THE EXTENDED STEREOSCOPIC HIGHLIGHTING TECHNIQUE FOR NODE-LINK DIAGRAMS: AN EMPIRICAL STUDY

Ragaad AlTarawneh, Jens Bauer, Shah Rukh Humayoun, Patric Keller, Achim Ebert
Computer Graphics and HCI Group, Software Engineering: Dependability Group
University of Kaiserslautern, Kaiserslautern, Germany
{tarawneh, j_bauer, humayoun, pkeller, ebert}@cs.uni-kl.de

ABSTRACT
The stereoscopic highlighting technique is a new emerging technique that supports using the depth cue in 3D devices as a highlighting technique for general node-link representations. One of the main abilities of this technique is isolating the specific graph portions to magnify them for a detailed exploration without resorting other highlighting attributes such as color or shape. In this paper, we measure the accuracy of this technique by evaluating the ability of general users in reading the variation of depth values to encode some data aspects. To achieve this goal, we carried out a controlled user-study in which we asked users from different backgrounds to perform a specified set of tasks. The results show that using the depth cue in stereoscopic devices is readable for medium data sizes with at most three or four different layers. This can be useful in classifying the data set into a set of categories according to the depth value of the elemental layer.

KEY WORDS
Information Visualization, Virtual Reality, Stereoscopic Devices, Stereoscopic Highlighting, Depth Perception

1. Introduction

The term visualization relates to the process of producing images of “hidden” data structures and dependences that are not originally accessible for the human perception. While the stereoscopic term is defined as the tool uses the stereoscope impression in a digital environment. Therefore, combining the stereoscopic devices with the visualization concept produces a new term, called as Stereoscopic Visualization, which is related to producing a depth cue impression in the image by combining two views of the object that were taken from slightly different points of the view. The first one is for the left eye while the second one is for the right eye.

However, perceiving the depth cue in the stereoscopic picture needs a special digital environment in order to offer this feature in the final image. Therefore, many technologies have been appeared to offer this environment. One of the common examples is the 3D display; that has been used in many application domains. For example, we have seen an increased acceptance of 3D displays in the entertainment industry due to the continue decreasing of hardware costs. Moreover, technologies behind the stereoscopic displays are advancing at accelerated steps with a high quality stereoscopic image. For examples, 3D displays that do not need expensive LCD shutter glasses to generate an active polarized stereo image are easily accessible to end-users these days. On the other side, these kinds of screens offer a great opportunity to be used in the research, as it has already been proofed in that users perceive depth cues more easily using the volumetric monitors than the other stereoscopic displays.

In this work, we show the ability of using the depth cue in stereoscopic displays as the highlighting technique for information visualization applications. However, the idea of mapping the data elements that lack the inherent relations among them into 3D elements is not common as in 2D representations. This is due to the extra overlapping that might appear in the final layout. Moreover, it requires extra navigation tools that are necessary to explore the data. Therefore, using the 3rd dimension in information visualization applications is considered as a complicated task. However, it can be useful to solve some scalability problems of the 2D representations.

One of the biggest challenges in the information visualization field is visualizing dens graphs into node-link diagrams using intuitive form of representations. These representations aim at highlighting the underlying relations among the data entities. However, the current state of the art lacks a pleasant representation for large and dense graphs due to the extra edge-crossings. Hence, many optimized solutions have been suggested to help in discerning the edges in such representations. For example, in the 3D node-link visualization has been proposed to reduce the edge crossings. The authors argue that the rotation of the layout in the 3D world can help in identifying the adjacency relations of certain elements. Also, it makes the task of counting nodes, which are accessible from a particular node, quite easier.

However, due to the perspective view in the 3D world, rendering a node-link diagram can lead to wrong conclusions about the importance degree of some nodes. This is because some nodes are rendered closer to the virtual viewpoint than the others, which increases the visual emphasis of the closer nodes. This situation occurs due to the graph layout algorithm or because of the
viewers’ viewpoint rather than the data set itself. In addition, 3D layouts require a high amount of viewpoint navigations. For example, when a node of interest is rendered at a further depth level the user needs to rotate, zoom or change the view angle to get a better view of the required node. This process affects on preserving the mental map of the layout because the graph appears differently each time to the viewer [1].

