Enabling Haptic Experiences *Anywhere, Anytime*

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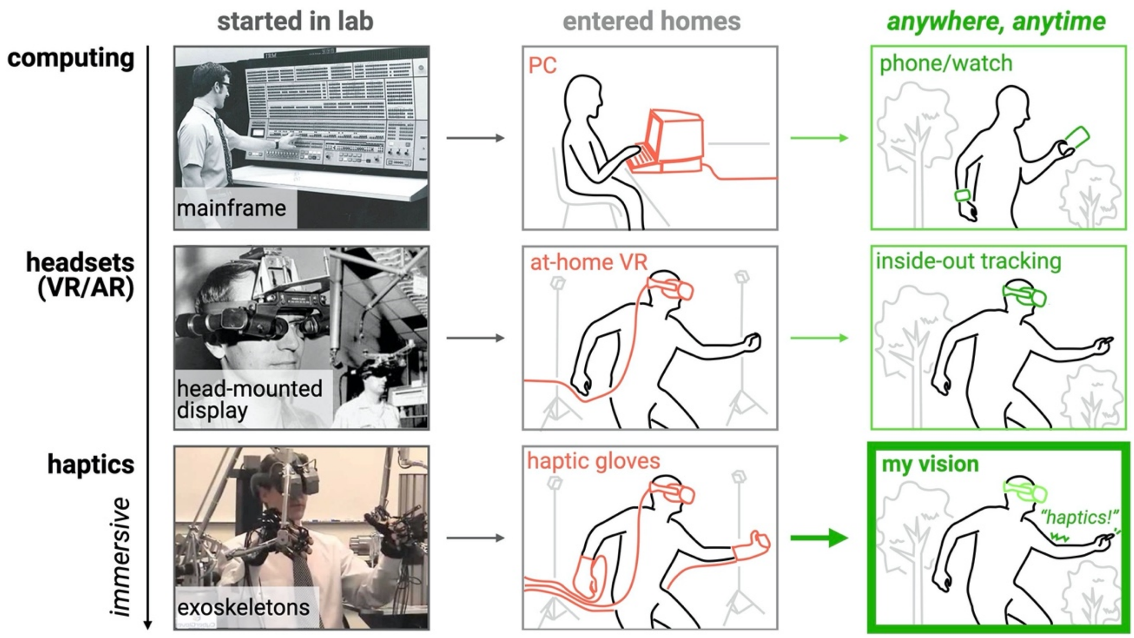

Figure 1: My research vision was inspired by how personal computing has evolved into mobile form factors. Yet, haptic devices have been trapped in labs and homes, I aim to tackle critical challenges and enable haptic experiences *anywhere, anytime*. (image courtesy: IBM 360/75, Ivan Sutherland, CyberGlove)

ABSTRACT

While seminal screen-based computing technologies (e.g., desktop or VR/AR headsets) have evolved to respond to users' needs for extreme freedom and mobility, the same cannot be said about rich haptic experiences (e.g., those that allow users to feel touch and forces). In my research I trace back the possible root causes to the way that haptic devices are engineered—to deliver realistic & immersive sensations, haptics devices use large actuators, which leads to two interface issues: (1) cumbersome form-factors that obstruct the user's body and prevent users from engaging in other dexterous tasks; and (2) extreme power consumption that causes these devices to have a short-lived life or even be tethered—all of which are incompatible with the users' needs and desires for freedom and mobility. The consequence of these two issues is that, as of now, haptics is mostly a tool for VR, but is absent from other interactive contexts, especially those where users move freely and interact with everyday tools (e.g., AR). As such, in my research I posit we need to redesign haptic devices with users in mind rather than only guided by the metric of virtual haptic realism. As such, I propose that (1) haptic devices need to play well with everyday tasks (e.g., they cannot prevent users from interacting with their loved ones or with their everyday tools), and (2) haptic devices need to be always available (without the need for bulky batteries or cables). In the following, I demonstrate two examples of wearable haptic devices that I engineered to illustrate that these goals are not just possible but desirable.

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1 INTRODUCTION

While seminal screen-based computing technologies (e.g., desktop or VR/AR headsets) have evolved to respond to users' needs for extreme freedom and mobility, **the same cannot be said about**

rich haptic experiences. When it comes to immersive haptic interfaces (e.g., those that allow users to feel touch and forces) these are lacking behind, only to be found, mostly, either at labs or in stationary at-home setups (depicted in Figure 1).

In my research I examine this challenge and trace back the possible root causes to the way that haptic devices are currently engineered, and the priorities taken during the interface design. The root cause is that to deliver *realistic & immersive* sensations, haptic devices employ *large actuators* [2, 7, 8], which leads to two interface issues: (1) cumbersome form-factors that obstruct the user's body and prevent users from engaging in other dexterous tasks (e.g., imagine the challenge: while wearing haptic gloves that provides tactile feedback for 3D modeling, now the user wants to grab a coffee cup or pick up a pen); and (2) extreme power consumption, which causes these devices to have a short-lived life or require enormous amounts of heavy batteries or even be tethered to power—all of which are incompatible with the users' needs and desires for freedom and mobility.

The consequence of these two issues is that, as of now, haptics is mostly for at-home VR, but is absent from other interactive contexts, including those where users move freely and interact with everyday tools (e.g., AR)—in other words, while mobile & wearable computers assist users wherever they go, the same is not happening in haptics, as users tend to be locked tethered to stationary-setups or wearing devices that are limited to interacting only with virtual content.

