Towards the Tangible Hyperlink

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***Abstract*—Thanks to the persistent decrease in cost and size of electronics, this century is experiencing an important scale up in number of devices surrounding us, with a subsequent increment on the complexity of the user interaction with such devices. The proposed interaction concept - the tangible hyperlink - demonstrates that it is possible to apply the capacitive coupling communication technology to simplify the interaction with embedded devices without preventing users from maintaining control on their privacy.**

Keywords-CHI; Personal Area Network; Tangible User Interface; Privacy.

I. INTRODUCTION

Abowd et al. [1], following Weiser's [2] vision, identified the requirement of "addressing some notion of scale [...] in *the number and type of devices, the physical space of distributed computing and the number of people using a system*". Thanks to the persistent decrease in cost and size of electronics, this century is experiencing an important scale up in number of devices surrounding us, with a subsequent increment on the complexity of the user interaction with such devices. Abowd et al. also proposed the request of providing "*natural interfaces* that facilitate a richer variety of communications capabilities between humans and computation".

Figure 1 illustrates the proposed concept: a *tangible hyperlink* that can be opened by physically "tapping" it. Information is transmitted bidirectionally to the wearable device through the skin of the user due to its capacitive property. This bidirectional transfer of information among devices through the recognition of the touch gesture entails both advantages and disadvantages. On one hand, it gives the freedom to develop such *natural interfaces* identified by [1], making it simpler to exchange information among embedded and wearable devices. On the other hand, a scenario where "devices and environments reveal not only personal information but also location and context information" [3] can make it incredibly complex for users to control their privacy. In this work, a novel concept of *tangible hyperlink* is presented as a mechanism to balance the usability of *personal area networks* (PAN) and the control that users maintain over their privacy. To achieve this balance, the key aspect is to use a metaphor (the hyperlink) to help users mimic the way they exchange tangible information to the way they exchange information on the web.

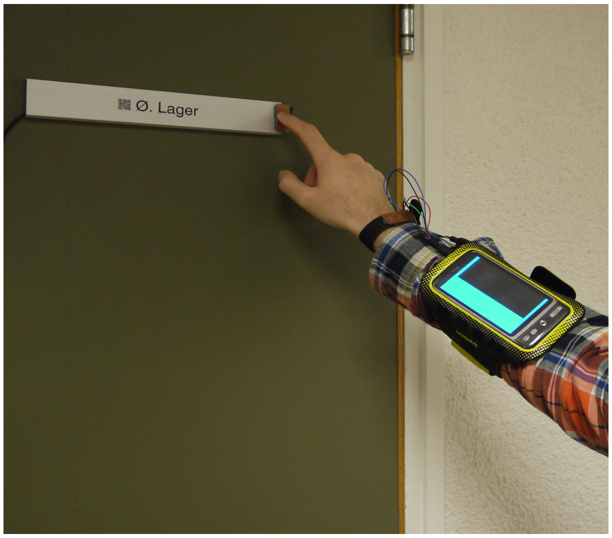

Figure 1: Concept of tangible hyperlink

The paper is structured as follows. In the next section, current related work is described. Section 3 describes the conditions in which the experiment was carried out. Section 4 provides the different results obtained from the experimental evaluation. The paper concludes with Section 5 with a summary and an outline of different possibilities for future research.

II. STATE OF THE ART

The first work presenting and demonstrating a device capable of communicating using an electrostatic capacitive coupled PAN is [4]. Based on this work, other authors such as Shinagawa et al. [5] propose different alternatives to improve the communication by means of using "electric-field sensor implemented with an electro-optic crystal and laser light". Hyoung et al. [6] study how different factors such as voltage, frequency and physical level codification affect communication performance. In contrast to most studies, Duck et al. [7] focus more on analyzing higher layers of the protocol stack communication. Hachisuka et al. [8] present a mechanism for simplification of modeling and fabrication of intrabody communication devices. They also analyze the impact on cost/performance of such devices when using four electrodes instead of two. Ishii et al. [9] introduce their vision of *tangible bit* and emphasize the need of allowing users to *grasp and manipulate* the information in their surrounding as a form of tangible user interfaces, claiming that the goal is to “bridge the gaps between both cyberspace and the physical environment”. Based on this vision, Parkes et al. [10] introduce a prototype consisting of a “modular scalable building system with the physical immediacy of a soft and malleable material”. Glumes are able to communicate to each other and exchange information using electrostatic capacitive coupling and are designed to be responsive to human touch.

III. EXPERIMENTAL SETTINGS

In this section, we describe an experiment carried out, in which a total of 19 participants were asked to use different devices designed to communicate to each other using electrostatic capacitive coupling and, afterwards, fill in a questionnaire. From the 19 participants, 12 were male and 7 female. 15 of the participants had some form of education on a technological field. The mean age was 25 years with a range from 20 to 42 years. The experiment was divided into two different phases and all the participants were involved in both of them. The first phase of the experiment consisted of an evaluation of a very basic application, *the tangible greeting* (Figure 2). This first application had as a main target to capture the opinion of different users about the exchange of information through the touch gesture. The second phase of the experiment was the result of a redesign of the prototype based on the feedback obtained from the participants during the first phase. Due to the lack of control users had on the information they were providing to the system, a new concept was introduced: the *tangible hyperlink*. The *tangible hyperlink* served as a mechanism to acquire a compromise between usability and privacy by means of implementing a metaphor of something the participant was already familiar with, the web hyperlink.

