Designing for Touch: Creating and Building Meaningful Haptic Interfaces

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Abstract: This paper presents our initial findings about the problems and challenges of designing haptic interfaces. We support our discussion with observations and analysis of design activities realized in by our research group and design students. We conclude with initial ideas about how to structure, document and evaluate haptic qualities in the design process. Our hope is to expose the many questions and issues in this nascent design activity to eventually expand our haptic design toolbox and library, and bring consistency and rigor within the field.

Key words: Haptics, Multimodal, Touch sense, Prototyping, Design Tools, Sketching in Hardware.

1. Introduction

Over the years, design researchers and practitioners have refined our understanding and mastery of building systems that human can interact with relative ease and success. Most of the systems and devices surrounding us can now sense, monitor and track our commands, actions and movements via diverse input mechanisms or interfaces spanning many if not all of our senses. Unfortunately, the output repertoire of these systems is generally limited to the visual (indicators, pixels, etc) and auditory channels. Very few systems actively engage with users over our other senses.

While designing nontraditional interfaces is increasingly popular [10], it is still a very young and uncommon field. Design tools, methods and vocabulary around and supporting the topic are scarce and many of the work can be seen as 'one-off' or tend to be very experimental [3].

Our research aims at exploring how researchers and designers can work in this new field, where the tools and techniques seem limited, and to some extend unstructured. Our work mostly focuses on designing haptic systems (for the sense of touch), where interfaces use the sensation of touch to provide information to the user [18].

Designing for touch poses many challenges. We have limited abstract representations and no clear lexicon to describe and quantify the perception of touch. Should a haptic stimulation be described by its mechanical characteristics (analogous to the decibel for sound) or by its perceptual qualities registered by the user? Building systems that provide haptic feedback tends to be technically challenging also. What kind of fidelity is acceptable while sketching haptic interfaces? Can designers use tools and languages from other disciplines (medicine, dance, linguistics) to ease the development and design of haptic concepts?

2. Understanding and designing haptic stimulations

The literature on haptic perception and haptic technologies is relatively large [1,6,10]. Our understanding of human perception mechanisms is considerable for vision and audition, but is more limited when it comes to multimodal systems and the sense of touch. Fortunately, the field of haptics is a very active research topic in various fields and application domains.

Touch stimulations are being registered quite differently depending on our own biological features and on the context in which they are happening. Perception on touch is all about a collection of small and converging cues. Some are easy to simulate like vibration and grounded force-feedback, others demand more work i.e. ungrounded haptics and high stiffness contact.

Despite the constant refinement of the available tools and technologies, haptic systems are still mostly found in laboratories and high-end simulators. Very few products reach commercialization and mass-market. Hayward and McKlean [5,15] recently published a good overview of the challenges and technical issues around building haptic interfaces. This work is remarkable because it directly aims at demystifying and democratizing haptics, opening the field and lowering the barrier to entry for non-experts. They note, like many others [3,9,12,13], the surprisingly limited body of knowledge around the activities and processes of designing haptics.

On one side, producing interfaces featuring proper haptic feedback is generally technically demanding. As haptic feedback has its roots in disciplines like automation, robotics and tele-operation, it is to be expected that researchers and authors typically present highly technical work and results in this area.

On the other side, designers excel mostly in designing and developing traditional interfaces based on vision and audition. Touch sensing technology is rapidly reaching mass-market, but only as input mechanisms. Haptics with its active and actuated feedback is still unfamiliar to most designers. This new design space can be daunting as very few tools and methods are available to tackle the numerous challenges surrounding the topic. Humans are very skilled at 'handling' interactions and sensations with the real world: playing a musical instrument, medical surgery, peeling a potato, riding a mountain bike. We have developed our nervous and motor systems in tune with the natural stimuli surrounding us. Recreating such stimulations successfully, and on-demand, on the touch sense is absolutely not trivial.

A major gap exists between the strong technical requirements and current design tools and knowledge. We think this large discrepancy can be reduced greatly to improve the haptic design activites and the products/services we get to interact with in our daily life.

3. Design cases

The two following design cases show case student projects where design activities were strongly related to haptics. We only present and eleborate on the aspects of the projects that seem relevant to haptic design.

