Digitus Touch, Tattoo-Based Bodily Interaction

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Abstract
With the future of ubiquitous computing in mind, we set out to design a prototype that would keep the power in our hands, literally. Inspired by recent developments in bodily interaction, microprocessors and epidermal electronics, Digitus Touch is our vision of tattoo-based technology that will allow users to interact with the devices in their lifestyle all through a simple tap of the finger. It is highly customizable in both its look and functionality thanks to the proposed mobile companion app. Whether to enhance your workout schedule, enable you to create music on the fly, or make your presentations run smoother, DT can be applied to great value. This design proposal shares our vision of the future, as well as our process to create the initial, working prototype.

Author Keywords
Interaction; touch controls; skin interfaces; e-skin; smart tattoos; bodily interface; ubiquitous computing; e-ink.

ACM Classification Keywords
Ubiquitous Computing

Introduction
Today's technology requires users to constantly focus on screens and controls, decreasing personal presence to one's environment. Everyday objects such as

Figure 1 A mockup of the aesthetic and operation of Digitus Touch.

computers, lights or televisions are each interacted with through their own controls. Whether through a physical button (e.g. a power button for a computer) or a remote control, we still end up with a collection of scattered points of interaction all around us. In recent years, steps have been made to create universal controllers, most recently aggregating this functionality on our mobile phones.

Our vision is a reality wherein technology and people combine such that our digital interactions become a more natural, integrated part of everyday life. We searched to find a technological solution that would let the user, regardless of her routines or interests, control the operational artefacts part of her specific lifestyle (projector, music player, lamps, etc.). In this design proposal, we explore the possibility of making use of bodily interaction for that purpose. More specifically, we envision technology that would turn the human hand and its fingers into a universal, programmable interface.

Building on these parameters we propose a concept of an interactive tattoo which works as a universal remote, enabling the user to activate her interactive products by only moving their fingers. For instance, while running, you could accept calls or control the music player with subtle gestures, such as by touching your thumb with the index finger (Figure 1). Our goal is not only to create a new way of interaction, but also to explore the possibility of harnessing the skin itself as a basis for digital interfacing. Therefore we looked at multiple branches of research that have pushed the field of ubiquitous interfaces in recent times.

Approach

We believe that designing innovative and vivid ways of interacting with technology is the future of the digital realm. Enabling users to act and engage with technology without the boundaries of screens and controllers is core to our own concept, inspired by ubiquitous computing [11]. As is an attribute of ubiquitous interfaces, the concept of 'exploiting personal intuition and familiar metaphors' was very present when we came up with our final concept [4]. *Digitus Touch* (DT) is a design proposal for using a person's skin as an interactive surface; in our example, using the hand and all its fingers.

The dexterity of touch combined with skin-based tactile feedback allows for accurate interactions on the go that require only one hand and no visual reference point. In addition, interactive skin might draw upon the high expressivity of human touch to extend remote communication [10].

In our brainstorming, we were heavily influenced by the existing and proven concepts of *Smart Tattoos* and *Skin interfaces*. We explored research regarding data-gathering electronic patches that can stick to the skin and stretch like a temporary tattoo [10]. Other interesting studies include Kim et al.'s *Epidermal electronics* [7] where they explored how the platform can integrate electronics and biology for monitoring in a natural environment, combining comfortable and flexible electronic components that could sense and communicate. Other researchers, such as Chortos & Bao [5] and Steimle [9], have explored the field of *Skin interfaces*. Steimle specifically discusses the opportunities of using skin as an interactive surface as well as using skin to interact with computers. Discussed are different technologies and research projects for on-skin input and output such as *Armura [3]* and *Sixth Sense [8]*, both using a camera and a projector to make skin interactive. Secondly, he considered aesthetic on-skin devices and skin-based interaction, using the sensing techniques for touch input on human skin involving acoustic, magnetic, infrared and capacitive sensors [9]. Chortos & Bao on the other hand looked at *skin-inspired electronic*

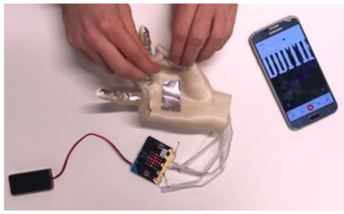

Figure 2: The finished prototype

Figure 3: Functional fingers were acquired through elastic wiring inside the hand.

devices, and their potential usage in robotics, prosthetics and health monitoring technologies.

