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The Use of Head-Worn Augmented Reality Displays in Health Communications

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Abstract. The health industry is always seeking innovative ways to use technology to create or improve the experiences of their professionals. Such improvements are seen in a variety of areas including the analysis of relevant health data and the establishment of new ways of communicating medical education and training. Advancements in head-worn augmented reality displays (HWDs), such as the Microsoft Hololens, present a unique opportunity to leverage technology in the ongoing challenge of creating meaningful and novel educational experiences. This paper will review contemporary HWD technologies, how these technologies are being used to enhance the work-training environment, and how these technologies might enhance the communication of health professionals.

Keywords. augmented reality, health information, information technology, algorithms, survey

1. Introduction

In the past decade, innovations in research and technology have made it possible to combine virtual and real environments. Within the health industry, many academic institutes and medical training hospitals are already using virtual- and augmented-reality technology to train medical students and practitioners. However, with many current simulation technologies [1], the equipment required is not portable and cannot be transported easily. The recent introduction of new, portable head-worn augmented reality technology devices (HWDs) have created numerous exciting new possibilities.

1.1. Purposes

This paper has three primary purposes: 1) to survey the current state of HWDs; 2) to explore how the application of HWDs can contribute to the health industry; and 3) to outline some of the current obstacles for an effective Augmented Reality (AR) experience.

1.2. Background

Augmented reality (AR) systems are defined as systems that enable real-time interactions between virtual and real objects that coexist in the same space [2]. These systems utilize

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many different forms such as head-worn displays, projections, and mobile phones to allow users to view virtual objects in the real world (e.g., Pokémon GO). For decades, researchers have recognized the great potential of AR to enhance activities in diverse fields such as geographic studies [3], data science [4], education, and health.

1.2.1. Potentials in Different Industries

Current AR research generally focus on three topics; 1) outlining AR's potential in different environments, 2) addressing the problems with AR, and/or 3) surveying the state of AR. These topics have been investigated in various industrial environments.

Within the manufacturing industry, Zhong et al. [5] and Boulanger et al. [6] describe how we can use AR to collaborate on training tasks. By sharing the view of the person being trained, wearing a head mounted display, their systems allowed the trainers in a remote site to view and manipulate virtual objects in a variety of training tasks.

In an educational environment, Bower et al. [7] looked into applications of AR and their potential to facilitate students' learning. The researchers highlighted the usage of mobile phones and tablets to overlay media onto the real world, making information available to students when they need it, on the spot. Bower et al. discussed potentially easing cognitive overload by providing students information when needed, in the palm of their hands. While we present only two examples of how AR is affecting manufacturing and education, we would like to acknowledge that there are many other industries that have been utilizing AR such as in museums, where this technology is being used to display information about their exhibits [8]. More importantly, in this paper, we will discuss the use of AR in health.

1.2.2. History of Head-Worn Augmented Reality Displays

Research on head-worn augmented reality displays (HWDs) has been conducted since as early as 1993. Feiner et al. [9] looked into implementing 2D interface windows in a 3D augmented reality (AR). One of the earliest works in AR, these researchers were able to create a system that overlaid images on a see-through display, simulating virtual windows containing useful information such as self written notes in a real-world environment (figure 1a).

Azuma et. Al [2] studied issues such as real-time tracking and portability, while also looking at advancements in and applications of the technology in the years prior to 1998. Their work provided a foundation for researchers interested in the field; many issues outlined by Azuma et al. continue to be addressed in recent years. Although research up until 1997 mostly focused on hardware aspects of AR, we would like to note that the hardware is only one part of the design required to create the smooth augmented experience desired by individuals and industry.

Aside from hardware advances, research on AR interfaces and interactions have led to numerous outcomes such as the presentation of digital objects in the real world. Bell et al. [10] described applying visual size, shape, and location constraints to the virtual objects projected on the user's visual area. They designed an algorithm to aid in managing constraints such as locating related virtual objects or preventing the objects from occluding each other. Although the algorithm yielded comfortable interactions, Bell et al. believed it could be significantly improved.

Newer head-worn systems such as Microsoft's Hololens [11] (figure 1b) or Magic Leap's Magic Leap One [12] are examples of powerful portable AR systems that are available to consumers. Not long ago, this technology was only available in labs and specialized environments. Through HWDs, a digital world becomes part of the environment, allowing users to interact with the objects and interfaces that these systems project.

There are few studies investigating use of these types of devices for health communication. Due to the novelty of these displays and the ongoing development of the software required to create applications for these displays, further investigation is crucial to bring these displays into health communications.

(b) Feiner's window system with an HWD in 1993 [9]. The large black cube and white triangle are transmitters for two 3D tracking systems. Tracker receivers are on the head-mounted display, waist, and wrist.