3.1 HAPI project

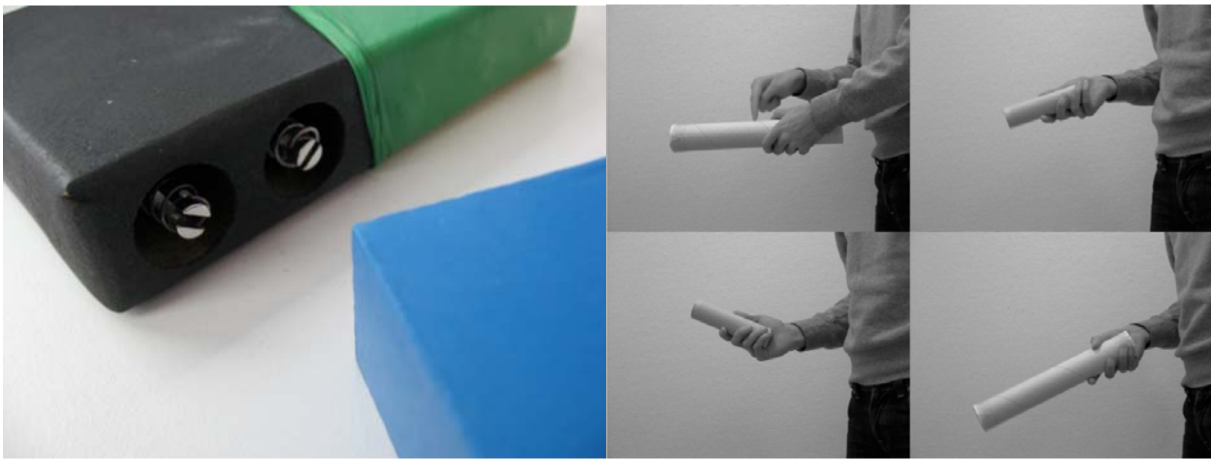

Figure.1 Testing different skins and covers for a poking grip, and evaluating haptic perception with users

The HAPI project consisted of various explorations around the design of new sensorial interaction techniques for mobile devices based on the touch sense. This Interaction Design Masters degree project specifically focused on the hardware sketching and experience prototyping methods to evolve new ideas and possibilities. The motivation was to adopt a "Prototype Early, Prototype often" or Getting Real [2,3,7] approach for haptic design. It was intentionally setup to limit the complexity of haptic interfaces in order to see how basic and simple explorations could provide insight during the process of designing haptics.

Around twenty different prototypes and models were produced during a period of 15 weeks. Some took only hours to build, others days, but never more than a week. The emphasis was put on making artifacts/prototypes to experience haptics, as words and graphical representations proved insufficient to discuss haptic concepts most of the time. Also by using a modular system, it was possible to reuse modules and software parts efficiently. The control and recording of actuation sequences applies to many different output mechanisms.

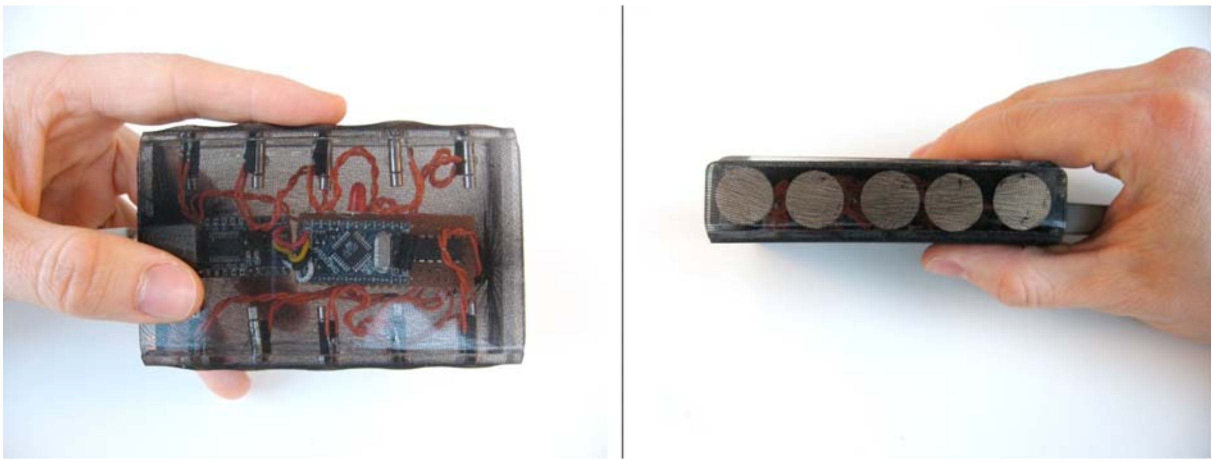

Figure.2 Grip with 10 vibrotactile disks, controlled over USB

It was also found that working with simple materials/devices (wood, balloons, solenoids, magnets) provide better raw haptic qualities than working with computer-controlled 3d haptic arms and apparatus. The high-end devices offer a high-level of control and repeatability, but they often lack proper stiffness and realism.