As such, in my research I ask: **can we re-engineer haptic devices so that can be used *anywhere, anytime*?** To this end, I have been rethinking how to integrate haptics into our lives. I posit that haptic fidelity is not the only goal to optimize for. In fact, I believe the next generation of haptic devices needs to be redesigned with diverse user interactions and environments in mind: **(1) haptic devices need to play well with everyday tasks** (e.g., they cannot prevent users from interacting with their loved ones or with their everyday tools), and **(2) haptic devices need to be always available** (without the need for bulky batteries or cables). In the following, I demonstrate two exemplary wearable haptic devices that I engineered to illustrate that these goals are not just possible but desirable.

2 CHALLENGE#1: ENABLING HAPTICS *ANYWHERE* [2X CHI '21, 2X UIST '21]

The first roadblock of current haptics research is that these devices are only useful in virtual interactions but do not allow interacting with augmented objects (AR) or with real-world objects (haptic augmentation). This happens because the mainstream way that researchers (and industry) implement haptics is by attaching actuators *directly on the user's skin*—users wear a haptic device, typically a glove [3, 7, 9], that renders a "tap" sensation when they touch a virtual object. However, this approach does not allow to touch real objects because the glove blocks the user from feeling the real object's texture. This not only limits the user's dexterity and haptic manipulation greatly, but prevents, almost all haptic devices from being used in situations where real-world interactions are a must, such as augmented reality (AR), VR with props, or, more strikingly, everyday tasks—imagine performing a mundane task such as repairing a bicycle while wearing gloves. To tackle this, I envisioned new types of haptic device that does not obstruct our sense of touch. The best example of these is *Touch&Fold* [CHI '21, Honorable-Mention] [11], a haptic-device that mounts on the fingernail, keeping the user's fingerpad free for everyday interactions. When a user needs to touch a virtual interface, my device "unfolds" and taps the fingerpad to provide a sense of touch. Yet, when not in use, it lets the user manipulate physical tools with dexterity—Figure 2 depicts a user interacting with a virtual screen that depicts an AR guide on how to fix their bike, as they tap on virtual buttons they feel every contact, yet, when they grab a real wrench, the device tucks away to not obstruct their physical tool manipulation. This device, alongside with [5, 6, 10] depict how we can re-imagine haptics so that devices are useful *anywhere*, rather than just in VR.

Figure 2: (left) My finger-worn haptic actuator (Touch&Fold) allows the user to feel the sense of touch from virtual object, yet the device folds back after the interaction, to allow the user to feel physical objects. (right) Unlike many haptic devices that work only for VR, my vision is to engineer devices that works in all realities, enabling haptics *anywhere.*

Figure 3: (left) My arm-worn haptic device has no battery, and it harvests kinetic energy from the user. (right) Unlike many haptic devices that run out of battery very soon, my vision is to harvest energy from the user, while they are enjoying multisensory interactions, enabling haptics *anytime*.

3 CHALLENGE#2: ENABLE HAPTICS *ANYTIME* [UIST '22]

The second roadblock of current haptics research is that these devices require so much power that they are only useful for very short durations or need to be tethered to a power source. This happens because the stronger the sensations a haptic interface is trying to convey, the more battery is needed to render this sensation (e.g., a tap might require only a few milliamps, while a texture might require dozens of milliamps, a weak force requires hundreds of milliamps, and a strong force requires a few Amps [1, 2, 4]). Unfortunately, there is no easy way to circumvent this as this is dictated by the laws of physics. Moreover, this forces users to stop and charge their haptic device more often that would be ideal. To provide a first step into resolving this, I proposed a haptic device (that can render touch and forces) but works *without batteries*. Instead, its sensations are coupled with energy harvesting. The device seamlessly harvests power from the user's movements, all while the user enjoys an immersive experience [UIST '22, Honorable-Mention] [12]. The harvested energy can be used to drive other haptic actuators, such as vibration motors, and electrical stimulation. This is achieved by harvesting user's movements in real-time while virtual contents (e.g., VR) to adapt and match the haptic sensation (Figure 3 depicts how harvesting is integrated into haptic experiences). This type of batteryless haptic device is different from traditional haptic devices in that it is the first kind of haptics that allows for "walk-up" use, even the user forgets to charge the device. This concept depicts how we can re-imagine haptics so that devices are useful *anytime*, rather than just after charging.

4 RESEARCH TOPIC AND EXPECTED CONTRIBUTION: *TAKING HAPTICS OUT OF LABS*

While haptic devices have been extremely successful at labs and others-controlled environments (e.g., museums, art shows, conference demos) the absence of haptics in mainstream experiences reveals a grand challenge for the field that has been largely ignored: how can we reap the benefits of haptics (higher sensory immersion & realism) while not restricting users to be in controlled environments, but, instead, use haptics anywhere and anytime? My vision is that haptics can be useful beyond these constrained environments but requires us to rethink the priorities of the field. In so far, researchers have been motivated by realism (i.e., precise sensations & high number of actuators covering the body) but this requirement is at odds with the user's mobility and dexterity. Through the work I propose, I want to depict that new possibilities become available once we prioritize for non-obstructing the user's body, rather than aim for maximum haptic fidelity. I posit that this will move haptics into new territories, such as haptics that support daily activities, mixed reality, and even in sports.

5 RESEARCH SITUATION AND DISSERTATION STATUS

I am currently a 4^{th} year PhD student in Department of Computer Science. I have published four papers on this topic.

6 FUTURE WORK

I plan to expand these key approaches technically and societally. First, technically, I will explore new haptic effects and new energy-generating mechanisms that use sources such as airflow or heat. Second, at a societal level, I want to use this work to unify the, unfortunately, separated virtual and real worlds, and will enable users to feel rich haptics anytime in our life—especially exploring new opportunities for training and learning with touch feedback.

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