To reduce the cons of using the 3D node-link diagram, a special environment is necessary to eliminate the problems of navigation and the wrong perspective. We suggest rendering the node-link diagram in a stereoscopic display to utilize the depth cue provided by this technology. Therefore, we use this highlighting technique to show some aspects about the data beside other static visual cues such as color or shape. Our work is built on the results of the work presented in [1], in which a controlled user-study was conducted to show the feasibility of using the 3rd dimension to highlight nodes in general graphs. In [1], authors provided a comparison of using the depth cue provided by stereoscopic displays as a highlighting technique beside other static visual cues on 2D or 3D graph layouts. They proved the ability of users to read the stereoscopic depth and used it as a highlighting technique for important nodes in the underlying graph. They claimed that using the stereoscopic depth as a highlighting attribute helps in saving other static visual cues for other usages, especially with highly attributed data. However, it can be used only as an ordinal property while the other static visual cues can be used to highlight nominal properties [1].

However, one of the potential drawbacks in utilizing the stereoscopic depth is the time that users need to realize the depth cue in the stereoscopic display. This is one of the big differences between using the depth cue and using the color cue for highlighting. The colors can be observed instantly, while perceiving the depth requires longer time. However, depth has an advantage over other static visual cues, as when elements in a set are associated together at the same depth level it gives a spatial relation to those elements. Also, based on the Gestalt theory the spatial association among the data elements is stronger indication than colors [16]. Moreover, [1] claims that nearly 8-10% of the population cannot judge the depth correctly as a cue. On the other side, around 10% of men and less than 1% of women population also face some degree of colorblindness [8], which makes it difficult for them to use color as a cue.

In this work, we measure the number of different depth layers that normal users from different backgrounds can detect, how high is the accuracy of and what is the average time to complete the detection. To achieve this, we designed a controlled user-study consisting of 3 tasks, where each task had a set of different configurations with different settings to measure the efficiency of stereoscopic highlighting technique. The remainder of the paper is structured as follows: Section 2 summarizes the related work. In Section 3, we explain the concept of stereoscopic highlighting technique. In Section 4, we present our hypotheses and discuss the outcomes of the conducted user evaluation-study. We conclude in Section 5.

2. Related Work

3D layouts have been used in many previous works. For example, the hyperbolic layout has been proposed by many [14, 15, 17, 18, 19] to show the information structure in the 3D world. In [22], Robertson et al. presented the cone tree layout method as a pure 3D layout algorithm for hierarchy structures. Beside this, space-division techniques have also been extended into 3D versions such as the Treecube technique [23], which is an extension of the traditional Treemap algorithm [24]. Another example is semNet that can be found in [11]. Those examples are based on using the animated 3D visualization and the lightening to realize the depth perception. The main drawback of using such approaches is the emerging overlapping among the layout elements. Moreover, the mentioned examples do not consider the variations in depth values while positioning the nodes in the 3D space, which affects the level of the data perception [4].

The 3D layout requires a special 3D display to perceive the correct impression. In a study evaluating the efficiency of 2D, 2.5D and 3D layouts in physical and virtual platforms, it has been concluded that 3D without the stereoscopic effect does not help in utilizing the spatial memory of the third dimension [4]. As a result of this finding, many scientific visualization applications receiving benefit from 3D display devices as many of these applications’ objects are inherently 3D objects [12]. At the same time, few believe that 3D visualization is not an appropriate solution for applications related to the information visualization [27]. This is due to the lack of the inherent spatial relations among the data entities. Beside this, the extra occlusion might appear as a result of node overlapping. Moreover, they say that 3D environments also need some additional interaction techniques to navigate through the data set [27].

Many efforts have also been done in showing the efficiency of using the 3D graph visualizations with high-resolution stereo displays [27, 28]. According to their results, 3D graph visualization is recommended only when stereoscopic cues and real time rotations are supported. Many applications use the stereoscopic effect as a technique to separate the set of images that share the same texture of the background. In addition to that, depth cues have also been used to separate the overlapped labels on the 3D world in order to reduce the cluttering effect [21]. In [6], the variation in depth was used to reduce the cluttering of information by filtering the data set. In [7], authors evaluated the pre-attentive visual features as basis for a highlighting technique in virtual reality environments. They showed that the stereoscopic depth has an additional advantage of facilitating an intuitive interaction technique, as it positions the relevant
information toward the user or pushes them away according to their importance degree.