The results of this project were interesting to us because they showed that with the proper attitude and tools, it is possible to come up, build and physically test haptic designs in very little time. Some of the prototypes were not precise or strong enough, but they still provided some kind of manifestations to experience haptic qualities (instead of talking about it) and ground design decisions (less assumptions). Not all aspects of haptic design can be quickly prototyped; some will always need a high level of refinement and technical development. It was found that timing and repeatability considerations were very important in some the explorations.

One other point that became apparent through the realization of the hardware sketches is that haptic qualities as tightly coupled with the material used in the models. Wood, cardboard, plastic, metal and foam have different intrinsic characteristics and properties that greatly influence haptics capabilities. The Industrial Design and Materials Science disciplines can definitely contribute to the development of new haptic interfaces.

GUI-less navigational aid

The aim of this project was to design a mobile navigation device with no Graphic User Interface for blind users. This project was developed over an 18-week period by an Industrial Design student at the Umeå Institute of Design (Sweden). The student had no prior experience in electronics nor haptic systems.

The design student started drawing and sketching various ideas and interaction techniques, but soon realized the limitation of such explorations. The different concepts he was developing were based on gestural interaction and haptic feedback. He found that he needed to validate his ideas before moving forward with the project, as his assumptions on haptic feedback were totally ungrounded.

Figure.4 Testing with mobile phones strapped on the wrists (left), manual poking (right).
Photos courtesy of Tao Lin

He first built a crude but clever system, using two vibrating mobile phones, attaching one to each wrist of a test user (Figure 3). He could provide vibrating navigational cues by calling the different phones. It was quick to setup, but the latency of the system turned out to be problematic for successfully navigating and guiding blindfolded test subjects indoors. He decided to subsequentially use a ' human tapping' system, where a human operator hints the user manually . With this method, the designer was able to quickly evaluate different design options or scenarios.

After confirming that feedback on the wrist was working, he decided to refine his explorations around the haptic feedback mechanisms. He built a bracelet containing seven vibrotactile motors controlled by a microcontroller (Arduino) and computer . The package was not mobile, the bracelet was tethered to a laptop, but it proved sufficient to test different vibrotactile sequences. He considered building a mobile version with wireless control and battery power for running the prototypes with real blind users on the street, but was soon overwhelmed by the additional technical challenges.

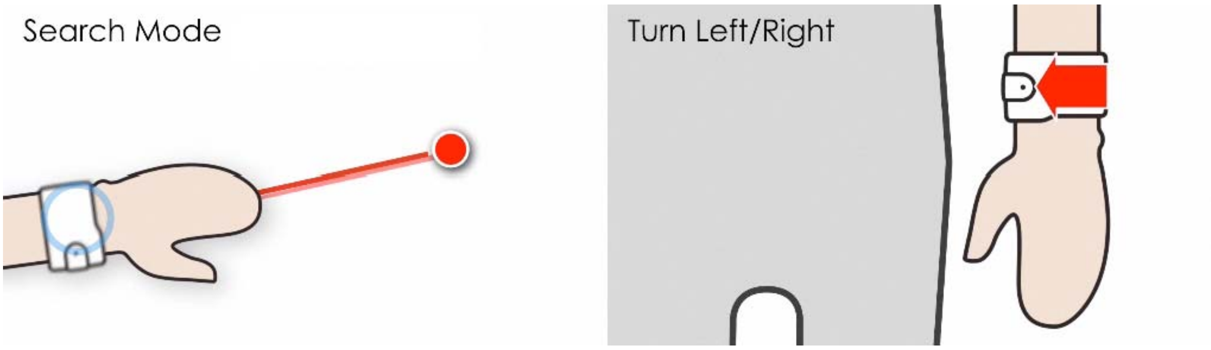

Figure.4 Graphically representing a vibrotactile sequence. Images courtesy of Tao Lin.

