Composition and Configuration Patterns in Multiple-View Visualizations

Xi Chen, Wei Zeng, Yanna Lin, Hayder Mahdi Al-maneea, Jonathan Roberts, and Remco Chang

Abstract— Multiple-view visualization (MV) is a layout design technique often employed to help users see a large number of data attributes and values in a single cohesive representation. Because of its generalizability, the MV design has been widely adopted by the visualization community to help users examine and interact with large, complex, and high-dimensional data. However, although ubiquitous, there has been little work to categorize and analyze MVs in order to better understand its design space. As a result, there has been little to no guideline in how to use the MV design effectively. In this paper, we present an in-depth study of how MVs are designed in practice. We focus on two fundamental measures of multiple-view patterns: *composition*, which quantifies what view types and how many are there; and *configuration*, which characterizes spatial arrangement of view layouts in the display space. We build a new dataset containing 360 images of MVs collected from IEEE VIS, EuroVis, and PacificVis publications 2011 to 2019, and make fine-grained annotations of view types and layouts for these visualization images. From this data we conduct composition and configuration analyses using quantitative metrics of term frequency and layout topology. We identify common practices around MVs, including relationship of view types, popular view layouts, and correlation between view types and layouts. We combine the findings into a MV recommendation system, providing interactive tools to explore the design space, and support example-based design.

Index Terms—Multiple views, design pattern, quantitative analysis, example-based design

1 Introduction

We present an in-depth study on how multiple views are used in practice, and integrate our results into a recommendation system for the layout design of a multiple-view visualization. Traditional visualization designs aim to maximize the utility of the visualization for specific data types or tasks. For example, line graphs show temporal information, maps display geographical information, etc. Multiple-view visualization (denoted as MV) is a technique that seeks to integrate these visualizations by compositing multiple views of different view types into a single cohesive representation [22, 39]. Since each visualization conveys a specific perspective of data, a well-designed MV enables the user to simultaneously see representations of the same data from different perspectives. In fact, the power of multiple views is well understood and the technique has nowadays become ubiquitous in exploratory data visualization [40].

However, despite the ubiquity of multiple views in visualization systems, there are few guidelines, and those that do exist are very general. For instance, researchers advise developers to use multiple views sparingly [5], and adopt consistent visual encodings across multiple views [36]. Additionally, while researchers have made recommendations for multiple displays [13], and collaborative tasks over large displays [27], the plethora of design considerations pose challenges to developers in practice.

The visualization community has developed many visualization authoring tools, such as Power BI [1], Tableau [3], and Spotfire [2]. These tools allow the user to quickly design prototypes of MVs using a set of predetermined templates for common data types, such as the sales dashboard templates offered by Tableau [3]. However, for more complex data and tasks, designers often still need to manually curate the layout of MVs through trial and error. This process can be tedious and time consuming, and sometimes produces results that fail to meet design guidelines [36]. Recently, researchers have developed techniques to automatically distribute multiple views in a visual space [18, 23, 26, 41]. While the layout of theses systems may appear arbitrary, users place the views side-by-side in a deliberate way.

The goal of this paper is to create an image corpus of real-world MV images, analyze patterns contained in this data, distill a set of guidelines, and finally to produce a recommendation system for the design of MVs. To code the design patterns of MVs, we first code each of the views in a MV in terms of its:

- *view type*: the mapping from data to visual form, *i.e.*, the result of a visualization technique (*e.g.*, bar and line charts);
- *bounding box*: position and size in the physical display space (most often in 2D) where the view is presented.

After each view is coded in terms of its *type* and *bounding box*, we then encode the overall MV design based on its:

- *Configuration*, including position and size of the bounding box of each view in the physical display space.
- *Composition*, including frequency, diversity, and correlations of view type usages.

Using this coding scheme, we collect and label images of MV designs from publications in *IEEE VIS*, *EuroVis*, and *IEEE PacificVis* conferences from 2011 - 2019 (Section 4.1). The result is a curated dataset of 360 MV designs, which are then manually coded using an annotation tool that we developed for this effort (see Section 4.2).

We perform in-depth analyses on this dataset, using a number of quantitative metrics from information theory and graphics, such as conditional probability and layout topology. The analyses reveal interesting composition and configuration patterns of MV design, including frequencies, aspect ratios, and positions of different view types (Section. 5). For example, aspect ratios of most view types are within [1/2, 2], except for some types like *Area* and *Panel* (see Figure 7).

Lastly, using the found composition and configuration patterns from the analyses, we develop an interactive recommendation system for designing MVs. In particular, this system: (1) enables multi-faceted

- *Xi Chen, Wei Zeng, and Yanna Lin are with Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences. Xi Chen is also with University of Chinese Academy of Sciences. Wei Zeng is the corresponding author. E-mail: {xi.chen2, wei.zeng, yn.lin}@siat.ac.cn.*
- *Hayder M. Al-maneea and Jonathan C. Roberts are with Bangor University. E-mail: {h.m.almaneea, j.c.roberts}@bangor.ac.uk. Hayder M. Al-maneea is also with University of Basrah.*
- *Remco Chang is with Tufts University. E-mail: remco@cs.tufts.edu*

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