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Visualising mixed reality simulation for multiple users

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Blended reality seeks to encourage co-presence in the classroom, blending student experience across virtual and physical worlds. In a similar way, Mixed Reality, a continuum between virtual and real environments, is now allowing learners to work in both the physical and the digital world simultaneously, especially when combined with an immersive headset experience. This experience provides innovative new experiences for learning, but faces the challenge that most of these experiences are single user, leaving others outside the new environment. The question therefore becomes, how can a mixed reality simulation be experienced by multiple users, and how can we present that simulation effectively to users to create a true blended reality environment? This paper proposes a study that uses existing screen production research into the user and spectator to produce a mixed reality simulation suitable for multiple users. A research method using Design Based Research is also presented to assess the usability of the approach.

Introduction

Blended reality collaborative learning environments strive to enhance learning through embodied co-presence in the classroom, allowing multiple learners to interact within one blended (physical and virtual) space (Bower, Cram, & Groom, 2010). Work to date in this area has looked in detail at how participants have collaborated across physical and virtual worlds, with promising results looking at the best practice to achieve this synchronicity, despite difficulties occurring in areas such as facilitating effective communication, enabling productive co-creation and establishing a sense of co-presence between virtual and physical participants (Bower, Lee & Dalgarno, 2016).

However, to date there has been limited research into how this concept of blended reality would fit into a situation involving multiple participants using mixed reality (MR) devices to experience the same digital reality simultaneously. This is important, because whilst mixed reality is having a resurgence in the literature, these experiences are often physically located within a space, complex to setup and individually focussed. Because of this, a single user at a time experiences the simulation, while other users are *stuck on the outside*, watching, unable to embody what the main user is fully experiencing (Loomis, 2016). Hence, a challenge presents itself, how can a method be developed that allows multiple users (located in a single space both physically and virtually) to experience this learning method simultaneously using currently available commercial technology, creating a true blended reality that uses mixed reality in the same physical space?

This paper will explore the use of new techniques in producing effective mobile mixed reality simulations that work to provide users with a true simultaneous mixed reality experience. Specifically, it will look at how the use of an in-headset view can be combined effectively amongst multiple users to produce a clearer idea of how the mixed reality intervention operates, proposing an experimental and research design to test various views of this concept and looking to answer the research question “How can a mixed reality simulation be experienced effectively by multiple users simultaneously?”

Background literature

Technologies such as 3D printing (3DP), augmented reality (AR), virtual reality (VR) and mobile bring your own devices (BYOD) have emerged as innovative technologies to assist learners (Adams et al., 2017). Similarly, the term mixed reality (MR) has become more popular as a mechanism to provide a framework to position these new technologies across real and virtual worlds (Milgram and Kishino 1994). This has resulted in the development of new paradigms, tools, techniques, and instrumentation that allow for immersive visualisations at different and multiple scales, and the design and implementation of comparative mixed reality pedagogy across multiple disciplines (Magana, 2014). More recently, researchers have started to explore the connections between these technologies to greater enhance learning through the affordances of each of these technologies in combination (Cowling, Tanenbaum, Birt & Tanenbaum, 2017). At the same time, researchers have continued to look at how the digital and physical worlds can be combined, and how students can work effectively in these worlds



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simultaneously in the form of blended reality (Bernard, 2014). This work builds on the work of Moreno & Mayer (2007) and Mayer (2014) that looked at how multiple forms of modality (in this case pictures and text) could be combined to provide a more cohesive environment. It also builds on work by Ainsworth (2014) that looked at ways to use multimedia environments for discovery learning.

Specifically, work by Bower, Lee & Dalgarno (2016) looked at how these new digital and physical environments could become true blended reality collaborative environments, bringing together participants in augmented reality spaces and allowing them to interact. This work found that whilst there were technological and logistical challenges, the technology did work towards communication, collaboration, and co-presence. However, it did acknowledge that the technology as implemented in the pilot study did maintain a hard distinction between the physical and the virtual environment, and required users to switch between communicating across and within spaces.

This hard distinction makes it difficult for current blended reality work to be applied to immersive mixed reality systems. Specifically, as noted previously, once a user puts on a headset, they are immersed in an individual world, and spectators are left on the outside (Loomis, 2016). Work has been done in this area in other disciplines, with Lukosch, Billingham, Alem, & Kiyokawa (2015) reporting on successful studies in product design, maintenance and factory planning. Billingham, Clark & Lee (2014) also note the use of collaboration systems in research contexts in mixed reality. However, little work appears to have been done on the use of co-presence mixed reality simulations in an educational environment for collaborative problem solving, skills development and training.

