Ring Graphs in VR: Exploring a New and Novel Method for Node Placement and Link Visibility in VR-Based Graph Analysis

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ABSTRACT

We present a new and novel graph visualization technique designed specifically for virtual reality (VR). Ring graphs organize graph nodes by categorical attributes along a ring that are placed in a sphere layout. Links between nodes are drawn within the rings using an edge bundling technique. This 3D placement of data takes advantage of the stereoscopic environment that VR offers. We conducted a user study that compared our ring visualization to a traditional node-based graph visualization and found that our ring graph method had higher usability, both in terms of accuracy in completing a set of tasks as well as lower task completion time.

CCS CONCEPTS

• **Human-centered computing → Virtual reality**;

KEYWORDS

Graphs, user study, virtual reality, visualization

ACM Reference Format:
Mikhail Sorokin, Galen Stetsyuk, Raghav Gupta, Alex Busch, Brian Russin, Celeste Lyn Paul, and Samir Khuller. 2018. Ring Graphs in VR: Exploring a New and Novel Method for Node Placement and Link Visibility in VR-Based Graph Analysis. In *Proceedings of SA '18 Posters.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3283289.3283371

1 INTRODUCTION

Graph visualization is a useful technique for exploring and understanding data. Many graph visualization packages have been developed such as NodeXL, GraphViz, Mathematica, Neo4j etc. A very typical and usable method for visualizing graph data is the node-link approach. In this method, we map every node to a location and display all of the links (edges connecting two nodes). A weakness of the node-link graph visualization method is that it does not scale well. Even with the use of layout algorithms optimized for usability and aesthetics, such as force-directed layouts Eades [3], small world graphs can quickly become visually complex, including prior attempts at utilizing the node-link display in a VR environment Sullivan [7]. Due to the recent popularity of head mounted displays (HMD) for virtual reality (VR) applications and gaming, we developed a graph visualization method in VR, and performed a user study to evaluate the effectiveness of using HMDs as a data visualization tool. A benefit of using VR is that there is potentially infinite space that can be used to place and visualize data. There have been some visualization methods that explore traditional node-link visualizations in 3D Alper et al. [1] and specifically VR Kwon et al. [6]. However, these methods have simply adjusted a 2D visualization to VR. A notable exception is the work by Halpin et al Halpin et al. [4] which allows the user to extrude nodes using the third dimension. Our approach is a new and novel method to visualize node-link graphs that takes advantage or the 3D and stereoscopic environment that VR offers.

2 APPROACH

Our Ring graph visualization approach was inspired by previous work in categorical and graph visualization. Organization of nodes along a ring was inspired by chord diagrams Holten [5] and circle packing Arendt et al. [2].Using edge bundling, as opposed to drawing straight lines between connected nodes was inspired by Holden Holten [5]. We first discuss the sphere model in detail. The structure consists of mono-chromatic rings oriented in a sphere where each ring is offset by a rotation on the vertical axis. This is what gives the data model its spherical shape. Each ring has a different color and represents a unique category - which would later be specified in the study as the publisher of movie titles - and is populated by small spheres that represent individual data points or nodes. These nodes would be used in the study to represent individual movies. The nodes that have associative properties would be connected with a curved edge weighted to the center of the sphere. In order to efficiently render the curve connections, we used splines of third-degree polynomials to produce curves that would not affect the frame rate negatively. Since performance is crucial in virtual reality, the model has to be running at 90 frames per second to prevent simulation sickness for most users. We solved a system of linear equations to get parameters for the original equation to construct a smooth curve among approximately 100 points for each line. Since we limit the number of divisions and exponentials in our calculations, we efficiently create the connections between nodes without reducing the required 90 frames per second to run a successful VR simulation. The data that we collected was parsed to highlight key features about the visualization. For this trial, we used comic book

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SA '18 Posters, December 04-07, 2018, Tokyo, Japan

