Considering Interaction Types for Geometric Primitive Matching

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ABSTRACT

Approaches to utilize everyday objects from a user's surrounding to provide passive haptic feedback suffer if the mismatch between two matched objects is too large, or the number of objects in the virtual scene exceeds the number of available physical counterparts. By automatically subdividing the virtual as well as the physical objects into geometric primitives and computing a match between them, these drawbacks can be softened. A single physical proxy can easily provide haptic feedback for different virtual objects by that, however, restricting the area on which users can interact to the underlying primitive. Depending on the size of these primitives, the user interactions are consequently restricted, too, e.g. to touching or pinching. Hence, this position paper proposes to already consider interactions during the matching process, e.g. to optimize the primitive matching towards a specific interaction type, or alternatively, to recommend an interaction type for a computed matching.

CCS CONCEPTS

• **Human-centered computing** → **Interaction techniques**; **Virtual reality**.

KEYWORDS

Virtual Reality, Everyday Objects

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1 INTRODUCTION

Providing haptic feedback for Virtual Reality (VR) systems is an ongoing topic of research. Approaches range from Active Haptic Feedback systems [5, 9] to Mixed Haptic Feedback controllers [7, 10] and finally to Passive Haptic Feedback (PHF) [3, 4]. The most basic approach to PHF is to provide a passive counterpart for each virtual object, which users interact with and by that perceive haptic feedback. These counterparts, which are also referred to as proxies or props, can for example be spatially tracked low fidelity replicas of the corresponding virtual item [3]. Although they differ in high fidelity characteristics like shape, size or texture, it has been shown that they nevertheless significantly improve the presence felt by users of a VR system [4], due to the fact that visual stimuli generally dominate haptic feedback [6]. However, the mismatch between the virtual and the physical object should not become too large, as the illusion might break otherwise.

Another disadvantage of providing low fidelity counterparts for VR systems is the repeated need to construct them. Not only is it time consuming to prepare the props for a Virtual Environment (VE) consisting of more than a few virtual objects, but it also complicates the extension of an existing VR environment with addition virtual items. One approach to overcome the need to repeatedly fabricate passive proxies is to utilize available everyday objects from a user's surrounding as passive counterparts [2, 8].

This position paper presents and discusses two existing approaches to PHF, which can be applied to everyday objects. Strengths and weaknesses are pointed out and a novel concept to utilize everyday objects for PHF is derived. Lastly, a research question that can efficiently be addressed with the derived concept is explained.

2 MATCHING PHYSICAL AND VIRTUAL OBJECTS

The Annexing Reality system by Hettiarachchi and Wigdor [2] extracts physical counterparts from a user's surrounding and matches them to a given set of virtual objects. This matching can be customized according to a developers needs. In more detail, the developer first generates a so-called haptic model for each virtual object by modeling geometric primitives and subdividing the object accordingly (Figure 1). Afterwards, the developer sorts the virtual objects for situations where their amount exceeds the number of available physical counterparts. According to whether only a single or multiple primitives should be considered during the matching process, the developer assigns priorities to them within each haptic model next, and finally, physical dimensions of the primitives have to be prioritized, too. Based on this customization, physical objects found in the user's surrounding can now be compared and matched to the objects present in the VE.

The approach by Hettiarachchi and Wigdor [2] promises convincing haptic experiences for Augmented Reality and Virtual Reality systems, because developers can precisely customize the matching

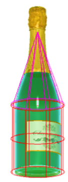

Figure 1: The haptic model of a bottle consists of a cylinder in combination with a cone. [2]

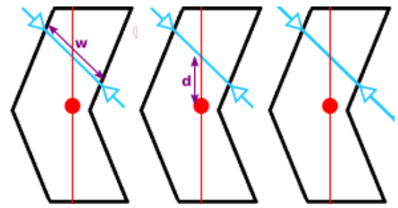

Figure 2: Local characteristics like the pinch diameter (left) or the distance to the center of mass (center) are combined to find the best pinch location (right). [1]

algorithm. On the other hand, generating a haptic model for each virtual object, as well as prioritizing each object, each primitive and the dimensions of each primitive within an object seems to be a lot of effort for VEs consisting of more than a few elements. Furthermore, precisely adjusting the priority scheme requires experience and time and lastly, if the number of virtual objects exceeds the number of available everyday objects, or if there are simply no matching everyday objects available, the Annexing Reality system is not capable of providing convincing haptic sensations for all virtual elements.