This raises the question, as education moves towards a multimodal pedagogy of online and face to face learning, and given the individual nature of mixed reality technology, how do we effectively produce a mixed reality experience for multiple users that blends the physical and virtual classroom? In this space, the field of screen production, and particularly research into new modes of screen production has the potential to help provide some answers to this problem. Berry (2016) uses the theory of Ingold's (2008) zones of entanglement to explain that mobile devices provide us with an environment which surrounds the organism. She argues that these notions provide alternative and useful ways to explore and reflect upon how this new participatory culture and creative vernaculars penetrate our everyday lives, as well as dynamic adjustment to our social and routine practices. Drawing on the work of Creswell (2011), Berry (2016) argues that this change is part of a

larger push towards mobility and movement and will only increase in the future.

Looking at MR and the growth of mobile MR, it's clear that these concepts apply even more strongly to the immersive world created in a MR context. And yet, as noted, it is difficult for mixed reality to present any more than a single user experience. Drawing on the view of Kerrigan (2016), it's clear that the role of spectator in the mixed reality space is yet to be well defined, and that they are not a part of the filmic reality when developing mixed reality simulations. A possible solution to this problem is presented by Kerrigan (2016), through the *Systems View of Creative Practices*. Using this framework, the role of the agent that participates in the simulation can be reframed to include somebody who poses simultaneously as both a user and a spectator. In this way, the roles become deeply interconnected, and the developer can work with this new type of agent in mind.

In practice, for mixed reality, this therefore gives us a way forward to develop mixed reality screen production that considers both the active user and the spectator. By embodying the new agent as described by Kerrigan (2016), and incorporating the work of Berry (2016) as well as the overarching theory of zone of entanglement as outlined by Ingold (2008), the developer can create a simulation that provides insight for both participant and spectator. The next section will explain how an intervention could be designed with these principles in mind.

Experimental design

Previous work by the authors piloted an approach to asynchronous multi-user mixed reality that can be used to ground this experiment. As detailed in (Birt, Moore & Cowling, 2017), a mixed reality implementation was conducted in paramedic science involving 3d printed tools and an augmented reality app. In addition to being provided with these components, students were also provided with a video explaining how to conduct the simulation. Following the theory laid out by Kerrigan (2016), this video was constructed for students using integrated knowledge of both the spectator and the user view. In practice, this meant showing students both views simultaneously using a picture-in-picture style screen production method.

Imagery from this video tutorial is shown in Figure 1. Sample videos can also be found on youtube at the following link (<http://youtu.be/wfwZFkISQU>). Students were shown how the whole procedure could be conducted from both the spectator view and the user view, and were then asked in surveys after the intervention how this helped with their learning. Response from students was that they felt the video was useful (with 95% of students that used the simulation indicating that the video was helpful), but data was not

collected on their specific perception of the mixed reality tutorial video.

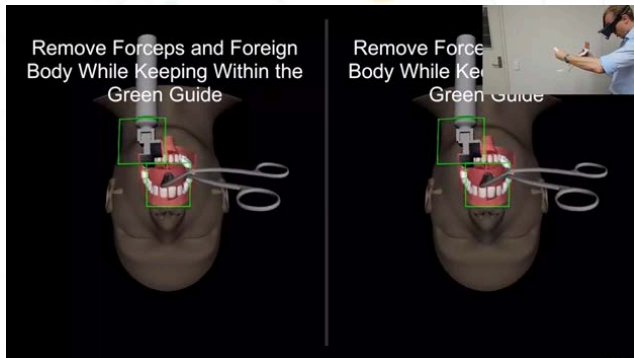


Figure 1: Screen Production of Student Tutorial Showing Combined Spectator and User Views

However, this view, whilst useful for confirming the spectator-user combination, does not allow for a true collaborative mixed reality experience, where agents can transition seamlessly from a user context to a spectator context as required to work with the simulation. Further, it does not show whether there is value in this type of true collaborative simulation in the classroom, as opposed to a view similar to that presented above.

