Accepted Manuscript

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Please cite this article as: Chun-Cheng Lin , Weidong Huang , Wan-Yu Liu , Wen-Lin Chen , Evaluating Aesthetics for User-Sketched Layouts of Symmetric Graphs, *Journal of Visual Languages and Computing* (2018), doi: https://doi.org/10.1016/j.jvlc.2018.08.004

Evaluating Aesthetics for User-Sketched Layouts of Symmetric Graphs

Chun-Cheng Lin[1], Weidong Huang[2], Wan-Yu Liu[3,4,*], and Wen-Lin Chen[1]

Abstract—In evaluating aesthetics of graph drawings, recent works have provided participants with an adjacency list of a graph and asked them to sketch a pleasing layout of the graph. However, this line of research has not considered aesthetics for user-sketched layouts of graphs with symmetries, which are an important property of a given graph drawing. Therefore, the work reported in this paper focuses on empirically evaluating aesthetics for user-sketched layouts of symmetric graphs. We provided participants adjacency lists of two symmetric graphs and asked them to sketch the two graphs. We analyzed whether symmetries were shown in user-sketched drawings, and further analyzed the aesthetics based on their drawing processes and drawing preferences. In addition, our experiment includes multiple stages to analyze whether the participants had the potential learning ability to draw symmetric structures of graphs. We found that in drawing symmetrical graphs, showing symmetry was likely considered more important than minimizing edge crossings, and that most participants made substantial progress in their ability to create symmetric drawings after going through the experimental stages.

Index Terms—Aesthetics, user-sketched layout, graph drawing, symmetric graph, learning effect

✦

1 INTRODUCTION

Graphs are widely used for presenting relational information such as social networks and biological networks [1]. A graph is often visualized as a node-link diagram, illustrating the relationship between nodes intuitively [2]. However, as the scale of graphs enlarges along with increasing amounts of information, graph drawing becomes increasingly complicated. Many algorithms have been developed to draw graphs automatically (e.g., [3,4]). However, individual aesthetic criteria conflict with each other; it is not possible to implement all of them at the same time in a single algorithm [35]. To address this limitation, Huang at al. [5] proposed a method to summarize the criteria for evaluating graph drawings generated by algorithms by combining and converting aesthetic criteria into a single value. Further, research has found that the most influential factor was the minimization of edge crossing, followed by the minimization of edge bends and the maximization of symmetry [6]. Subsequent studies on graph drawing algorithms have investigated aesthetic standards [7–9]. However, since Lombardi [10] used arcs as the edges of graphs, some researchers have suggested that this type of drawings are more aesthetically pleasing [11]; thus, Chernobelskiy et al. [12] designed an algorithm to quickly convert graphs into Lombardi drawings. Additionally, Xu et al. [13] conducted an experiment in which participants compared straight lines, curves, and Lombardi drawings, and found that the straight lines were more aesthetically pleasing and more favorable among participants. This finding was different from the experimental results of [14], where participants preferred curves. Huang et al. [40] conducted a study investigating the effects of curves on graph comprehension. It was found that curves could be used to avoid

1. *Department of Industrial Engineering and Management, National Chiao Tung University, Hsinchu 300, Taiwan. E-mails: cclin321@nctu.edu.tw, amber0507@hotmail.com*

2. *Department of Computer Science and Software Engineering, Swinburne University of Technology, Hawthorn, VIC 3122, Australia. E-mail: weidonghuang@swin.edu.au*

3. *Department of Forestry, National Chung Hsing University, Taichung 402, Taiwan. E-mail: wyliu@nchu.edu.tw*

4. *Innovation and Development Center of Sustainable Agriculture, National Chung Hsing University, Taichung 402, Taiwan.*

* *Wan-Yu Liu is the corresponding author of this paper.*

crossings to make pictures more visually pleasing, while users had better task performance when curves were used to increase crossing angle.

Despite those commonly used graph drawing aesthetics and associated algorithms that aim to generate drawings with pre-defined aesthetic criteria, research has been done to derive aesthetics based on preferences and graph drawing behaviors of end users [39]. As graphs are drawn for users to understand, it would help if aesthetic criteria used for algorithm design are verified by users or directly derived from user feedback [15].

One of the approaches to deriving user centered aesthetics is to ask users to draw graphs and then analyze the drawings to see what criteria were used by users to make the drawings [39]. A number of studies have been conducted along this line and some interesting findings have been reported. For example, when asked to adjust a given layout, participants tended to put clusters in a convex hall [15]. When asked to draw graphs based on an adjacency list, participants tended to align nodes and edges to an underlying grid [19]. In these studies, simple general graphs were often used. However, symmetry is one of important graph properties [31] and possible impact of symmetry on user graph drawing behavior has not been well studied before.

In this paper, we report on a user study that we conducted to investigate how users draw symmetric graphs and how the symmetry property affects users' drawing behaviors. The main contributions of this work include: 1) we conducted a study that investigated user behaviors of drawing symmetric graphs; 2) an in-depth analysis of users' drawing behaviors and visual characteristics of resulting drawings was conducted from multiple perspectives: drawing product, drawing process and drawing preference; and 3) we found some interesting results that lead to further research directions. The rest of this paper is organized as follows. We first review related works in Section 2. Section 3 describes the design of this study and the equipment used in the experiment. Section 4 presents the statistical analysis of the collected user-sketched drawings. Section 5 discusses the results of the analysis and experimental limitations. Section 6 provides conclusions and future research directions.

2 RELATED WORK

Recent studies have found that inviting participants to create graph drawings can yield more concrete aesthetic suggestions [16]. In this type of research, simple graphs have been used that allow participants to intuitively sketch drawings on an existing graph