Haptic Tools: Enhancing Tool Capabilities by Tactile-kinesthetic Feedback

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Adding tactile-kinesthetic feedback to tools is a novel concept that aims at creating physically computable tools, either augmented ones or virtual ones that act as controllers, which makes tool usage feeling realistic and enables rich user experience (UX). We extend existing approaches of haptics in digital object manipulation, such as vibrotactile and pseudo-haptic feedback, through integrating tactile-kinethics.

When using traditional tools, such as saw, hammer, and drilling machine, we feel rich haptic feedback, such as weight change, force feedback, and tactile-kinethetic feedback. Such feedback not only provides information about the position of our tools and the progress of the work we do with them, it also constrains or even stops the movements of the tools we hold in hand.

In this position paper, we point at limitations in realism and UX of haptic feedback during object manipulation and tool usage. We discuss how to possibly extend capabilities of future tool with a focus of adding haptic feedback that makes digital tool use feel "real". We finally highlight challenges we expect to face during our project.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**; **Mixed / augmented reality**; **Ubiquitous computing**.

Additional Key Words and Phrases: augmented tools, haptic feedback, force feedback, tactile-kinesthetics

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1 INTRODUCTION & BACKGROUND

In recent years, researchers have shown an increased interest in haptic feedback, since this technology enables to provide tactile-kinesthetic sensations to enrich multimodal interactions. For instance, several studies have found that haptic feedback is beneficial to improving immersion in VR through simulating realistic interactions using actuators or haptic illusions. Haptic feedback has been studied extensively in VR to understand how to simulate sensations that allow perceiving virtual environments through the sense of touch [14]. These stimuli are mainly yielded by certain actuators embedded in VR controllers or through illusions that are supported mainly by visual stimuli. As a result, researchers have found that the use of these technologies can enrich realism in VR experiences mostly within three categories: *Exploration, Hand Interaction* and *Manipulation* [4].

Exploration: Refers to being able to perceive the environment. In this sense, Electrical Muscle Stimulation (EMS) is a technology that induces power into muscles to yield a counterforce, for example, simulating a repulsion on the user's hands when found against virtual walls or boxes [11, 12]. In addition, CLAW is a VR controller that enables to simulate: grasping and touching virtual objects by moving the finger position that is placed on a controller using a servo motor [5].

Hand Interaction: The physical world allows us to perform tasks naturally using bare-hands. However, as is purposed by the God-object principle, the VR controllers are also understood as an extension of the hands [21], since in many scenarios users need to use specific tools like in medical surgeries, craftship, and industry. Hence, researchers have developed controls that adapt to different needs. For instance, Drag:on is a shape-changing VR controller that can generate forces by using an embedded hand-fan-like proxy. That can shift its size dynamically to vary its air resistance when the user translates it and rotates it. Thus, it enable to simulate tools such as a shovel, wooden signs or rotating buttons. Similarly, Shifty is a VR controller that can change the location of an inner mass to render the illusion of lifting different amounts of weight [20]. Likewise, the Thor's Hammer project uses jet-propellers to simulate feeling water, walking a lamb, pushing buttons, and lifting different weights [7].

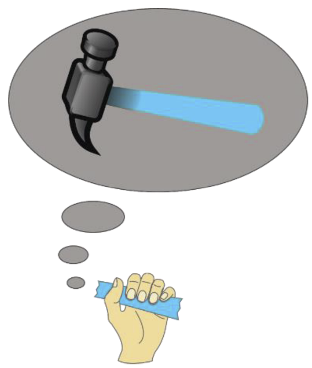

Fig. 1. Concept of a realistic haptic hammering experience, including weight shift and counter force feedback, when using a controller that only provides pseudo-haptics

Manipulation: Users can manipulate an object when they can change its position and orientation. In this context, pseudo-haptic feedback is another field of study that has been used in VR to yield an alteration of the perception, self-awareness and cognitive prediction by reconciling these factors through haptic and visual stimuli [6, 10]. Thus, for example, researchers have recreated the illusion of force resistances using screwdrivers against walls [18].

