The spatiotemporal multivariate hypercube for discovery of patterns in event data

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ABSTRACT

Event data can hold valuable decision making information, yet detecting interesting patterns in this type of data is not an easy task because the data is usually rich and contains spatial, temporal as well as multivariate dimensions. Research into visual analytics tools to support the discovery of patterns in event data often focuses on the spatiotemporal or spatiomultivariate dimension of the data only. Few research efforts focus on all three dimensions in one framework. An integral view on all three dimensions is, however, required to unlock the full potential of event datasets.

In this poster, we present an event visualization, transition, and interaction framework that enables an integral view on all dimensions of spatiotemporal multivariate event data. The framework is built around the notion that the event data space can be considered a spatiotemporal multivariate hypercube. Results of a case study we performed suggest that a visual analytics tool based on the proposed framework is indeed capable to support users in the discovery of multidimensional spatiotemporal multivariate patterns in event data.

Keywords: Coordinated and multiple views, Visual knowledge discovery, Field studies, Multidimensional data, Visual analytics.

Index Terms: H.1.2 [User/Machine Systems]: Human information processing – Visual Analytics; I.6.9 [Visualization]: information visualization.

1 INTRODUCTION

Event data can hold valuable information to support decision making processes. Based on for instance highway incident data, tight road work budgets can effectively be used to improve infrastructure. In epidemics research, the data about the occurrences of diseases can be used to take effective actions to prevent spreading. The key to extracting this valuable information, is the ability to recognise and interpret patterns present in the event data.

Discovery of interesting patterns in event data can be a complex task, mainly because so many variables can play a role. This, along with the fact that the patterns of interest are complex, call for support of the human pattern detection capabilities by interactive visualisations [2]. Various visual analytics tools for dealing with spatial, temporal and/or multivariate data have been described in literature. Few do, however, consider all three dimensions space, time and multivariate in one framework. And even if they do they often visualise two dimensions for the first step of analysis, and provide information about the third dimension after selection and filtering operations in the first two dimensions. This does not necessarily support the discovery of all spatiotemporal multivariate patterns in the data. As argued by Gatalsky et al. in their plea for the space-time cube [1], selection and filtering operations on the spatial and temporal dimensions create a sort of 'space slices' or 'time slices' which allow for analysis of temporal patterns at different places or spatial patterns at different times, but not both. To really detect spatiotemporal patterns, they argue that both must be considered in unison. As an integrated solution, we propose the spatiotemporal multivariate hypercube along with a visualization, transition, and interaction framework consisting of rules that should be taken into consideration in the design of the visualizations and interactions (see figure 1 for an overview of the concept). We put this framework to the test in a case study involving a visual analytics tool we built using this framework, and expert users.

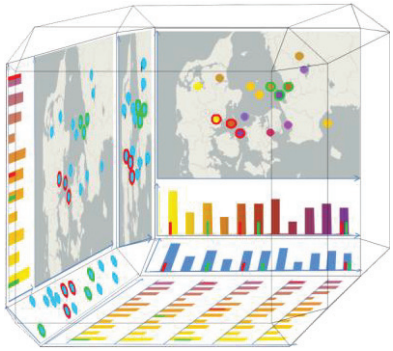

Figure 1 – The spatiotemporal multivariate hypercube: a metaphor for considering spatiotemporal multivariate event data in one integrated visualization, transition, and interaction framework to support the detection of multidimensional patterns.

2 THE SPATIOTEMPORAL MULTIVARIATE HYPERCUBE

As the spatiotemporal multivariate event data contains more dimensions than can be visualized at once, we investigate how we can accomplish an integral view on all dimensions, using multiple coordinated views. This should be done in such a way that all dimensions can indeed be considered together, thus overcoming the traditional problem of 'space slices' or 'time slices'. We think that the key to providing an integral overview can be found in the fact that the spatial, temporal, and multivariate dimensions of event data are in fact three dimensions of the same date (namely the *where*, *when* and *what* dimensions identified by Peuquet [3]). As these dimensions describe different and, to a large extent, independent aspects of the same data, these dimensions can be considered orthogonal. Hence, the search space for patterns in this data can be considered a cube, or in fact a hypercube, as depicted in figure 2, because the spatial and multivariate dimensions are multidimensional themselves.