Our own study is similar to the work of Kao et al. who explore the area of miniature wearable devices [6]. In their 2016 study, they created prototypes for an on-skin interface aesthetically inspired by tattoos that they call *DuoSkin*, using gold leaf as the key material. This is a similar approach as ours; what differs is the way the user interacts with the interface and what material the interface is made of. While the *DuoSkin* focuses on using the tattoo as an additional surface on top of the skin for interaction, we strive to make the Digitus Touch a customizable in-skin interface.

The functionality of *Digitus Touch* was inspired by what we saw as an opening in the existing research domain, using our oldest tools (our fingers) to bridge the gap from physical to digital in a new way. We felt that this approach would create something accessible and relatable for the user by keeping the concept simple but powerful.

Implementation

Design Proposal

In our ideal vision, Digitus Touch will be implemented using a future-model microprocessor and personalized tattoos that customers will get on their hands or other requested areas, with several requirements:

- The tattoo's ink must be conductive
- The tattoo must be isolated from the rest of the skin through means such as silicone gel or an outer layer of non-conductive ink
- Each point of input (such as a fingertip) must reach the microprocessor through an uninterrupted tattoo, independent of any other point of input's tattoo
- The independent tattoos must be able to close an electrical circuit through touch on these selected points of input only

The separate tattoo lines will each reach and have permanent contact with a microprocessor that is small enough to fit just under the skin (such as in the palm of the hand) without discomfort, while advanced enough to maintain a wireless connection with linked devices as far away from the user as the scope of the product requires. Each unique connecting action between the points of input (e.g. the index finger touching the thumb) will be recognizable as a separate user-issued command to the microprocessor.

To program the use of these now operational points of input, a companion app is to be developed (Figure 1) to give users the ability to create separate, themed profiles in which each mentioned command corresponds to a use. This allows the technology to fit any lifestyle, and stops us from unintentionally limiting its use cases.

Low-cost prototype

The proof of concept prototype (Figure 2) we built also functions as an example of how the basic concept could be implemented using low-cost materials and only a little amount of engineering and programming knowledge.

A micro:bit processor functions as the controller as well as Bluetooth transmitter that enables you to connect any Bluetooth device to the product.

The tattoo aspect of the proposed product was simulated using conductive thread, running from the micro:bit processor's pins to the fingertips of our 3D printed hand [1] where it was secured using conductive tape to mimic a tattooed surface large enough to enable consistent success. As the thumb is used in every interaction, it was wired through the thread to the GND (ground) port of the micro:bit. The other four fingers were each wired to pins 0, 1, 2 and 5 [2]. Thus, touching any of the hand's fingers to its thumb completes the electrical circuit which allows the micro:bit to sense which finger was made to touch the thumb/which port was connected with GND.

Figure 4: Programmable profiles

Interaction
Given that it is not uncommon for humans to have their fingers touch occasionally, the Digitus Touch prototype was programmed as off-by-default. Only after signalling the microprocessor to activate, in our case by keeping the pinky finger and thumb touching for at least four seconds, do the (Bluetooth) connected devices start responding to DT interactions.
Our current prototype only supports interaction in the form of finger taps, to adjust phone volume and move between music tracks. The proposed design should however be expected to identify tapping, holding, and swiping as unique types of input, increasing the baseline functionality exponentially. While the former two can easily be supported through programming means alone, for the concept to support swiping it would require a different approach:

- More separate points of input than just one per finger, OR
- A different mechanism that relies on more non-binary input, such as heat sensors or proximity sensors

Results
We have given shape to our vision of tattoo-based, bodily interaction: a prototype of our concept *Digitus Touch* that is an innovative way to interact with surrounding technology and will simplify the everyday lives for general people of different lifestyles. The prototype consists of a micro bit controller and sensors on a 3D-printed hand with joints that are movable, and an application for mobile devices with the purpose to show how the users would customize their own way of digital interaction.

Future work
The concept behind Digitus Touch is at the moment still an ongoing project with a larger vision and more potential. We have created a framework and a functional prototype that, with more knowledge in engineering and programming and with better material and resources, can be turned into a usable product. Our 3D-printed prototype of the hand will act as a substitute for the human hand until we get to the point where it can be tested on our own skin. Furthermore, future research could focus on other areas of the body that this technology could inhabit, with different purposes, such as the soles of our feet.
With this paper we hope to highlight the potential of viewing the human body as the centrepiece of future development of interactive interfaces, truly embodying ubiquitous computing.

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