Identification of Everyday Proxies for Tangible Augmented Reality

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ABSTRACT

Using everyday objects as proxies for interaction with virtual objects is a good way to take advantage of tangible interaction without having exact replicas on hand. Since it is not possible to have the exact physical replica in place for every application, everyday objects located in the environment must be identified that are suitable for interaction. The objects must be such that interaction with them feels as realistic as possible and the user experience is not significantly worse compared to interaction with an exact replica. While there are already several studies on this in VR and video see-through AR, very little research has been done in the area of optical see-through AR, although this area is becoming more and more prominent.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; *Haptic devices.*

KEYWORDS

tangible augmented reality, optical see-through augmented reality, tangible interaction, haptic devices, everyday proxy objects

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1 INTRODUCTION

Augmented Reality (AR) enables applications to add visual augmentations to the user's perception [1] and gains increasing attention in diverse areas like education [4] or surgery [16]. By using physical proxies to manipulate or rearrange virtual content, Tangible Augmented Reality (TAR) allows users to interact with virtual objects as they would in the real world. Thereby TAR enables intuitive and natural interaction [2] allowing new use cases [5]. Due to the increasing number of AR headsets on the market, there is also an increasing number of optical see-through AR applications. This technology provides a less obstructed view of reality compared to video see-through AR [13]. Due to technical limitations a complete coverage of physical objects cannot be achieved with optical see-through AR. As the overlays are always slightly translucent, findings from video see-through AR studies cannot be transferred to optical see-through AR. Optical see-through AR, in contrast to mobile video see-through AR, has the advantage that both hands are free for interaction, so that physical objects can be interacted with naturally. However, it is important to find out which everyday objects can be used to interact with virtual objects in Augmented Reality. Both, Szemenyei and Vajda [15] and Hettiarachchi and Wigdor [9] have developed algorithms that identify objects in the environment best representing the virtual objects in terms of their shape. The latter additionally overlay the proxies with the corresponding virtual models in optical see-through AR. The implemented algorithms only consider how well an object fits in terms of shape, size is not taken into account. The authors only evaluated how well their algorithms worked, but not how users would rate the interaction with the selected proxies.

In this position paper we want to show which aspects play a role in the choice of a suitable proxy for tangible interaction in optical see-through AR and therefore need to be investigated in more detail in user studies. In addition, we explain how the different aspects can be evaluated in optical see-through AR.

2 DETERMINATION OF SUITABLE PROXIES IN OPTICAL SEE-THROUGH AR

In the field of VR, there is already research on how well everyday proxies can represent their virtual counterparts during interaction. Simeone et al. [14], e.g., explore, to what extent the physical proxy can vary from its virtual representation without breaking the VR illusion. They represent the measure of dissimilarity by different levels. Starting from the exact replica, over aesthetic differences, like a changed material in the virtual representation and addition/omission of features, as well as functional differences between virtual and physical object up to a virtual representation with a severly different shape (categorial difference). Similar to their approach in VR, research must also be conducted in AR to determine which objects are suitable as tangible proxies. In contrast to the investigations of Simeone et al., in which in one level even several features, e.g. material and weight, differ between virtual and physical object, our approach is to first determine for each feature individually to what extent a deviation can exist here. If different changes are mixed in the investigations, for example shape and material, their individual effect cannot be determined and thus it

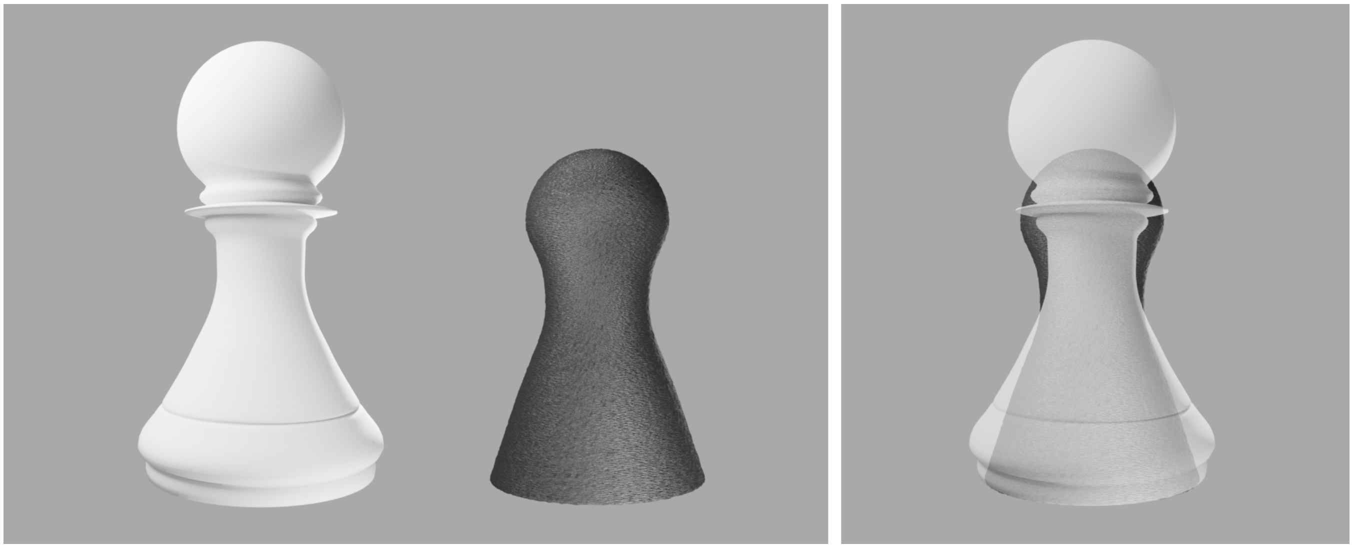

Figure 1: Left: Virtual and physical objects differ in shape, size, material, texture, weight and perceived temperature. Right: An optical see-through AR overlay is semi-translucent, not covering the physical proxy behind.

