Mixed and Augmented Reality

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ABSTRACT
The aim of this paper is to provide a broad analysis of Mixed Reality (MR) and Augmented Reality (AR). The recent origins of the concepts of mixed and augmented reality will be briefly outlined, and how far it has come will also be explored. These concepts will be put into context with other related concepts, and the distinctions between them explained. The challenges of using and implementing these kinds of technologies will be highlighted, along with different areas that are using these applications and their benefits. Finally, this paper will delve into some potential future applications of this technology.

Author Keywords
Virtual reality; VR; mixed reality; MR; augmented reality; AR: augmented virtuality; AV; head mounted display; HMD; motion sensor; pupil tracker; hand gestures; remote collaboration; education; healthcare; social media; brain-computer interface; BCI.

INTRODUCTION

With the seemingly exponential explosion of advancements in technology that we have seen in recent years, technology has been getting faster and more powerful while simultaneously becoming smaller and more portable. Our computing devices are able to perform better in every regard and they last longer while doing so. While Virtual Reality has been a concept in the literature since the 1960's [3], it has not been exempt from the speed of advancement we have all seen in our lifetimes. Mixed Reality, existing as a continuum containing Augmented Reality and Augmented Virtuality, is a derivative of Virtual Reality itself [5]. This conceptualization has stood the test of time and has served as a useful guiding framework through many major studies on this topic [5], [3], [8], [4].

Although technology has obviously changed since the formulation of Milgram & Kishino's MR continuum [5], this technology and how it is used can still be incorporated into such a continuum. Modern applications of MR and AR include head-mounted displays, pupil tracking devices, and even motion sensors calibrated to recognize certain hand gestures [8]. Even with such advances in technology, certain challenges still exist in its implementation, including but not limited to physical, social, mobility and performance issues [1], [6].

While challenges certainly exist, many fields are nonetheless seizing upon the opportunities for innovation afforded by MR applications. Education, healthcare, and even social media are but a few such fields [10], [9], [7]. The benefits of using this technology in these fields have only begun to be actualized.

As with any technology, it is always useful to discuss potential future applications. Building upon the functionality offered by virtual reality and the corresponding MR and AR/AV applications, the prospect of brain-computer interface control in such a virtual environment is certainly on the horizon [2]. Based on current research, this could reasonably be employed in the so-called 'internet of things' to help users control smart devices in their home [2].

MIXED AND AUGMENTED REALITY EXPLAINED

Mixed Reality

While there have been many surveys of, and studies on, mixed and augmented reality throughout the years, in the majority of these papers the operational principles have relied upon the same foundation. That foundation is Milgram & Kishino's 'Virtuality Continuum' [5] or, as shown in Figure 1, the slightly different-named 'Reality-Virtuality Continuum', as used by Piumsomboon et al in a recent comprehensive study within this spectrum [8]. As first laid out by Milgram & Kishino in 1984, the mixed reality continuum is a subset of virtual reality more broadly [5].

As one can see in Figure 1, we have the real environment at one end of the spectrum and a virtual environment at the other [5]. As the name 'mixed reality' implies, this continuum encompasses any blend of the two [5]. According to Milgram & Kishino, mixed reality denotes an "environment [where] real…and virtual…objects are presented together within a single display…between [this] continuum" [5].

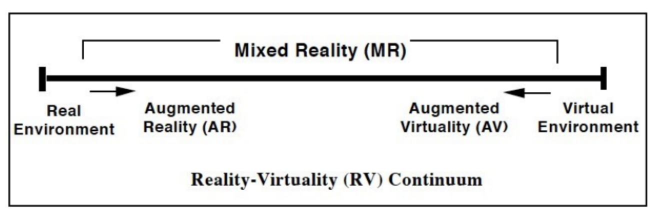

Figure 1. Mixed Reality Continuum

Augmented Reality

We have to take a closer look at the mixed reality spectrum to understand the more nuanced augmented reality. But in order to fully grasp the concept of augmented reality (AR), it helps to put it into context with augmented virtuality (AV). Here, it is useful to refer to the more recent study by Piumsomboon et al and their explanation [8]. That is, whereas AV "captures real objects and superimposes them into the virtual environment", AR "overlays virtual objects into the real world" [8].

As aptly noted by Milgram & Kishino in their pioneering paper, AR does not have to just encompass visual stimuli [5]. AR can also include auditory, haptic (touch) and vestibular (motion) inputs as well [5]. As reiterated by a 2009 survey on MR, especially when it comes to haptic input, the real and digital aspects inputted into the system need to be as close as possible for the user experience of AR to feel as natural as possible [3]. As seen in Figure 2, a recent paper out of China exploring AR provides us with a useful model of its architecture [4]. One can see how the blend of real and virtual is incorporated into a single user interface [4].

