[DC] Annotation in Asynchronous Collaborative Immersive Analytic Environments using Augmented Reality

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ABSTRACT

Immersive Analytics (IA) and Augmented Reality (AR) head-mounted displays provide a different paradigm for people to analyze multidimensional data and externalize their thoughts by utilizing the stereoscopic nature of headsets. However, using annotation in IA-AR is challenging and not well-understood. In addition, IA collaborative environments add another complexity level for users operating on complex visualized datasets. Current AR systems focus mainly on synchronized collaboration, while asynchronous collaboration has remained unexplored. This project investigates annotation in IA for asynchronous collaborative environments. We present our research studies on virtual annotation types and introduce a new filtering annotation technique for IA.

Index Terms: Annotation, Immersive Analytics, Collaborative Augmented Reality, Asynchronous Collaboration

1 INTRODUCTION

The rapid development of immersive technologies such as Augmented Reality (AR) and Virtual Reality (VR) provides new opportunities for data visualizations to overcome the limits of paper and 2D screens. VR/AR head-mounted displays (HMDs) enable a new opportunity for Immersive Analytics (IA), which is 3D visualization in stereoscopic displays. IA provides a viable solution for users to interact with data in a three-dimensional (3D) environment to help them to understand complex and large datasets easier than 2D environments [7]. Fonnet and Prié found 6 out of 11 papers that compared IA environments to standard 2D displays had better performance in IA environments [1]. IA is an important tool where multiple challenges remain. While VR/AR annotation has received a fair number of articles on the topic, the research in IA annotation is extremely limited, with only eight papers on the subject [1]. IA research has concentrated, in most part, on looking at the gulf of evaluation (i.e., barriers of understanding) with a lot less work in the gulf of execution (i.e., barriers of interaction) [1]. Using annotation, eye gaze, hand gestures, and speech will continue to improve the gulf of execution in IA systems. This **Ph.D. research** explorers annotations in **asynchronized collaborative IA environments**. I will design several user studies that focus on investigating annotation techniques and challenges in a 3D environment.

Data visualization tasks often require the collaboration of multiple users. Immersive technologies offer various interesting features that support immersive collaborative analytics by connecting multiple users to the shared environment which are either synchronized or asynchronized. Asynchronous collaboration provides the opportunity for users to collaborate on a task at different times and from different geographic locations, which seems an inseparable part of the collaboration on documents and data analysis [11]. However, most previous work in IA have focused on synchronized collaboration. This Ph.D. will contribute to improving AR-HMDs IA annotations for collaborative environments.

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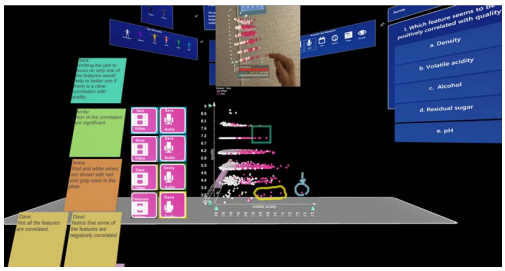

Figure 1: Immersive environment

2 RELATED WORK

There are some studies on annotations for immersive technologies [2, 12] and annotation for data visualization in a 2D setup (web-based applications) [4, 9], however, a very limited number of studies investigated annotations in immersive analytics [5, 10, 13]. This gap gets even more apparent when it is narrowed down to specific annotations or interaction techniques.

While text [4, 9, 13], shapes [4, 9], drawn lines [4], and highlights [6, 10, 13] are the most common annotation forms in data analysis tasks, to the best of our knowledge, no previous study benefits from image, audio, video, and gesture annotations in previous IA studies. It should be noted that the use of these types of annotations has been shown in other applications of immersive technologies [2, 8, 12] and non-immersive data analysis [9]. Although some previous studies have used various input methods for producing different annotations, such as AR/VR controllers [12, 13], 3D gestural input [10], VR pen [3], eye gaze [10], and speech [10], more studies should be designed to find the best methods and input device for each annotation type.

3 CURRENT RESEARCH

My research includes a series of studies aimed at exploring different annotation forms and techniques for analyzing 3D data visualizations in an asynchronized collaborative environment using AR-HMDs. The primary HMD used will be the Microsoft HoloLens 2 (optical-see through). Two modes are considered in our studies: annotator mode and viewer mode. In annotator mode, users can generate new annotations or modify the existing annotations, while in viewer mode, users can only review the existing annotations.