Figure 2: The Tangible Greeting Application

1) First Phase: Tangible Greeting: The first phase of the evaluation consisted of a basic application displaying a personalized greeting message to the participants on a screen display.

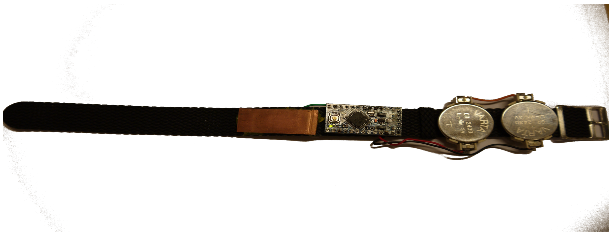

Figure 3: The UTnP Bracelet

Each participant was asked individually to wear a *Universal Touch and Play* (UTnP) bracelet (Figure 3) to later touch a small metal surface connected to a PC. The *UTnP Bracelet* is implemented with an Arduino Pro Mini [11] (Figure 4) connected to a pair of electrodes. The electrodes are a pair of copper plates of 5.25 square centimeters, lying in parallel and separated from each other through a layer of a plastic insulator material (silicon and ethylene-vinyl acetate have been used without any noticeable performance decrease). The signal electrode is in contact to the skin of the participant, while the ground electrode is only in contact to the air. A ceramic capacitor of 1nF is used, connected in parallel, both to the signal and the ground electrodes, as proposed by [4]. The same configuration is applied on the signal receiver. Each UTnP Bracelet generates a fixed *frequency-division multiplexing* (FDM) signal [12] that is decoded on the PC, after being transformed into the frequency domain. Figure 5 shows the received signal pattern, which ranges from 0.9Khz to 1.1Khz. The square wave generated from the ATmega produces a number of harmonic components after the base frequency. This redundancy is used as a mechanism to reduce the rate of false positives.

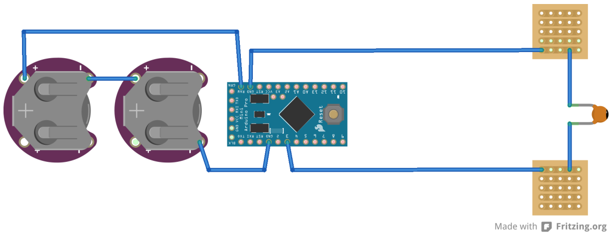

Figure 4: Implementation of the UTnP Bracelet

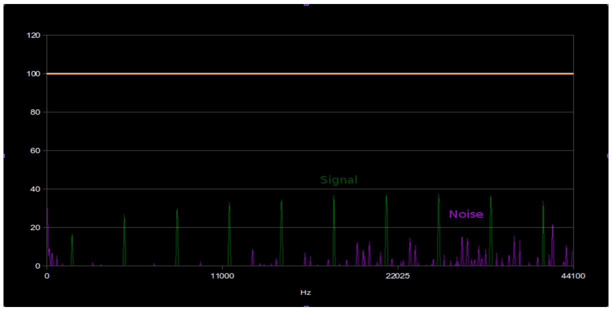

Figure 5: Frequency representation of received signal in percentage of magnitude

2) Second Phase: The Tangible Hyperlink: For the second phase of the evaluation, a change on the design was made. Instead of being the device of the participant the responsible for sending the information, it becomes a passive receiver, allowing the participant to decide on the amount of information that will be given away. For the implementation of the second phase, an Android Smartphone located in an arm band was used in combination with the electrodes (Figure 1). The Android Smartphone was used to receive and process the signal generated from an Arduino Fio [13] embedded on a name plate (Figure 6). The participants were asked, invididually, to send a personalized greeting to a fictional person called Øyvind Lager. This task was performed by *clicking* on his *tangible link* (represented by a plate with his name). *Clicking* on the *tangible link* requests the participant to provide some personal information, including name, language and a greeting message. Participants were aware of the possibility of faking their identity or even cancelling the process at any time, which was a major difference comparing to the experiment of the first phase.