One approach that matches virtual and physical objects without additional effort for a developer is presented by de Tinguy et al. [1]. Given a set of virtual and physical objects, the pinch interaction points, which provide the best match between what a user sees and touches are computed based on local characteristics (e.g. pinch diameter, pinch tilt, surface normal; Figure 2).

Mapping pinch interaction points based on local characteristics promises to find convincing matches even if the underlying sets of virtual and physical objects differ strongly. Although their system does not support it, de Tinguy et al. [1] furthermore state that a single physical prop can easily provide pinch sensations for several virtual items, overcoming the need to provide as many physical proxies as virtual objects are present in the VE. However, for bigger objects, pinch interactions using thumb and index finger solely seems rather unnatural and for counterparts which are quite similar, there is no need to restrict the user in how they interact.

While both of the discussed systems aim at finding the best match between a given set of virtual and physical objects, their approaches are rather opposite. The Annexing Reality system [2] does not restrict users in how they interact, while the approach of de Tinguy et al. [1] supports pinch interactions exclusively. On the other hand, their is capable of providing convincing haptic sensations for all virtual objects in a VE, even if their amount exceeds the number of available physical counterparts, or if the sets of virtual and physical objects differ strongly, while the haptic feedback provided by the Annexing Reality system suffers in these situations.

The presented approaches represent a crucial trade-off, which has to be considered carefully while matching virtual objects to real counterparts. On the one hand, restricting users to touch or pinch interactions increases the probability to find convincing matches. On the other hand, this also needlessly restricts users if there actually are proper counterparts of the virtual objects available. To address this aspect, the type of user interactions can already be considered during the matching process.

3 CONSIDERING INTERACTION TYPES FOR GEOMETRIC PRIMITIVE MATCHING

This position paper proposes to utilize everyday objects for passive haptic feedback according to the following concept. Similarly to the Annexing Reality system, potential proxies are extracted from a user's surrounding first. Both, the extracted proxies, as well as the virtual objects are subdivided into geometric primitives and a matching between the virtual and physical primitives is computed. In contrast to the Annexing Reality system, which matches objects based on their geometric composition, each virtual object is internally reduced to the primitive with the highest similarity to its found counterpart, consequently, restricting users to interact only with this specific geometric element later. In addition, the user interaction type should already be considered during the matching process, ensuring that users are not needlessly restricted to a specific interaction type. This could be achieved by varying the scale of the geometric base primitives and computing matches for each scale. In addition to the similarity information of a matched pair, the system could now further evaluate, whether the underlying primitive fits a specific interaction type, e.g. a small primitive should rather be approached with pinch or touch interactions than with grasping.
Following this concept, matches between virtual objects and everyday proxies could be optimized targeting a specific interaction type. Alternatively, a system could recommend the interaction type most feasible for a specific set up, or even recommend a different interaction type for each pair of virtual and physical object.

Depending on the scale of the geometric primitives, the proposed concept computes different matches between virtual objects from a VE and passive everyday proxies from the user's surrounding. The area on which users interact strongly depends on the size of the primitives, which means that including bigger primitives leads to bigger interaction areas on the objects and vice versa. In addition, the size of the primitives also directly impacts the fidelity preserved during the matching process: providing smaller primitives subdivides the objects into smaller regions, thus, a higher accuracy is preserved during the matching process (Figure 3). Both, the size of the interaction area as well as the similarity of what the user sees and touches also affect the realism of haptic feedback, hence, the proposed approach can additionally be used to investigate the trade-off between a larger interaction area, enabling natural interaction using the full hand but providing lower similarity between virtual and physical object, and a smaller interaction area, restricting users

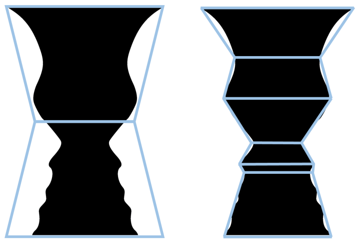

Figure 3: Depending on the underlying set of primitives, objects are subdivided differently. Bigger primitives lead to bigger interaction areas, but also to a bigger difference of what a user sees and touches (left). Smaller primitives lead to a higher similarity between what a user sees and touches, but also restrict the interaction area (right).

in how they interact but providing higher similarity between what a user sees and touches.

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