# Exploring Strategies for Sustainable Design and Deployment of Novel Haptic Interfaces

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## ABSTRACT

The vast and complex design space for haptic technology demands a diversity in form factors, type of stimuli and application contexts. While research has introduced a large variety of different haptic interfaces as a response, the number of technical contributions has produced a new challenge for reusing and sharing new hardware designs among researchers. In this workshop paper, we identify typical adoption barriers and discuss new strategies and ideas for the design process of haptic devices, to enable more sustainable growth for the design of new haptic technology.

## CCS CONCEPTS

• **Human-centered computing → Haptic devices**.

## KEYWORDS

haptic devices, haptic design, sustainability

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## 1 INTRODUCTION

In contrast to the visual or auditory sense, the haptic sense is spread all over the human body. This presents a wide and complex design space for technology for creating meaningful haptic experiences. To address different locations and areas of the human body, a variety of form factors were proposed ranging from e.g., bendable handheld controllers [22, 23, 34] over retractable wires to constrain hand movements [8], to rings worn on users' fingers [1, 18] and chemicals for different skin sensations [13], or systems incorporated into a head-mounted display (HMD) to target the user's face [31]. The complexity of the design space further increases with the type of presented stimuli such as vibrotactile and squeeze feedback [20], temperature [3, 19] or force feedback [9], as well as their targeted haptic experiences e.g., conveying weight [4, 6, 29], shape [2] or textures [30]. The result is a multifaceted landscape of custom-built hardware solutions that are, however, difficult to adopt, scale, or build upon. This barrier can have a negative effect on the impact of technical contributions to the haptic research community.

In this workshop paper, we identify typical barriers in the development of new haptic technology that discourage adoption and reuse among researchers and discuss several strategies in the design process to mitigate these barriers and facilitate an easier exchange of novel hardware designs. To this end, we discuss existing approaches, examine similarities in form factors, hardware components and application contexts of haptic designs and explore opportunities to utilise these overlaps to foster a long-term and sustainable exchange and deployment of haptic technology. In addition, we examine approaches on how to incorporate standardised interaction devices to elevate haptic feedback capabilities of consumer systems to move towards standardised haptic technology.

## 2 ADOPTION BARRIERS IN SHARING AND REUSING HAPTIC TECHNOLOGY

Designing and building new hardware is an essential area of research to enable the computation of haptic experiences. This is especially true considering the limited availability of standardised haptic systems on the consumer market. However, while such technical inventions contribute to the necessary foundation for designing and exploring haptic experiences, several challenges arise when sharing these contributions among students and researchers. In this section, we identify common challenges as the first important step towards mitigating their adverse effects on the deployment of new haptic interfaces.

*Device dependency.* Publishing a new haptic feedback design often goes hand in hand with introducing a custom-built device that is used for generating such feedback. While large parts of the contribution such as the documentation of the hardware design or its evaluation can be published and made accessible through a scientific paper, the device itself remains inaccessible. Such contributions often have, therefore, a strong dependency on the proposed device itself. Especially when it comes to conveying the produced human haptic experience, language lacks sufficient vocabulary and cannot replace the experience of trying out the device. The dependency on the physically inaccessible device strongly limits the opportunities to extend or build upon such hardware contributions.

*Feedback dependency.* Due to the nature of the experimental and exploratory approach, the computational capability of a new haptic system can often produce only one particular stimulus, e.g., resistive forces, skin stretch or electrical muscle stimulation (EMS).

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The narrow range of achievable haptic feedback and stimulation can, therefore, limit the scope of feasible application cases and the "out of the box" reuse of an introduced system. This constraint further reduces the generalizability of the design of a haptic interface.

*Limited scalability.* Rebuilding an introduced haptic device inside the lab would enable students and researchers to use the proposed system and conduct further investigations with it, scaling the value of the contribution. This would, especially, provide members of the haptic research community with necessary hardware, whose research focus lies on designing and studying human haptic experiences and less on hardware construction. However, the absence of sufficient documentation with detailed instructions, the necessary parts and the used tools rules out the possibility for others to benefit from the engineering work and design new haptic experiences for a proposed system.

## 3 SUSTAINABLE DESIGN CHOICES FOR HAPTIC TECHNOLOGY

To overcome such difficulties and challenges in the future, in this section we explore possible strategies and ideas for researchers and engineers to consider, for making a new haptic interface more accessible to the community. The concepts can be applied at different stages of the design process, and their feasibility varies on a case-by-case scenario.