The final deliverable of this project was a video presenting a usage scenario (screenshot presented in Figure 4). The haptic feedback was represented graphically with arrows and 'vibrating ripples' in the video. The student omitted his semi-working prototypes from his presentation, as he judged them not good enough as presentation material.

It is interesting to note the choice of modality regarding working with haptics versus communicating the haptic ideas. In one case, it is considered essential to test and experience the real thing, as for the other, graphics are judged sufficient. Another note of interest is the decision to revert to human operation after noticing a major latency problem in his first run.

4. Discussion

4.0 Qualities and Aesthetics of haptic interfaces

Touch is a very complex and sensitive system. Our body and touch sense are constantly sensing the environment and the physical world around us. Introducing a self-actuated device in our tactile eco-system usually results in an unpleasant, or at least, less than satisfactory general experience. Successful haptic interfaces need to achieve a difficult balance between aesthetic and functional qualities.

Haptic interfaces are characterized by many factors. The more obvious general ones are: timing, quality/precision of the touch stimulations, consistency and robustness. MacLean [14, 15] details many attributes that should be taken into account when designing manual and haptic interfaces. Most of them evolved from the way we have learn to interact with the world over the years. ‘Naturalistic’ interactions will also usually fit well with our sensorimotor and social precondidtions, even though this is not an absolute rule. Also she suggests aiming for a tight sensory coupling for perception of control while designing haptic interfaces. We tend to agree with her guidelines as it is reflected in our own observations. The haptic interactions tend to be generally appreciated if the latency is low, even if the signal is weak or even wrong.

As we have mentioned previously, haptic perception is greatly influence by other senses. When trying to tackle haptic design, we should probably consider multimodal design instead. Sensory integration is not well totally understood, but many researchers have demonstrated that vision and audio can augment or diminish haptic perception [17]. The phenomenon could be use to support and enhance weak prototypes or stimulations. Opposite to this, absence of cross-modal interaction or use of distractors can be an effective way to avoid precondition while testing or developing haptic systems.

4.1 More than input

Designers and developers are more and more exposed to work with various touch input mechanisms like touchscreen, multitouch and gestural interfaces. Simulators and guidelines for such interaction techniques are improving and becoming common these days [16]. However, as projects try to include or embrace haptic qualities, and work specifically with output on the touch sense, many challenges suddenly arise.

4.2 Generating haptic feedback

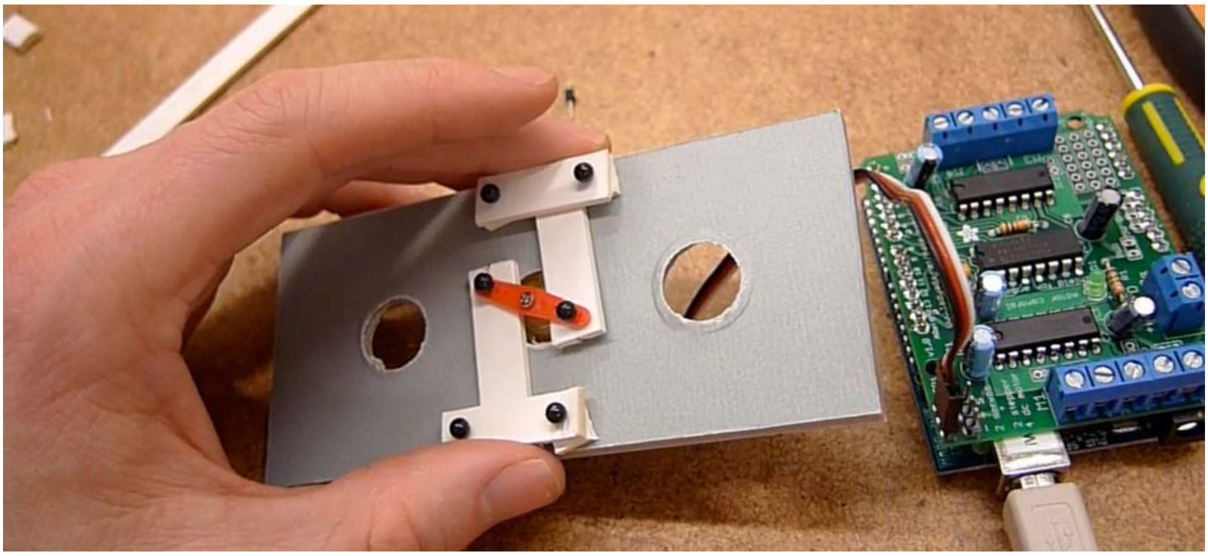

Figure.5 Quickly building a cardboard haptic device

Generating haptic feedback is not trivial. Most of our haptic perception comes from applied forces on our skin and body. Moving, actuating and influencing the world and its atoms require its load of energy and some level of control. Human action or human-operated mechanisms are probably the simplest way to provide haptic feedback (like poking someone to wake him up). The level of precision and repeatability is dependant on the skills of the operator/experimenter.

