Augmented Tasks: A Study of Leveraging Augmented Reality Head-worn Displays in Procedural and Analytical Tasks

by

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Abstract

The vast health industry is always looking for innovative ways to use technology in order to create or improve the experiences of their professionals. The improvements are welcomed in a variety of areas from analysing relevant health data to establishing new ways of delivering medical education and training. With advancements in head-worn immersive mixed reality displays (HWD) such as the Microsoft Hololens, we must look into the feasibility of leveraging the technology to aid us in the ongoing challenge of creating these meaningful and educational experiences. In this research, I will be evaluating the efficiency of using an immersive HWD in order to perform procedural tasks such as completing stepwise objectives as well as analytical tasks and how we can present data in an immersive form. The objective of this research is to develop a set of guidelines that assists in the creation of 2D information spaces. These guidelines would enable opportunities to create mixed reality applications that would improve the educational and training aspects of the health field. I hope to create a framework that would inspire discussion as well as the creation and evaluation of different information space designs on HWDs.

Contents

1 Introduction

I propose to investigate the potential outcomes of providing supplementary information on a mixed reality device while performing an intricate procedural task. I plan to explore if there is a significant difference between using a mixed reality head worn display to provide the information and the current conventional ways, such as using posters, charts, and other physical mediums. Procedural tasks require a set of step by step instructions in general. If the task at hand is complex, the instructions need to be simple in order to reduce the cognitive load. For example, medical procedures often require the task to be completed piecemeal, so the task can be completed successfully and importantly, in a timely manner. Indeed, various medical procedures often consist of numerous convoluted steps, and thus challenging. I believe that having new technology, which allows users to view informative data while they are executing a procedural task, will be beneficial. By using a modern wearable mixed reality device such as the Hololens, various types of useful/important information can be provided consistently across multiple areas in an assistive information space: We are able to leverage the new head-worn display's spatial mapping and positional tracking technology to maintain consistent positioning of the information space layout. By providing the user essential information concerning their task (e.g., instruction) and supplementary data in an adaptive information space, I hope to reduce the users' cognitive load to facilitate their performance.

2 Literature Review

Augmented reality systems (AR) are defined as systems that enable real time interactions with virtual and real objects that coexist in the same space [1]. These systems come in many different forms such as head-worn displays, projections, and mobile devices that allow you to view virtual objects in the real world. For decades, researchers have observed the great potential of using augmented reality to enhance certain aspects in fields such as geographic studies [19], data science [20], education, and health. Unlike virtual reality (VR), augmented reality (AR) allows for an digital experience in a real environment rather than a fully virtual environment. In some cases, interactions within an AR environment are more advantageous than the VR environment [14]. Bower et al. [5] highlight the usage of mobile phones and tablets to overlay media onto the real world in order to make information available to students when they need it, on the spot. Bower et al. discuss the potential reduction of cognitive overload by providing students real time information. Augmented reality has also found a home within the health field, specifically the medical field, where it is used in various medical tasks and procedures.

This work will primarily be focused on head-worn see-through display such as the Microsoft Hololens [15], a new headset that enables users to interact with virtual objects in the real world. Due to the novelty of this display and the ongoing development of the software required to create applications for this display, there are not many studies involving the Hololens as of yet. Design choices outlined in Kress et al.'s work [13] show the carefully thought out architecture of the Hololens. The balance of comfort and performance for the first fully untethered mixed reality headset makes this ARHWD one of the most advanced and the currently the best candidate to use within the augmented reality reasearch space.

Designing interactions in AR has been a topic of discussion for as long as the concept of AR existed. In 1993, Feiner et al. [11] looked into implementing 2D windows in a 3D augmented reality. This was one of the earliest works in augmented reality, and they were able to create a system that overlaid images on a see through display, simulating virtual windows containing information in a real-world environment.

