intensity is indicated with color as noted in legends. The list of retrieved earthquakes is displayed at upper-left part, in which each earthquake is indicated as its time and date of occurrence (timestamp). By locating a mouse cursor on a timestamp, the corresponding hypocenter as well as observed seismic intensities is highlighted in the map. On the other hand, locating a mouse cursor on a hypocenter on the map highlights the corresponding timestamps. Furthermore, the corresponding news article is displayed by clicking either a timestamp or hypocenter on the map.

When "graph" is selected in the query form, the frequency of earthquakes in the retrieved result are calculated and displayed in a different window as a line chart. The temporal granularity used for calculating the frequency can be changed according to specified time period.

When swarm earthquakes are included in a retrieved result, a term "swarm earthquakes" is contained in the timestamp list, just before the corresponding earthquakes. Locating mouse cursor over the term highlights the timestamps of earthquakes constituting the swarm earthquakes as well as those corresponding hypocenters and observed seismic intensities on the map. At the same time, a bar chart is also displayed in a different window, which shows the interval of the corresponding earthquakes.

3. Visualization cube

By extending the functionality of the information visualization system for earthquake trend information that is described in Sec. 2, this paper proposes a visualization cube as a reference model for spatiotemporal trend information. This section briefly introduces existing taxonomies and models for interactive information visualization and introduces the concept of visualization cube.

3.1. Taxonomies and models for interactive information visualization

As information visualization is a technology that makes use of human's cognitive ability, it inevitably involves interaction. Recently, more active role of human experts is required in various fields such as interactive data analysis, active mining [5] and chance discovery [6]. In such cases, information visualization plays an important role as an interface between huge-volume, multi-dimensional data and human experts. That is, a view generated by information visualization techniques is not just a result of data processing, but also a means to access data.

A reference model for visualization has been proposed [1], which defines visualization as adjustable mapping from raw data to visual form that is presented to human perceiver. This model also shows a series of mappings; data transformations, visual mappings, and view transformations. Data transformations extract data to be visualized from raw data set, and transform those into the form suitable for visualization (data tables). Visual mappings transform obtained data tables into visual structures. Finally, view transformations create view (picture) of the visual structure by specifying parameters for drawing a view, such as color, position, and scale. As these mappings involve human interaction, the model is useful for designing interactive information visualization systems as well as analyzing the interaction design.

As the target data of information visualization is usually huge, there is a tradeoff between viewing overview of data space and viewing detailed data. A visual information-seeking mantra [7] refers to user's information seeking process with using visualization as the repetition of "overview first, zoom and filter, then details on demand," which implies that visualizing overview and details separately is not enough. Overview lets user notice particular data subset of interest. The "focus+context" [1] also refers to the similar concept, in which "focus" means the access to detailed information, whereas "context" corresponds to overview or relationship among data. Panning and zooming are one of famous approaches for interactively switching overview and detailed view. As the overview plays a role of context, it should be presented together with detailed view. Fisheye [10] is one of the visualizing techniques for satisfying such requirement.

Yi et al. classify existing interaction technologies that have been used for interactive information visualization system into the following categories in terms of user's intent [11].

- Select: mark something as interesting.
- Explore: show me something else.
- Reconfigure: show me a different arrangement
- Encode: show me a different representation
- Abstract/Elaborate: show me more or less detail
- Filter: show me something conditionally
- Connect: show me related items

These taxonomies and models are not mutually independent, but describe the same target from different viewpoints. For example, the panning and zooming, which relate to the concept of "focus+context," correspond to Explore and Abstract/Elaborate categories, respectively. The visual mappings of the reference model for visualization correspond to Encode category.

3.2. Concept of visualization cube

Although the taxonomies and the models introduced in Sec. 3.1 are useful for designing interactive systems, more detailed model specific to a type of target data is preferable. Furthermore, those do not focus on the transition between different views, which is one of important interaction in information visualization. Therefore, this paper proposes a visualization cube as a reference model for spatiotemporal trend information.

