Research Article

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TouchYou: A wearable touch sensor and stimulator for using our own body as a remote sex interface

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Abstract: In this article, we present TouchYou, a pair of wearable interfaces that enable affective touch interactions with people at long-distance. Through a touch-sensitive interface, which works by touch, pressure and capacitance, the body becomes the own input for stimulating the other body, which has a stimulation interface that enables the feeling of being touched. The person receives an electrical muscle stimulation, thermal and mechanical stimulation that react depending on the touch sensed by the first interface. By using the TouchYou, people can stimulate each other, using their own body, not only for sexual relations at a distance but for the production of affection and another way of feeling. We discuss the importance of the touch for human relationships, the current state of the art in haptic interfaces and how the technology can be used for the affection remote transmission. We present the design process of the TouchYou sensitive and stimulation interfaces, with a contribution of a method for developing custom touch sensors, we explore usage scenarios for the technology, including sex toys and sex robots and we present the concept of using the body as a remote sex interface.

Keywords: affective computing, teledildonics, long-distance relationships, haptics, human-computer interaction, affective touch, touch sensors, sex toys

1 Introduction

One of the main benefits of developing technology is to improve one or more aspects of the human life. The evolution of the communication channels over the decades was presented as a great advantage for connecting people, but

traditional devices mostly use only visual and auditory information. Although making it possible for people to communicate over long-distances, traditional channels do not reduce or solve one of the major problems of people in long-distance relationships (LDRs), i.e., the lack of physical contact. The touch has a great importance in human relationships because it can modulate physiological responses, increase trust and affection and help to establish bonds. Haptic interfaces are devices that can generate mechanical signals for stimulating human touch channels, and its commercial applications range from the medical to entertainment industries. Haptic sensor and actuator technology has the potential to be used in the affective remote communication, and research in this topic are included in the subject of human-computer interaction (HCI).

The TouchYou interface was developed with the aim of applying haptic sensing and stimulation technologies for reducing the problem of the lack of physical interaction between couples and relatives living apart. We developed a pair of sensing and stimulation interfaces that are portable, wearable and can communicate wirelessly with computers and smartphones for enabling the transmission of the touch over the Internet. The sensing interface is based on a flexible capacitive touch sensor, which is explained in this work, that can detect the location of the touch and the force applied, measure these variables and transmit it for other applications. The stimulation interface is based on three different technologies: electrical muscle stimulator, thermal and mechanical stimulation, by using vibration motors. This interface can simulate the touch by changing the conducting electrodes and the individually activating the vibration motors and flexible heaters. The wireless stimulation is controlled by Bluetooth communication, and the information of the stimulation is detected by the touch-sensitive interface (Figure 1).

Finally, we also explored the usage of the TouchYou interfaces for sexual purposes, by presenting the concept of using our own body as a remote sex interface and by showing how the haptic technology can be applied to the sex toy and sex robot industry, creating more sophisticated products.

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Figure 1: Concept of the TouchYou. A pair of touch-sensitive and touch-stimulation interfaces enable the touch communication over the Internet.

2 Background

We explored aspects from different subjects including psychology, human interaction, computer science and engineering during the development of the TouchYou concept and prototype. We applied the concepts of traditional and state-of-the-art haptic devices during our design, and we explored the existing research and devices for affection transmission. In the following subsections, we briefly explain about each topic and its importance to our work.

2.1 LDRs and the importance of the touch

Touch is a very powerful sense, often neglected within the cognitive structure of our society, which privileges the sense of sight. Even in relationships, when the touch is extremely important for increasing affectivity, other stimuli as the sight have greater importance, making the appearance of the body more important than the sensation brought by the partner's physical presence [1].

Faced with this problem, when it comes to LDRs the privilege of vision is even bigger. With a spread of mobile communication devices, an exchange of images, by video or by photos, also video calls, ends up overcoming any other type of affective construction at a distance. The touch, essential in this construction, loses space [2]. That is why in this work we have chosen to solve this gap. When we observe the market of sexy toys we do not find capable devices that solve this question. All stimulations always end up being absolutely sexual. But why could not a sex toy, besides the construction of pleasure, help in the affective construction of couples at a distance?

The design of TouchYou arises to, in addition to solving this question, help in the development of other forms of feeling with the body. The haptic system, which is related to touch, is one of the most stimulated and programmed. This confers a possibility of “feeling

educated”, much related to the process of affective construction mainly in children. As adults we react to stimuli and stimulate according to what has been learned, and often the introduction of other forms of touch, not directly human touch, helps us explore other possibilities.

