Helical time representation to visualize return-periods of spatio-temporal events

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Abstract

Numerous methods have been developed to integrate temporal dimension in geovisualization environments. However, the return-period of cyclic spatio-temporal events is still difficult to visualize in most time visualization tools used in geovisualization, like timelines or timewheels. However, some temporal diagrams, which combine linear and cyclic aspects of time, allow the visualization of the return-period of these events. These diagrams represent time by a chronological succession of instances of a considered period. If this period and the events return-period are equal, the return-period can be highlighted. Among these diagrams the time coil diagram proposed by Edsall and Peuquet represents time with a helix. These diagrams are interactive and the represented period value can be modified to visualize the return-period of different cyclic events. However, the values set to the period represented by the diagram are generally limited to usual periodic scales like hours, days, weeks, or months. In this paper we propose a new geovisualization tool, based on the time coil diagram that allows user to dynamically set any value of the represented period in the helical diagram. This new visualization tool enables both to explore data and to find possible new cyclic events types as well as illustrating the return-period of any cyclic event type.

Keywords: return-period; cyclic time; helical diagram; geovisualization; spatio-temporal event

1 Introduction

Over the last 10-15 years, geovisualization research has focused on the development of conceptual frameworks for representing spatial dynamics. Different computer and cartographic methods have been proposed to represent temporal dimension of spatial events: maps collections, animated maps, geovisualization interfaces [3]. One widely used solution consists in integrating into a multidimensional interface a cartographic representation to visualize the spatial organization of events, and a temporal graphic to represent its temporal distribution.

These frameworks make possible a visual exploration of spatio-temporal data. Two types of tools are mainly used to represent time dimension corresponding to two conceptualizations of time: the linear timeline for a linear and chronological representation and the timewheel for a cyclic representation [6]. The choice of these representations directly depends on the type of temporalities: the timewheel is used to represent cyclic events with data which are collected according to a regular cyclic time step (each season, each day); the timeline is more used to represent a series of events organized chronologically.

Regarding exploratory analysis of spatio-temporal data through geovisualization, one of the issues is that some spatio-temporal events can have cyclic components, which do not correspond to the regular cyclic time step used to collect the data. The identification of these cyclic components can be essential in fields, like natural hazards analysis, which focus on the analysis of historical data. The description of return periods of volcanic hazards, for instance, is essential for forecasting high intensity eruptions [10]. Our goal is to propose geovisualization methods and tools allowing the user to identify spatio-temporal cycles and similarities from space-time series of data. Data Visualization Sciences, which focus on time series, offer several methods for representing cyclic variations [1]. However these time-dominant visualizations do not integrate the spatial dimension. It is thus difficult to identify the spatio-temporal relations. Edsall and Peuquet [6] proposed a cyclical legend using a coil metaphor. It is a temporal helical diagram, which combines linear timeline and timewheel representations. As a temporal representation in a multidimentional geovisualization tool, this proposal could be used to visualize spatio-temporal cycles.

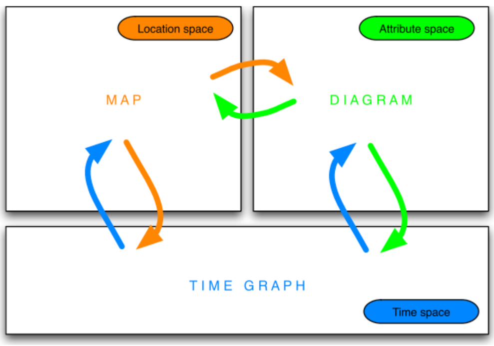
In this paper, we first present the principle of the use of timelines and timewheels to represent time into multidimensional geovisualization environments. Then we expose the advantages of several temporal diagrams, which associate the linear and cyclic aspects of time, to represent cyclic events. Then, we propose an extension of the helical diagram proposed by Edsall and Peuquet [6], which is integrated in a multidimensional geovisualization tool. This extension should allow any cyclic spatio-temporal event to be visualized, and to visually explore data to identify cyclic events groups.