In a survey done by Azuma et al. [1] to provide a beginning point for researchers interested in this area, outlined the advancements in 1997, the applications of AR, and some issues such as real-time tracking and portability. Many issues outlined by Azuma et al. in their survey have been address in recent years. The hardware is only one part of the design required to create a smooth augmented experience. Future research focuses more on the interface and interactions with the virtual objects in the real world environment.

Early works, such as the work done by Bell et al. [3], they describe maintaining visual constraints on the virtual objects projected on the view plane. Simply put, they attempted to design an algorithm to aid in managing constraints such as locating related virtual objects or preventing the objects from occluding each other. Their algorithm yielded comfortable interactions, however, Bell et al. believed it could have been significantly improved.

In subsequent years, a plethora of research on AR becomes a cycle and blend of outlining potentials, addressing issues at the time, and a survey of the state of AR. Works such as the ones done by Zhong et al. [21] and Boulanger et al. [4] outline the potential in using AR in industrial training. Bower et al. [5] look into the applications in education and its potential to improve learning in schools. In the health industry, researchers such as Barsom et al. [2], Chan et al. [6], Chen et al. [7], and Okamoto et al. [16] look at AR's potential in surgery and medical training. However, many of the works outlining potentials do not develop as well as evaluate the application leading to inconclusive results.

Barsom et al. [2] details the effectiveness of augmented reality applications in medical training. These applications are used to blend virtual and digital elements with a physical environment in order to introduce new educational opportunities for medical professionals. Barsom et al. reviewed seven applications over twenty-six studies and concluded that although these promising applications are generating public as well as scientific interest, they are lacking evidence in the literature that the applications are able to transfer information to the user.

In recent years, researchers have investigated the use of AR in order to improve surgical navigation. Both Okamoto et al. [16] and Chen et al. [7] developed AR-based simulations with the aim to improve the safety and reliability of surgery. Okamoto et al. developed an application for navigation surgery in the abdominal field. Their system leverage a see through display and a rigid scope that enables the surgeons to obtain a 3D view. Through their study, they are able to identify several problems such as organ deformity, evaluation of utility, portability and cost. In the same year, Chen et al. leveraged a head-worn display and created an application that was tested against actual patient structure data in a real world scenario. They verified and demonstrated the accuracy of their application was sufficient to meet clinical requirements. However, this is so far only true with a simulated environment. Within the same area of study, Pratt et al. [17] looked the use of the Hololens in order to provide a means of bringing a new level of precision and planning into reconstructive surgery. Through preliminary studies, the authors were able to demonstrate that using the ARHWD could help with the precise localisation of perforating vessels. Hanna et al. [12] have also showed that the Hololens has the sufficient power and comfort to be useful in facilitating autopsies, microscopic examinations, and digital pathology. There are

In the past, there have seen very few works involving the use of augmented reality head-worn displays (ARHWDs), the popularity of the concept due to it's portability has been steadily increasing, however, there is still room for improvement in order to give the user a more comfortable experience [18], which may in turn provide a more efficient experience. Although, work such as The Personal Cockpit [10], an evaluated design space for effective task switching on ARHWDs and Ethereal Planes [8], an extensively reviewed design framework provide guidelines to assist in the creation of meaningful layouts and interfaces to experiment with. As far as I know, there has not been any work done on determining the efficiency of using AR head-worn displays such as the Hololens to act as an aid in completing procedural or analytical tasks.

(a) Feiner's window system with an HWD in 1993 [11]. The large black cube and white triangle are the transmitters for two 3D tracking systems. Tracker receivers on the head-mounted display, waist, and wrist.

(b) One of the latest ARHWDs released. It requires no external component and all the sensors are implemented with the device.

