Eurographics Conference on Visualization (EuroVis), Posters Track (2017)
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Interactive Lens for Effective Time-Series Animation

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Abstract

We present a lens-based approach to explore animated data visualizations that involve time-series. The core of the approach lies in a novel combination of Lagrangian and Eulerian lenses, which allows us to leverage their complementary advantages to analyze data elements in complex spatial-temporal space. Film art techniques are employed to advance the way shifting the elements across different time and spaces. We illustrate the approach using animated bubble charts.

CCS Concepts

•***Human-centered computing*** $\rightarrow$ *Information visualization; User interface design;*

1. Introduction

At least since Hans Roslings famous TED talks, the usage of animation for displaying time becomes favorable in bubble charts and widely spreads among different types of visualizations. This kind of animation, better known as time-series animation, presents spatial-temporal dynamics of visual elements (e.g., bubbles) in which the elements temporally change locations according to the time-series data they represented. It is preferred in presentation-oriented visualization where a presenter guides observers' attention on patterns in the animation [KM13]. However, when the attention guidance is not available (e.g., in an exploratory analysis), audiences could easily be overwhelmed by changing graphics, and thus are exposed to change blindness that yields unawareness of important changes of the patterns [HR07]. The failures of visual experience force them to replay the animation many times for revisiting the missing patterns.

Interactive interfaces have been acknowledged as key to enhancing the exploratory usage of time-series animation. In this work, we focus on such an interactive approach where lens is leveraged to facilitate an unobstructed pattern re-examination for overcoming the blindness issue. When an observer feels that she loses track of a pattern (e.g., a cluster) during an animation, she pauses the animation and uses a lens to deploy her attention on the cluster (Fig. 1(a)). After she specifies a time period of interest, the lens shifts the cluster to its past status † and replays the evolving cluster along the period (Fig. 1(c)), from which key properties can be perceived to gain insight into the evolutionary context. Meanwhile, the previous properties can be easily related to current patterns outside the lens, enabling an identification of their relevance in the present context.

It is challenging to explore the interactive lenses with the time-series animation because it not only traces the movement of visual elements but also compares their properties across different spatial-temporal spaces (or status defined in this paper). Given the complex interplay among time, space, and visual elements, there lacks effective exploratory mechanisms that can incorporate them into interactive lenses. Moreover, the techniques that enable a smooth transition between two spatial-temporal spaces are also underexplored. To address the challenges, our solution incorporates concepts from physical sciences and film techniques.

2. Approach

In physical sciences, there have been two descriptions of a dynamical system as follows: (1) The Lagrangian point-of-view for tracing the motion of particular objects through time and space; and (2) the Eulerian point-of-view for looking at object motion at focal locations in the space. These two perspectives are largely complementary and are coupled to enable effective analysis of phenomena in spatial-temporal space. They imply two complementary types of lenses as corresponding interactive tools to explore the dynamical visual elements in time-series animation.

- **Space lens:** Following the Eulerian view, the lens focuses on a specific area of a visualization view. For bubble charts, the area presents value ranges of the corresponding attributes represented by chart axes. Users can directly manipulate the lens to define the location and area. For example, in Fig. 1(d), a space lens is deployed to specify an area presenting the "Middle-Income Trap" (GDP per capita between \$8k and \$10k). The bar chart below the lens shows the number of countries inside the area along with T. Based on the pattern, users can select a period of interest on the bar chart. Then, the lens plays the evolving elements inside this area along the specified period (Fig. 1(e)).

† Given a set of times T in a time-series animation, a status of visual elements is presented by their locations at a time step t where $t \in T$.