Through digital technologies we can act in this type of mediation with the body. New embodied experiences into our sensory repertoire help us to enlarge our emotional repertoires. In this sense, all mechanical stimulations cause a physiological alteration. The body being the locus of desire, and the great stimulating pleasure in the creation of new habits and synaptic routines, we can perceive how powerful the introduction of this type of programmed stimulus in a relationship can be, even more when the bodies are not together. Feeling the body of the other, near, becomes real.

The use of the haptic system enhances the gestures, which also act on the stimulation inputs in the other body. The use of the sensitive body, which can perceive different pressures, textures, vibrations and the simulation of it can provoke a mediated relation, shows that presence need not exist for the same feeling. When we mix these touch technologies with others, such as virtual reality (VR), the potentialization of what is felt is huge, confusing with the real. This, in addition to being powerful for LDR, can be configured as a new way of relating. The evolution of our body in society ends up evolving with the technologies, which allow us to feel things that were not felt before. This evolution of the technological body, or of the body as a device, also evolves the possible way of relating, such as our ways of feeling pleasure, having sex and even reproducing. We can say that these new social relations place the mediation of relationships in another cognitive register, since we are able to create new synapses for felt sensations. This empowerment not only is a resolution for relationships at a distance but rather puts the body as a new platform of technologically emulated perception, sensation, feelings and affections.

In a society that increasingly uses digital devices to virtualize presence, the intention of the project is to approach virtually. We cannot forget that despite the virtualization of bodies, things and spaces, practices, relationships and processes, we still have a physical body. The resumption of physicality is increasingly important when we think of the potential of technologies.

2.2 Haptic devices and their benefits to the society

Differently from traditional interfaces that provide visual and auditory information, haptic interfaces generate

mechanical signals for stimulating human kinesthetic and touch channels [3]. One of the first large-scale applications of tactile display was the vibration function on mobile phones [4], but traditional applications include the enhancement of the existing graphical user interfaces, for example, by rendering the sensations of pressing physical buttons, clicking, dragging and sliding in the virtual environment [3]. Haptics was widely used by the games industry for applying force feedback to the player, enhancing the immersion in the game story.

Besides the traditional usage, because of its interdisciplinary background, haptic interfaces can be explored for helping people in different scenarios. Certain highly specialized professions can use augmented haptic feedback for assisting their tasks, for example, astronauts teleoperating a robot outside the international space station for maintenance tasks, or a surgeon using a robot to perform a delicate procedure [5]. Haptics can also be used for replacing the sense of touch that was lost owing to disease or accident, for example, by integrating an interface to a prosthetic, enabling the amputee to sense haptic interactions between itself and the environment. Other examples include using haptic interfaces for helping blind people to learn mathematics, playing computer games and obtaining access to graphical user interfaces [6]. The use of haptics combined with VR in stroke rehabilitation presented many advantages over the traditional rehabilitation therapy [7].

Current research is developing new methods for designing and exploring the usage of new actuators. Common technologies for tactile stimulation include electrostatic (which reproduces friction), vibrotactile (pulsed or sustained vibration), temperature shift system (for recreating temperature changes), pneumatic pressure, direct finger pressure and others [8]. The design of new actuators provides new means of stimulating the body, for example, the skin-dragging haptic [9] for recreating textures, an electrotactile display [10] for activating the sensory nerves in the skin and the combination of mechanical and electrical stimulation [11,12] for interactions with the virtual world.

2.3 Technologies for reducing the problem of being distant

Researchers are developing different technological approaches within the field of HCI for reducing the problems of the distance between humans. The aim of the prototypes is enabling humans to remote communicate emotions, helping to maintain their emotional bonds during adverse conditions.

The integration of tactile stimulation devices, other stimulation and sensing means, with conventional communication technology (e.g., instant messengers and video chats), has a great potential of enhancing the quality of life of people living apart.

Within the field of affective computing, which is an interdisciplinary field combining ideas from psychology, cognitive science and computer science, we have the concept of affective detection. This concept can be defined as the ability of a computer to characterize aspects of the emotional status of its user. Recently, researchers started exploring the possibility of employing haptic technology in the process of detecting, displaying and communicating affects [13], which is a novel research area called affective haptics.

Several projects focused on reducing the lack of physical contact for couples in LDR by exploring the transmission of the touch. Devices to hold hands at a distance [14], for simulating the stroking and the touch of the hands [15,16] and for simulating the gestures and movements [17] are examples of using mechanical stimulators for affect transmission. Besides the touch transmission, other approaches explore the transmission of hugs [18,19] and kisses [20–22] by using mechanical and thermal actuators, while others explore the sound [23,24], the vision [25] or a set of multiple stimuli [26] for transmitting emotions.

