Accessible Real-World Tagging through Audio-Tactile Location Markers

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ABSTRACT

Real-world tagging technologies, such as RFID or visual codes, have enabled new application scenarios that foster mobile interaction with the physical world. While the application scenarios are promising for many contexts, the technologies are currently lacking accessibility. Especially blind and visually impaired people are not able to interact with tags if they are not aware of their presence. We propose audio-tactile location markers as a remedy to this problem. An audible signal leads users to the tag, which can be identified through tactile exploration. Preliminary user studies with four blindfolded subjects using an initial prototype showed the applicability of using an audible signal for locating tags.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *prototyping, user centered design*.

General Terms

Design, Human Factors

Keywords

NFC, near field communication, blind, visually impaired, assistive technologies, locating, tagging.

1. INTRODUCTION

Mobile interaction with physical objects represents a new paradigm that has emerged due to technological advances in mobile devices, which are nowadays equipped with sensors, such as integrated cameras, radio frequency identification (RFID), or barcode readers [5]. The mobile device has therefore become an enabler for mobile interaction with physical objects. Various technologies for real-world tagging have been investigated to support this new paradigm, including augmented reality [7], visual codes [8], and near field communication (NFC[1]) [1]. Application scenarios include museums that are equipped with tags for interactive exhibition guides [9], and interactive posters for purchasing tickets through mobile interaction with real-world tags attached to the poster [1].

While recent studies demonstrated the potential of different approaches for real-world tagging [1,9], to our knowledge there have been no research efforts to investigate the accessibility of this new paradigm. Accessibility is an important concern, especially for applications, which address a broad audience, such as exhibition guides or interactive posters, and because mobile devices are already in use by blind people [6]. An inherent problem of current real-world tagging technologies is their lack of affordances for user interaction. This is even more problematic when designing accessible applications for blind and visually impaired users[2], who require assistance in locating and identifying real-world tags. Especially RFID tags are difficult to locate for those users due to their design and appearance. The goal of this work was therefore to develop techniques for making the tags' presence available to users without changing the tagging technologies themselves.

In this paper we introduce the concept of audio-tactile location markers (ALMs), which use a combined approach of audible signals and tactile identification for making real-world tags accessible for users. An audible ticking signal makes users aware of the presence of a real-world tag in their vicinity. Once they have reached the tag, they can identify its purpose through tactile exploration and access information connected to the tag by touching it with the mobile device. Our approach is based on traditional designs of audible pedestrian signaling devices.

2. BACKGROUND

The problem of accessing real-world tags is directly related to challenges that users experience in their everyday lives: locating and identifying objects or places (points of interests) in their vicinity [4]. Examples for points of interests (POIs) are elevator buttons, vending machines, or personal belongings, such as audio compact discs. We identified three categories, which define the difficulty of locating POIs: (1) known points of interest, (2) expected points of interest, and (3) unknown points of interest.

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[1] NFC describes an RFID standard that allows the transmission of data over very short distances (< 10cm).

[2] From hereafter we will call blind and visually impaired users simply "users".

Figure 1. Braille labels inside an elevator (left) and an audible device at a pedestrian crossing that promotes its location and provides further information through tactile coding (right).

Known points of interest. The first level describes POIs that are known to the users, e.g. the kitchen table or doors in their apartment. This level mainly includes POIs in a private context, but can also be applied to public environments to a certain degree, if the users know where to find a POI (e.g. they can remember its location or they were given correct directions).

Expected points of interest. Entities from this category depend on the users' experience and expectation. There are certain standards, which (if followed by designers) help people to look for POIs 'at the right places'. For example, elevator buttons typically feature Braille labels (Figure 1, left). A further characteristic of expected POIs is therefore that they feature some information, which is already in place and accessible to blind users. These public POIs can be augmented with information stored on real-world tags.

Unknown points of interest. This category describes POIs whose location is unknown to users. In a first step, it is therefore necessary to make users aware of the existence of POIs in their vicinity. In a second step the users can identify the purpose of tags attached to those POIs through touch. An example scenario for this category is a blind person approaching an unknown crossroad. An audible pedestrian device feeds its environment with constant sensory information. The device's signal attracts the blind person, who can explore the nature of the crossing through a physically imprinted map on the device. (Figure 1, right)

The first category typically neither requires locating nor identification of POIs, since they are familiar to users. Since expected POIs (second category) already feature information accessible by and designed for blind people, we can assume that users are able to determine their location. Therefore it is only important to support identification through tactile information when augmenting expected POIs with real-world tags. Users know neither the location nor the purpose of real-world tags attached to POIs from the third category. Therefore tags designed for such POIs have to support both locating and identification. Consequently we focus on the second and third categories in this paper.