For this reason, a further experiment in multi-user mixed reality is being proposed. Using existing mobile mixed reality hardware similar to that presented in the previous trial, five views will be constructed and presented to participants. Based on the previous screen production research identified, these views will all involve a single user and multiple spectators, and will comprise:

1. **Multiple Spectators via non-immersive POV:** In this view, a single user will wear the headset to complete a simple task, with other users viewing what they see (their Point-of-View or POV) on a standard screen. This represents the baseline usual representation of how multiple users experience a mixed reality simulation – via an external 2D view from the user's perspective.
2. **Multiple Spectators via immersive POV:** In this view, the single user view will be replicated into other immersive stereoscopic headsets worn by the other participants. Spectators will not be able to manipulate the simulation, but will be able to see it from a first person POV but with depth. Previous work has indicated that this view might cause motion sickness and disorientation for spectators as they have no control over their view or actions (Suma, 2010).
3. **Multiple Spectators with POV and PiP:** Replicating the previous study, this view will show spectators both a POV for the mixed reality user, as well as an in-set non-enhanced

picture-in-picture (PiP) view of the user from a second spectator-style angle.

4. **Multiple Spectators with non-immersive third-person view:** Working to enhance the PiP approach, this view will incorporate a third-person view of the mixed reality user enhanced with digital objects from the mixed reality simulation. Rather than showing POV for this user, spectators will be able to view the conducted simulation in third-person view through a screen.
5. **Multiple Spectators with immersive third-person view:** As per option 4 above, this view will give the spectator a third-person viewpoint. However, rather than a screen, it will use existing stereoscopic immersive mobile mixed reality hardware. This is expected to be the most immersive experience for the participants of the options given.

For each of these described views, a user will be asked to perform a simple mixed reality task, with participants viewing under each of these conditions. Details of the research method used during this experiment and data collected is provided in the next section.

Research method

The theoretical framework underpinning this work is design-based research (DBR) methodology (Anderson & Shattuck, 2012), with an underlying action research mentality (Kemmis, McTaggart, & Nixon, 2014) implemented in the conduct of the research in the classroom. Specifically, the four steps of the DBR methodology will be followed through the first loop analysis of the problem and design of the current simulation solution (as detailed in the section above), and then an evaluation will be conducted by several industry experts. This first loop will be followed by the proposed second loop pilot study that will involve an iterative implementation of the new solution using the feedback from the first loop experts and delivered into the classroom by a discipline expert practitioner positioned to evaluate the effectiveness of the solution who will provide detailed feedback on the re-design from the student stakeholder perspective. This will then result in a loop back for design refinement and further iterative testing and evaluation.

Participants will be shown a demonstration as both users and spectators in each of these views, and for each view will be asked to complete a survey to assess the effectiveness of the tool. Categories were developed for both the observation as well as the data collection for surveys. These are based on previous work conducted by one of the authors (Birt & Horvoka, 2014). For the second loop, an undergraduate class at the lead authors institution will be recruited as per the studies ethics to perform the testing. Specifically, a small sample of

students ($n \leq 30$) will be selected for this initial student usability test in line with common first phase software usability testing practice (Nielsen, 2012), so that it would be possible for a single research assistant to interact with these students in depth and collect rich feedback on their use of the tool. Data from these loops will then be analysed and used in a DBR process to assess and refine the prototype. Future testing of the system in the classroom will then be conducted to determine which multi-user mixed reality can most effectively be used for learning.

Conclusion

Mixed reality is a new and growing area. In addition to challenges related to how mixed reality can be used to improve pedagogy and skills development, screen production challenges also exist on how this experience can be made accessible to multiple users, both synchronously and asynchronously. This paper has provided some insight into how these challenges might be addressed, proposing a research and experimental design seeking to answer the research question "How can a mixed reality simulation be experienced effectively by multiple users simultaneously?". Specifically, a methodology involving simultaneous viewing of the mixed reality experience from both the spectator and user view is proposed, and a research design based on Design Based Research has been proposed to test this approach.

Future work will look at how this approach can be extended to more complex synchronous mixed reality experiences. In particular, thought will be given to how multiple users within mixed reality can be given a seamless mixed reality experience, and how their perception of their role as spectator or user effects their ability to interact in this context. This will require connection between mixed reality devices as well as a clear understanding of the zone of entanglement, or environment which surrounds the organism, as outlined by Ingold (2008).

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