To improve haptic experiences in VR and AR, we must first improve tracking.

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Abstract

Current research prototypes provide haptic experiences unthinkable with current commercial devices. As haptic feedback is complex and multi-faceted a significant research effort has been put into developing elaborate feedback devices. We believe that haptics must be considered as a coupled input/output system. Looking at commercial VR / AR systems it appears as if the work on the output side has far outpaced the work on the input side. We therefore argue that the next step in improved haptic touch and communication systems lies not in better output technologies, but in better input and position tracking technologies. In this position paper we provide context to this claim, explain how our backgrounds put us in a uniquely suited position to explore this topic further and present some discussion points which we wish to consider in our future work.

Context

Haptic feedback technologies have become incredibly sophisticated. Using intricate measuring and actuating devices, users can feel, in real time, the physical forces of a microscopic probe hitting the surface of a drop of water, before being pulled inside by its surface tension [2]. Using pre-recorded data, it is possible to simulate the texture of arbitrary materials as a pen moves over a flat surface [5]. Using simple physics models it is

Figure 1 - Telerobotic System for exploring Mediated Touch [9].

Figure 2 - Participant testing input parameters for rendering of non-grounded mid-air textures [10].

possible for users to asses the weight and compliance of a virtual object [8].

A plethora of devices have been designed to support haptic output in VR and AR [3]. There appears to be an unspoken assumption that - similar to the various head-mounted displays that we use today - we will one day have devices that allow us to touch virtual worlds in the manner that we now have visual access to them. These devices are often designed as special purpose output devices, aimed at providing the user with distinct sensations such as compliance, texture, shear force or a caress.

Such output focused devices however seem to ignore a key difference between touch and visual perception. I see things distributed in space. To an extent the proximity of my eye to the object I am looking at is irrelevant. In contrast, if I touch an object, I feel the touch where it occurs. The only way I can perceive an object through the *sense of touch* is to reach out and perform the *action of touch*. If one wishes to present a visual virtual world, this can be done without precise knowledge of what the user is looking at. If, however, one wishes to present a virtual world of touch at the user's fingertips, the touch perceptions can only be represented if one has precise information of the touch action performed by the user.

Existing VR platforms track the position of hands or hand-held objects poorly. Commercial VR systems such as the HTC or Oculus Rift can have significant miss-alignment between the position of their controllers and their virtual counterparts. Using hand-tracking systems such as leap motion can create uncanny experiences as the hand is almost tracked, or grotesque distortions

when the physical hand is oriented in a way that fails to meet the trackers assumptions. Reaching and grasping for objects using AR glasses such as the Meta 2 can be an exercise of guessing where the system believes ones hand to be and acting accordingly.

Touch is both an action and a sensation. To render a texture [5], material properties [8], or physical forces [2] one needs to precisely understand the action performed to provide an appropriate response. Current systems, that do this well, operate in a constrained environment. We believe that, now, a major challenge is to develope better tracking and input technologies, to fully leverage existing haptic output devices.

Our Research Background

Paul Strohmeier's first exploration of haptics was for a telerobotics project (Figure 1). The mediated touch system consisted of robotic puppet with an actuated head [9]. Eight capacitive touch sensors were also placed on the robotic puppet. A 'remote user' could log into the system by wearing a system consisting of vibration motors and video goggles. When the 'remote user' would move their head, so would the robotic puppet. The video goggles allowed the user to see what the robot saw. Each sensor activated the corresponding vibration motor attached to the body of the robot. When the vibration motors were set to either be on or off, remote users felt like 'there were phones buzzing on [their] body' or 'like [they are] a door, and there is somebody ringing all the doorbells'. Participants preferred a non-binary condition, were the information of the approach behavior was encoded in the intensity of the feedback. Playing with this system made the importance of carefully designing the input for touch communication apparent.
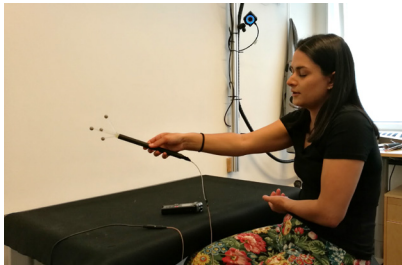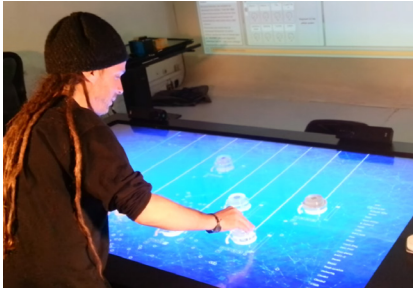
Figure 3 - Performer using TD's tangible controller system with Ableton Live
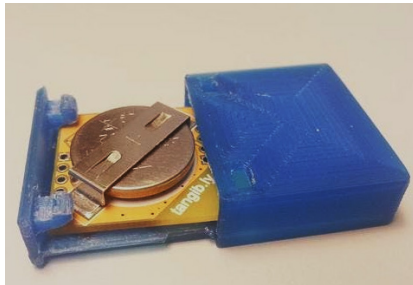

