DMiner: Dashboard Design Mining and Recommendation

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Abstract—Dashboards, which comprise multiple views on a single display, help analyze and communicate multiple perspectives of data simultaneously. However, creating effective and elegant dashboards is challenging since it requires careful and logical arrangement and coordination of multiple visualizations. To solve the problem, we propose a data-driven approach for mining design rules from dashboards and automating dashboard organization. Specifically, we focus on two prominent aspects of the organization: *arrangement*, which describes the position, size, and layout of each view in the display space; and *coordination*, which indicates the interaction between pairwise views. We build a new dataset containing 854 dashboards crawled online, and develop feature engineering methods for describing the single views and view-wise relationships in terms of data, encoding, layout, and interactions. Further, we identify design rules among those features and develop a recommender for dashboard design. We demonstrate the usefulness of DMiner through an expert study and a user study. The expert study shows that our extracted design rules are reasonable and conform to the design practice of experts. Moreover, a comparative user study shows that our recommender could help automate dashboard organization and reach human-level performance. In summary, our work offers a promising starting point for design mining visualizations to build recommenders.

Index Terms—Design Mining, Visualization Recommendation, Multiple-view Visualization, Dashboards

1 Introduction

Multiple-view (MV) visualizations composite multiple visualizations into a single cohesive representation. Due to its power to support users in exploring several perspectives of data simultaneously, a large number of MV visualizations have been created and shared on the web by various domains, from biomolecular to multimedia to business. Creating an MV visualization typically starts with selecting views of interest, followed by presenting the selected views and adding interactions between views [1]. This paper refers to the presentation and interactions as layout arrangements and coordination, respectively. Arranging and coordinating views are vital when explaining the widest range of usability problems in visualizations [2]. Specifically, a proper arrangement can maximize the utility of the limited display space and improve the effectiveness and expressiveness of the information exchange, improving the usability of the system [3]. Besides, coordination among visualizations can make cross-view data relationships more apparent and reduce users' cognitive burden [4].

However, it remains challenging to create effective MV visualizations with a proper view arrangement and coordination. From a theoretical perspective, existing guidelines on MV visualization designs focus on high-level recommendations, e.g., drawing users' attention to the right view and making cross-view data relationships more obvious [1]. They are insufficient in providing lay users with actionable suggestions to adjust their designs. From a practical perspective, while researchers have recently developed some recommenders or authoring tools to assist lay users in creating visualizations and MV visualizations, few of them have focused on the arrangement and coordination among views. Existing tools (e.g., Tableau [5], Power BI [6], and MultiVision [7]) provide default layout templates that require manual adjustment to achieve satisfactory MV visualization designs. This process is tedious and time-consuming, given that the potential layouts increase exponentially with the increasing number of views.

We present DMiner, a data-driven framework for mining dashboard design and automating the layout arrangement and view coordination for MV dashboards (Figure 1), thus reducing the design burden of designers. Specifically, MV dashboards are one of the most common genres of MV visualizations [8]. In this paper, we use the term MV dashboards and dashboards interchangeably to represent multiple-view dashboards. Given that end-to-end ML-based visualization recommenders suffer from poor explainability and can confuse end-users [9], we aim to develop an explainable approach by first mining design rules from an MV dashboard dataset and further recommend appropriate layout arrangement and view coordination in MV dashboards.

Due to the lack of MV dashboard datasets, we first crawled a large number of dashboards created by Tableau, a common dashboard authoring tool, from GitHub [10]. We deduce a set of features that influence the arrangement and coordination of these views through reviewing prior studies, and further identify the mappings among them (Figure 1 (A)). With the collected dataset, we then extract features from two perspectives: 1) the single-view features describing each view in terms of its visual encodings (e.g., color), encoded data (e.g., data types), and

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