Haptic Feedback for Interactive Collaboration: Challenges and Outlook

ALEXANDER ACHBERGER, University of Stuttgart, Germany
MICHAEL SEDLMAIR, University of Stuttgart, Germany

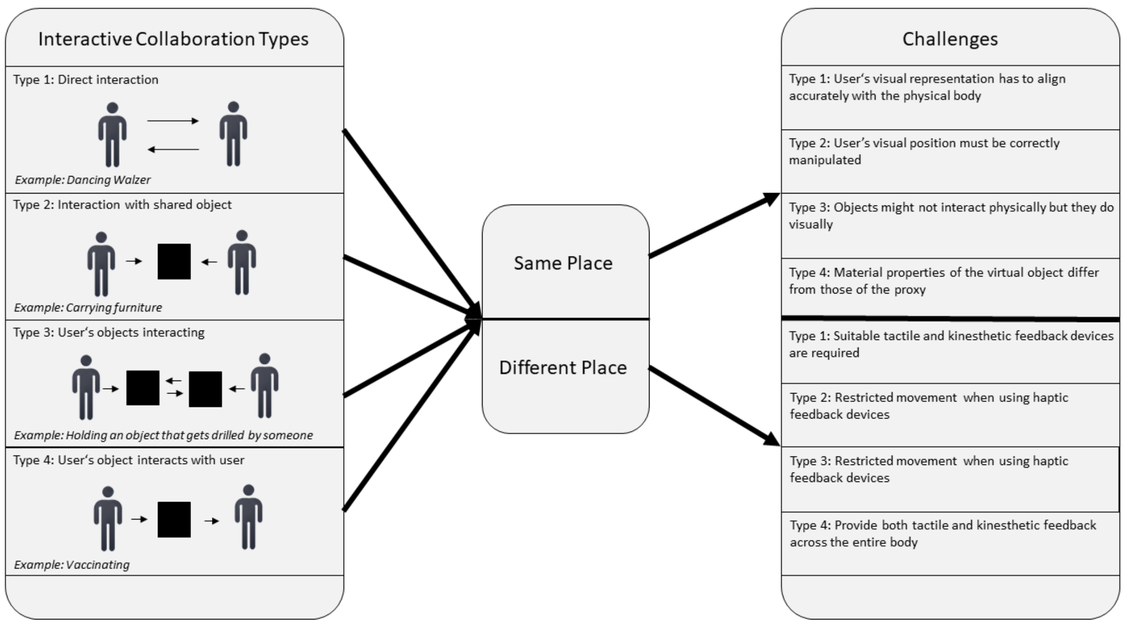

Fig. 1. The challenges of simulating haptic feedback for our four defined interactive collaboration types depend on whether the VR users are located in the same place or in different locations.

We explore the challenges of interactive collaboration in VR, with a particular focus on haptic feedback. First, we define and describe four different types of interactive collaboration, each of which presents unique challenges related to haptic feedback. Next, we outline the haptic feedback challenges for each collaboration type, considering whether users share the same physical space or are in different locations, as this distinction influences the challenges and requirements for haptic interactions. We believe that well-designed haptic feedback devices can play a crucial role in enhancing collaboration on physical tasks in VR.

CCS Concepts: • **Human-centered computing → Haptic devices**.

Additional Key Words and Phrases: Haptic Feedback, Virtual Reality, Collaboration, Interaction, Human-Computer Interaction

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Authors' Contact Information: Alexander Achberger, University of Stuttgart, Stuttgart, Germany, alexander.achberger@visus.uni-stuttgart.de; Michael Sedlmair, University of Stuttgart, Stuttgart, Germany, michael.sedlmair@visus.uni-stuttgart.de.

1 Introduction

Virtual Reality (VR) is becoming increasingly popular and is now used in various domains, such as education [5], entertainment, art [7], training, and industry [10]. One key feature of VR is the ability to collaborate with other users while seeing their virtual bodies aligned with their physical movements. A common form of collaboration involves chatting, discussing, and interacting with 3D data [6].

With advancements in hardware, interactive manipulation of virtual objects is gaining more attention. However, many challenges remain when collaborating interactively in VR. One of the most important challenges is the lack of haptics as haptics can support the users in VR collaboration tasks [8].

However, existing haptic feedback devices are mostly limited to stationary and specific applications [9]. Applications such as, if two users in VR attempt to grab the same virtual object — such as a couch — and place it in a specific location, the absence of haptic feedback prevents them from feeling whether the other person is pushing or pulling the object. This can result in an inconsistent object position, reducing realism and immersion.

To enable effective collaboration, appropriate haptic feedback is necessary. The suitability of a haptic feedback device depends on whether the VR users share the same physical space or are in different locations. Additionally, the type of interaction plays a role, for instance, whether users are manipulating the same object or interacting directly by touching each other.

We believe that well-designed haptic feedback devices can play an important role in fostering collaboration on physical tasks in VR. Therefore, in this position paper, we explore and categorize different types of interactive VR collaboration, analyze their haptic feedback challenges, and speculate about potential solutions.

2 Interactive Collaboration Types

By interactive collaboration types, we refer to interactions in which two or more VR users are actively involved, rather than cases where additional users are merely observing without direct participation.