2 Time representation in geovisualization environments

2.1 Multiview framework

The integration of temporal dimension in geovisualization tools is based on four main approaches [3]: animated maps, where the time is represented by the time of the animation; the maps collection (small multiple maps), where each map represents the spatial distribution at a specific temporal moment; the space-time cube proposed by the Time Geography [7], and the multi-view geovisualization interfaces. Those interfaces follow the orthogonality principle of spatio-temporal information described by Kraak [11] and Davoine [14]. They are based on the use of interactive visual queries, and are structured into three synchronized windows; each one represents one spatio-temporal information dimension (spatial, temporal and thematic dimension) (Figure 1). In these tools, the time graph is considered as a query tool allowing the selection of data according to different temporal criteria (date, period) and different levels of temporal granularity and scale.

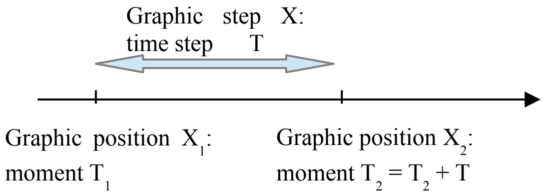
Figure 1: Principle of spatio-temporal geovisualization interfaces [11]



2.2 Timeline and timewheel in geovisualization interfaces

Two main tools are usually used to represent time in geovisualization environments [5]: a linear temporal diagram called timeline, and a cyclic temporal diagram called timewheel. Timeline is a representation of a linear succession of events, which are represented by graphic objects along a graduated linear axis: a time instant (date, moment) is represented on the timeline by a point; a time interval (period) is represented by a distance between two points along the time axis (Figure 2).

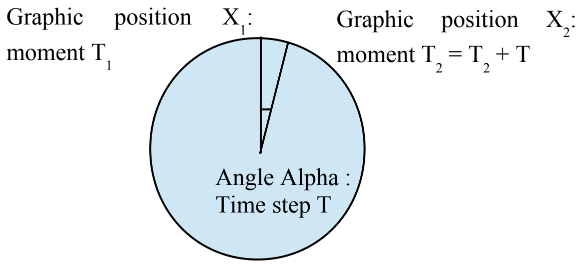
Figure 2: Principle of linear timeline



Timewheels follow the concept of a cyclic time, where time evolution is the repetition of a cyclic temporal period (daily, weekly, monthly, annually). The timewheel describes a circle representing the considered time period (an instance). A point on the circle curve represents a time instant. A time interval is represented by a distance along the circle curve and by an angle of the circle (Figure 3).

The timewheel only represents the temporal interval, which corresponds to the instance of the considered time period. Timewheels are used to represent the temporal arrangement (moment of appearance, duration, order of appearance) of cyclic events, which appear during every period at the same moment. For each instance of the considered cyclic period, graphical objects representing cyclic events will always be put on the same circle section.

Figure 3: Principle of timewheel

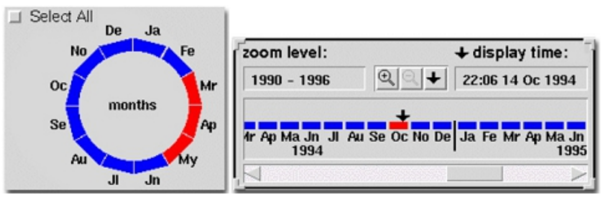


An interactive timewheel allows to change the represented instance of the considered time period, and so, to change the represented section of time. It is also possible to change the temporal granularity and the temporal scale of the timewheel. The different represented time scales correspond to considered cyclic periods. For instance, in Tempest project, Edsall and Peuquet created an interactive timewheel where the represented time scales are hours, days, weeks, months and years [6].

The main advantage of the timewheel is to visualize cyclic aspects of time evolution. But the timewheel will not be sufficient if the events we focus on are not cyclic, or have a different return period than the period used as timescale on the timewheel. Difficulties would also arise if events don't appear in every period of the temporal area we study.

Edsall and Peuquet [6] proposed to combine a timeline and a timewheel in a same time visualization tool, to select spatio-temporal data according to the two conceptualizations of time (Figure 4).