Many examples have been provided by [5, 10] for showing the usability of using the third dimension in encoding different aspects of the data. This can be achieved by isolating a subset of a 2D graph representation to a separate layer, thus a 2.5D would be created. In this case, the third dimension can be used to encode aspects of the data rather than the relationships among nodes [3]. For example, the third dimension in [3] has been used to show the evolution of the node-link diagram over time, where each layer encodes a 2D representation of the graph at a certain time step. In another example by [10], the third dimension was used to depict the hierarchical nesting of clusters in the graph using a set of transparent layers. However, above mentioned examples did not exploit the depth cue nor they provided a quantitative criteria to measure the usability of the approach. While in [1], the third dimension has been used as a tool supporting the low-level graph analysis tasks. In their work, the authors combined the usage of stereoscopy and 2.5D graphs and then apply them to a node-link diagram. The depth cue was used to show the importance degree of the graph elements by rendering them closer to the viewpoint. Much effort has also been invested on highlighting techniques for 2D node-link diagrams. Authors of [26] have shown that highlighting is important for identifying the adjacency relations in node-link diagrams. They proved that not only static visual cues, such as color or shape, are effective but motion cues can also be effective somehow at the same degree. Moreover, they argued that combining two highlighting techniques could be more effective in results than using a single highlighting technique. In our work, we measured the ability of users to read the variation in the depth values in stereoscopic devices as a way to encode data aspects. We conjunct the stereoscopic highlighting with other visual cues, such as color or/and shape, to measure a user's ability in interpreting the different visual cues simultaneously.

3. The Stereoscopic Highlighting Technique

As it is already mentioned in [25], the 3D node-link diagram technique can be used to reduce the edge-crossing problem in the 2D layout [25]. This is achieved by isolating the set of edges that overlaps in the 2D version. However, producing a 3D diagram makes it difficult to preserve the mental map of the dynamic graph and may produce a more occluded layout that needs extra interaction tools to navigate through it.

The stereoscopic highlighting technique, as proposed in [1], utilizes the stereoscopic depth to highlight the important regions in a 2D diagram by bringing them closer to the viewer. This helps in reserving other highlighting attributes like color or/and shape for encoding other data properties. The concept is to use the variation in depth to highlight the multiple elements that share the same attribute values in the diagram. One of the biggest advantages of using the stereoscopic highlighting technique is its ability to achieve the focus+context views naturally. This is because it brings the region of interests to the foreground, while keeping the rest of the graph in the background. Therefore, it reveals fewer details.

Furthermore, the stereoscopic highlighting technique offers an effective interaction approach by arranging the graph nodes into a set of layers according to the depth values. This can be useful in analyzing a set of nodes together by bringing them at the same depth layer, and toggle naturally between the different layers. Moreover, the stereoscopic environment allows a visual search at different layers simultaneously. This has been shown by [20] where authors concluded that stereoscopy disparity allows for parallel conjunctive search. They proved the human ability to perceive similar color and motion attributes on different layers that are isolated using different depth values.

In this work, we implemented a prototype to evaluate the accuracy of the stereoscopic highlighting technique that has been proposed in [1]. We measured the normal users’ (from diverse backgrounds) ability in perceiving the depth variations also the number of depth layers that can be detected accurately, as well as the number of nodes associated to each layer. We measured the users' ability to read different configurations where each configuration use different visual cues like color or/and shape beside the depth cue. The goal was to measure their abilities to distinguish between the different encoding attributes and interpret them independently. In our controlled study, we used seven different configurations that were switched at random based to reduce the learning effect on users. Each user started with a simple 2D node-link layout rendered in a 3D context as it is shown in Figure 1(a) where all nodes had the same shape, the same color, and the same depth value. Then we changed the depth values for a predefined set of graph nodes to create a 2.5D representation of the configuration. The users were able to see only the front view of the layout and they were not allowed to rotate the layout. In a more advanced configuration, we added other visual cues such as color or shape or both to encode extra data attributes as it is shown in Figure 1(b), Figure 1(c), and Figure 1(d) respectively. It is worth mentioning that in [1], the authors measured the feasibility of using the stereoscopic highlighting technique solely. They provided an interactive framework to allow users to arrange the discrete layers. Their framework also allows finding out the set of neighbors of the highlighted node and the number of all nodes that are along the shortest path between the selected nodes. They claimed that users were able to identify the number of layers and the number of nodes that are associated to each layer. However, there is no information about the number of layers that users were able to detect accurately or about the number of nodes associated to each layer. We tried to measure the accuracy of using it by giving a rough indication of the number of layers that a user can really read and can use to encode
some information about the data itself. We describe our performed controlled user-study in the coming section.

Figure 1. 2D Sample configurations for each task: (a) uniform configuration, (b) same color with different shapes configuration, (c) same shape with different colors configuration, and (d) different shapes with different colors configuration.