Figure 4 – Twiz (Tiny, Wireles, IMUz) in 3d printed enclosure.

Paul revisited haptic feedback again through his work with flexible displays. With colleagues from the Human Media Lab at Queen's University Paul presented a flexible smartphone, Reflex [11]. Reflex measures the strain placed on its display and uses this information to generate haptic feedback. Difference in sensing fidelity of prototype iterations further underlined the importance of precise measures and high temporal synchronization between measures and actuation.

Together with Kasper Hornbaek, Paul further investigated the parameter space of feedback generated by user motion. For example, they used a linear slider and a recoil-type transducer [13] for adding textures to the slider movement. Using this setup they explored how changing feedback parameters changed the experience of the users [12]. A follow up study added the same actuator to a pointing device, similar to those used in contemporary VR setups. Using optical tracking, the pointer was augmented with 'in-air-textures'. They conducted a study that explored how changing what aspects of a movement are used to generate a texture changes how it is perceived [10] (Figure 2).

Cedric Honnet originally started working with tangible interfaces at Sifteo, the company emerging from the Siftables [1] project. At Sifteo he worked on firmware, software and R&D projects, but in his free time he developed various applications including position-aware games or tangible music interfaces. He took this work from San Francisco back to Paris where he co-founded Tangible Display (TD) and expanded his work on designing spatially aware systems. Systems designed

by TD used their own patented markers to track the absolute position and orientation of tangible controllers on interactive surfaces.

Similar systems had become quite popular with musicians, for example, Bjoerk famously used the Reactable in her 2007 world tour. Some of the systems developed by Tangible Display were also deployed for playing and performing music (Figure 3). When placed on the interactive surface, tangible pucks come to life. However, once lifted, they 'vanish' in terms of their interactive ability and transform back into generic non-interactive objects. Bothered by this limitation, Cedric started adding inertial measurement units (IMUs) to the pucks, to track their trajectories once lifted off the surface.

This work eventually led to a stand-alone inertial tracker, called Twiz[1]. The Twiz consists of a 9DOF IMU and a microcontroller with integrated Bluetooth (Figure 4). The Twiz was used in various HCI explorations, including playful explorations that sample the movement of the things around us [6, 7].

In interest of easier integration with VR and AR systems and to facilitate embedded haptic systems Cedric is working on the HIVE tracker [4], a system that merges the approach previously explored with the laser positioning of the HTC Vive Lighthouse system. Using the Lighthouse signal to correct for drift, and the inertial data for fine-grained movement, the HIVE tracker can report its position and movement with sub-millimeter precision.

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[1] https://www.hackster.io/cedric/twiz-da5c63

Future Work

We are interested in combining our knowledge of haptic feedback design and position tracking to create an embedded self-contained haptic input and output device. We envision a general purpose platform that combines high resolution tracking with a haptic actuator and driving circuitry, as well as wireless communication. We hope to participate in the in-touch workshop to help understand how to position our future work. We are especially interested in discussions regarding the concept of 'embodied interaction' as used by the tangibles research communities and how it relates to the concept of 'transparency' as used by the robotics communities. We are further interested in how insights on the design of 'embodied' or 'transparent' systems might be used to provide access to information about the world that we typically do not have access to.

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