The visualization cube defines the data structure of spatiotemporal trend information, type of views, and interactive operations for generating views. Data structure is defined as the extension of OLAP (online analytical processing) [2]. It is defined as 4-dimensional cube as shown in Fig. 4, of which dimensions correspond to temporal axis, spatial axis, type-of-view axis, and statistics value axis. Temporal and spatial axes are hierarchically organized. For example, statistics values are aggregated per prefecture, region, and whole of Japan. Each statistics value and view type can be viewed as a layer along the corresponding axis, as shown in Fig. 4.

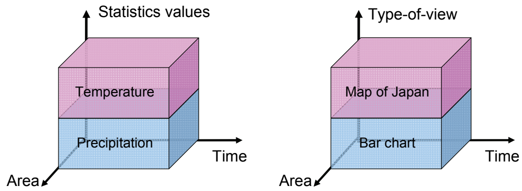

Figure 4. Image of visualization cube

One of the important characteristics of the visualization cube is that it focuses on the transition between views. That is, interactive operations for generating views include operations for generating new view from the current view. The interactive operations for generating various views are defined, such as follows.

- Drill down/up: breakdown / aggregation of statistics value in terms of temporal or spatial axis.
- Comparison between areas / statistics values
- Spin: Switch between spatial and temporal axes
- Transition: Switch between different view types.

The drill down/up operations are similar operations in OLAP, and other operations are defined as the operations specific to visualization cube.

One of the contributions of the visualization cube is that it can be used to analyze interaction of various information visualization systems. For example, Kato and Matsushita have studied the transition between different charts in multimodal dialogues [3]. Although their work mainly focuses on the cooperation between natural language processing and information visualization, it considers various kinds of transitions between charts. It is expected the visualization cube can be applied to understand the transitions in their system.

4. Interactive information visualization system based on visualization cube

Based on the visualization cube, an interactive information visualization system is developed with Java. As the system is designed to be used for elementary school students, most of the operations are available with mouse only so that students can use the system intuitively. The current system has two types of views: chart including plot and bar charts and map of Japan.

4.1. Interactive operations for generating views

Figure 5 shows the drill down/up operations that are applied to bar chart. Left graph in the figure shows annually aggregated data, whereas the right graph shows monthly aggregated data. Figure 6 shows the same operation applied to map of Japan. The left figure shows comparison between districts all over Japan, whereas the right figure shows comparison between prefectures in Kanto district.

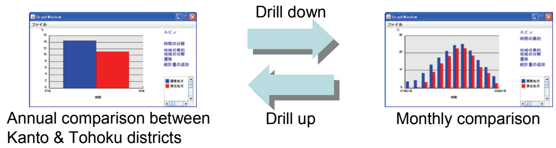

Figure 5. Drill down/up for bar chart

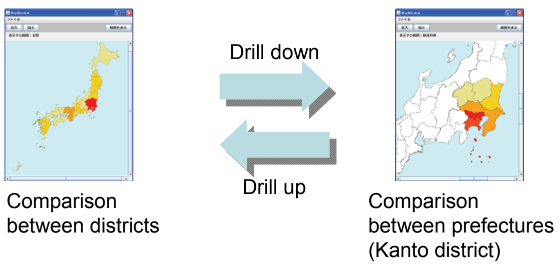

Figure 6. Drill down/up for map of Japan

Figure 7 shows the example of performing a series of comparison operations. An initial bar chart shows precipitation of Kanto district, to which the precipitation of Tohoku district is added for comparison between those districts. Finally, new statistics values, temperature for both districts are added.