4. The User Evaluation Study

We carried out a user evaluation study for evaluating the accuracy of using the stereoscopic highlighting as part of an advanced highlighting technique to identify the critical nodes in node-link diagrams. We also analyzed the effectiveness and the feasibility of this approach. The purpose was to check whether users from different backgrounds are able to perceive the variations in depth levels in the provided environment. Moreover, we were also concerned about the efficiency of viewers to correctly perceive the extra information available beside the depth cue. In this study, users from different backgrounds evaluated the technique through controlled task-based evaluation tests [8] and provided overall feedback through sets of questionnaires (open-ended and closed-ended). The results of this study are promising and show the possibility of using the stereoscopic highlighting in simple node-link diagrams to encode ordinal quantities of data attributes. However, the study also shows some limitations of the approach that is because users require time and training to get used to the technique and the 3D environment. In the following subsections, we describe the settings of experiment, details and the analysis of results for each task, and discuss the conclusions.

4.1 The 3D Display Setting

We carried out the evaluation experiment tests using a Zalman stereoscopic 3D display equipped with 3D glasses. The Zalman 3D glasses are designed to create stereoscopic optical 3D image with reduced eyestrain. The display size was 60 cm with 16:9 wide as a display ratio. The resolution was 1920 x 1080 pixels with 5ms response time. The frequency rate was 38 ~ 40 KHz in the Horizontal and 56 ~ 75 Hz in the vertical mode. Each user wore the polarized glasses by Zalman to view the 3D effects. They were seated directly in front of the 3D monitor. A precession was performed to insure that each user was able to see the 3D effects accurately. We allowed each participating user to adjust the height of the seat until he/she sees the 3D effects properly, with almost the same distance for all participants.

4.2 Goals

The user evaluation study goals were:
- To know the users’ abilities in perceiving the variations in depth values. We also wanted to know whether the depth variations could be used to encode ordinal data attributes beside other visual cues, like color or shape.
- To judge whether users are able to perceive the variations in depth more accurate and quicker with passage of time after getting more experience.
- Finally, to investigate the users’ abilities to interpret the depth variations into some meaningful information related to the underlying diagram.

4.3 Hypothesis

Based on our study observations, we were expecting the following results:
- **H1**: for all configurations in which the nodes representing components that have the same colors and shapes, three-layer configurations will be the most readable configurations in compared to the other experiment configurations.
- **H2**: we expect that combining more than one visual cue with the depth cue will not affect on the users’ abilities in achieving the required task from the final layout.
- **H3**: users get familiar with the variations in depth values by the experiment time (which is 30 min in our experiment). Therefore, the accuracy of the depth detection will be increased by the passage of time.

4.4 The User Groups

The participants in our user evaluation study were from three backgrounds. The first group, the safety-expert group, consisted of people having background in safety area, because this work is part of a project for visualizing failure scenarios of embedded systems. The second group, the visualization-expert (vis-expert) group, consisted of people having background in the visualization area to measure how the variations in depth can be used in encoding some information aspects in general. While the third group, the non-expert group, consisted of people from other backgrounds than the above mentioned. Based
on their feedback we intended to measure how accurately they detect the variations in depth and how they perceive it.

At the beginning of each test, we asked each participated user to provide some personal information including age, gender, sight/perception problems or any form of color blindness in order to analyze the results from different perspectives. We asked 20 participants (6 females, 14 males) to undergo our experiment. Out of those 20 participants; 7 were from the safety-expert group, 7 were from the vis-expert group, while the remaining 6 belonged to the non-expert group. The participants’ age ranged from 23 to 60 years with a mean age of 32 years.

4.5 The Experiment Layout

We implemented the visualization application using the VRUI framework [2], which is a toolkit to provide a virtual reality development environment. The VRUI package shields the application developing process from the particular configuration of the VR environment. VRUI works on many different hardware platforms. Therefore, it is possible to render the application in many different environments such as 3D displays, power-wall displays, or cave systems. This feature increases the scalability and the portability of our developed application. Our initial 2D visualization shows a tree structure consisting of 16 nodes (see Figure 1(a)), which represents a potential failure scenario extracted from a formal component fault tree model related with the underlying project [13]. This visualization representation is based on the radial layout algorithm [9]. The tree nodes were represented using a set of cubes connected to each other through a set of tubes in the 3D world. In Figure 2(a) we show the initial appearance on the layout in a 2D representation, while in Figures 2(b), 2(c), and 2(d) we show the 3rd dimension impression of the layout with different configurations.