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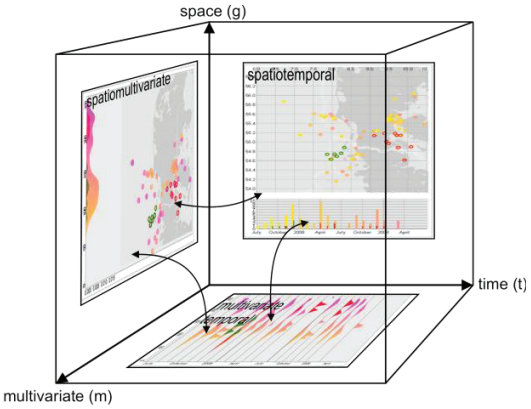

Figure 2 – Abstract representation of the spatiotemporal multivariate hypercube. In the developed tool, each projection shows a set of juxtaposed visualisations per variable. Framework rules ensure integral overview when transitioning from one projection to another.

3 Visualization, Transition and Interaction Framework

The visualization, transition and interaction framework must ensure that the individual dimensions space, time and multivariate as well as their pair wise projections onto the orthogonal planes of the hypercube are connected in such a way that the user is provided with an integral overview of all three dimensions in unison without actually visualising them all at once. This means that it must provide rules for the individual visualisations of the projections, for the interactions with each visualisation, and for the transition from one projection to the other.

3.1 Rules for visualization and interaction

Based on an analysis of literature, we established the following rules for the visualization of the various dimensions and projections, and the interaction with the visualizations. The first three rules stem from the observation that the tool must provide an integral and concise overview of the three dimensions.

Rule 1: *The dimensions space, time, and multivariate must be visualized in a similar, consistent way in each of the projections that they are part of.*

Rule 2: *Interaction with the visualization must be consistent across all projections.*

Rule 3: *Selections within one projection must be marked within all projections and the way in which selections are marked must be consistent across projections.*

The fourth rule is based on the fact that when searching for patterns in data, the user specifically searches for clusters that make a part of the data stand out from the rest of the data [1]. This means that distribution of events or event values is important and that absolute values are of lesser importance.

Rule 4: *In each projection, the distribution of events and event values must be visualized.*

When trying to reason why the identified cluster exists, the user will need to compare the cluster to other parts of the data. This allows the user to analyse why a selected cluster of the data is different from other parts of the data.

Rule 5: *The user must be able to select two regions within the data, and compare those regions.*

Based on rules 3 and 5 selections must also be marked in the other projections, and care must be taken to ensure that it is clear to the user which data is part of which selection.

3.2 Transition rules

The established rules also dictate how transitions between the projections are handled. Rules 1, 2, and 3 deal with the consistency of the way in which dimensions are visualised. When transitioning from one projection to the other, the dimension that is shared by the projections should remain constant, and the representation of distribution of events should not change. These rules also imply that when selections are made or aggregates are shown in one projection, the same selections and aggregates must also be shown in the other projections.

4 Case Study

In order to evaluate if the proposed framework enables users to discover true spatiotemporal multivariate patterns in event data, we put the framework to the test in a case study. We built a visual analytics tool based on our framework, and evaluated its performance using an actual air traffic control event dataset (flight positions and times, event conditions etc.) and actual air traffic control event analysis experts. For the purpose of the case study, we selected a small, relevant and complex subset of the available data (78 events) that would normally be selected interactively in the first step of the visual analytics mantra (‘analyze first – show the important’). From the results of this case study it can be concluded that the visual analytics tool based on the proposed framework actually provides true insight into spatiotemporal multivariate patterns. Of all patterns that were found, 84% involved at least two dimensions (e.g. space and time) or two variables. The experts even found a pattern including all three dimensions: “In the south, all events that happened during high workload, happened in the fourth quarter of 2008”. The analysis of the actions of the experts reveals that, before arriving at an insight, in many cases the expert used multiple projections for the discovery and subsequent verification of potential patterns.

5 Conclusion

Based on the notion of a hypercube, we presented a visualization, transition, and interaction framework for visual analytics tools supporting discovery of patterns in spatiotemporal multivariate event data. This framework makes explicit the rules to be taken into account when designing such a tool, to ensure that the spatial, temporal and multivariate dimensions of the event data can be considered in unison. Thus it allows the discovery of complex, multidimensional patterns in the data. In a case study with real world event data and experts on this data, we showed that a visual analytics tool based on the proposed framework is indeed capable to do so. The experts discovered several interesting patterns in the data that they were not aware of beforehand. The case study reveals that even for small datasets, the complexity of the patterns of interest requires a visual analytics approach. Future work will focus on making the techniques scale to large collections of event data.

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