(a) One of the latest HWDs released: Microsoft's Hololens (2016) [11]. It requires no external component and all sensors are implemented with the device. Inputs are in the form of air gestures.

Figure 1. A Comparison of HWDs

The Hololens is one of the most advanced devices and currently the best candidate for use within the AR research space, due largely in part to the hardware design choices. Kress et al. outlined [13] the carefully thought out architecture of the Hololens and showed the balance of comfort and performance achieved by the first fully untethered mixed reality headset.

1.3. Motivations

AR has found a home within the health field and specifically the medical field where it is used in various medical tasks and procedures. The use of AR for medical training is becoming increasingly common because of the realistic experiences AR can offer. This could be because blending virtual objects with the real world provides students and professionals novel possibilities for learning complex procedures. Barsom et al [1] showed that when compared with traditional training apparatus, HWDs allow for new levels of accessibility at a fraction of the cost.

2. Applications in Health

2.1. Medical Training

Barsom et al. [1] systematically reviewed the effectiveness of AR 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. The researchers concluded that although these AR applications are generating public as well as scientific interest, there was not sufficient evidence to conclude that the applications were capable of effectively transferring retainable information to the user.

Recent studies have investigated the use of AR to improve surgical navigation. Both Okamoto et al. [14] and Chen et al. [15] developed AR-based simulations with the aim of improving the safety and reliability of surgery. Okamoto et al. [14] developed an application for surgical navigation in the abdominal area; the system leverages a see-through display and a rigid scope that enables the surgeons to obtain a 3D view. Okamoto et al.'s study identified several problems linked to the use of AR, such as viewing organ deformity, the difficulty of evaluating the utility of the device, lacking in portability, and high cost.

Chen et al. leveraged a head-worn display, created an application, and tested it with actual patient data in a real-world scenario; they verified and demonstrated that the accuracy of their application was sufficient to meet clinical requirements (However, only within a simulated environment). Pratt et al. [16] adopted the Hololens in order to bring a new level of precision and planning into reconstructive surgery. Through preliminary studies, Pratt et al. were able to demonstrate that using HWD could help with the precise localization of perforating vessels. In summary, AR has been an asset in medical training and the introduction of HWDs precludes a new level of precision for some procedures.

2.2. Collaboration

The study of collaboration in AR is becoming increasingly popular. HWDs enable a new type of accessible collaboration in the form of group interactions with a single digital object in a real-world environment. Users are now able to collaborate on complex data sets using 3D visualizations, which can be shared between individuals wearing HWDs. Current research on collaboration primarily revolves around having one HWD receiving instructions and a computer or a mobile device sending the instructions. Ryskeldiev et al. [17] looked at using mobile video streaming to create StreamSpace, an application that provides remote collaboration by sharing one user's environment with another. This type of collaboration can be readily applied in the health industry for medical training purposes, understanding health data visualizations, or any other collaborative tasks that might benefit from a remote collaboration. Velamkayala et al. [18] studied the effects of using Hololens in navigation tasks. Velamkayala et al. asked participants to navigate the university library while wearing a HWD and following the instructions given in-situ by an operator who was remotely connected to the navigating user's camera. The researchers found that, compared to other devices such as the iPhone, the Hololens system yielded improved performances. Moreover, the participants using the Hololens felt a lower cognitive workload when navigating the library. However, users had negative feedback pertaining to the comfortability of the device. A more comfortable experience may in turn generate more efficient outcomes.

To the extent of our knowledge, due to the novelty of the devices, using HWDs for collaboration within the health industry has not yet been looked into and show potential as a useful form of communication.

2.3. Information and Data Presentation

Head-worn augmented reality displays (HWDs) offer an immersive way for users to visualize and interact with data. Hoffman et al. [19] introduced a Hololens method for visualizing and interacting with complex molecular structures: the Hololens provides the authors with a 3D structure, allowing for a deeper level of understanding than the commonly used 2D screen is able to provide. Similarly, Hanna et al. [20] have showed that the Hololens has the sufficient power and comfort required to be useful in facilitating autopsies, microscopic examinations, and digital pathology; they tested the Hololens by having Pathology residents perform an autopsy while wearing the device. During the study, instructional screens and diagrams were displayed to successfully guide the user through an autopsy.

In other disciplines such as city planning and physics, users are already taking advantage of AR to discover new ways of visualizing complex, multi-dimensional data. Zhang et al. [4] used the Hololens to visualize Toronto's city data. Strzys et. al [21] leverages the Hololens by combining aspects of AR with a well-known thermal flux experiment. Strzys et al. showed that this combination facilitates students' learning process by allowing them to visualize an otherwise invisible process.