Figure 1: A Comparison of ARHWDs

3 Problem Statement

Only in the past few years have we seen advancements in the technology enabling us to effectively implement this type of research. With new head-worn displays (HWD) such as the Hololens [15], we are given the opportunity to create spaces using the design framework [8] or implementing the spaces in order to test the effectiveness of them while performing in-situation tasks. In the field of medicine, augmented reality applications (ARAs) are used to help educate medical practitioners in various techniques: These applications are used to support their training and provide them with a way to practice with simulated experiences. [2] reviewed the validity and the effectiveness of using ARAs in medical training. They investigated various applications, from giant workstations to virtual reality, and found that mixed reality can bring digital information into the real world. Using the HWDs as an assistive tool in procedural tasks is a novel topic in HCI, and can be beneficial in various fields (e.g., medical). Thus far, researchers have focused on designing and developing mixed reality interfaces. However, perhaps due to hardware limitations, there is no research testing these interfaces while performing a complicated task on a dedicated HWD thus far, despite the prospective benefits. Therefore, we propose to study the effectiveness and the potential benefits of performing a procedural task while receiving supplementary information from a dedicated HWD. In this work, I will be addressing three issues in order to optimize the placement of the supplementary information given the space around the user. Based on the user's environment, I will be investigating:

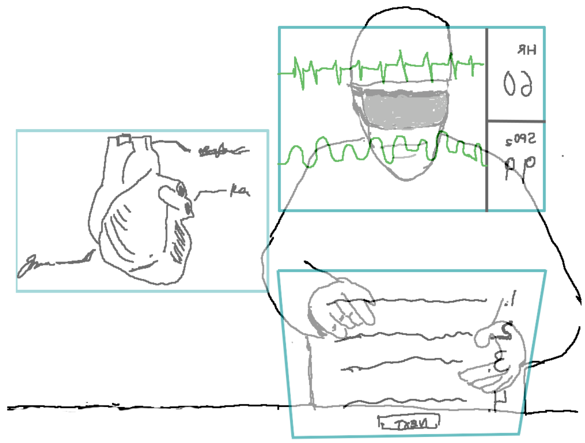
1. How the information should be positioned around the user.
2. How the information should adapt to visually 'cluttered' and 'busy' spaces within the user's viewpoint.
3. Finally, I will be looking at how we can provide the proper level of information in order to complete a task.

4 Potential Solution

- The biggest challenge I face, is the lack of knowledge in the field of medical procedures. I will be exploring the current technology being used for training and simulation in the health field in order to grasp the tasks and steps that will help with the creation of the studies using the Hololens.

- Getting familiar with tools and devices being used is important, with no prior knowledge of medical procedures or analytical procedures to observe data, taking measures to understand the current state, as well as interviewing primary users such as medical professionals and scientists is crucial to developing effective guidelines for creating virtual information spaces for ARHWDs.

- I propose an algorithm that optimizes the placement of information based on certain criteria. This work aims to find that criteria as well as test the criteria against real-world applications and simulations. I will be looking at the efficiencies of different layouts while performing tasks, the way the windows adapt to visually busy areas, as well as what level of information about the should be displayed without confusing or impairing the task at hand.



(a) A sketch of the windows adapting to the head position with no busy areas.

(b) A sketch of the windows adapting to the head position in a busier area

Figure 2: Visually Flat Areas vs. Visual

5 Evaluation

This research will be evaluated based on three studies:

1. The first study will determine the design space for the application. Based on professional interviews and questionnaires, a few virtual layouts will be discussed and implemented for a study that determines how the users interact with the different virtual layouts in a within-subject study where each participant will be testing all three layouts. I will be observing the effects of each layout and answering questions such as: Which had the greatest error rate? Which was the most accurate? In this study, qualitative feedback will also be obtain from the participants and looked at as well. An Analysis of Variance (ANOVA) will be used to determine the effects of each virtual layout.

2. Based on the results of study 1, the experiment will be modified to test the dynamicity of the information spaces. Using the layout(s) which show significant effect, I will be evaluating the effectiveness of mesh-aware information spaces and the space's ability to adapt to the user's head position. This study will determine the effectiveness of having the virtual 2D windows adapt to certain real-world spaces such as walls, tables, and other objects. Simply put, in this study, I would like to observe the effects having the information space adapt to visually busy areas and see how variables such as the direction that the information adapts to (in front, behind, up, down, right left of the busy area) effect the same variables tested above.