ACM ISBN 978-1-4503-6063-0/18/12.
https://doi.org/10.1145/3283289.3283371

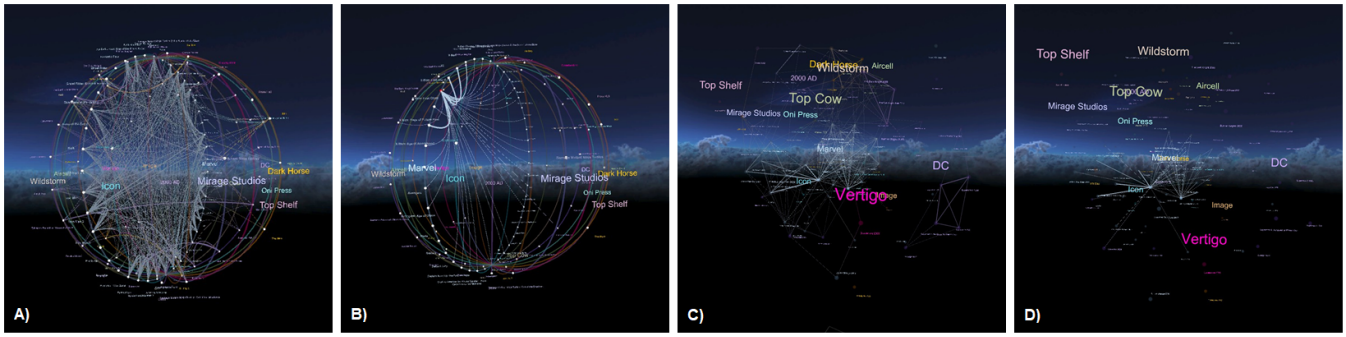

Figure 1: Node-link graph visualizations explored in 3D VR using an HMD: A) Ring graph with all links visible; B) Ring graph with only selected links visible; C) Node graph with all links visible; D) Node graph with only selected links visible.

superhero movies with actors to represent connections between them. If an actor played a role in two separate movies, that would be represented by a connection between the nodes corresponding to the movies. If more actors shared roles in corresponding movies, the denser the line would become. Our system was built using Unity, and implemented on the HTC Vive. The dataset used for the user study contained 13 publishers, 16 distributors, 46 studios, 94 movies/comic books and 457 actor objects - which includes the role, actor and name in the movie. There are 429 unique roles and names associated with all of the actors. Note that some actors portrayed more than one character across all movies they were in and the size of the publisher name is just its proximity to the user.

3 USER STUDY

Our user study had two goals: 1) compare the Ring graph to a traditional node-link graph plotted in 3D space; 2) explore how link visibility affects performance and usability. The user study was a 2 X 2 mixed-design experiment. The within-subject condition was Visualization type (Ring vs. Node) and the between-subject condition Link visibility (Visible, Hidden). We developed VR visualizations using our Ring graph method and a node-link graph with nodes positioned using a force-directed layout in 3D space (Fig. 1). Both graphs visualize the Comic Book Movies dataset (Sec. 2). Forty participants (9 Female, Mean Age = 22 ±3.5) were recruited from a large public University. All but two participants had previous experience with VR, AR, or 3D games. Participants completed the following graph analysis tasks:

(1) Which publisher has produced the most movies?
(2) Which movies have the most actors in common?
(3) Are there movies that have no actors in common?
(4) Are there actors that have been more than one super hero?
(5) Is there an actor connection between Movie A and Movie B?

After completing a demographics and training session, participants completed the listed tasks for both Visualization conditions with either Visible or Hidden links. In addition to performance on the tasks, participants were asked to rate immersion and usability for each of the visualizations.

Results. Overall we found that the Ring graph performed better and was more usable compared to the Node graph. The Ring graph performed best in Tasks 1, 3, and 4. In Task 1, the Node graph with Hidden links had the worst performance. In Task 3, the Ring graph with Hidden links performed best. In Task 4, Rings had higher performance with both Hidden and Visible links. There were no differences between Visualization or Link conditions for Tasks 2 and 5. The Ring graph was easier to use, more effective, more intuitive, easy to learn, and participants would like to use it frequently. The Node visualization was found to be more complex, harder to use, and would need more technical support. However, participants found both the Ring and Node graphs fun and engaging to use. See supplemental materials for performance and usability scores.

4 CONCLUSIONS

We examined a novel approach to visualize network graphs using an HMD in VR. The primary benefit of a VR-based visualization is to have a low processing power requirement with a light HMD which can be a cheap alternative to a massive display wall. We explored different network visualization methods and showed that 3D visualizations can be extremely effective to work with and visualized network data based on a detailed user study with 40 participants. Overall, we found that a VR-based visualization viewed through a HMD can be an excellent tool to analyze and interact with network graphs. This research suggests that when appropriately designed, 3D displays can be effective and the VR platform can be constructively leveraged for developing interactive displays.

ACKNOWLEDGMENTS

This work was supported by LTS Award number H98230-13-D-0056-0027. The content is solely the responsibility of the authors and does not necessarily represent the views of the funding agency.

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