The experiment test in this study consisted of three tasks where each task aimed to measure a specific goal. Following is the description of each task:

**Task 1:**
1. The Goal: Measuring the number of different layers that can be detected by the viewers and the number of nodes associated with each layer.
2. Configuration Features: All nodes have the same size, color and shape. For all configurations, the node cubes were in blue color but with different depth values.
3. Participated Configurations: Configuration 1, 2, 3, 5, and 7.

**Task 2:**
1. The Goal: Task 2 aims to judge the ability of users to perceive depth more efficiently with time.
2. Configuration Features: All nodes have the same size, color and shape. For all configurations, the node cubes were in blue color but with different depth values.
3. Participated Configurations: Configurations 3 and 7.

**Task 3:**
1. The Goal: Task 3 aims to measure whether the depth variations can be used to encode information beside other single or multi visual cues like shape or/and color.
2. Configuration Features: All nodes have the same size while different visual cues like shape, color, or both for nominal data, with different depth values representing the ordinal data.
3. Participated Configurations: Configuration 4 has different colors (blue, pink, and yellow) but with the same shape, configuration 6 has different shapes (cube, cone, and cylindrical) but with the same color with different depth values, while in the configuration 8 all nodes have the same size with different colors and different shapes at different depth values.

![Figure 2. (a) The graph representation using the radial layout algorithm, (b) the view after embedding with the depth cue.](image)

4.6 The Experiment Details

For all participants we kept the same order of tasks, but the given sequence was not following the same hardness pattern as we intended to switch from an easy task to a harder one and vice versa. The reason was to train the participant to read the configuration at a random base. Through this, we can measure easily how participants react with the variations of the depth in each scenario. In order to reduce the learning effect influence on participants, the configurations were different for each task. We added a simple animation to indicate the changing process between the depth values of graph nodes in the set of configurations in real time. For each task, we gave the participants the option of skipping the task if he/she feels any confusion.

The order of the tasks was carefully assigned as we started with an easy configuration to train participants to use variations in depth values as a cue to interpret data attributes. After that we switched to a harder task, in which the participants had to detect the critical nodes based on the associated depth values. We switched between four different depth values for the layers. The number of layers ranged from 2 to 5. Results show (see Figure 3 and Figure 4) that participants detected the three-layer configuration more accurately than the four- or five-layer configurations. All participants detected very easily...
the two-layer configuration but the majority preferred the three-layer configuration because it conveys more information.

At the end of the experiment test, we gave each participant a closed-ended questionnaire form and an opened-ended questionnaire form in order to get their feedback and impressions regarding the overall environment and the proposed approach. The open-ended questionnaire form consisted of 12 questions. For each question there were six options (strongly disagree, disagree, neutral, agree, strongly agree, and don’t know) based on the likert scale. In addition to these two questionnaire forms, the safety-expert group was given one additionally questionnaire form targeting to the safety systems environment. Each participant was given a maximum of 30 minutes to complete all the tasks. This excludes the training time and the answering time to the questionnaires.

4.7 Results and Discussions

The results of our user study provide an indication of the possibility of accurately using the depth cue as a highlighting technique in stereoscopy devices. The average accuracy for all groups in all configurations (with same color and same shape) of task 1 is 86% (see Figure 3). This result is less than (0.94) that was achieved by [1]. This is because of using a different stereoscopic device technology, a different user group size (i.e. 20 users from different backgrounds), and also as our test itself had different sets of tasks. The average time for all configurations (with same color and same shape) of task 1 and for all groups is 48.57 seconds (see Figure 4), which is higher than the average time (15.46 second) in [1], due to the difference in the test setting and the test configuration.

However, results show that participants get experienced with time as configuration 3 and configuration 7 have the same number of layers, but the order of their appearance in the experiment was different. The configuration 3 appeared before the configuration 7 and the results indicate (see Figure 5 and Figure 6) that the accuracy and the average time of participants’ picking of nodes and layers at different depth levels improved significantly over the time.

The goal of task 1 was to determine how strong the number of layers could affect the viewers’ performance in detecting the different layers correctly. The configuration 2 had 4 layers while the configuration 5 had 5 layers; therefore, participants needed more time to detect the variation among the depth values with less accuracy. Results indicate (see Figure 3 and Figure 4 - where 4 layers bar is for the configuration 2 and 5 layers bar is for the configuration 5) that average accuracy is reduced as the number of layers goes beyond 3 layers. In the open-ended questionnaire, we asked the participants about the number of layers to detect easily and 95% of the participants choose 3 layers as the most readable configuration.