Design frameworks such as The Personal Cockpit [22], (an evaluated design space for effective task switching on HWDs) and Ethereal Planes [23] provide guidelines to assist in the creation of meaningful information layouts and interfaces of superior utility both quantitatively and qualitatively, for use in any field, including health. This research could also be applied to create meaningful layouts for new health applications. Ens et al. also introduced a layout manager [24] that allowed users to find virtual applications quickly in their real-world environment by using a novel algorithm which carefully chooses where windows should be placed, based on the user’s surroundings. Future research is needed to generalize these findings in medical procedural and analytical tasks. To our knowledge, there is limited research examining the efficiency of using HWDs such as the Hololens in completing procedural or analytical tasks in the field of health communication.

3. Future Directions

As emphasized in the previous sections, HWDs such as the Microsoft's Hololens are novel, powerful, and portable; hinting at much untapped utility. However, like every technology, there are some limitations which must be considered. Currently, such devices are limited by their field of view (FOV). Still, even with such limitations, the current iteration of the Hololens is sufficiently functional for investigating means to improve overall user experience as it relates to AR and HWDs.

Another limitation features the in-situation awareness of information placement: where do we place information based on the environment around the user of the device? Displaying crucial, supplementary data in AR for use in procedure or training proves difficult for a plethora of technical reasons. A visually busy environment such as a procedure room for neonatal resuscitation training (See Fig. 2), illustrates numerous potential dilemmas such as: What type of information should be displayed?; How should the information windows adapt when a person or object, enters or leaves the environment? These environments are often not only visually busy, but physically chaotic.

In future work, we plan on exploring the limitations outlined in Ens et al's work on spatial memory [22]. Combined with the mapping of virtual information spaces to a physical environment [23], we hope to create an algorithm that would facilitate the work of the AR users (figure 2). Furthermore, the intuitive way of presenting data and information, as well as the collaborative aspects of the Hololens present opportunities to expand into new research areas within the health industry such as health informatics.

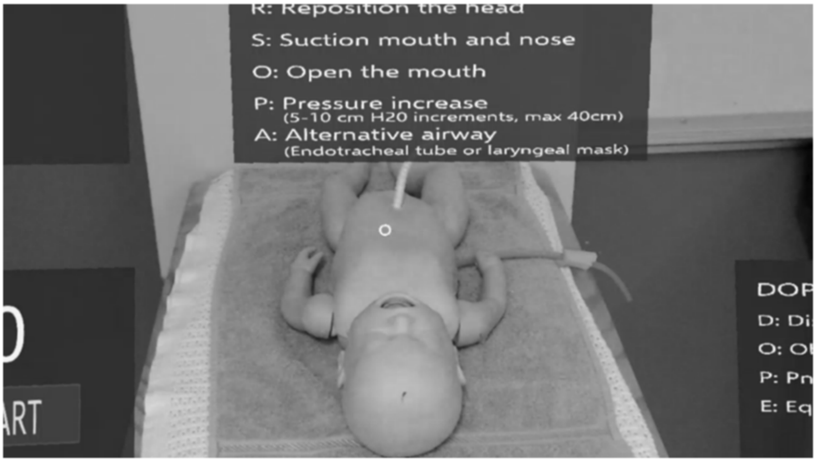

Figure 2. A possible information space for neonatal resuscitation

4. Conclusion

In conclusion, the use of new head-worn augmented reality displays (HWDs) such as the Hololens and MagicLeap One could prove to be quite beneficial within the health industry. Augmented reality (AR) allows us to work with digital objects in a physical environment, while enhancing a variety of tasks such as analyzing complex data, or medical training. Additionally, the improved portability of contemporary HWDs allow users to have an untethered experience while interacting with digital objects. This paper explored the potential use of HWDs for important applications in health communications. We also provide an up-to-date look at the current research going into HWDs. Although there is still some work to be done in order for these HWDs to be more effective, the current state of these devices provides us with a good beginning point for the development and research of portable AR applications within the health industry.

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References

[1] E. Z. Barsom, M. Graafland, and M. P. Schijven, "Systematic review on the effectiveness of augmented reality applications in medical training," *Surg. Endosc. Other Interv. Tech.*, vol. **30**, no. 10 (2016), 4174–4183.

[2] R. Azuma, "A Survey of Augmented Reality," vol. **4,** no. August, (1997), 355–385.

[3] W. Wang, X. Wu, G. Chen, and Z. Chen, "Holo3DGIS: Leveraging Microsoft HoloLens in 3D Geographic Information," *ISPRS Int. J. Geo-Information*, vol. **7**, no. 2, (2018), 60.

