

Timeline Kit - A New Interactive Tool to Explore Spatio-temporal Data at Multiple Temporal Granularities

Peng Wang Menno Jan Kraak

Abstract—The visualization of spatio-temporal data in geographical applications is often challenging on the temporal part. A timeline in such applications can help to indicate temporal information. However, the timelines in these applications may not be able to display temporal data in different granularities because of the limitation of its arrangement and interactive design. This paper proposes a novel interactive tool named Timeline Kit to help users explore both linear and cyclic patterns in different granularities and better answer time related queries. The design of the interface including a multi-scale time wheel as a selector, a corresponding time calendar interface to show multi-granularity temporal pattern and two summary timelines which summarize cyclic change of attribute data. Different temporal queries can be “plotted” on the Timeline Kit. The Timeline Kit allows users to flexibly select different granularities and to explore temporal information by showing periodic patterns, especially the regularity of the data.

Index Terms—Spatio-temporal data, temporal visualization, multiple granularities, calendar view, cyclic pattern, interactive tool

1 INTRODUCTION

In the geography domain, there are numerous applications for spatio-temporal data visualization. Some applications use a timeline as an interactive tool or a data representation medium (e.g. [1] [2] [3] [4]). The timeline in these applications can indicate changes of events, which particularly refer to attribute and location changes, and help users obtain information from the temporal perspective.

Many spatio-temporal data visualizations involve cyclic patterns, like changes of temperature or energy consumption. These data also show different cyclic pattern in different granularities, such as the daily or seasonal changes of temperature. Therefore, visualizing spatio-temporal data, which have cyclic features, from multiple granularities is necessary. Thus, an effective tool is required to display cyclic pattern in multiple time granularities.

This paper proposes a new approach (the Timeline Kit) to explore various granularities of spatio-temporal data. The Timeline Kit is an interactive browsing tool for temporal events, which provides a flexible approach for constructing, manipulating and comparing multiple temporal related queries in different granularities focusing on cyclic arrangements.

2 BACKGROUND

Several solutions have been proposed before. Based on Peuquet’s triangle model [5], Edsall and Peuquet [6] focused on the representation of time in a GIS user interface, and implemented a prototypical Temporal GIS named TEMPEST. With the prime consideration of flexibility and customization of the system through the interface, TEMPEST makes answering of temporal queries straightforward by using a multi-granularity interactive interface with both linear and cyclic representations. Lee et al. [7] proposed two methods, which allowed users to zoom and pan to improve temporal navigation, and implemented these methods as two types of sliders which supported linear and cyclic operations. However, these above approaches ended up with a time control panel or a time slider as an interactive tool without direct attribute or location information involved.

There are also some applications that directly show cyclic

temporal patterns on the interface like Spiral display [8], Circle view [9], and Kaleidomaps [10]. Spiral display bends a linear timeline continuously on a plane and makes a spiral form. It is divided into several equal sub-cycles from the centre of spiral to display attribute data. Circle view is the combination of several concentric circles. It is divided into several equal parts from the centre, and each part represents a variable. Kaleidomaps shows data with gridding. The arcs indicating days and diameters show the lower-cycle.

Applications like Ring Map [11], Time Calendar [4] and Time Wave [3] are tools for temporal visualization in multiple granularities, each with their own advantages and disadvantages. Ring Map has multiple branches bending as different-size rings appearance to visualize patterns, which look like cyclic but is a linear application. Each branch is a separated linear timeline to display the data of an independent object. Time Calendar allows users to observe short-term patterns and long-term trends of data. It thus supports multiple time granularities as well, but it only shows data in the fixed granularities. To compare different time granularities flexibly, Time Wave serves as a multi-granularity tool. The Time Wave can show both linear and cyclic patterns, but as with other solutions mentioned, there are limitations to the amount of granularities to us.

All of the applications have their limitations when it comes to flexibly exploring temporal information, which is in direct relation to space and attribute information at different granularities.

3 PROPOSED APPROACH

This research introduces the Timeline Kit as an alternative interactive tool to help users observe temporal patterns of attribute data in different granularities. Timeline Kit can visualize attribute data in different user-defined temporal granularities to show periodic patterns, revealing (ir)regularities and trends. A user can flexibly select, compare and adjust different temporal units in the selector of the Timeline Kit. The corresponding calendar view shows the trend and regularity of temporal data in different granularities.