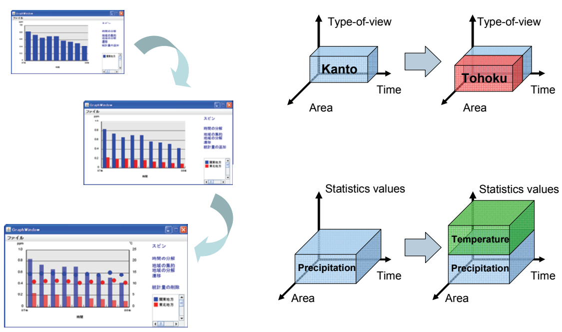

Figure 7. Comparison: addition of area and statistics value

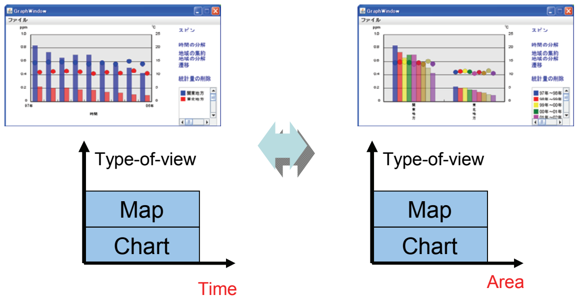

Figure 8. Spin between time and area axes

Figure 8 shows the example of spin operation, which compares the temporal trend of precipitation and temperature between Kanto and Tohoku districts. Although both of the left and right figures show the same trend, the axes of the left and right figures are temporal and spatial ones, respectively.

Figure 9 shows the example of transition operation, in which the left figure compares precipitation of each district, whereas the right figure shows the temporal trend of same statistics value of the whole country.

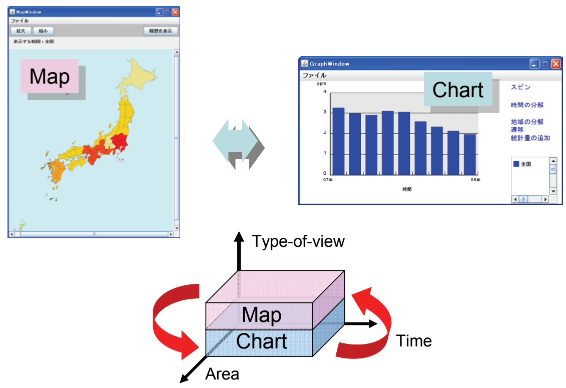

Figure 9. Transition between different types of views

4.2. Experimental results

The system was used in actual classes of fifth grade students in an elementary school. Eleven students used the system for study on environmental issues. After short instruction of using the system, the students could freely use the system for their own studies. After using the system, they were asked to answer the questionnaire asking the usability of the system. Five questions were issued, to each of which the students answered with 5-point scale (5:best, 1:worst). The questions and average scores are as follows.

- (Q1) How is the overall impression of using the system?: 3.73
- (Q2) Did you have any new findings by using the system?: 3.18

- (Q3) Could you investigate the data sufficiently?: 3.09
- (Q4): Could you get views as you expected?: 3.36
- (Q5) Will you want to use the system in the future?: 3.64

As we could not prepare the system for each student, they had to share the system. As a result, it is observed that students who could not spend enough time on using the system tended to answer for Q2 and Q3 with low score (2). That is why the average scores for Q2 and Q3 are lower than other questions.

We also asked each student about their computer skill, and most of them were familiar with using mouse but had difficulty in using keyboard. Of course, the students have never used this kind of systems. From those results, we can conclude the system can let students without enough computer skill perform exploratory data search without training.

5. Conclusions

As a free subtask of MuST in NTCIR-7 workshop, this paper proposes the visualization cube as a reference model for spatiotemporal trend information. The concept of visualization cube is obtained by extending the functionality of the information visualization system for earthquake trend information, which is developed at MuST in NTCIR-6 workshop. The visualization cube defines the data structure of spatiotemporal trend information, type of views, and interactive operations for generating views. The interactive operations for generating various views include drill down/up, comparison, spin, and transition.

The interactive information visualization system for spatiotemporal trend information was also developed based on the concept of visualization cube, which was used in actual classes of an elementary school. The result shows the system has enough usability for 5th-grade elementary school children to perform exploratory data analysis. It is expected that the concept of visualization cube will contribute to the improvement of the visualization platform developed by MuST workshop.

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