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Using polymorphic glyphs to support the visual exploration of hierarchical spatio-temporal data

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Abstract. Studying spatio-temporal data is essential to understand the processes of the real world. However, the design of effective visualizations to explore spatio-temporal data is not a straightforward task due to the inherent multidimensional aspects of the data. In this paper, we explore the usage of polymorphous glyphs (i.e. glyphs that change shapes according to the context) to support the exploration of multiple hierarchical levels and dimensions of the data. We implemented our approach in the form of a web-based visualization interface that we demonstrate through a case study of the ISSA KG, which describes scientific publications in the field of agriculture, thus supporting domain experts on investigating where, when and how different crops are cultivated.

Keywords: Information visualization · Polymorphous glyphs · Linked data visualization · Spatio-temporal visualization.

1 Introduction

The study of spatio-temporal data (i.e. data described through geographic and temporal information) is essential to understand the processes of the real world. The widespread use of Linked Open Data (LOD) in the form of RDF (Resource Description Framework) knowledge graphs (KG) results on the availability and easy access of numerous datasets describing the semantics of real-world spatio-temporal entities and their relations on the Web, leading to huge amounts of geo-referenced information. Nevertheless, the value of these data depends on efficient tool support to extract relevant information to communicate the underlying phenomena. The design of efficient data representations to support the exploration of spatio-temporal data is particularly challenging. Further to being able to represent the multiple dimensions and levels of spatial (e.g. countries, regions, neighborhoods, etc) and temporal (e.g. years, months, days, etc.) granularity, a visualization technique should reflect the inherent properties of the data (i.e. the geographical arrangement of locations and the ordering of time units).

Multidimensional visualization is a challenge on itself: as the number data dimensions increases, a single view displaying all the information at once is no longer suitable due to cognitive overload and visual cluttering [5]. The coordinated multiple views paradigm tackles the problem of representing multidimensional data through a predefined set of views that represent different perspectives to the data [7], while providing coordinating operations between views to support reasoning [9]. However, the plethora of existing visualization techniques [4,

6] makes it unfeasible to determine a single combination of visualization techniques capable of solving every domain-related task.

Glyph-based data representations are another popular approach to deal with multidimensional data in information visualization due to their ability to convey multiple attributes in a small and compact visual representation. These are powerful visual representations capable of stimulating more cognitive activity during visualization than other forms of visual design [1]. Nonetheless, they are often static representations, displaying a large yet single perspective to the data. In this paper, we investigate the usage of polymorphic glyphs (i.e. glyphs that change its shape according to the surrounding semantics and/or user actions) to assist the exploration of hierarchical spatio-temporal data. As a proof-of-concept, we implemented our approach in the form of a web-based visualization tool, called *PHiTGlyph* (**P**olymorphic and **H**ierarchic **T**emporal **G**lyph), that uses interaction to activate the polymorphous aspect of glyphs.

Finally, we demonstrate the suitability of our approach by exploring the ISSA KG [8], which describes over 110,000 scientific resources (i.e., book, book chapter, article, thesis, etc.) in the field of agriculture. Each data record is enriched through named-entity (NE) linking, which assigns a unique identity to entities (e.g. locations or crop cultures) mentioned in the text. Thus, each data record corresponds to a scientific publication described through information such as title, authors, publication date, abstract and associated to a number of geographic and thematic NEs. Each geographic NE is described through a name and a geographical position (i.e. latitude and longitude).

2 PHiTGlyph: Polymorphic and Hierarchic Temporal Glyph

Similar to previous works [2, 10, 3], we geo-locate glyphs encoding attributes of the data records. The thematic dimension of our data comprises the research topic of each publication, which information is hierarchical, composed by categories and sub-categories. Visualization techniques such as treemap, sunburst, circle packing and tree diagram are well-known to represent hierarchical data. However, as the number of categories and hierarchical levels increase, the visual legibility of these techniques reduces significantly. Although interaction supports navigating up and down the different levels of the hierarchy, such navigation happens one category at the time, which hinders comparison tasks. For this reason, we chose to design a polymorphous glyph, which different shapes can represent different levels of the hierarchy, thus improving legibility and between-category comparison. Particularly, we follow a stacked-bar graph-like design to represent the count of data records (size of bar sectors) associated to each category (color). When placed over a time axis, it can encode the temporal distribution of data records, while being easy to read and supporting comparison tasks. According to Borgo et al. [1] the chosen design respects criteria of typedness, visual orderability, channel capacity, separability, and learnability.