2.4 Current touch sensing technology for sexual purposes

The touch sensor technology can already be found on sex toys available in the market. Most of the examples are sex toys that change their vibration pattern or intensity depending on the touch applied to their surface. Pearl 2, from Kiiroo, is a touch-sensitive G-spot vibrator that claims to respond to the natural movements of the user's body. Other product is Luxe, from CalExotics, which is a touch-sensitive wand that has two touch-sensitive sensors that measure the thrusting depth and adjust the vibration intensity. Crowdfunding platforms such as Indiegogo are also a channel for companies developing touch-sensitive sex toys to get funds to launch their products. Some products like Sirens (which claims to be the world's first sensitive sex toy) and HUM (which claims to be the first artificially intelligent vibrator) appeared as Indiegogo campaigns and are sex toys that can measure the touch and change their functioning depending on the touch. Using the touch-sensing technology, for example, by measuring the position of

the touch using electrodes and capacitance, would increase the possibilities of interaction between the sex toy and the user. The media also reported some sex robots (dolls) that could react to touch, for example, “Samantha” from the designer Sergi Santos. The creator says that his doll could change her mood depending on the way it gets touched but, from the videos of the robot available, it seems that the pressure sensors and few body positions are used for detecting the touch and actually does not involve the use of a “smart skin” technology.

3 Design process

3.1 System overview

The TouchYou is a pair of sensitive and stimulation interfaces that is able to measure the touch and remotely provide a multisensorial stimulation, simulating the touching of the skin. The system consists of the sensitive interface, which is a wearable and flexible touchpad-like sensor for detecting the position of the touch and its pressure against the skin, and its pair, the stimulation interface. The stimulation is provided by a matrix of electrodes connected to an electrical stimulator (e-stim), vibration motors and flexible heaters for simulating the temperature of the skin. In the following, we will detail the design process of the touch sensor, the hardware components used to build the prototype of each interface and the software designed for converting the sensor inputs to the stimulation output and managing the communication between the interfaces.

3.2 Design of the touch-sensitive interface

The design of the touch-sensitive interface included the touch sensor itself and the electronic hardware for interfacing the sensor and making it able to communicate wirelessly. The sensor is based on the working principle of projected capacitive (pro-cap) technologies [27], which can detect the touch by measuring the capacitance at each electrode. The electrodes are arranged in a two-layer matrix pattern, one layer for the lines and the other for the columns. By detecting which line and column have been touched by measuring their capacitance variation, the system can detect the X, Y location, where the sensor has been touched.

For the purpose of this work, we needed a touch sensor that could be worn and stay in contact with the

Figure 2: The flexible touch sensor is made of two layers of lines and columns of electrodes, which combined form a matrix with 5 lines and 7 columns. Each sensitive element is an intersection of a line and a column. Adapted from ref. [27].

skin, so when one touches the sensor, it feels like it is touching one’s own skin. The sensor needed to be flexible and thin enough, yet with a good response, robust and low cost. We decided to develop our own touch sensor, so it could meet the requirements and we could design it with any dimension, which would be an advantage for our application.

The first step of the sensor design was to choose the area that the sensor matrix would cover, for example, when placed around an arm. The chosen dimension was 80 mm × 50 mm; and by defining this dimension, the electrode size, gap spacing, line and row pitches were defined. We also had a restriction of the total number of electrodes we could use, which was 12 and limited by our chosen electronic hardware. By having this limitation, we could work with any matrix dimension, with the number of lines plus columns not exceeding 12, and we have chosen to use a 5 × 7 matrix. The final design of the pattern and its main dimensions is presented in Figure 2.

After choosing the dimensions and creating the pattern, we developed the sensor matrix by using an adapted method of building homemade printed circuit boards (PCBs), which is known as PCB tone transfer [28]. In this method, the PCB traces, footprints and vias template from bottom and top sides are printed in a specific type of paper called heat toner transfer paper by using a laser printer. After that, the paper is placed over the surface of a blank copper board, with the printed pattern in contact with the copper and then a source of heat is pressed against the paper and the copper board, by causing the transfer of the printed pattern to the board. The paper is removed and the copper board can go through the etching process, in which a chemical reaction will remove the copper of the board, except where the circuit pattern was transferred. The

Figure 3: The pattern is printed in a tone transfer paper (a) and then positioned over the copper foil tape (b).