At the other end of the spectrum, devices like haptic arms are commercially available to programmatically deliver force feedback to user through their interface. Such machines offer full control, precise measurements and multimodal synchronicity. The general consensus is that this type of apparatus delivers low quality stimuli compared to real physical interaction with the world.

In the middle lies an interesting compromise: self-contained non-programmable mechanical devices. Hayward [4] believes that this type of devices is very interesting for experiencing haptic feedback efficiently. They are fairly easy to build and usually eliminate or minimize the role of the operator/experimenter.

4.4 Prototyping skills and attitude

What technology to use and how to design the haptic characteristics/qualities are totally up to the designer in the end. As with any technical systems, it can be temping to push back design activities until the technical details are solved or limit explorations to the tools available at hand. In our opinion, designing haptics should be a journey that starts with human-centered considerations. We believe and have observed that haptic design can be developed very early on in the design process [2,3], with basic items like magnets, plastic cups and rubber bands. More and more tools are becoming available to support prototyping tangibles and electronics. It is also very helpful to use, repurpose and adapt devices with actuators.

Designers should exploit fully the fact that the touch can be tricked or fooled, like any other sense. Faking, taking shortcuts or using other representations are all part of the toolbox to obtain interesting results in a timely manner [2,3].

4.5 Description and lexicon

Haptic stimulations are often described by their mechanical characteristic: force, amplitude, oscillation speed, area of contact, space resolution, successive limen, etc [10]. This way of describing stimuli is convenient technically, but can fall short once we dive into human haptic perception. Sensory receptors related to touch are varied and all have their own characteristics and behaviors. Medicine and other fields like dance and gestural interaction have established high-level lexicon to describe movement and touch-related attributes. As a designer, how should you deal with the situation? Should we aim at high-level description, independent of the hardware implementation, or should we specify forces in relation to specific devices? How does a bump or a poke translate in Newton and square millimeters, and how long it last at a minimum? Does it compare across users or devices? It is far from obvious and we certainly do not have a clear answer for now.

Hayward [4] recently introduced a brief taxonomy of tactile illusions that put forward terms and notions like disjunction-conjunction, change numbness, distal attribution and more. These terms are very useful to summary and communicate often very complex sensations and illusions. As we understand how these tactile illusions work, we can develop a better understanding of haptic notions and concepts.

We believe that the young discipline of haptic design will greatly benefit from a large and diverse lexicon. Communicating and verbalizing touch sensations is not natural to us. We usually experience these sensations directly, but do not talk about them explicitly in details.

5. Future work

For future work, we would like to extensively document how designers and researchers get acquainted with haptic concepts and interfaces. We are not so interested in the pure technical achievement in relation to haptic interfaces, but more excited about how designers and non-engineers can work in this new field, by faking and combining partial haptic cues with other systems. They might not have all the technical know-how, but they can bring interesting and creative contributions to the field.

We would also like to explore more various tactile and visual illusions. These interesting phenomenon can help us understand better haptics and many underlying principles related to human perception.

6. Conclusion

Designing haptic interfaces is absolutely not trivial. Designers are generally unfamiliar with the domain, and the challenges can be very daunting at first, as the current haptic systems are commonly very expensive and/or highly complex technical contraptions. Our current research explores some of the problems and challenges that designers face when designing interfaces that dynamically use the touch sense. This paper provides insights from two design projects with strong haptic components. In some cases, the designers were able to build haptic sketches to communicate and support their design process. In other cases, the challenges were too demanding and the designers circumvented or reframed their ‘haptic features’ by using other tools, methods or representations. Based on these observations and our own exposure to similar situations, we propose initial ideas about how to structure and approach the design of haptic interfaces early in the development process.

We believe this nascent design space is destined for a great future. Simple, meaningful and appropriate haptic qualities can make the systems and devices around us much more humane and enjoyable. We hope that numerous designers will explore this new field and that we can collectively expand our haptic design toolbox and library, and bring consistency and rigor within the field.

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