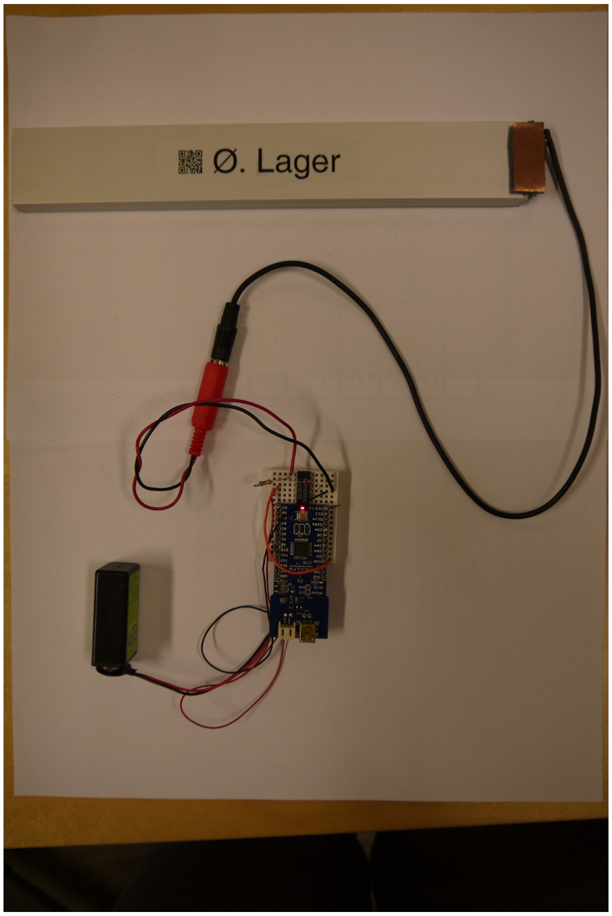

Figure 6: Name plate of a fictional person that encodes a tangible hyperlink

IV. EVALUATION RESULTS

After allowing the participants to familiarize and "play" within the scenario of each phase, they were given a questionnaire to fill in.

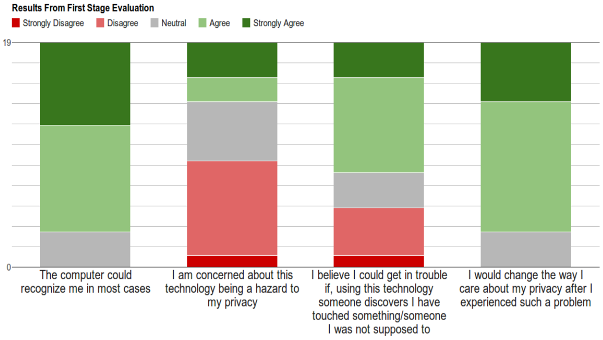

Figure 7: Results from questionnaires of first evaluation

First, it is possible to observe in Figure 7 that the prototype on the first phase behaved robustly, presenting little or no false positives or false negatives. 84.21% of participants stated that the computer was able to identify them. Something that can be interpreted as a paradox, from the second and third questions, is that 47.7% of participants disagreed with the statement that capacitive coupling can become a hazard to their privacy, while 57.89% agreed or strongly agreed that they could get in trouble if someone discovered that they had "touched something/someone they were not supposed to". This apparent paradox has its origin in the relative importance that participants give to this particular technology to their privacy. Participants stated that they were even more concerned with their privacy when using other technologies, including GPS, web browsing and social networks, because of their massive use.

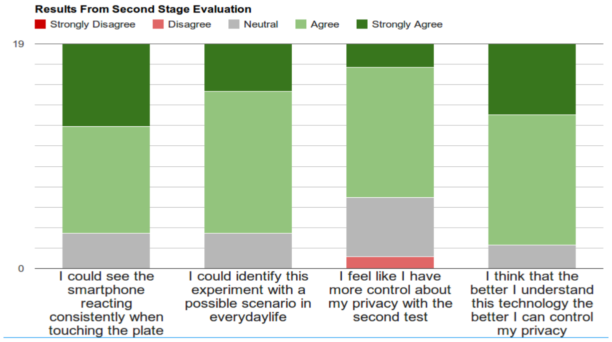

Figure 8: Results from questionnaires of second evaluation

The feedback obtained from the questionnaires of the first phase triggered a redesign of the prototype used in the second phase (Figure 8). Participants perception of the accuracy of the prototype was maintained, compared to the first phase. 68.42% of the participants claimed to have a better control on their privacy or the information they were providing with the second prototype. When asked which prototype they preferred, all the participants but three assured they preferred the last version, while the rest remained neutral. The results from the second phase suggest a qualitative improvement on the acceptance of the participants for those changes.

V. CONCLUSIONS AND FUTURE WORK

Electrostatic capacitive coupling is an extremely powerful mechanism to share information among low powered embedded and wearable devices. It can enrich the touch gesture and make it become a much more meaningful component for many *pervasive applications*, but it can also become a hazard to privacy. The *tangible hyperlink* has been proposed as an approach to let the user have more control on the information that is provided to the system. It becomes highly important to incorporate metaphors to existing concepts, when designing new applications, so that it becomes easier for the user to have an understanding of the information flow. Arduino and Android devices have been used to implement a functional prototype for information exchange using electrostatic capacitive coupling. This setting is not optimal to achieve a high performance of data bandwidth and low power consumption but, instead, it offers a way to rapidly develop applications that need to adapt to very different and varying scenarios.

This study was carried out in the frame of a very basic application. The interest of the research will surely grow as the complexity of the scenario is increased. Further investigation is required to identify possible challenges and future findings. Part of this further investigation will consist of comparing this technology with other mechanisms of information exchange.

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