Figure 4: The heat press printer machine (a) is used for transferring the pattern from the paper to the copper foil. The copper foil is glued in the polyamide tape (b) and the parts of each layer are joined (c).

final result is a circuit board with traces connecting the component pads that can be cleaned, finished and is ready for the component soldering.

Our method for creating the flexible touch sensor was similar to the aforementioned one, but instead of using a copper board, we used a copper foil tape and a polyamide tape as the substrates. We chose the polyamide tape because of its relatively low cost and its insulating and high temperature stability characteristics. We printed the pattern for the lines and columns separately in the heat toner transfer paper and then fixed each pattern over the copper foil tape (Figure 3).

The copper foil tape, with the printed paper, was then placed on the surface of a heat press printer machine (Figure 4a), which could be substituted by a clothes iron. The advantage of using the machine is to control the pressure applied to the hot surface, the temperature and the time of the process. In our method, we used 180°C and 70 s, which was enough for transferring the pattern from the paper to the copper tape. As our polyamide width and copper tape width were smaller than the sensor dimensions, we needed to join the strips for creating the substrate and the full sensor pattern (Figure 4b and c). The copper tape was then glued on the polyamide tape.

The last step of making the flexible touch sensor was to etch the copper in a similar way that is done for the PCBs. We dipped the copper and the substrate in a solution of ferric chloride, responsible for corroding and removing the unwanted copper, leaving only the pattern of lines and columns of electrodes and its contacts. The

Figure 5: The layers are positioned to form the matrix (a), resulting in a flexible sensor that can be placed in any surface, for example, an arm (b).

two layers (lines and columns) were then cleaned, dried and glued one on the top of the other, creating the matrix pattern (Figure 5a). The sensor was flexible enough, so it could be placed around the wrist, meeting the initial requirement of designing a wearable touch interface (Figure 5b).

The hardware for measuring the touch sensor and for communicating with the computer and the stimulation interface of the TouchYou needed to meet some requirements, for example, being portable and having wireless communication. For reading the touch sensor, we used a breakout board with the MPR121 capacitive touch sensor controller [29]. This module features 12 electrodes' detection, configurable I2C address, a filtering system with debounce, proximity detection and autocalibration. The interface with the touch controller was made by using an Arduino Pro Mini board that was connected with an HM10 Bluetooth module for the wireless communication. We also included a 3.7 V Lipo battery and a USB Lipo charger module, for hardware portability. A button for selecting the function mode, an LED and a vibration motor were also included for visual and tactile responses for the hardware functioning. Figure 6 represents the hardware of the touch interface.

In addition to measuring the position where the touch occurred, we also measured the pressure (or the force) of the touch. For the pressure-sensing function, we chose to use two force-sensitive resistors (FSRs) attached to the surface underneath the touch sensor (Figure 7). The FSRs are sensors that allow detecting physical pressure, squeezing and weight [30]. Their resistance decreases when a force is applied to their surface, and by using a voltage divider circuit, we could measure a variation in an analog voltage depending on the force applied to the sensors. The final design of the touch

Figure 6: Block diagram of the hardware used for measuring the touch sensor and transmitting its information.

Figure 7: Position of the force-resistive sensors in the touch matrix.

interface includes an elastic fabric with Velcro for wearing the sensor as a bracelet or a watch.

3.3 Design of the touch-stimulation interface

The touch-stimulation interface was designed for providing the feeling of being touched remotely. This interface is wearable and its output, or stimulation response, depends on the touch detected by the sensitive interface (Section 3.2). The design of the touch-stimulation interface is considered meeting the requirement when it creates a sensation of a moving touch through the skin, not only by mechanical stimulation but also by other stimuli. In addition to the vibrations, the interface is able to stimulate the skin and muscles thermally and electrically.

For covering a relatively large surface of the skin while the interface is being worn, we decided to place the electrodes in a matrix pattern, where each element of the

Figure 8: The top side of the electrodes with the 3D printed caps (purple) connected as lines and columns and the bottom side which is in contact with the skin.

matrix is a pair of electrodes. We used two types of electrodes: 15 spike dry electrodes [31] and 9 wet electrodes [32], combined in a total of 12 pairs. In this design, the use of spike dry electrodes was preferable because these electrodes do not need conductive gel and have a better performance when in contact with hairy skin, but the total required numbers were not available at the time of prototype making. The electrodes of the lines and columns (3×4) were connected to each other, respectively, and a 3D printed cap was fitted over the head of each electrode and wire, keeping the connection safe and fixing the set in the elastic fabric (Figure 8).