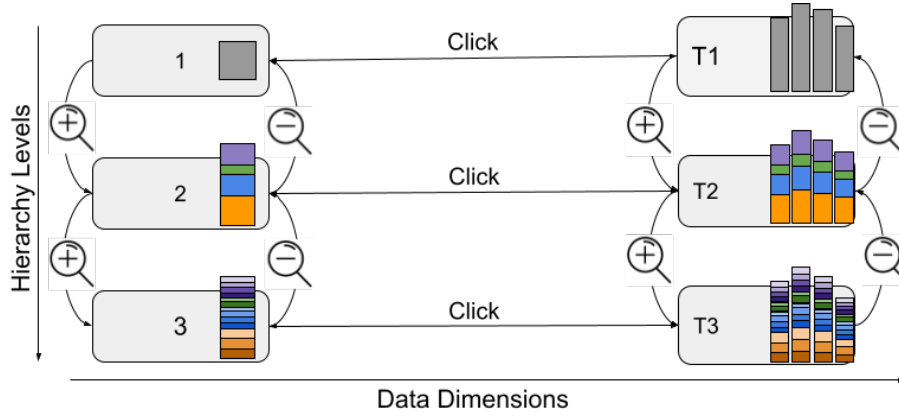


Fig. 1. Overview of glyph states and interactions.

The diagram illustrated in Figure 1 represent the different states of our glyph, which are activated through interaction: zooming with mouse scroll enables a hierarchical browsing of the data from the total count of publications to the distribution per sub-category, while the use of an arrow placed next to the glyph reveal the temporal distribution of publications for a particular country, either the total count or the distribution per category and sub-category. Upon hovering over the glyphs, the system displays a tooltip showing detailed information about the represented data. Finally, to assist the user on answering questions such as “how is a crop cultivated in a particular country?”, upon identifying the country where the crop is cultivated, the user can hover the glyph and select the category to see what publications in the dataset refer to that category.

3 Exploring the temporal evolution of crop culture across different regions

In this scenario, we assist Bob in his research to understand (i) the temporal evolution of crop culture mention in the literature of different countries, and (ii) how the cultivation methods evolve over time. Bob starts by searching for the countries of interest, e.g., France and Costa Rica (Figure 2a-b). As he is interested in exploring the differences between cereal culture and livestock breeding, he filters out non interesting crop cultures. Bob then zoom into each country to reveal the distribution of publications per category (Figure 2c-d), where he observes a similar count of publications. However, he wants to know if this distribution is even across time periods. Thus, he uses the arrows next to the glyphs to deepen the exploration by revealing the temporal distribution of those publications according to the selected categories (Figure 2(e-f)). The glyphs display the count of publication over a time period from 2015 to 2018, where one can observe that the literature in both countries refer to those cultures in a different frequency

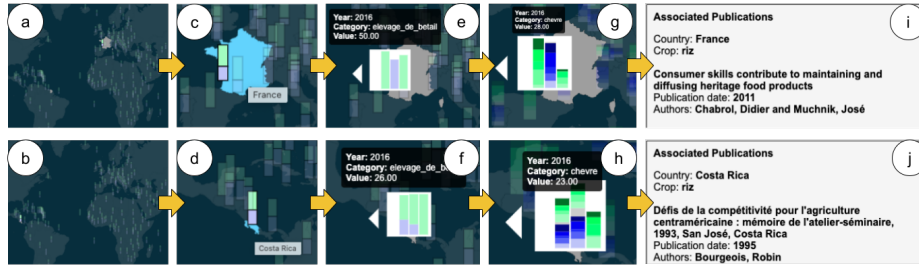


Fig. 2. Usage of PHiTGlyph. The user search for the countries of interest (a-b). They navigate to the temporal distribution of publications per category using the arrows next to the glyphs corresponding to each country (c-f). By zooming into the glyph, they reveal the temporal distribution per subcategory (g-h). Then, to proceed their research and compare crop culture across country, they access the associated publications to the time period of interest (i-j).

in the years 2016 and 2017, when France has only references to either livestock breeding (2016) or cereal culture (2017) while Costa Rica has references to both crop categories. Going further, Bob zoom into the glyphs to reveal the temporal distribution of crop reference within each category (Figure 2g-h) and explores the associated publications to each crop to identify the differences between their cultivation methods in each country (Figure 2i-j).

4 Conclusion and Future Work

In this paper, we propose the use of polymorphous glyphs to represent multiple hierarchical levels and dimensions of spatio-temporal data. We rely on simple visual channels (i.e. size and color) to support a smooth learning curve, while providing interactions such as zoom and click to guide the user through the different hierarchical levels and data dimensions. We demonstrated our approach through a case study of the ISSA KG to support researchers in agriculture on answering questions such as “where and when are crop cultures mentioned in the literature?” and “how does a particular crop culture evolve over space and time?”. A limitation of our approach refers to visual scalability: we illustrated it through four topics and time periods, as we are limited by the number of colors one can perceive visually. Although we mitigate the issue through filtering out uninteresting information, studies are necessary to understand how our approach deals with visual scalability and how efficiently is the proposed solution.

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