3. Finally based on both studies, I hope to test the algorithm created with the primary users within their environment. The primary users of this algorithm would be the physicians doing procedural tasks within their work environment. I hope to combine aspects of study one and two in order to create an experience that would prove the results of both studies and in turn, validate the guidelines created.

6 Current Progress

Thus far, a pre-study and the first study had been conducted. The pre-study investigated the design space, an extension of the Ethereal Planes framework [8], while the subsequent study used the feedback of the investigation to test different layouts in a simulated task.

- Pre-study: The goal of this study was to identify which factors in the design space had the most impact on users. The study investigated four categories:

  - Visual Adaptivity Preference: The users' preference of the placement of content when in an environment that is visually busy or visually flat.
  - Window Transform Behaviours: The users' preference in the movement of windows based on the position of the head.
  - Spatial Region Preference: The users' preferred regions where they would like their content to be displayed displayed.
  - Window Organization: The users' preferred location for the content in the specific regions noted in the Spatial Region Preference.

  The context of the procedure being explored was neonatal resuscitation. We collected feedback from four experts with years of experience with the procedure, and recorded their experience with the Hololens.

- Study 1: Using results from the feedback of the pre-study, a study protocol was created to test the efficiency of different layouts. The participants were asked to use the information streamed through the Hololens in order to complete the tasks and objectives of a simple maze game. There were three layouts tested in this study, two were created based on previous research [9, 10], and one was created based on the guidelines extrapolated from the pre-study. This study was conducted with twelve participants (M=8:F=4), the data was analyzed, and no significant effect was found ($p > .05$). In order to improve the experimental procedure, adjustments based on the feedback obtained is required.

7 Expected Outcomes

In terms of contribution, the expected results of this research are related to the advancements in supporting disciplines with complex procedural tasks. When conducting a task that require stepwise instructions, I hope to improve the experience of completing these tasks by using augmented reality head worn displays (ARHWDs). I expect to develop a set of guidelines for the implementation of information-displaying applications on ARHWDs. As a result, I also expect to develop an algorithm to optimize the placement of information on ARHWDs. The algorithm would improve the user experience by adapting to the environment in way where the user can efficiently complete a task.

8 Timeline

Tasks	Estimated Start Date	Estimated End Date
Prepare Study 1	May 5, 2018	June 20, 2018
Run Study 1 (12-15 Participants)	June 20, 2018	June 27, 2018
Study 1 Analysis	June 28, 2018	July 8, 2018
Adjust experiment for Study 2 based on Study 1 results	June 28, 2018	July 16, 2018
Prepare Study 2	July 17, 2018	July 20, 2018
Run Study 2	July 23, 2018	August 1, 2018
Study 2 Analysis	August 2, 2018	August 8, 2018
Create validation study based on Study 1 and 2	August 9, 2018	August 20, 2018
Run validation study	August 21, 2018	August 31, 2018
Analyze validation study	September 1, 2018	September 8, 2018
If more studies are required, prepare and run additional studies	September 9, 2018	December 31, 2018
Thesis compilation, writing, completion	January 2019	February 2019
Submit to advisory committee for review	February 2019	March 2019
Review feedback and refine thesis	March 2019	March 2019
Appoint examining committee and submit thesis	April 2019	April 2019
Book and complete thesis defence	May 2019	May 2019

9 Conclusion

This research aims to create a set of guidelines that aid in the implementation of efficient information spaces for performing procedural and analytical tasks with an augmented reality head-worn devices (ARHWD). With the emergence of new immersive ARHWDs such as the Microsoft Hololens, this research looks into the possibility of leveraging these technologies to support us in performing procedural tasks in a variety of disciplines such as medical training and simulations. This research evaluates different layouts and spaces based on previous research as well as expert preferences in order to compare the most optimal ways to design a supportive ARHWD application. Through the user studies, I hope to create a novel framework based on the results and comparisons that will help others create a effective information spaces to efficiently complete tasks that require additional information.

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