For creating the sensation of a moving touch, the pair of conducting electrodes is automatically changed based on the line and column that are active, and the electrical stimulation would occur in the closest pair of electrodes. In addition to the electrical stimulation, we included six coin vibration motors, as shown in Figure 9, between the electrode pairs. The motors were used for creating an additional sensation of touch, for example, simulating the moment that the finger touches the skin or when the finger slides from one point to another.

The third touch stimulation method is by thermally stimulating, i.e., simulating the temperature of the human body. For creating this effect, we used three flexible heaters or polyamide heating film plate. Each heater was of 30×40 mm dimension, could be supplied with 5 V and provided 1 W of power, which was enough for maintaining their temperature at about 37°C . The heaters were glued to a smaller elastic fabric (Figure 10a) and then fixed over the

Figure 9: Six vibration motors were added to the set of electrodes.

Figure 10: Three flexible heaters and temperature sensors (a) were added to the set of electrodes and motors (b) for simulating the temperature of the skin.

Figure 11: The stimulation interface worn in the biceps of a user.

initial set of electrodes and motors by using Velcro (Figure 10b). We also installed temperature sensors for each heater, so we could control the temperature for not overheating the system and the skin in contact with the interface. The touch-stimulation interface can be worn in any part of the body, and in Figure 11 we show the interface being worn in the arm.

The hardware of the touch-stimulation interface is responsible for creating the touch sensation by activating the three stimulators (electrodes, motors and heaters). A 9V battery is used for supplying energy to the microcontroller and the other components, and to reduce

Figure 12: Block diagram of the hardware for controlling the stimulation interface.

the voltage for the required levels (3.3 and 5 V), we used two adjustable step-down voltage converters. The electrical muscle stimulation (EMS) signal came from the circuit of a commercial e-stim (or transcutaneous electrical nerve stimulation) massager, which can vary the amplitude and timing of the electrical stimulation, causing different sensations. The EMS signal is the input of a multiplexer circuit that can change based on line and column of the electrode matrix that are active and then choose one of the 12 possible pairs to be active. An ESP32 development board has the function of controlling the e-stim intensity and the multiplexer and driver circuits, besides enabling the circuit for the wireless communication. The heaters and motor drivers are responsible for supplying the heaters and the vibration motors with enough power, and three LM35 temperature sensors are used for controlling the temperature of the heaters. Each of the six motors and the three heaters can be controlled individually. The block diagram representing the hardware components and their connection is presented in Figure 12.

3.4 Touch recognition and stimulation software

The TouchYou software was designed for communicating with both the touch-sensitive and the touch-stimulation interfaces and for converting the inputs of the first into the output of the second interface. The software was developed in Python programming language, and the software for controlling each interface (Arduino and ESP32 boards) was developed in the Arduino IDE.

The touch recognition is done by detecting the position where the touch sensor was touched and the force of the touch. Because there are only two force-

sensitive sensors beneath the touch interface, we needed to consider the effect of the position of the pressure on the nearby electrodes. Matrix T (equation (1)) represents the value of the electrodes of the touch interface, where -1 represents the “not touched” state and the 1 represents the “touched” state. The weighted pressure sensor matrix is represented by W (equation (2)), the value 1 represents the electrode of the touch interface right above the pressure sensor, and smaller values represent the area influenced by the force of the touch.

$$T = \begin{bmatrix} -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & 1 & 1 & -1 \\ -1 & -1 & -1 & -1 & 1 & 1 & -1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix} \quad (1)$$

$$W = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.1 & 0.25 & 0.1 & 0 & 0.1 & 0.25 & 0.1 \\ 0.25 & 1 & 0.25 & 0 & 0.25 & 1 & 0.25 \\ 0.1 & 0.25 & 0.1 & 0 & 0.1 & 0.25 & 0.1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (2)$$

After detecting the places where the touch occurred, the software considers the value measured by each force sensor, which ranges from 0 to 1.2. The value of the first sensor is multiplied for all the elements of the columns 1, 2 and 3 of W (equation (2)), and the second sensor value for the elements of columns 5, 6 and 7. In our example, the measured value was 0.14 for the first sensor and 1 for the second, resulting in matrix WP (equation (3)). The influence of the measured pressure values needed to be combined with the information of the touch location, which was done by summing the elements of matrices T and WP , resulting in matrix TP (equation (4)), where the negative values represent not touched, 0 represents touched without pressure and positive values represent the touched and the intensity of the force applied.

