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An Analytical Study of Human Body as an Input Surface by Skinput Technology

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***Abstract* - We present Skinput, a technology that adapts the human body to acoustic transmission and allows the skin to be used as an entry surface. In particular, we determine the position of the finger strokes on the arm and the hand by analyzing the mechanical vibrations which propagate through the body. We are recording these signals using a new range of sensors that are worn like an armband. This approach offers an always available, naturally portable and body-mounted finger entry system.**

Keywords: Bio-acoustics, finger input, buttons, gestures, on-body interaction, projected displays, audio interfaces.

I. INTRODUCTION

Devices with considerable computing power and performance can now be easily transported on our body. However, their small size generally leads to limited interaction space and therefore reduces their usability and functionality. Because we cannot simply enlarge the buttons and screens without losing the main advantage of the small size, we are considering alternative approaches that improve interaction with small mobile systems. The use of the human body as an input device is interesting not only because we have about two square meters of outdoor space, but also because a large part of it is easily accessible to our hands. The main purpose of Skinput is to provide a mobile entry system which is always available, i.e. an entry system in which the user does not have to carry or pick up a device.

1.1 Bio-Acoustics

Skinput uses the natural acoustic conduction properties of the human body to provide an input system and is linked to previous work on the use of biological signals for computer input. Bone conduction microphones and headphones are an additional biosensor technology that is relevant to the present work. These take advantage of the fact that the sound frequencies relevant to human language propagate well through the bones. The forearm and hands contain a complex combination of bones, which increases the acoustic differentiability of different places. To capture this acoustic information, we have developed a non-invasive and easily removable portable bracelet. When a finger taps on the skin, various forms of acoustic energy are created. Part of the energy is emitted into the air in the form of sound waves. This energy is not recorded by the skinput system. Among the acoustic energy transmitted by the arm, the transverse waves are the most easily visible, which are generated by the displacement of the skin by an impact of the finger.

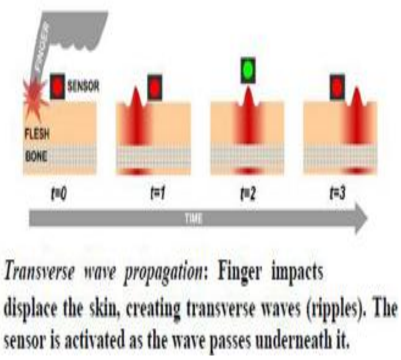

Figure 1: Transverse Wave Propagation

1.2 Sensing

In order to capture the variety of acoustic information described in the previous section, we evaluated many sensor technologies, including bone conduction microphones, conventional microphones coupled to stethoscopes [10], piezoelectric contact microphones [2] and accelerometers. However, these transducers have been developed for applications other than measuring the acoustics transmitted by the human body. For this reason, we have found that they lack importance in several respects. First and foremost, most mechanical sensors are designed to provide relatively flat response curves over the frequency range relevant to our signal. However, since only a certain set of frequencies crosses the arm in response to the tap input, a flat response curve leads to the detection of irrelevant frequencies and therefore to a high signal-to-noise ratio. Although bone conduction microphones seem to be an appropriate choice for skinput, these devices are generally designed to capture human voice and filter energy below the range of human speech. Therefore, most of the sensors in this category were not particularly sensitive to low frequency signals (e.g. 25 Hz), which we found crucial for the characterization of fingerprints

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in our empirical pilot studies. To meet these challenges, we have moved from a single sensor element with a flat response curve to a series of highly tuned vibration sensors.

1.3 Arm band Prototype

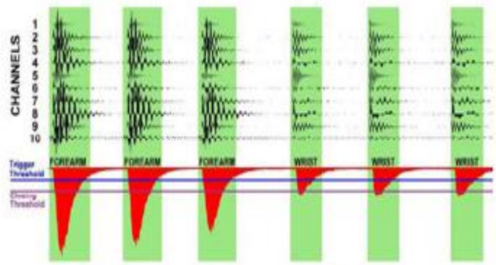
Our final prototype consists of two matrices with five sensor elements which are integrated into a bracelet form factor. The decision regarding two sets of sensors was motivated by our focus on the input arm. Especially when putting on the upper arm (above the elbow), we were hoping to collect acoustic information from the fleshy bicep area in addition to the firmer area under the arm, with better acoustic coupling to the humerus , the main bones that go from shoulder to shoulder. at the elbow. When the sensor was placed under the elbow on the forearm, there was a pack near the radius, the bone which goes from the lateral side of the elbow to the side of the thumb of the wrist, and the other near the ulna which is parallel to it. on the medial side of the arm closest to the body. Each location thus provided slightly different acoustic coverage and information, which is useful for distinguishing the entrance location. Based on the acquisition of the pilot data, we selected a different set of resonant frequencies for each set of sensors. We have adjusted the upper sensor housing to be more sensitive to low frequency signals, as these occur more frequently in more fleshy areas. Conversely, we set the lower sensor network to higher frequencies in order to better detect the signals transmitted through the bones (denser).