3.1 Interface Design

The Timeline Kit is composed of a multi-scale cyclic timeline as a selector, a corresponding time calendar interface to show, and two summary linear timelines (Figure 1).

The multi-scale time selector is the combination of several concentric circles with time scale of nested granularities on them. The scale gets more detail toward the outside, for instance the core represents the year, the second (outer) ring represents the months, the third ring shows the days and so on.

• Peng Wang is with University of Twente, Faculty of Geoinformation Science and Earth Observation, Department of Geoinformation Processing. E-mail: p.wang@utwente.nl.

• Menno Jan Kraak is with University of Twente, Faculty of Geoinformation Science and Earth Observation, Department of Geoinformation Processing. E-mail: m.j.kraak@utwente.nl.

The time calendar shows the multi-granularity temporal pattern of attribute data. The selector can adjust the scales of the calendar's two axis. Vertical axis represents higher time scale while the horizontal axis represents lower time scale respectively, e.g. months and days, days and hours.

The summary timelines beside the time calendar summarize the cyclic change of the attribute data along the vertical axis and horizontal axis during the whole period of the calendar. The value of the graph is calculated by the calendar.

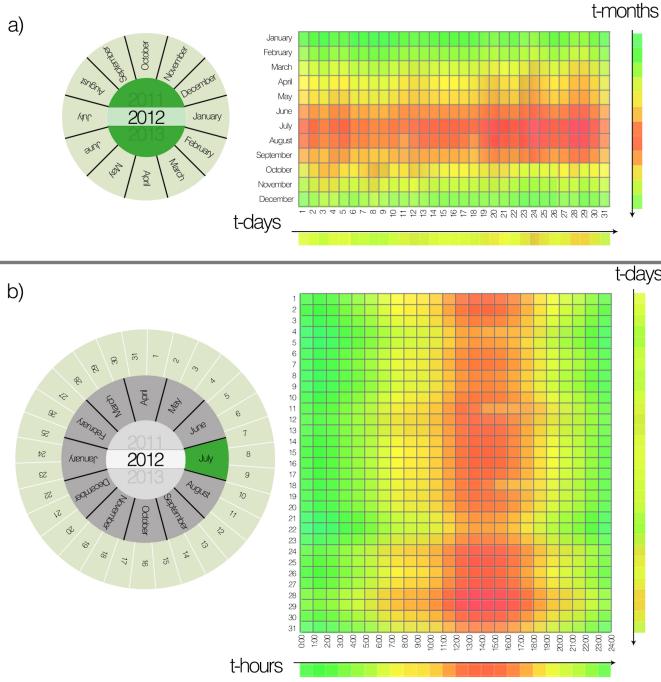


Fig. 1. Example of the temperature change in different time granularities. Figure (a) shows selecting a year (2012) from the selector (left) and the corresponding visualized time calendar (right) while the months of the year is encoded on the vertical axis and the days of each month is encoded on the horizontal axis. The summary timeline $t\text{-months}$ summarizes the cyclic change of the average temperature along horizontal axis during each month of a year while $t\text{-days}$ shows the cyclic change of the average temperature during each day of a month. Figure (b) shows a selected month (July) of the core (year), and the outer ring representing days pops up with the corresponding visualized time calendar. Days of the selected month are encoded on the vertical axis and the hours of each day is encoded on the horizontal axis. The regulation of temperature can be observed from both of the axes within different time granularities. The summary timeline $t\text{-days}$ shows the cyclic change of the average temperature during each day of a month while $t\text{-hours}$ shows the cyclic change of the average temperature during each hour of a day.

3.2 Temporal Queries and Timeline Kit

The basic temporal questions introduced by MacEachren [12] can be answered by the Timeline Kit. These queries include if, when, how often, how long, what order. Besides, the Timeline Kit can also deal with trends and regularity effectively.

When & if

The answers of the questions like when & if (time instant) can be presented in the calendar view with different granularities through the adjustment of the selector. Users can select the proper time scale to observe this time instant. The calendar emphasizes the position of a time instant in the total time interval, which has two dimensions with two different granularities.