$$WP = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.014 & 0.035 & 0.014 & 0 & 0.1 & 0.25 & 0.1 \\ 0.035 & 0.142 & 0.035 & 0 & 0.25 & 1 & 0.25 \\ 0.014 & 0.035 & 0.014 & 0 & 0.1 & 0.25 & 0.1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (3)$$

$$TP = \begin{bmatrix} -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -0.985 & -0.964 & -0.985 & -1 & 1.1 & 1.25 & -0.9 \\ -0.964 & -0.857 & -0.964 & -1 & 1.25 & 2 & -0.75 \\ -0.985 & -0.964 & -0.985 & -1 & -0.9 & -0.75 & -0.9 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix} \quad (4)$$

Because the matrix of touch electrodes (5×7) had more elements than the matrix of electrodes pair on the

stimulation interface (3×4), we needed to map the first matrix to the second. This conversion was done by using the `resize` function of the `skimage` python module. The new information represented by matrix E (equation (5)) was used for controlling the components of the stimulation interface, where the higher value element is the pair of conducting electrode and its intensity.

$$E = \begin{bmatrix} -0.992 & -0.995 & -0.387 & -0.697 \\ -0.923 & -0.968 & 0.968 & 0.281 \\ -0.992 & -0.995 & -0.970 & -0.947 \end{bmatrix} \quad (5)$$

4 Technical evaluation

For demonstrating the functioning of the TouchYou, we first decided to test the touch-sensitive interface and the stimulation interface separately and then integrate. In this section, we present the tests and their most important results for evaluating the prototype.

4.1 Touch detection

The touch-sensitive interface can detect the touch and the release in any element of the 5×7 electrode matrix, besides the force applied by the touch. The wearable touch sensor was connected as described in Figure 6, which was able to detect the change in the capacitance value of the electrodes and send this information to a computer by Bluetooth. The state of electrodes is sampled at 40 Hz rate, and the information is transmitted to the computer at 9600 baud. During our tests, the touch detecting was presented as reliable and accurate, in the cases where the interface was worn by a person or was flat in table surface. We plotted a real-time representation of the touch interface by using a python script for evaluating the prototype. In Figure 13, the first element of the touch matrix, i.e., the intersection of the first line with the first column, was touched, and this condition was represented by the red color, while the blue color represented the electrodes that were not touched.

The same test was repeated for two distinct situations: the touching of two distant electrodes (Figure 14) and the touching of multiple nearby electrodes, or an area (Figure 15). In both cases, the touch detection was accurate and the prototype presented repeatability of results when the touch detection test was repeated for other electrodes.

Figure 13: Touch detection on one point at the first electrode.

Figure 14: The touch can be detected in multiple points at the same time.

Figure 15: A touch in an area is also possible of being detected.

4.2 Touch and pressure integration

We have also tested the touch force detection integrated with the touch position. The touch interface has two force sensors, both are rounded and have 10 mm of diameter, and they are located behind the electrodes from line 3 and columns 2 and 6. The test consisted of detecting the touch of an area and varying the force applied. The more the force applied, the redder the image, representing the touch and the pressure (Figure 16). For plotting these images, we used the Gaussian interpolation for better representing the effect of the touch.

4.3 Touch to stimulation conversion

The same software developed for recognizing the touch on the sensitive interface was used for activating the components of the stimulation interface. The software

Figure 16: Touch detected in an area of the sensor (not blue) and variation in the force applied: (a) weak, (b) medium and (c) the strongest touch.

Figure 17: Conversion of the touch detected to electrode activation. The redder color represents the pair of electrodes that should be activated and its intensity.

processes the information received from the sensitive interface, for example, the touch location, and converts it to the information of which electrode pair must be activated. Since the number of sensitive elements (5×7) was higher than the stimulation elements (3×4 electrodes), we need to map the values of the first into the second interface. For an area activation condition with strong pressure (Figure 16c), we converted the touch for activating the correct electrode pair, and the result is represented in Figure 17. The redder color indicates which pair should be activated, in this case the pair from the second line and the third column. The redder it is, the more intense is the signal from the electrical stimulation device. Rapid transitions of the electrode state activated the respective vibration motor, whose information was also converted from the touch sensor, as represented in Figure 18. In this case, we have a 2×3 motor matrix, lighter color represents which motor was activated (both motors from the second column).