In this respect, to change the perception of the weight of a mass that is being lifted, the research Pseudo-HapticWeight found a control-display ratio that can create an illusion of weight by remapping the virtual hand e.g. showing it below of the actual position of the user's hand to lead the feeling of a greater weight [2, 16]. Similarly, Virtual Muscle Force generates the illusion of a mechanical resistance in hand tasks such push doors, turn wheels and lift objects [15].

Along the same line, pseudo-haptic feedback have examined the perception of distinct physical properties such as size shifting [3], weight shifting [2, 16], surface deformation [19] and stiffness sense [1, 13].

2 LIMITATIONS & CHALLENGES

A clear benefit of haptic feedback is the enrichment of interactive experiences. To achieve this aim, haptic feedback is regularly designed by imitating familiar interactions from the analog world. However, for unknown contexts, there is a lack of a standard 'haptic language' that can represent a recognizable message through haptic feedback and can support new interactive experiences [8, 17].

Another limitation that haptic feedback faces, is the fact that users recognize and react to haptic stimuli in different ways [17]. The next section discusses some challenges that have to considered when resolving the mentioned limitations.

In UX, realism is one dimension researchers want to improve by integrating haptic feedback in the design of devices. However, it is not the only dimension, since *Harmony, Expressivity, Autotelics,* and *Immersion* are also relevant to enhancing and understanding UX of haptic technologies [9]. Based on Kim and Schneider, *Harmony* is about how haptic feedback fits with other stimuli e.g. visual or auditory. *Autotelics* is related to how the solution is self-explained, *Expressivity* is associated with the variety of haptic messages that can be yielded and that these can be recognized by the user by the sense of touch. *Immersion* consists out of the degree of engagement, since haptics can support immersion by working with other dimensions. Finally, *Realism* is the dimension that attempts to imitate the haptic feedback from the physical environment.

Traditional haptic feedback can generate dynamically different stimuli to simulate certain responses from the virtual and physical world. However, for our project, we identify three challenges to be reached for our future haptic tools.

First, *Recognize the Environment:* It refers to track elements and digitize their physical properties to be potentially simulated by the device. Second, *Simulate the Enviroment:* Haptic feedback implies that when tools are used in the real world, for example to represent the use of a hammer, it will be necessary to go beyond of current tactile-kinesthetic feedback to represent the counterforces that are involved in hammering a nail. Third, provide haptic feedback to *Support User Performance:* For example *Haptics Tools* will inform the users haptically how close or far they are approaching a target.

Through the previous three challenges *Haptics Tools* have must meet the following criteria to be feasible to be used by users: *Portable:* The device must be able to incorporate the necessary actuators to generate different tactile-kinesthetic feedback in a hand controller that can be held by a user. *Intuitive:* The device must be easy to use during the task is made for, reproduce elements from conventional tools and provide haptic messages that must be recognizable by users to guide them smoothly.

Besides haptic feedback, in this project we will explore the integration of visual feedback using virtual reality and augmented reality technologies, as resources to support interactive experiences by performing tasks using *Haptics Tools* to manipulate physical and virtual objects.

3 FUTURE OF HAPTIC TOOLS

In daily life, there are gadgets like the conventional computer mouse and mobile devices that provide haptic feedback capabilities that are intuitive and universally understood. Haptic research has shown advances in VR increasing realism through simulating physical environments by integrating haptic technologies mainly to hand-held controllers.

Haptics Tools is a project endeavouring to design tools that allow to improve the UX by the use of haptic technologies and also support by mixed reality environments. *Haptics Tools* will focus on kinesthetic feedback to guide user performance. *Haptics Tools* will allow acquiring knowledge from experts that can feel the sensations that learners are perceiving in real-time during elaboration of crafts, playing instruments and industry procedures.

This implies that *Haptics Tools* allow us to think on potential scenarios where digital tools can recognize the environment either physical or virtual and therefore provide extra information to the user to manipulate objects being supported by visuals or haptic feedback in order to improve the performance of tasks e.g. gain precision.

In addition, we truly believe that *Haptics Tools* project has the potential to design novel tools that can interact with objects and also collaborate between users and other tools. In this way, these approaches will enable to design of tools to work collaboratively and foster the transmission of knowledge from an expert, who perceives the environment with a haptic tool, to a learner that is immersed in the workplace.

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