In the following, we describe four types of interactive collaboration (see Figure [TODO]) and provide an example for each:

(1) **Direct user interaction:** Two or more users directly touch or interact with each other. This interaction can be perceived actively or passively or both simultaneously.
Example: Dancing a waltz in VR, where both users must physically engage with each other.
(2) **Interaction with a shared object:** Two or more users hold and manipulate the same object. Each user can feel the interactions of the others through the object, such as pushing, pulling, or rotating it.
Example: Two users carrying a couch together.
(3) **Interaction between user's object and user:** One user interacts with an object that directly affects another user. Depending on the object's material, the forces exerted and received may differ. This interaction can be perceived actively or passively or both simultaneously.
Example: Administering a vaccine to another user in VR.
(4) **Interaction between users' objects:** Each user has their own object, and these objects interact with each other. The interaction forces depend on object properties such as material, size, and weight, which influence how one user's actions are perceived by the other.
Example: One user holds a wooden board while another user drills holes into it.

3 Challenges

Collaboration is typically categorized along two axes: time and location [4]. Regarding time, we distinguish between synchronous and asynchronous collaboration. In this paper, we focus only on synchronous collaboration. The second axis differentiates between collaboration occurring in the same physical space and that taking place in different physical locations. This distinction impacts the challenges of VR collaboration, particularly in determining the most suitable form of haptic feedback for various interactive collaboration types. Based on these factors, we classify the challenges we have identified according to these two properties.

3.1 Same Place

In this subsection, we discuss the challenges of integrating haptic feedback for each interactive collaboration type in scenarios where one or more VR users share the same physical space, potentially leading to collisions between users or their haptic feedback devices. However, this setup also offers certain advantages in terms of haptic feedback, which we will explore in the following discussion for each interactive collaboration type.

Direct user interaction: This is the simplest interaction type for users sharing the same physical space, as they can directly interact with each other. A key challenge is that the **visual representation aligns accurately with the physical body** of the other user, ensuring they can perceive their exact position in virtual reality. Therefore, in our example of dancing, no additional haptic feedback device is required.

Interaction with shared object: This interaction type requires **active haptic feedback**, meaning users must be able to feel forces when another user pushes a shared object toward them. Therefore, passive devices, that only can stop and restrict movement, such as the string-based haptic feedback device STRIVE [1], could only simulate pulling forces. However, in this scenario, also pushing forces are required, which needs active haptic feedback.

An alternative approach is using a physical proxy for the furniture—any large enough object that both users can grasp, such as a stack of wood, which is visually represented as furniture in VR. The main challenge here is that the **visual position of the users must be correctly manipulated**, as the physical proxy will likely have a different shape and size than the virtual object.

Interaction between user's object and user: The simplest approach for this interaction type is to use a physical proxy, with its visual representation manipulated to resemble the intended virtual object, such as an injection. However, this presents the same challenge as before, ensuring that the **visual representation of the other user is correctly adjusted** if the proxy's shape and size differ from its virtual counterpart.

Additionally, another challenge arises when the **material properties of the virtual object differ from those of the proxy**. In such cases, incorporating vibration feedback into the proxy could help enhance the sensation of interaction, making the experience feel more natural and immersive.

Interaction between users' objects: This is the most complex interaction type, yet it shares the same challenges as the previous cases. Here, both users hold physical proxies, allowing them to interact with each other through their respective objects. However, if there is a difference between the physical size and shape of the proxies and their virtual representations, the **objects might not interact physically as they do visually**.

To address this challenge, haptic retargeting [2] could be explored as a potential solution, ensuring that the interaction feels realistic despite the discrepancies between the physical and virtual objects.

3.2 Different Place

In this subsection, we discuss the challenges of interactive collaboration when both users are in different physical locations. Since they cannot interact with each other directly or use shared physical proxies, the nature of the challenges differs from those encountered in same location collaboration. Also, collaboration across different locations presents the technical challenge of establishing a fast connection to enable real-time synchronization between users.

Direct user interaction: Unlike in the same-location category, this is the most complex interaction type when users are in different locations. Depending on the usage scenario, various forms of haptic feedback, such as **suitable tactile and kinesthetic feedback, are required**. In our dancing example, users need tactile feedback when one user touches the other, as well as active haptic feedback when one user pushes or pulls on the other's body.

Interaction with shared object: In contrast to the same-location category, users require an active haptic feedback system capable of applying forces to their hands. Ideally, the system should provide forces and torques in three degrees of freedom each, such as the Vituose 6D [3]. However, depending on the specific use case, the challenge of **unrestricted movement** becomes relevant. Most haptic feedback devices, do not allow the user to freely rotate 180 degrees. Addressing this would require a haptic feedback system that can move and rotate along with the user.

Interaction between user's object and user: In this interaction type, the challenges depend on which user is using an object to interact with the other. If a user is holding an object, they require an **active haptic feedback device**, similar to the challenges discussed above. However, if a user is being interacted with by an object, the required haptic feedback depends on the usage scenario. A major challenge is that the object could collide with any part of the user's body, making it nearly impossible to **provide both tactile and kinesthetic feedback across the entire body**. However, in certain cases, kinesthetic feedback may not be essential. For example, in our vaccination scenario, tactile feedback alone would generally be sufficient to simulate the sensation of an injection.

Interaction between users' objects: This interaction type presents similar challenges to direct user interaction. Both users require an active haptic feedback device to interact effectively. Depending on the usage scenario, they must also **balance the need for haptic feedback with mobility constraints**. This means that haptic feedback devices must provide realistic force feedback while allowing users to move freely within the virtual space.

4 Conclusion

In this position paper, we explored the challenges of interactive collaboration in VR, with a particular focus on haptic feedback. We categorized collaboration types based on whether users share the same physical space or are in different locations, as this distinction impacts the challenges and requirements for haptic interactions.

We believe that well-designed haptic feedback devices can play an important role in fostering collaboration on physical tasks in VR. While existing haptic feedback devices can provide a good starting point, much more research and new devices are needed to fully address them.

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