Figure 2: External View of Armband Prototype

Figure 3: Internal View of Armband Prototype

II. PROCESSING

In our prototype system, we use a Mackie Onyx 1200F audio interface to digitally capture data from the ten sensors (http://mackie.com). This was connected via Firewire to a conventional desktop computer on which a thin client written in C was connected to the device via the ASIO protocol (Audio Stream Input / Output). Each channel was sampled at 5.5 kHz, a sampling frequency deemed too low for speech or ambient audio, but could represent the relevant frequency spectrum transmitted by the arm. This reduced sampling frequency makes our technology easily transferable to integrated processors. For example, the ATmega168 processor used by the Arduino platform can sample analog measurement values at 77 kHz without loss of precision and could therefore provide the sampling power required for the skin input (55 kHz in total). The data was then sent from our thin client via a local socket to our main application written in Java. This program has three main functions. First, a live visualization of the data from our ten sensors was provided, which was useful in identifying the acoustic characteristics. Second, it segmented the data flow entries into independent instances (taps). Third, it classified these input instances.



Ten channels of acoustic data generated by three finger taps on the forearm, followed by three taps on the wrist. The exponential average of the channels is shown in red. Segmented input windows are highlighted in green. Note how different sensing elements are actuated by the two locations.

Figure 4: Acoustic Data Generated by Three Figure Taps

2.1 Experimental Conditions

We selected three groups of inputs from the large number of possible location combinations to test. We think these groups are of particular interest when it comes to interface design and at the same time extend the limits of our ability to perceive. From these three groups, we have derived five different experimental conditions, which are described below. Fingers (five positions) In a series of gestures that we tested, the participants tapped the tips of each of their five fingers. The fingers offer interesting advantages that force them to enter. First, they provide clearly discrete interaction points that are even aptly named (for example, ring fingers). In addition

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to five fingertips, there are 14 phalanges (five major, nine minor) which together could offer 19 easily identifiable entry points on the fingers alone.

Second, we have exceptional dexterity, as we can demonstrate by tapping our fingers when counting. Finally, the fingers are arranged in a linear fashion, which can be useful for interfaces such as entering numbers, controlling the size (for example volume) and selecting menus. At the same time, the fingers are among the most regular members of the body, all except the thumb having a similar skeletal and muscular structure.

This considerably reduces acoustic fluctuations and makes differentiation difficult. In addition, the acoustic information must pass through up to five joints (fingers and wrists) to reach the forearm, which further attenuates the signals. For this reason, we decided to place the sensor networks directly under the elbow on the forearm. Despite these difficulties, the pilot tests showed measurable acoustic differences between the fingers that we have theorized, which are mainly related to the length and thickness of the fingers, interactions with the complex structure of the wrist bones and fluctuations in properties of acoustic transmission of muscles, which vary from fingers to to extend the forearm.

2.2 Whole Arm

(Five locations) Another set of gestures examined the use of five entry positions on the forearm and hand: arm, wrist, palm, thumb and middle finger. We chose these locations for two important reasons. First of all, they are different and named parts of the body (for example "wrist"). This allowed participants to reach these places exactly without training or marking. In addition, these locations were found to be acoustically different during piloting, the large spatial dispersion of the entry points offering new variations.

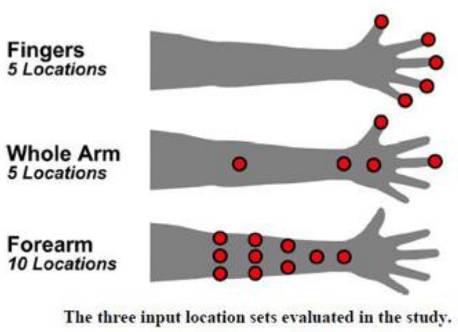

Figure 5: Input Location Evaluated in Study

We used these locations under three different conditions. In one case, the sensor was placed on the elbow, in another under the elbow. This was included in the experiment to measure the loss of precision on this important point of articulation (the elbow).

III. CONCLUSION

In this article, we presented our approach to the appropriation of the human body as an entry surface. We have described a new arrangement of portable bio-acoustic sensor that we have integrated into a bracelet to detect and locate finger strokes on the forearm and hand. The results of our experiments have shown that our system works very well for a number of gestures, even when the body is in motion. In addition, we have presented initial results that show other potential applications of our approach that we would like to explore further in future work. This includes gestures with one hand, typing with different parts of the fingers and distinguishing between materials and objects. We conclude with descriptions of a few prototype applications that demonstrate the diverse design space that we believe Skinput enables.

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