[4] L. Zhang, S. Chen, H. Dong, and A. El Saddik, "Visualizing Toronto City Data with HoloLens: Using Augmented Reality for a City Model," *IEEE Consum. Electron. Mag.*, vol. **7,** no. 3 (2018), 73–80.

[5] X. Zhong, P. Liu, and N. D. Georganas, "Designing a Vision-based Collaborative Augmented Reality Application for Industrial Training," vol. **45 (**2003), 7–19.)

[6] P. Boulanger, "Application of augmented reality to industrial Tele-training," *Proc. - 1st Can. Conf. Comput. Robot Vis.*, pp. 320–328, 2004.

[7] M. Bower, C. Howe, N. McCredie, A. Robinson, and D. Grover, "Augmented Reality in education - cases, places and potentials," *EMI. Educ. Media Int.*, vol. **51** no. 1 (2014), pp. 1–15.

[8] R. Wojciechowski, K. Walczak, M. White, and W. Cellary, "Building Virtual and Augmented Reality museum exhibitions," *Proc. ninth Int. Conf. 3D Web Technol. - Web3D '04*, vol. 1, no. 212, p. 135, 2004.

[9] S. Feiner, B. MacIntyre, M. Haupt, and E. Solomon, "Windows on the world," *Proc. 6th Annu. ACM Symp. User interface Softw. Technol. - UIST '93*, no. July, pp. 145–155, 1993.

[10] B. Bell and S. Feiner…, "View management for virtual and augmented reality," *Proc. 14th Annu. ACM ...*, vol. 2001, pp. 101–110, 2001.

[11] Microsoft, "Microsoft Hololens." 2018.

[12] M. Leap, "Magic Leap One." 2018.

[13] B. C. Kress and W. J. Cummings, "Towards the ultimate mixed reality experience: Hololens display architecture choices," *Dig. Tech. Pap. - SID Int. Symp.*, vol. **48**, no. 1 (2017), 127–131.

[14] T. Okamoto, S. Onda, K. Yanaga, N. Suzuki, and A. Hattori, "Clinical application of navigation surgery using augmented reality in the abdominal field," *Surg. Today*, vol. **45**, no. 4 (2015), 397–406.

[15] X. Chen *et al.*, "Development of a surgical navigation system based on augmented reality using an optical see-through head-mounted display," *J. Biomed. Inform.*, vol. **55 (**2015), 124–131.

[16] P. Pratt *et al.*, "Through the HoloLens™ looking glass: augmented reality for extremity reconstruction surgery using 3D vascular models with perforating vessels," *Eur. Radiol. Exp.*, vol. **2**, no. 1(2018), 2.

[17] B. Ryskeldiev, M. Cohen, and J. Herder, "StreamSpace: Pervasive Mixed Reality Telepresence for Remote Collaboration on Mobile Devices," *J. Inf. Process.*, vol. **26**, no. 0 (2018), 177–185.

[18] E. R. Velamkayala, M. V. Zambrano, and H. Li, "Effects of HoloLens in Collaboration: A Case in Navigation Tasks," *Proc. Hum. Factors Ergon. Soc. Annu. Meet.*, vol. **61**, no. 1 (2017), 2110–2114.

[19] M. A. Hoffman and J. B. Provance, "Visualization of molecular structures using HoloLens-based augmented reality.," *AMIA Jt. Summits Transl. Sci. proceedings. AMIA Jt. Summits Transl. Sci.*, vol. **2017 (**2017), 68–74.

[20] M. G. Hanna, I. Ahmed, J. Nine, S. Prajapati, and L. Pantanowitz, "Augmented Reality Technology Using Microsoft HoloLens in Anatomic Pathology," *Arch. Pathol. Lab. Med.*, vol. **142** (2018) May, p. arpa.2017-0189-OA.

[21] M. P. Strzys *et al.*, "Augmenting the thermal flux experiment: a mixed reality approach with the HoloLens," vol. **376 (**2017), 10–12.

[22] B. M. Ens, R. Finnegan, and P. P. Irani, "The personal cockpit: A Spatial Interface for Effective Task Switching on Head-Worn Displays," *Proc. 32nd Annu. ACM Conf. Hum. factors Comput. Syst. - CHI '14*, no. August 2016, pp. 3171–3180, 2014.

[23] B. Ens, J. D. Hincapié-Ramos, and P. Irani, "Ethereal Planes: A Design Framework for 2D Information Space in 3D Mixed Reality Environments," *Proc. 2Nd ACM Symp. Spat. User Interact.*, pp. 2–12, 2014.

[24] B. Ens, E. Ofek, N. Bruce, and P. Irani, "Spatial Constancy of Surface-Embedded Layouts across Multiple Environments," *Proc. 3rd ACM Symp. Spat. User Interact. - SUI '15*, no. September, pp. 65–68, 2015.