Figure 4: Timewheel and timeline in Tempest project [6]



3 Visualization of temporal cycles

3.1 Representation of temporalities

Hewitt, DiBiase, MacEachren and Allen [2,4,8,13] described six "temporalities" characterizing the spatio-temporal events:

- moment
- duration
- return-period
- order of appearance
- chronological space
- synchronization

Moments, duration and return-period concern one event; the three other temporalities describe the temporal relationships between different events. Moment, duration, order of appearance can be directly visualized in timelines and timewheels: the moment corresponds to a position on the diagram; the duration to a distance between two points on the diagram; the order of appearance by a position of an event on the diagram compared to the position of other events.

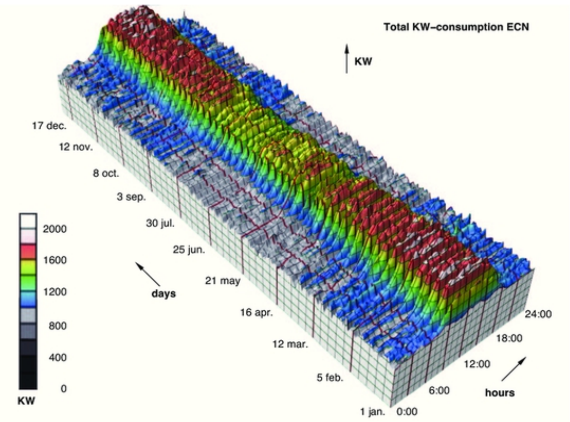
The return-period defines the duration between the appearances of several instances of a cyclic event. This temporality cannot be directly visualized by a timewheel or a timeline. In a timeline, the user has to identify the regular distance between each position of the event instances on the diagram. This distance corresponds to the return-period of the cyclic event. Cyclic events are difficult to identify with this method.

In a timewheel, if the event return-period and the timewheel represented-period are different, the user has to identify the regular distances between each position of the event instance as in timelines. Otherwise, the user has to know that timewheel represented-period and the event return-period are equal.

3.2 Combination of linear and cycle representations

Other methods have been developed for integrating linear and cyclic temporalities into a single time diagram [1]. For instance, Van Wijk [15] proposes Cluster Calendar using a 3D matrix diagram (Figure 5).

Figure 5: Cluster Calendar [15]

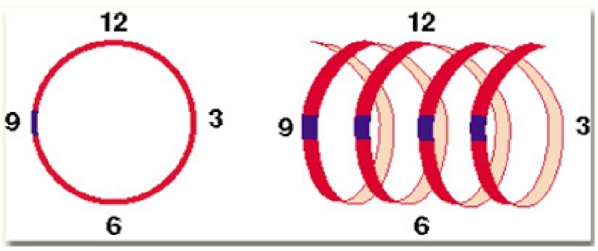


In Figure 5, the time is represented by two horizontal axes (x and y) defined according to different temporal granularities. The vertical axis and the color are used to represent variable values. The "hours" axis represents a time scale according to an observed periodicity, which is considered as a cyclic period; the "days" axis represents the time duration of the observation period according to another temporal granularity. This representation combines different temporal granularities and scales and visually identifies the return-periods and time cycles.

Edsall and Peuquet [6] proposed a temporal diagram called "time coil", which combines the timeline and the timewheel. The time coil is represented by a helical curve created along a linear axis (timeline), which represents linear evolution of time. For each instance of a chosen period, the helical curve revolves around this linear axis. In this diagram:

- a moment corresponds to a point along the helical curve
- a temporal interval corresponds to:
  - a section of the helical curve
  - a rotation angle around the central linear axis
  - a translation vector along the central linear axis

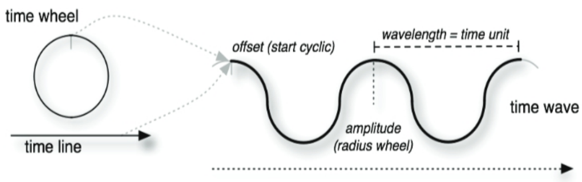
Figure 6: Helix temporal diagram [6]



For instance, in Figure 6, a revolution of the helical curve around the linear axis corresponds to a repetitive period of one half-day.

Li and Kraak [12] have proposed a similar temporal diagram model called "Time Wave". The Time Wave is developed along a linear axis, which represents the linear evolution of time, as in a timeline (dashed line below the time wave in Figure 7). The wavelength represents one period of time, which is equal to one cycle of the timewheel.