How long

The answer of the questions like how long (time interval) can be shown as a consecutive time instant in the calendar view, which represents the length of time. By selecting suitable time granularities, users can view the length of a typical event and focus on the start and end point of the duration.

How often & Order

To answer the questions like how often and order, users have to identify all of the time instants, and then count or rank them on the calendar view. The selector allows users to explore the quantity or order of time instants by groups, which can be observed in different granularities. With the help of summary timelines and calendar view, the Timeline Kit can show the order of a same event in absolute and relative time. For instance, the sequence of the rent payment days in each month during a year, or the sequence of ice day in each year during one century.

Regularity & trends

To answer the questions about regularity and trends, summary timelines can often well display average (ir)regularity and trends with the the calendar view showing detail information. The view of two different axes shows the (ir)regularity and trends of the attribute data in two types of granularities. With the function of the selector, the Timeline Kit supports exploration of potential regular patterns, as it flexibly visualizes multi-granularity information. Ways of displaying attribute on the calendar vary. Colour and brightness can be used as visual variables to show attribute data on calendar.

3.3 Interactive Functions

To answer temporal queries in different granularities, the interactive functions of Timeline Kit have been developed. The multi-scale time selector is designed for users to flexibly select from different temporal granularities from inside out by scrolling and clicking the mouse. The outer ring will pop up once users have made a selection. In the calendar window, all of the temporal patterns of attribute data are visualized into different colors or brightness. The horizontal axis and vertical axis are directly linked with the time selector, and they will display different granularities according to users' selection. If users choose a certain month or a day by clicking on the selector, the corresponding data will be highlighted on calendar. The summary timelines alongside the calendar are the projection from horizontal and vertical view of the average value of data. The granularity of timelines can be adjusted according to time selector.

Additional potential functions of the selector can be developed. For example, each slice of the selector in different granularities can be extended to an extra linear sub-timeline as is shown in figure 2. Regularity and trends of the data can also be seen in the selector in a cyclic way. For several linear sub-timelines, more effective and flexible functions can be developed, like adding multiple attribute information and location information or implementing timeline cartogram on the sub-timelines.

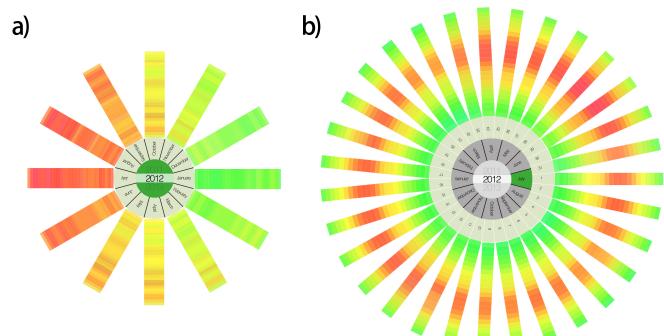


Fig. 2. Example of potential functions of the selector.

3.4 Timeline Kit in CMV environment

Spatio-temporal queries are often more complex than the temporal queries mentioned above. To answer such complex queries, attribute and location information need to be observed with temporal information simultaneously. The ‘coordinated multiple view’ (CMV) technique can be implemented to dynamically support linked triple views, including a time space as the Timeline Kit, a location space as a map, and an attribute space as a diagram. Through the interaction of each space, spatio-temporal queries can be answered. Users can observe location and attribute data from other two windows clearly and can explore the regulation of location and temporal data. The selector, the calendar and the summary timelines part of the Timeline Kit in time space allows users to interact with in many ways, e.g. selection, comparison, animation.

4 DISCUSSION AND FUTURE WORK

This paper proposes a novel timeline toolkit for visualizing attribute data in different temporal granularities. With the help of the interactive methods, users can observe cyclic pattern in different granularities and further explore potential regular patterns.

However, problems and challenges still exist, such as how to show location information like the movement of people, environment changes of an area combining with the Timeline Kit; how to compare multi-object’s time patterns on multiple calendars.

In the future, further improvements will be considered:

1. The function of selector will be further developed with Timeline cartogram to display location information.
2. A multi-layer calendar will be designed for the comparison of multi-object’s time patterns in a certain time interval.

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