Individual and Collaborative Cross-reality Immersive Analytics – Initial Ideas

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ABSTRACT

This paper presents research questions on supporting analytics work using cross reality (CR) and the initial idea of the investigation we want to conduct.

KEYWORDS

cross reality, augmented reality, virtual reality, immersive analytics, data visualization

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CR is a f eld that aims to create interactive environments that allow users to seamlessly interact with information across the virtuality spectrum. Data can be placed on traditional displays, in a physical space using AR tools or in a virtual space using VR approaches. Different users can chose in which space they want to utilize to engage with their information. Collaborative CR applications allow different users to use different interaction modalities. Our work aims to develop the processes and guidelines to create CR applications offer users a better understanding of complex datasets across immersive environments.

1 INTRODUCTION

CR is a field that aims to create interactive environments that allow users to bring virtual content into the physical or bring physical world objects into the virtual world to help users to have a better perception of data and information. Our work aims to develop the CR application to offer users a better understanding of complex datasets in the immersive environment.

The term mixed reality has been around for decades , but real-world deployment has recently exploded due the availability of commodity hardware. Hardware is available for applications targeting the whole Milgram reality-virtuality spectrum. Affordable hardware and software enable researchers and developers to create augmented-reality (AR), extended reality (XR), mixed-reality (MR) and virtual-reality (VR) applications on smartphones, tablet or Head Mounted Displays (HMDs).[5] The term "cross-reality" (CR) is relatively new and describes a new kind of software systems that bridge between two or more points on the Milgram spectrum(Figure 1). Such applications allow their users to move data or visualizations from a PC to a physical space and/or a virtual space and back.
In our studies, we want to explore how to support analytics work using CR from both individual and collaborative perspective.The SIERA project done by Lawton et al. is an example of using the virtual reality application for understanding complex datasets(Figure 2).[2] We consider the following **Research Questions (RQs)** as objectives of our studies:

- **RQ1: How can we support analytics work by moving visualizations across the Milgram continuum ?**
  Data analysis is the process of discovering useful information by cleaning, inspecting, transforming, and modeling data.[6] Data visualization helps data analysis and interpretation. In a CR environment, information can be presented at any point of the Milgram spectrum and the application or

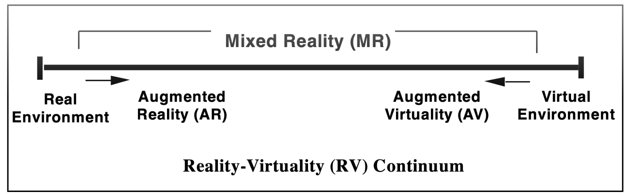

Figure 1: Diagram showing a representation of Milgram et al. Reality Virtuality Continuum.

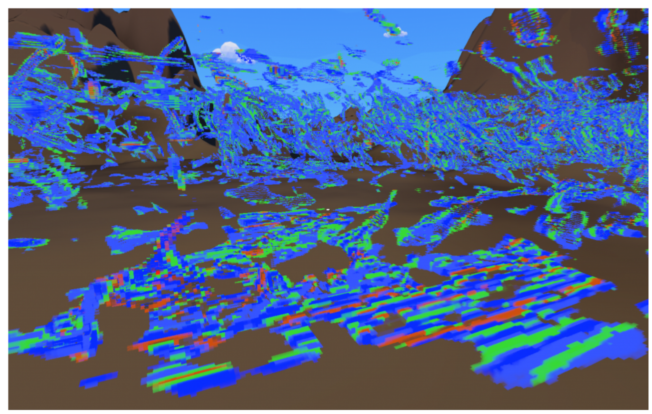

Figure 2: Screenshot of immersive analytics data visualizations from the SIERA project [2]

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the user can determine where it should be presented to fit their needs.[4] In our study, we want to explore information visualization across the continuum to determine what kind of information is best presented at specific levels of virtuality to provide better support to analytics work.

- **RQ2: What interactions do users naturally use for cross-reality applications?**
  With the support of XR, users could interact with data in 3D space without the limitation of the 2D screen, keyboard, and mouse. The XR environment that will be created for our study will be a mix of the physical world and the virtual world. Our study will explore under what circumstance users want to move visualization from monitors in the physical world to virtual space and how they will do it. We also want to study how users want to interact with visualization in XR space naturally when they have more options, including hand gestures and eye gazing.
- **RQ3: How does control over a shared reality impact team collaboration?**
  Collaboration in the physical world can make reasonable assumptions about a shared reality: when two people work together in a room, they have an intuitive understanding of what the other person can see and not see. They also know that if they both look at an object in the room, they both see the same object. This creates an intuitive shared understanding of the world around them. CR applications can break this intuition: the CR system can show one object to one person, and a different object - in the same place - to the other person. This "unsharing" of real-world intuition can be accidental (e.g. incorrect calibration resulting in a shift of an object), on purpose (e.g. orienting text towards people on opposite sides or showing additional information to only a domain expert) or even malicious (e.g. a hacker creating a misunderstanding). We want to investigate how to balance between shared and unshared reality to enhance team collaboration efficiency.

2 INITIAL IDEAS TO INVESTIGATE

CR is a new research area with plenty of unknowns, creating immense research opportunities ranging from questions related to cognition all the way to engineering processes and development guidelines. In this spectrum, we will be focusing on a small number of specific research topics.

2.1 Move information from a 2d screen to a 3d space and back

To better support analytic work, we want to investigate applying CR to increase productivity and enhance sense-making and communication. A previous study shows that work stations with more monitors could potentially increase productivity.[3] We want to investigate how to move information from a 2D monitor to a 3D space and back in order to overcome the limitation of the number of the physical display. Haskell and Wickens show that 3D displays are more useful for lateral and altitude flight path tracking. In the meantime, 2D displays have an advantage in the accurate measurement of airspeed.[1] We will conduct case studies to explore what visualizations should be moved to 3D AR space to support individual and team collaboration. We will also investigate how user want to interact with CR applications.

2.2 Impact of mixing AR and VR collaborators

We want to explore mixing analytic data collaborators with different systems work in the same extended reality space. We will investigate the potential impact of collaborators using devices with different degrees of virtuality across Milgram's continuum. We are particularly interested in studying how collaboration works out when some participants are using AR while others are using VR spaces.

2.3 Natural gestures to support interactions

We will conduct an elicitation study to investigate how individuals and teams want to interact with the CR system with natural gestures intuitively. He hope that a common set of gestures and interactions will materialize so that toolkits can be developed to support them.

2.4 Engineering guidelines

In the long run, we would like to develop engineering guidelines to provide evidence-based advice to developers on how to design CR applications and which kind of data should be presented on specific places of the virtuality continuum.

2.5 "Unshared" experiences in cross-reality visualizations

As CR systems can overcome physical limitations, we are interested to investigate if creating realted but different realities can support collaboration of hinder them. We will conduct studies to explore how to present user-specific perspectives on shared information while users are in different locations in a virtual space. Questions include: How far can a virtual representation deviate from intuitive physical norms without hindering collaboration? Can we enhance collaboration by "unsharing" visualizations of information?

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