4.4 System limitations

Most of the limitations found during the tests of the TouchYou were related to technical features, which can be improved in the future. Regarding the touch-sensitive

Figure 18: Motor activation converted from the touch information. The lighter color represents the motor that should be activated, in this case both motors from the second column.

interface, one of the main limitations, considering that the interface initial requirement was to be wearable, is that it is not stretchable. The lack of the stretching feature is because the substrate of the touch sensor comprises a polyamide tape and the method used for creating the copper tracks and electrodes in that substrate. Trying to stretch the sensor would cause the tracks to break, which in turn would reduce the number of working electrodes, decreasing the touch-sensing resolution. Another limitation of the touch sensor is that to increase the sensor dimension, we need to choose between increasing the size of electrodes, reducing the spatial resolution or increasing the number of electrodes, since the total number is limited by the electronic hardware. Thus, this option would increase the cost of the project and increase the processing power need. It would also be desirable to measure the pressure of the touch along all the sensor areas. In the current prototype, we are measuring the pressure using two FSR sensors located above two electrodes. Increasing the number of pressure sensors would increase the cost of the prototype using this technology. A possible solution would be using a different technological approach, by integrating the touch sensors and the pressure sensor [33,34].

The main limitations of the stimulation interface were power consumption and the type and size of electrodes. The power consumption is higher on the stimulation interface than in the sensing interface mostly because of the heater's current and the need for supplying an additional circuit, which is the EMS device. Designing our own and integrated EMS circuit would reduce the power consumption by removing unnecessary circuitry and functions. The elevated power consumption requires a larger battery, which reduces the device portability. The second limitation is because of the electrodes used. As mentioned before, we used the electroencephalography electrodes, which are not the most

Figure 19: Representation of a couple in an LDR using the TouchYou. The man is in Brazil and uses the touch-sensitive interface, while the girl lives in France and uses the touch-stimulation interface.

suitable for our application. They are not small enough; and for increasing the stimulation spatial resolution, a higher number of electrode pairs are needed, which increase the size of the stimulation interface. Using the technology with different electrodes, for example, screen-printed Ag/AgCl electrodes, would reduce the size of the device and hence making it possible to integrate the stimulation and the sensing interfaces in the same sensor layer.

5 System description and exploration of its usage

The TouchYou can be used for sensing the touch physical characteristics in one person and transmitting it to another person who is apart from the first one. Couples being in an LDR can benefit from this technology for both affective touch sensation and sexual purposes. The technology is also promising in the field of robotics and sex toys.

5.1 Remote touch transmission

The primary use of the TouchYou is to transmit the sensation of being touched. In our fictional example, we have a couple in an LDR: the man works in Rio de Janeiro, Brazil and his girlfriend studies in Paris, France (Figure 19). The couple can use both the touch-sensitive interface and the touch-stimulation interface during their daily activities and eventually touch their respective devices when they miss their partners. The gesture is captured by the touch-sensitive interface and reproduced by the touch-stimulation interface, which tries to mimic the detected touch by changing the intensity of how its simulator component works. Both interfaces are battery powered and have wireless communication, so they can be paired with the

Figure 20: The flexible touch-sensitive sensor can be applied for recognizing gestures in vibrators and other sex toys.

couple's smartphones and be integrated with instant message or video chat applications.

5.2 A smart skin for sex toys and sex robots

The TouchYou, specifically its touch-sensitive interface, can be integrated in the design of other products. The interface has a flexible touch sensor that has the advantages of being easily manufactured (or even being made at home), being low cost and having a versatile configuration. The sensor can detect the position of the touch over surface areas and additionally detect the force applied during the touch. The electrodes' dimensions can be changed and the pattern matrix dimensions can be reduced or increased, for example, by adding lines and columns to the original design by including another touch-controller module.

We present here the possibility of using the touch interface as an integrated sensor for sex toys (Figure 20). The touch sensor can be wrapped around the cylindrical body of a vibrator or a dildo and be used for detecting how the sex toy is manipulated. The sex toy can use this information for controlling the pattern and intensity of its vibration or any other stimulation method. The sensor can also be used in specific parts of the sex toy for enabling special functions, for example, detecting how deep the toy is being penetrated and activating a hidden pattern of the G-spot stimulation. Because of its capacitance-detection technology, the sensor does not need to be exposed and can be installed under the silicone sleeve (Figure 21) as normally used by high-quality manufacturers.

Sex robots and their consumers can also benefit from the flexible touch sensor presented in this work. Like the example of the sex toy, the touch sensor can be used as a "smart skin" for any kind of robot, especially social and sexual bots, and for detecting touch gestures (Figure 22). The touch information can be used by the robotic system as a feedback response of its physical and emotional responses, changing the way the robot will interact with humans or even with other robots. Smaller

Figure 21: The touch-sensitive interface can be installed beneath the silicone sleeve of the sex toys and continue to detect the touch.

