There Is No One Size Fits All: The Need for Evaluating MR Interaction Techniques

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ABSTRACT

In WIMP and touch interfaces, we are restricted to keyboard, mouse, and touch screens with corresponding gestures. In contrast, Mixed Reality (MR) enables a much wider set of interaction techniques requiring more diverse hardware and design patterns. This means, when designing MR applications, we need to decide which interaction technique works best, which hardware is hence required, and which design patterns may apply. Therefore, we propose that MR developers should put a certain emphasis on the selection of the best interaction technique, hardware and pattern for a specific application. This includes implementing multiple techniques for interactions that are specific for the application under development and testing them with users to assess the respective User Experience (UX) and usability. This allows to select the best interaction solution for a specific MR application.

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**.

KEYWORDS

augmented reality, virtual reality, mixed reality, XR, interaction techniques, usability, user experience

1 THE DIVERSITY OF MR

Mixed Reality (MR) became more widespread and offers high potential for many application areas [6]. Through this, it is important to consider aspects like User Experience (UX) and usability of MR systems and virtual environments [1]. Only if both are good, MR is likely to become a technology of daily use.

MR comes with a different set of interaction hardware [7]. In contrast to keyboards, mice and touch screens known from traditional user interfaces, MR interaction devices can be headsets, controllers, hand trackers and gloves, suits, treadmills, and even more complex setups to reach a high level of immersion and presence. In addition, users do not have a standardized set of hardware but their equipment varies depending on the availability of affordable devices.

Potential applications of MR are manifold [15]. Starting with gaming, it also serves industrial purposes like design tasks, teaching, visualization, and evaluation, as well as private scenarios, like pre-purchase product visualization and try-outs. Each scenario comes with different requirements towards user interaction. For example, in a design scenario it is important to manipulate 3D objects in size, shape, and color, while for trying out a coffee machine, the focus lies on pressing virtual buttons in a close to natural fashion. Naturalness in general has an important influence on MR interaction. Some MR applications play with beyond natural elements. They visualize things that are not real or unfeasible in the real world (e.g., non-euclidean spaces [13, 14]). Other MR applications need to be close to reality, e.g. when visualizing virtual prototypes of technical devices or machinery. This has implications on the interaction techniques. For strictly natural MR the chosen interaction technique should strive for naturalness not to break with the users presence. For less natural experiences a non-natural interaction may be more appropriate.

2 THE BEST INTERACTION TECHNIQUES FOR MR

There have been many analyses in the past focusing on interaction techniques. Some focused on selecting and manipulating objects in Virtual Reality (VR) (e.g., [2, 3, 18]), others on mobile Augmented Reality (AR) (e.g., [4, 8, 16, 20, 23]. Mendes et al. [17] provide a survey of interaction methods for 3D object manipulation covering mouse and keyboard interaction, touch-based interaction, as well as mid-air interaction based on tracked controllers or hands. They identified more than 35 techniques that all could be applied one or the other way to MR. In addition, they state that for some areas, such as AR, even more research is required to find efficient techniques.

Having these studies and the variability of MR equipment and application areas in mind, it is questionable, whether there is the one and only standardized interaction technique and hardware for all applications. Instead, more interaction methods, techniques, and devices are likely to develop in the upcoming years to serve dedicated purposes. It is yet unclear which interaction technique or device fits best for a certain application area of MR. For example, a controller based interaction works well if the controllers represent a virtual object (e.g., a tool) worn in the hand because the controller provides a sufficient haptic feedback of the virtual object [15]. But considering other application areas using controllers may not be the best choice. That is the reason why basic literature (e.g., [7, 15]) typically proposes multiple interaction techniques from which to select for a certain implementation.

This overall situation raises the question which interaction technique to decide for when starting the implementation of an MR application. We also had this question when starting with our work on usability testing of virtual prototypes. In this context, the basic idea is to use MR to evaluate user interfaces of technical devices. To achieve this, we create MR experiences including virtual prototypes for the purpose of testing them with users. Virtual prototypes of technical devices typically come up with diverse interactive elements, e.g., buttons, knobs, and touch screens.

Considering MR we needed to decide which interaction techniques works best for interacting with virtual prototypes. For example, if users want to press a button on a virtual prototype, we were unsure whether this interaction is done best with a controller or with hand tracking. And if we used a controller with a virtual laser pointer for object selection, what are potential issues that may arise? For example, does this work equally well for smaller and larger buttons? Therefore, we conducted studies to analyse this. In a study for VR we found that moving objects works best with a controller based interaction. However pressing buttons on virtual prototypes worked best using hand tracking [11].

With this experience, we learned that there is not the one interaction technique suitable in every scenario. In addition, within a certain scenario developers may have to make a compromise. If they find an interaction technique that works best for a certain interaction, it may serve less for another interaction in the same virtual environment. Therefore, when designing MR experiences the focus should not only be on the design of the virtual world while relying on standard interaction techniques. Instead, we should strongly focus the decision which interaction technique fits best for a certain application. This requires not only an educated guess when deciding between a wide set of techniques and devices, but also a thorough testing which techniques provide the best UX and usability for a specific application.

Figure 1: One of the virtual prototypes we used in our interaction technique study [11].