can only be assumed which feature had the main influence on the evaluation results.

2.1 Features for Investigation

There are a variety of characteristics in which a physical object may differ from its virtual representation that need to be evaluated in studies:

- Shape: Physical and virtual objects can have different shapes. This not only creates a different feel when grasping, but also a visual mismatch.
- Size: The objects can differ in size from one another, even if their shape coincides. This also results in a different haptic and visual perception.
- Material: The surface material used also influences the visual perception and the feeling when touching the physical proxy.
- Texture: The use of a different texture influences visual perception, which plays an important role especially in the field of optical see-through AR due to the semi-transparent overlays (see figure 1 (right)).
- Weight: A proxy, even if its virtual representation is identical in shape and color, can, e.g., feel heavier than one is used to and would assume.
- Temperature: The (perceived) temperature influences the haptic perception of an object just like the weight. A physical object can differ from its virtual representation in terms of the measured temperature, or it can feel colder/warmer due to the material used, even though the measured temperature is the same.

In figure 1 (left) an example of differences between virtual and physical object is presented. On the left, you can see the chess piece that the user wants to manipulate in the virtual world. Right next to it, you see a physical proxy that represents the tangible object that the user is interacting with. This example visualizes the differences in all six features. The shape of the physical proxy is more abstract, the size is smaller, the material is rougher, the texture is dark gray instead of white, it is much heavier because it is made of iron and therefore it is also perceived much colder than if you were to touch a wooden chess piece. As seen in this example, physical and virtual objects in a realistic use-case will differ not only in one but probably several features at once. Nevertheless, all possible feature differences must first be examined separately to find their individual effects. In a second step, by examining combinations of features, it is then possible to identify which features have a particularly strong influence and must be prioritized when selecting a suitable proxy object.

2.2 Criteria for Evaluation

When differences between a virtual and a physical object are investigated, there are different quality criteria to consider:

- Performance
- Usability
- Presence

The effect on performance in solving tasks is especially important in goal-oriented applications and can be measured by task completion time or error rates. Another criterion closely related is usability which can be addressed for example by asking users how disturbing the difference between the virtual object and its physical proxy was. Additionally, there are standard ways to assess the usability of a system like the NASA-TLX [7] and the System Usabiliy Scale (SUS) [3]. While performance and usability are not specific to optical see-through AR, presence in this setting is different from presence in Virtual Reality where it is defined as the feeling of being in the virtual environment [8]. Instead, the focus is on the extent to which users feel they are truly interacting with the virtual objects themselves.

2.3 Related Investigations

Besides the aforementioned work by Simeone et al. [14], there is further research on differences between physical and virtual objects in VR. For example, de Tinguy et al. [6] examined differences in size separately. They investigated to what extent a virtual object may differ from its physical proxy without the user noticing. Additionally, they also considered local orientation and curvature as features of interest concerning object shape. In video see-through AR, Kwon et al. [10] conducted experiments about shape and size differences between the objects. They mixed both features in their first experiment and added another one only regarding size differences to determine which feature contributed the main effect in their first investigation. In optical see-through AR, so far no publications regarding differences between tangible proxy and virtual representation exist. Because in this setting the physical object users interact with can also be perceived visually (see figure 1 (right)), findings from VR and video see-through AR cannot be transferred.

2.4 Investigations in Optical See-through AR

To evaluate the influence of individual features (see 2.1) in optical see-through AR on the basis of the presented criteria (see 2.2), it is necessary to track the physical objects in the room while users interact with them and to display corresponding AR overlays in the correct poses. We developed a framework for conducting such studies and enabling participants to perform different interaction tasks. A motion capture system by OptiTrack [12] identifies different predefined physical proxies in the interaction area and provides accurate position and rotation data. These are processed to supply our HoloLens 2 [11] application with descriptions of where to display which virtual overlays.

We recently conducted a first study using this framework which resulted in first insights regarding size differences. Further studies, e.g. regarding shape differences, are already designed and will be conducted in the near future.

3 CONCLUSION

In this position paper we highlight that the use of everyday proxies for tangible interaction also plays a major role in the field of optical see-through Augmented Reality. The differences to VR and video see-through AR are mentioned and a list of features provided in which a physical proxy can vary from its virtual representation. We propose that it is necessary to evaluate each feature individually in a first step and provide criteria for evaluating the difference between virtual object and physical proxy. Finally, we describe how it is possible to perform studies regarding tangible interaction in optical see-through AR by roughly outlining the framework we have established for our own studies.

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