Figure 22: The touch-sensitive interface can be used for gesture and touch recognition in social and sex robots. The touch and the pressure can be measured and used for emotional feedback.

electrode matrices can detect more detailed information of the touch and be used for representing sensitive areas of the robot, for example, the lips, the tip of the fingers or the genital parts.

5.3 The body as a remote sex interface

In this work, we propose the use of the TouchYou interfaces for sexual purposes, in addition to the transmission of the touch. The concept of using our own body as a sexual interface for remote encounters can be made possible by the technology of sensing the touch and stimulating the remote body for recreating the sensation of being touched. The touch-sensitive interface can be worn in any part of the body, for example, the arm or the thigh, but also be adapted to attach to the underwear. By touching the interface, the user can have his gesture tracked and measured; and because the sensor is of thin layer, the user can sense his own touch.

Figure 23: By using the TouchYou device, the couple can use their own body for receiving and transmitting remote sexual stimuli.

The information is transmitted wirelessly to a computer or smartphone and then is used for controlling the stimulation interface. The stimulation interface can also be attached to the underwear and could stimulate any part of the body, by heating, vibrating or electrically stimulating the skin and muscles. In a fictional example, a couple who is separated by thousands of miles could connect their interfaces to a computer and start a video chat. During the chat, depending on the arousal moment, the man could start touching his sensitive interface, which is placed over his groin, and by this start controlling the stimulation interface, which is being worn by the woman in her bra. During the virtual sex, the couple could change the location of their interfaces and enable more possibilities of remote physical and sexual interaction (Figure 23).

5.4 The body as a dispositive for enhancing perception

The skin is our largest organ endowed with nerve endings throughout its length. This makes the body the largest sensor capable of feeling all kinds of environmental changes and all kinds of touch, vibration, pressure and friction. By touching and being touched, the body is able to feel different sensations, ranging from the production of affection to the release of hormones capable of modifying and modulating the form in which we feel. In this way, the gestures produced by our body due to the touch are part of our most potent nonverbal communication, which are essential for socio-cognitive development and our positioning as relational beings in the collective and political body. Through our intricate haptic system we are able to modify the way we perceive through the sensors of our senses and we are able to

develop our interpersonal relationships. In this sense, touch is essential in the construction of human relationships, ranging from the relationship of the mother to the child to those involving sexual relationships and touches that go beyond the outer skin.

With this, the skin, more than an interface with the outside world, is able to feel. When technologies are capable of amplifying, potentiating, or even programming and modulating the way we feel, we can also evolve in the way we perceive affect and our relationships. The development of TouchYou, in addition to LDR, shows us that the body, as a device or programmable platform to feel it, is capable of reaching other levels of perception, creating new synapses and recreating our haptic cognition.

When we go to feel it together, relational and on a large-scale, the mediation of the social touch can be more potent, since this interface can be used collectively. This feeling together extrapolates what we are capable of today, after all what would it be like to feel with another body, several bodies or through other bodies? Our work intends to question these limits, to erase perceptual boundaries and to show that from the modulation of feeling and touch we can also modulate and emulate other perceptions and resignify the touch beyond presence or proximity.

6 Conclusion

This work presented the TouchYou, which is a pair of touch-sensitive and touch-stimulation interfaces for detecting the touch and simulating it to a long-distance. We presented the design process, which includes a contribution on how to manufacture a homemade touch sensor, the technical evaluation and exploration of the usage possibilities. The primary use is for transmitting the touch for couples in an LDR, but the touch interface can be used as a smart skin for sex robots and sex toys, besides the possibility of the couple using their own bodies for stimulating their partner remotely during the virtual sex. The TouchYou presents as a good option to overcome the problem of lack of physical contact for couples and relatives who are living apart, and its technology is promising in the field of HCI.

6.1 Future work

In the current prototype, the touch-sensitive interface is capable of detecting the position of the touch and the

force applied only in two different points. We plan on adding more force sensors and also a gesture-recognition algorithm, probably driven by some degree of artificial intelligence. With this function, the touch interface will be capable of detecting the touch in a detailed way and will have more possibilities for controlling other devices. The design will be altered for integrating the touch interface with the stimulation interface, so the user need not wear two distinct devices. The portability will be improved, by reducing the dimensions of the electronic hardware and integrating it with the sensitive and stimulating interfaces. We will be evaluating the prototype by testing with a group of potential adopters of the technology and use their insights and impressions for improving the design of the TouchYou device.

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