*Open source for reproduction.* Publishing comprehensive building instructions and the corresponding software application provides an opportunity to improve the scalability of new haptic technologies. This allows students and researchers to recreate a device on their own and to overcome the inaccessibility of the original system. Scenarios can include researchers rebuilding a device in their lab or at an organized workshop at a haptics conference. In addition, incorporating such a building project into teaching haptics can provide students with hands-on experiences for educational purposes. Documentations for haptic devices have been previously published in an online repository such as GitHub alongside the scientific publication, e.g., Zenner & Krüger [32] referring to [33], or Seongkook et al. [10] referring to [11]. To further lower the entry barrier, we see a video tutorial shared on online platforms such as YouTube or Vimeo as another medium for a more elaborate demonstration of the instruction process. Another strong benefit of this open source approach is also that it can be prepared for already existing and published haptic hardware designs.

*Building with off-the-shelf components.* An important aspect to keep in mind during the design process is the availability of the various hardware components that are incorporated into a new device. Whenever possible and feasible, using off-the-shelf products that are easily available and of reasonable cost makes the haptic design more verifiable and accessible. A common technique for manufacturing individual components is 3D printing, as it provides the often required freedom and flexibility for achieving a meaningful haptic experience. While 3D printers might be available at university labs or other research institutions, it can be an exclusion criterion for members of the research community to adopt the haptic design.

*Sharing components of similar designs.* Despite the vast diversity in hardware designs of haptic interfaces, typical form factors such as finger-worn devices and their shared application contexts dictate commonly reoccurring features and physical specifications. Looking at similar haptic interfaces at the beginning of the design process and identifying overlaps and similarities between the own undertaking and existing systems would allow reusing, rebuilding, or adopting already evaluated and reliable artefacts where feasible. While this reduces the risk of reinventing hardware for identical or similar functionalities, it also reduces the time, cost and complexity that goes into the construction. Similarities in form factors and application cases that might offer potential for reusing a haptic design might be, e.g., the mechanics that are needed for strapping and actuating a tiny belt around the fingertip used for different haptic experiences to create skin deformation [16, 18, 25], or movable plates used by several other devices to achieve a similar sensation at the finger pad [5, 26, 27].

*Designing modular or transformable haptic devices.* Widening the range of computational capability and possible form factors during the design process can reduce the use case dependency and open up the technology to be used and build upon in a broader scope. The gained flexibility might particularly enable a more long-term and sustainable haptic design contribution that can be adopted and extended by researchers of similar research areas and for more diverse solutions and scenarios. Different techniques for modular concepts have already been proposed [12, 14, 17] such as a haptic interface that can be adapted and reused to render pressure and thermal feedback at multiple locations of the human body [36].

*Diversify feedback through pseudo-haptics.* To reuse an existing haptic device while still widening the range of stimuli, pseudo-haptic cues have been shown to be an effective design choice for new haptic experiences [35]. Such visual-haptic illusions are induced through software-based techniques, allowing to avoid any hardware modifications. Since sharing software applications can be easy, this multimodal technique can also enable more remote interdisciplinary collaborations, in which some team members contribute to the software side of the haptic experience, and others to the hardware side of the experience. A possible scenario for combining a haptic device with pseudo-haptic cues can be, e.g., the simulation of weight in VR. Hardware-based techniques used for virtual weight such as Triggermuscle [29] or Grabity [6] can be complemented with software-based techniques used for virtual weight such as the manipulation of the control-display ratio [21, 24].

*Designing for standardised input components.* Taking established input components of current interaction devices into consideration when designing new haptic experiences can be a way for the research community to contribute to the development of standardised haptic technologies and reduce the dependency on custom-built systems. In the context of VR haptics, consumer handheld controllers typically offer a shared standard set of buttons including push buttons, trigger buttons or trackpads. As these controllers are easily available and accessible, an elevation of their hardware capabilities for haptic rendering can be a crucial factor towards scalable and more accessible haptic design research. For instance, in our previous work we explored the feasibility of augmenting an established input component such as the trigger button with haptic feedback [29]. For the purpose of simulating the weight of virtual objects, our controller Triggermuscle changes the resistance of the trigger button and adapts the intensity according to the simulated virtual weight. Another haptic device, CLAW, followed a similar concept by extending typical functionalities of a VR controller with different types of haptic sensations [7]. Since the availability of such standard buttons and functionalities is not limited to consumer VR controllers, such concepts of haptic designs are adaptable to a number of interaction devices. For instance, Sony recently released the DualSense controller for PlayStation 5 with actuated triggers [28], while Microsoft announced a locking feature for the triggers of the Xbox Elite controller [15].

## 4 CONCLUSION

In this workshop paper, we looked at current challenges for sharing novel haptic devices with the research community and explored different steps researchers can take in the design process to promote an easier deployment and adoption of their technical contributions. Due to the limitation of standardised systems with haptic computing capabilities, we see an increased level of collaborating, sharing and extending of existing and future haptic technologies as an imperative step for a sustainable growth of haptic research. For a holistic reflection, further discussions are necessary regarding standardisation of measurements, haptic design tools and programming language.

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