![Figure 3. Average accuracy for all configurations of task 1](image3)

![Figure 4. Average time in seconds for all configurations of task 1](image4)

![Figure 5. Average accuracy for configurations 3 and 7 in task 2](image5)

![Figure 6. Average time in seconds for configurations 3 and 7 in task 2](image6)

The configuration 4 was dedicated to measure the effects of adding different colors to the depth cue and the
configuration 6 was dedicated to measures the effect of different shapes but with unified color. While in the configuration 8 we combined three visual cues (i.e. color, shape and depth) together. The overall goal in these configurations was to measure the accuracy of the depth cue in presence of color and shape encodings. The performance of participants in task 3 indicates (see Figure 7 and Figure 8 - where the blue bar refers to configuration 4, the red bar refers to configuration 6, and the green bar refers to configuration 8) that adding other visual cues to the set of configurations 4, 6 and 8 did not affect much the accuracy of the depth as a highlighting technique. As a comparison of the results between these three configurations participants' accuracy in the configuration 4 is overall higher than those of the other two configurations. The participants' efficiency in the colored-node’s configuration (88.57%) was superior to the other two configurations (83.09% for shaped-node and 84.52% for the combined color and shape configuration).

Figure 7. Average accuracy for configurations 4 (color+depth), 6(shape+depth), and 8(color+shape+depth) in task 3 with combined visual cues

Figure 8. Average time in seconds for configurations 4 (color+depth), 6(shape+depth), and 8(color+shape+depth) in task 3 with combined visual cues

Participants described that the color cue with the depth cue convey the information intuitively. Some participants experienced that colors supported the understanding of the scenario more quickly. Most of the participants answered in the questionnaire form that different colors or different shapes were easy to detect in each layer, without doing any affect on the depth cue for the node. This finding is an indication of the possibility to combine other visual cues with the depth cue. This gives us the possibility to keep colors or/and shapes to encode other attributes for the underlying data, but with longer required time.

Overall, results (see Figure 3 and Figure 7) show that experts (either safety or visualization) and non-experts achieved almost the same accuracy, which gives us an indication of the understandability and usability of the stereoscopic highlighting for the public usage. On the other hand, results also indicate that people need some time to get familiar with the technique and with the stereoscopic devices, and need to adjust the sight with the depth cue. Moreover, the standard deviation value of the accuracy for all users in all configurations is around 0.014, which indicates that participants’ performance in all configurations was approximately the same. However, the deviation of the required time for all configurations is around 14.3 seconds. This gives us an approximate vision about the differences in the participants' response time for the depth variations. Some participants needed more time to read the configuration while others reacted faster with the changing process. For example, we observed that females were slower than males especially when dealing with high number of layers.

5. Conclusion

We presented an evaluation for the accuracy of the promising stereoscopic highlighting technique. This work is part of a big project [30] that supports handling and analyzing of embedded systems more efficiently in immersive environments. We aimed to make the process of identifying the critical components in safety critical systems more interactive in a pure 3D environment. Therefore, we carried out a user evaluation study in order to judge the accuracy and efficiency of using such technique to highlight important aspects of the underlying graph. From the results of the conducted study, we can conclude that the stereoscopic depth in stereoscopic devices is an accurate technique to highlight important nodes in the graph, presumed it has been applied in a pure stereoscopic environment. Results indicate that people need time to get familiar with perceiving the depth and then detecting the important graph feature according to that. We also noted that other encoding techniques, such as color or/and shape to highlight nodes in a graph, do not affect the depth cue highlighting technique. In fact, those other encoding techniques help the viewers to get more insight about the data.

Although, as we mentioned earlier that our data size was not big enough to generalize this set of findings. But, it can be useful to give an impression of the possibility of using such technique in graph visualization applications. We believe that combining this technique with other highlighting techniques can be more effective in solving issues regarding the scalability aspects in 2D graph visualizations. However, this needs to be proved by investigating this technique with different data sizes and with different stereoscopic display devices in different
application domains. The further steps of our work are to evaluate the stereoscopic highlighting in power-wall or in CAVE systems using larger data sets and with different set of configurations to provide further evidences about this technique’s feasibility in general.

Acknowledgements

This work is part of ViERforES2 project [30] and partially funded by IRTG 1131 (DFG) and BMBF. Many thanks go to the Software Engineering and Dependability Group at University of Kaiserslautern headed by Prof. Dr.-Ing. habil. Peter Liggesmeyer for their support.

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