Figure 7: Time wave [12]

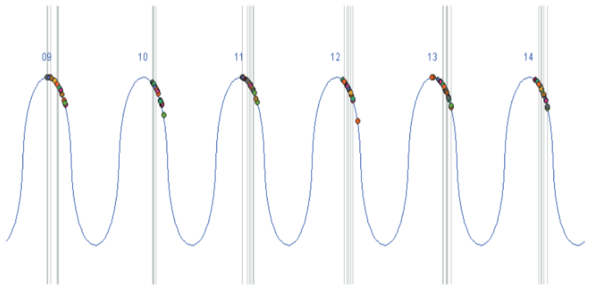


These types of diagrams, improve the visual analysis of the return-period of cyclic events. In the Cluster Calendar diagram, the high values are observed each day around midday. These regular high values can be interpreted as the result of cyclic events with a return-period of one day, which is the period covered by the first temporal axis of the matrix diagram. The colors and the three dimensional height corresponding to these high values take the same position for each row along the second temporal axis, and form a line parallel to this axis.

For the Time Coil method, a line parallel to the central axis is also formed by several blue sections of the curve, which are visible at the same position on every circle the helix makes around the central axis. These blue sections are graphical objects corresponding to instances of a specific type of event, which is cyclic with a return-period equal to the helix revolution period.

Figure 8 shows an example of a Time Wave representation. Graphical points are located on the same section of each wave. Each color corresponds to one type of event. The lines drawn between points of the same color are almost horizontal. The return period of each type of event is nearly equal to the period corresponding to the wave length. Each color corresponds to one type of event.

Figure 8: Screen capture of time wave tool [11]



In the diagrams represented in Figures 5,7 and 8, the return-period of a type of cyclic event is visualized by the line formed with the different graphical objects corresponding to those cyclic events.

By adding the possibility to use different periodic scales to represent the cyclic aspect of time, different values of return-periods can be represented. However, this possibility is limited by the values that can be set to the period represented by the diagram structure.

4 Proposition

4.1 Objectives and Principles

According to Hornsby and Egenhofer [9], the frequent occurrence of cyclic representations of time is a reflection of its close association to nature and the rhythms in everyday life. Periodic scales are created from usual time periods corresponding to cycles we naturally observe like days or seasons. The values generally considered for these diagrams are limited to these usual time scales.

Our goal is:

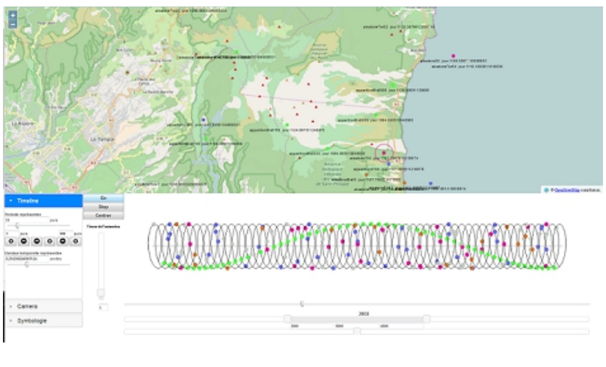
- to improve the visual analysis of spatio-temporal events in order to identify the cyclic appearance of specific types of events.
- to visualize any return-period of events, whatever the time scale and the observed period duration.

With the "Time Coil" representation [6], it can be possible to visualize the return-periods of the events if they are equal to the helix revolution period. We propose "Helical Timeline", an extension of "Time Coil" diagram, based on the following principles:

- To visualize any possible return-periods, we have to add the possibility to define any value to the period corresponding to the helix revolution around the central axis, including values that do not correspond to the usual way to describe time cycles. The period of helix revolution could be equal, for instance, to one month, one day, or a fraction of a day.
- The events are visualized in the helix timeline by graphical objects. These graphical objects have a specific shape and a specific color according to the type of event. With a dynamic variation of the helix revolution period, based on the interactivity, the user can see the formation of a line made by cyclic events (graphical objects) when the helix period value is approaching the return-period value. This line is formed by the objects that share the same graphical aspects.