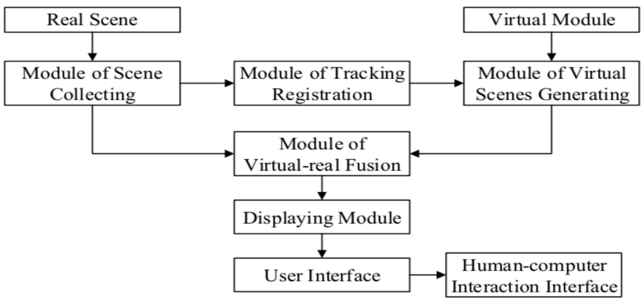

Figure 2. Augmented Reality Architecture

IMPLEMENTING MIXED AND AUGMENTED REALITY

Details

An illustrative example of the implementation of mixed and augmented reality is the recent one by Piumsomboon et al, where an AR user within a precisely organized room was digitally paired with an AV user in another room designed to be an exact replica of the AR user's room [8]. Whereas the AR user was wearing a head-mounted display (HMD) with a semi-transparent lens, the AV user was wearing a visually enclosed HMD.

Just as laid out by our previous explanation, the AR user had digital images overlaid onto their display whereas the AV user had real objects inputted as digital images into their display [8]. The users' head and eye movements within the two identical rooms were tracked, and even specific hand gestures were registered, with the other user able to 'see' them in their room [8]. The application in this study was for people to 'physically' collaborate together regardless of their location, but we can see here the utilization of the various stimuli just as laid out by researchers of the past [5], [3].

Challenges

Upon close analysis of the previously cited study by Piumsomboon et al, one can already begin to see some of the potential challenges [8]. To start, we have the physical challenges of real-world objects needing to be near-perfectly aligned and the hardware challenges of the two users' MR systems having to be fully compatible with one another [8].

However, even more challenges are revealed upon closer examination of the field of MR as a whole. As noted by Bhutta et al, for these technologies to be incorporated into society in the first place, we need to get over the inevitable social acceptance and human interaction challenges more generally first [1]. On top of that, we will also need to eventually address the mobility and performance issues around MR systems, especially when it comes to their portability and outdoor use in the less-forgiving nature of the natural environment [1].

If that were not enough, motion sickness has also been a notable problem for many users [6]. Luckily, machine learning algorithms are beginning to be employed to deal with the long list of technical complexities related to this [6].

APPLICATION AND BENEFITS

Education

A cross-institutional study conducted by students from The US and China found that virtual reality education applications can be useful for student learning due to its ability to immerse students and help them develop an intuitive sense of what they are learning [10]. The researchers noted that MR and AR applications in particular would be beneficial, and that utilizing this kind of technology could reduce both the cost and risk of some kinds of learning [10].

Healthcare

A study out of Egypt explored the idea of mapping an x-ray image onto a patient's body for minimally invasive orthopedic surgery [9]. The researchers note that this can both aid a physician while doing their job in the operating room itself, as well as substantially lower the number of x-rays needed prior to performing surgery [9].

Social Media

Researchers from Korea have proposed the idea of using AR to allow users to save and share "site-specific memories in virtual space" [7]. The authors note that this could help reduce instances of vandalism to culturally- and historically-important landmarks, as tourists could still 'leave their mark' without physically damaging any real-world strucutres [7].

FUTURE OF MIXED AND AUGMENTED REALITY

Research out of The US has explored the possibility of using VR applications together with a brain-computer interface [2]. This would allow users a new dimension of control over devices they are interacting with, or even over devices in their physical proximity, such as smart devices in their home [2]. This could be done through an 'internet of things' network in their home, for instance, to control the heat and lighting in their home [2]. The researchers note that not only could this help disabled persons, but could be of interest to people in general as well [2].

CONCLUSION

While the VR and motion-sensing devices required for the everyday user to experience the benefits offered by MR and AR are still expensive and suffer from some practical limitations, we have seen a rapid growth in the research and interest surrounding them. Despite the challenges [1], [6], researchers continue to explore this technology and push the boundaries of what can expect from our devices in the near future [8], [2]. It is refreshing to see papers both referring back to the roots of our understanding of MR and AR [5], [3] as well as further develop a nuanced understanding of it [4]. In the meantime, the exploitation of this technology will hopefully lead to the improvement of many people's lives, making education more effective [10], healthcare more efficient [9], and even protecting cultural monuments [7].

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