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DOI: 10.2312/eurp.20171167

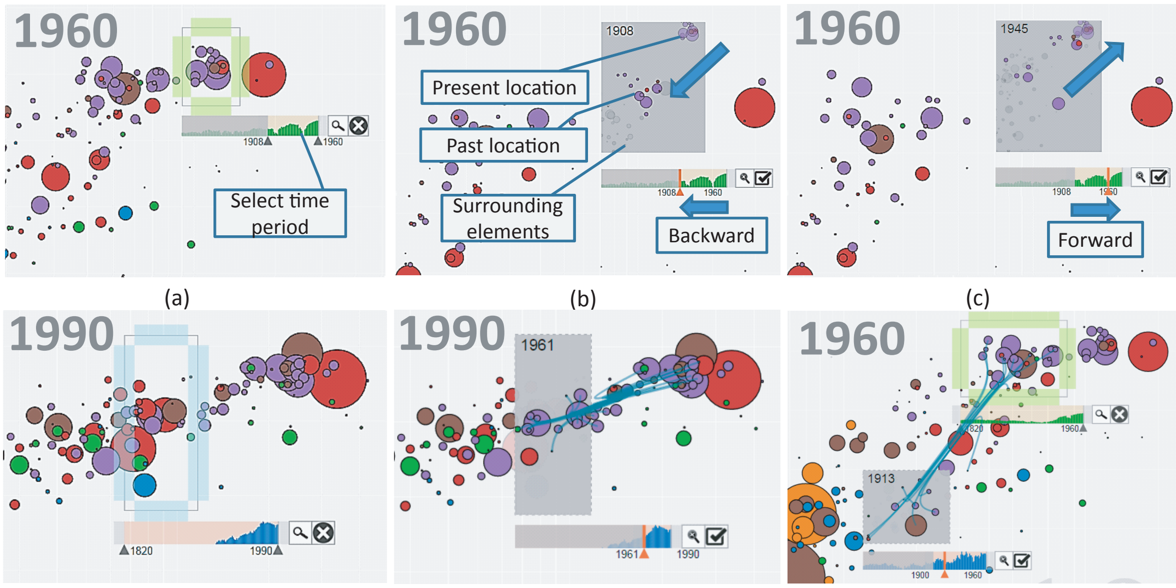

Figure 1: *Interactive lenses for animated bubble charts (x: GDP per capital, y: life exp., bubbles: countries). (a) deploy a trace lens on a cluster at the time of 1960. Set flashback time 1908; (b) the lens shifts the cluster backward to 1908; (c) the lens replays the evolving cluster at 1945; (d) deploy a space lens on an area at the time of 1990; (e) the lens dissolves the area from 1990 to 1961, where elements of the previous status are displayed with links to their present counterparts; (f) combine and correlate the two lenses for advanced analysis.*

By re-examining the animation, the users can understand which countries are slow down falling into the area.

- **Trace lens:** Based on the Lagrangian view, the lens focuses on a set of elements. Users can select multiple elements and their traces over any specific time period will be animated. For example, in Fig. 1(a), a cluster of high-income countries are selected by the trace lens. By viewing the historical trend of the average distance of the countries, users can quickly identify moments where significant changes occur in cluster behaviors. Replaying the evolving cluster in these moments allows for understanding the changes, e.g., to find anomalies at the moments (Fig. 1(c)).

Spatial-temporal transition: When lenses shift their views to past status, transition effects are provided to (1) prevent sudden changes between the two consecutive views; and (2) provide exogenous cues for conveying the temporal and spatial changes. In film art [BT03], abundant techniques have been developed to facilitate the spatial or temporal transition between film scenes. Two techniques are employed to leverage the power of film art in the spatial-temporal transition of the animated visualizations:

- **Dissolve** is used to narrate a flashback between two consecutive views of the space lens, in which it dissolves from the present view to its first status from a past period. Visual elements inside the present view gradually fade out, and slowly replaced by elements from the past status. Breaking the fade-in transition into different stages allows for identifying the differences between the present and past status. For example, in Fig. 1(e), courtiers that are still falling into the area at present fade in first followed by countries that have moved into high-income nations.
- **Reverse motion** plays elements of the trace lens backward (or time-reversed), and in a fast speed to condense the transition time. Before reversing the visual elements, the trace lens enlarges its size and downscales the elements (Fig. 1(b)). As such, both the origin and destination of the motion can be simultaneously displayed in the enlarged lens view, enabling a full picture of the spatial changes. The view outside the lens is distorted in accordance with the size change to preserve the context.

After the lenses shift to past status, a special thematic color is applied to its background for distinguishing the flashback from the present view outside the lens. In the trace lens, elements that surround the focused elements are displayed as context.

Spatial-temporal connection: When the space lens replays evolving elements in an area, links are drawn to connect them with their present counterparts outside the lens (Fig. 1(e)). The color of a link indicates the time of the corresponding elements enters the area (light colors indicate newly entered elements). To reduce visual clutter, the links are bundled [Hol06] based on the clusters of the elements. For the trace lens, hover over an element of the lens will highlight the corresponding location outside the lens, from which it can be compared with elements in the present view.

The two lenses can be paired to answer more complex questions. For example, in Fig 1(f), a cluster is observed in the space lens and its present counterpart is highlighted in the present view. By replaying the latter in the trace lens, users can understand how the cluster evolved outside the specific area of the space lens.

3. Future Work

In the future, we will evaluate the approach and extend it to different types of time-series visualization, such as dynamic graphs [BBDW14] and streaming text visualization [ACZ*11].

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