Most previous studies explored annotations from an annotator point of view. Our first study considers user preference and performance from viewers' perspectives and compares various annotation forms and their effects. For this purpose, we designed an augmented reality environment including scatter plots, some pre-designed annotations, and a filtering box for annotation forms. A wine quality dataset is used for creating the scatter plots. The 3D plots are annotated in a way that helps the participant to answer several questions (e.g., "which feature seems to be positively correlated with the quality of the wine?"). To answer these questions, participants need to explore the 3D scatter plots and their annotations. To have a fair comparison, different forms of annotations cover the same pieces of

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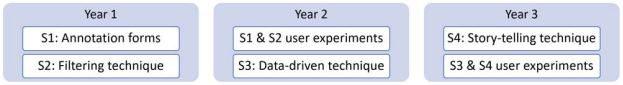

Figure 2: Proposed course of studies

information. Both objective measurements (average working time by each type of annotation, the number of visiting and revisiting an annotation, the first type of annotations that participants use, task time completion, the correctness of answers, and error rate) and subjective measurements (two questionnaires to rank different types of annotations and evaluate the system usability) will be collected. The aggregated results will be analyzed to find the best forms of annotations in terms of user preference and user performance.

The second study aims to examine how filtering tools can reduce the cognitive load of the participant and enhance their performance. The environment of this study is similar to the first study. However, there are four filtering boxes that allow the participant to filter the annotations based on the annotator, the confidence degree of the annotator, the plot number, and the annotation form. The plot number and the annotator filtering boxes filter annotations based on the plot number and the person who annotates that, respectively. Different colors and the name of the annotators are used to distinguish the annotations. Each annotation has a confidence degree of 1 to 5 that shows the confidence degree of the annotator for that specific annotation. The user can take these into account in exploring the plots; for example, in the presence of many annotations, they can keep only the created annotations with a higher degree of confidence. Participants will perform a search task in two conditions: without filtering boxes and with filtering boxes. We will use the first condition as our control condition and the latter as the comparison. Figure 1 shows a snapshot of the environment.

4 FUTURE RESEARCH

The next two studies will address other unexplored challenges for annotations in IA. A summary of the experiments to be completed during this Ph.D. is found in Figure 2.

The goal of the third study is to investigate data-driven annotations in an asynchronous collaborative environment. Data-driven annotations indicate annotations corresponding to a specific target type. Participants can assign the annotations they create to a particular target type, for example, assigning a text to the z-axis label. This study will be implemented in annotator mode, meaning participants can generate new annotations or modify the existing annotations. Different inputs will be used for creating different annotation types such as AR pen, a virtual AR keyboard, hand gestures, and speech.

This study includes two tasks. The first task aims to familiarize participants with generating different annotation forms and techniques, for example, selecting and annotating four individual data items or dragging text annotations to correct positions. For the second task, the annotators will illustrate the process of annotating plots through a usage scenario. In this scenario, participants will be asked to annotate the scatter plots in favor of a given statement (for example, alcohol feature is positively correlated with quality of the wine) to help their collaborator solve a question. Then, in the viewer mode, the collaborator will answer the question related to the scenario based on annotations that annotators created (similar to the first study).

The fourth study explores the storytelling annotation technique and its effect on user performance and preference. The experiment setup is similar to the previous ones, except that the annotators must assign an ordering number to their annotations. This will show the annotations in a specific order to allow the users to tell a story. The viewer mode will be evaluated under three conditions: (1) without storytelling, (2) storytelling based on the same order that annotations were created by the annotators, and (3) storytelling based on the orders that annotators have assigned to their annotations. Finally, we will evaluate the performance and error rate of the viewer for these three conditions. Our hypothesis is that viewers will perform better in the third condition compared to the other two conditions.

5 CONCLUSION

With AR-HMDs becoming more commonplace, immersive data visualizations are becoming more accessible. However, annotation techniques and inputs for these devices are critical to their acceptance for data visualization applications. These techniques should be investigated from the end-user's point of view. This Ph.D. work will contribute to developing a set of user studies exploring annotation in IA for asynchronized collaborative augmented reality. In addition, the implementation of these annotations techniques from the user studies will be provided with each paper as open-source whenever applicable. This work will provide insights on user preference and performance while using these environments.

6 QUESTIONS

1. Is there any other annotation techniques in 2D that I should consider? 2. Should I compare the experiment with a 2D web-based version? 3. Has an important metric been overlooked?

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