Figure 9 represents the current aspect of our proposition. The temporal dimension of events is shown in the helical timeline displayed at the bottom of the screen. The animated map is showing appearance of spatial objects corresponding to the events (in this example we are showing appearance events).

Figure 9: Screen capture of the current tool



We can see a formation of lines made by cyclic events when the helix period approaches a duration corresponding to a multiple of the cyclic events return-period. If events have a return-period equal to T, we shall see one line for a helix revolution period equal to T, two lines for a period equal to 2*T,etc (see Figures 10.d and 10.e).

The type of timeline graphical objects depends on the classification of the displayed spatio-temporal events. By dynamically and interactively changing the classification of the spatio-temporal events, we can change the aspect of the graphical objects of the timeline. We can thus visualize other alignments made by other groups of graphical objects, and so identify other groups of cyclic events.

We propose several ways to classify them:

- by the spatial object affected by the event
- by the type of the modification affecting the event (appearance, movement...)
- by the extent of this modification
- by the type of the event (an eruption, a flooding)
- by the geographic area of the event

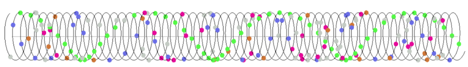
4.2 Experimentation

First, we tested our helical timeline representation on a dummy dataset. We created a first time-series of events, which includes one type of cyclic events that appear every 50 days, and four types of randomly created events.

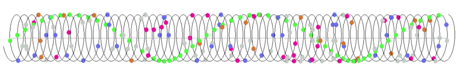
Figure 10 shows some results of our experimentation to identify cyclic events with a dynamic change of the helix revolution period. Several helical timelines are shown, for periods equal to respectively 53, 52, 51, 50 and 100 days. When the period is equal to 53 days (Figure 10.a), the position of the green points relative to the cyclic events form a helical curve. The more the helix revolution period approaches the value of 50 days (Figures 10.a to 10.d), the more the events are aligned along a straight line. When the helix revolution period is equal to 50 days (Figure 10.d), the position of the green points relative to the cyclic event form a straight line parallel to the central axis. When the helix revolution period is equal to 100 days (Figure 10.e), the position of the green points relative to the cyclic events form two straight lines which are parallel to the central axis.

Figure 10: The helical timelines for helix revolution periods equal to respectively 53, 52, 51, 50 and 100 days

a



b



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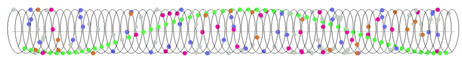
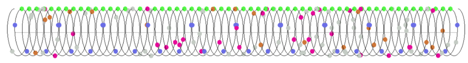
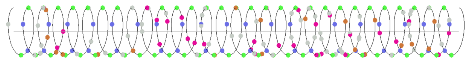


d

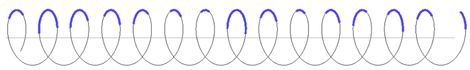


e



In a second step, we created another time-series of events, which include events with duration. For each event, beginning and ending dates were chosen in a range around a regular moment, which appears every 210 days. The helical time line is shown in Figure 11 for a revolution period corresponding to 210 days. It is clearly shown that the graphical objects are aligned with the central axis.

Figure 11: The helical timeline for a helix revolution period equal to 210 days



5 Conclusion

The integration of a helical temporal diagram into multidimensional geovisualization tools is proposed in order to achieve a visual analysis of spatio-temporal dynamics.In addition to other visual representation tools, our proposal should allow to better visualize the return-period of any type of cyclic events and to enable the user to explore the dataset in order to identify cyclic event types.

The next task is to apply our tool on various case studies such as volcanic eruptions and flooding risks. These future tests will prove if this tool, combined with large possibilities of event classification could be a good way to visualize cyclic events return-period among natural hazards data. Among the possibilities of event classification, we want to improve the capacity to classify an event according to its spatial location, in order to allow the identification of return-periods in specific territories. The future applications will allow to test the ability of the tool to identify return period of events and cyclic spatio-temporal phenomena. This visual analysis could be a complementary tool to mathematic analysis of data (Fourier transform).

6 Acknowledgments

This research was supported by the region Rhône-Alpes.

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