3 EVALUATION OF MR INTERACTION TECHNIQUES

When considering MR interaction techniques, the good old usability comes into play. The interaction itself serves a good portion to the overall UX of an MR. To fulfil its purpose, it must be effective and efficient, two criteria that usability focuses on. Effectiveness ensures that users can complete their tasks while efficiency considers the effort spent for task completion. A bad interaction technique can strongly decrease the users' effectiveness and efficiency and hence negatively impact the overall UX. Therefore interaction techniques must be evaluated with respect to usability.

In our previous work, we did this for interacting with virtual prototypes [11]. We evaluated for four established interaction techniques for VR which one works best. We first implemented two VR experiences, each with a different virtual prototype. One of them was the coffee machine shown in Figure 1 the other a virtual copier. Then we implemented the four interaction techniques to work for both VR experiences, only one being active at runtime. Finally, we performed traditional user tests with thinking aloud [19, 22] to determine the most appropriate interaction technique.

For these user tests we recruited 85 test participants. Upon arrival of each participant, we informed them about the basic purpose of the study and that they are free to participate and to cancel the test. Afterwards, we provided them with the VR headset (an HTC Vive [5]) and let them visually explore a default 3D environment (none of our implemented ones). Depending on the interaction technique, we also introduced them to additional hardware, e.g., the controllers. Then we started our first scene and asked the participants to interact with the respective virtual prototype. In case of the coffee machine, this meant to brew a coffee, in case of the copier, they had to copy a sheet of paper. To see what the participants did, we mirrored their view onto an external monitor and recorded it as screen cast. When they finished their task, we asked them to put down the headset and interviewed them about their experiences with the interaction method using four guiding statements. Afterwards, they put the headset back on to perform the task with the second virtual prototype. After this task, they again put down the headset and we interviewed them about their experience with the virtual prototype. Finally, we thanked for participation and concluded the test.

We did these tests as a between-subject design. Each fourth of our participants (around 20 per group) performed the tasks with a different interaction technique. We also altered the order of the virtual prototypes. Based on the statements of the participants, our observations, and the screen casts we were able to identify the interaction technique that worked best for the individual parts of the tasks. For example, our participants complained about difficulties moving the cup under the outlet of the coffee machine when using an interaction technique based on hand tracking. This was backed by longer durations for solving the tasks and more unintended drops of the cup (both metrics measured using the screen casts). In contrast, the hand tracking worked best when pressing buttons on the virtual prototypes. More details on the study can be found in [11]. Based on the study, we were able to decide which interaction technique to use for our work.

For industrial production of MR experiences, such an elaborated study may be too much effort, especially for MR experiences with small user groups. Therefore, we also analysed if an AI-based algorithm developed in our group [10] provides helpful insights as well. For this, we recorded the user interactions in a rather detailed manner. We performed the recording on event level similarly to analytics approaches. As results, we got lists of actions performed by our participants. For the coffee machine in Figure 1 these actions included grabbing the cup, releasing the cup, and pressing specific buttons on the coffee machine. We also recorded pose changes of the VR headset as actions. For each action, we recorded time stamps and 3D-coordinates telling us when and where the interaction took place.

Then we analyzed the recorded data. In addition to analytics we first automatically detected common patterns in the user interactions. This resulted in so called task trees, a data structure that can represent the typical action combinations taken by the user. Then we assessed these task trees with respect to inefficient user behavior. This is one variant of so called *usability smell detections* [9, 12, 21]. An example is searching for repeatedly executed action combinations or action combinations that incorporated a large number of head movements. An advantage of this approach is, that it neither requires labeling the recorded data nor specifying an exact problematic pattern to search for. A detailed description of this approach is beyond the scope of this position paper, but details can be found in [10].

We showed that the results of these analyses provide indicators that users have issues during the interaction. For example, in correlation to the fact that users had trouble moving the cup in the above example with the hand tracking based interaction technique, we found many corresponding repetitions of the action combination grabbing, moving, and releasing the cup. This was not the case for the other interaction techniques.

This kind of evaluation cannot only be done while designing an MR experience, but also after its deployment and during its regular usage. This allows, similarly to A/B tests [19, 22], to deploy multiple interaction variants in parallel and to assess afterwards, which one is to be preferred. In addition, if the results are set into relation with, e.g., the utilized MR device and details of the attached hardware, the providers of MR experiences can determine whether it makes sense to implement different interaction techniques depending on a user specific hardware setup.

Bringing this together and considering the success of our study, we think that our evaluation approach is worth being applied by other developers when designing MR experiences and deciding for interaction techniques. Therefore, we propose it in the following as a generic step by step guidance:

(1) Determine which interactions in the MR experience are likely to be performed.
(2) Implement several interaction techniques and try out in traditional user tests which technique performs best for the interactions identified in Step 1.
(3) Implement the MR experience using one or two interaction techniques that showed to perform best in Step 2.
(4) Release the MR experience and continue tracking the user interaction using event based recording mechanisms.
(5) Continuously and automatically analyse the recorded data from Step 4. with respect to inefficient user interactions to identify further culprits and to improve the interaction techniques in subsequent releases.

4 SUMMARY

In this position paper we focused on interaction techniques in MR. We showed that there are many options to select from when designing MR applications. However, not every interaction technique fits for every purpose. Therefore, we concluded that the interaction techniques require a special consideration when developing MR applications. For this, we propose an approach to evaluate interaction techniques separated from the actual MR application with a focus on application specific interactions. With this, developers are able to make educated guesses which interaction techniques serves best for their MR applications and which compromises they need to accept depending on the selection. In addition, they can revise and correct their decision for new releases based on AI-based analyses of recorded usage data.

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