3. RELATED WORK

The Chatty Environment [3] uses electronic markers to track and locate objects in the users' vicinity. The authors describe two different approaches following a push and pull model. In push mode, objects immediately present themselves to the user as soon as they are sensed by the users' device. In pull mode, users explicitly have to choose an item to receive further information about it. The Chatty Environment therefore addresses the first and second categories. The authors also mentioned the navigational part of the system, i.e. how to locate objects, which would correspond to the third category, but they did not present any solution to this issue. Sherlock [2] is a similar but simpler system, which is commercially available and based on RFID. It implements the first category and therefore neither addresses locating nor identification. Seeyingeyephone [10] is an NFC-based system developed by the VTT Technical Research Centre of Finland. It implements the first and second categories and exploits NFC as a ubiquitous low-cost technology, foreseeing a future where every object (e.g. in a supermarket) will feature RFID tags, thus enabling a pervasive use of their device.

4. APPROACH

To ensure both the applicability and usability of our proposed solution, we follow a user-centered design process, involving an expert interview and evaluations with blindfolded users as well as blind and visually impaired people. In a first step we developed a concept based on the results from our expert interview and implemented a prototype addressing locating real-world tags. This initial prototype was evaluated with four blindfolded users. In a next step we will address the problem of identification. The final prototype will be evaluated with real users.

5. EXPERT INTERVIEW

To collect background information about our target group and existing assistive technologies we conducted an open-structured interview with a blind employee at the BBI (the federal pedagogic institution for the blind in Vienna). The interview lasted about 60 minutes and was held at the BBI.

A major issue, which became apparent in the interview, concerned the costs of assistive technologies. Although being obvious, this issue hardly ever seems to be reflected by research in this area. It is however reflected by recent developments in desktop computer usage by the blind community. While there is research on technologies that could substitute traditional input and output devices for desktop computers [4], the majority of blind users tend to stick to conventional hardware setups equipped with text-to-speech software. As we learned during the interview, the reasons for this are twofold: firstly, traditional desktop hardware is more affordable than assistive products and secondly, it allows blind users to keep pace with the fast development of computing technologies. This result motivates the investigation of the mobile device as assistive device for application scenarios beyond the desktop computer.

To learn more about the navigation part of our concept, we asked questions about wayfinding in public contexts. According to our interview partner, tactile navigation assistance through leading lines physically integrated into the floor is often difficult to implement due to various constraints. He further explained that audible signals, such as found at pedestrian crossings, are preferable. According to his experience acoustic feedback is generally preferred to tactile feedback.

Regarding the identification of real-world tags, the results from the interview suggest the usage of individual symbols rather than using Braille letters, since they are not multilingual. An important issue in this respect was also the suggestion to keep the information density as low as possible.

6. A PROTOTYPE FOR LOCATING TAGS

Based on the results from the expert interview we developed a concept for locating real-world tags and implemented a working prototype, which was evaluated in a preliminary user study.

6.1 Concept

We chose the application of NFC technology for our prototype because it has some advantages compared to other real-world tagging technologies. Users simply have to touch the tag with their mobile device and therefore NFC is easy to use. In contrast to visual codes it is further independent from environmental conditions (such as light). NFC tags are also relatively robust and therefore applicable in outdoor environments.

Since NFC tags are activated at low ranges (below 10cm) it is not possible to locate them from greater distances without drastically changing their technical design. We therefore chose Bluetooth as an auxiliary technology to indicate the presence of a POI (in this case an NFC tag). Every Bluetooth device has a unique 48-bit address (BD_ADDR), which it broadcasts when Bluetooth is activated and the device is in discoverable mode. For better usability, a device may also have a device name which is a human readable text string. This device name may be set by the user or software. Since Bluetooth communication is per default unencrypted, it is possible to receive the device names of all active and discoverable devices within range without exchanging encryption keys. We therefore use the device name to discover the presence of users.

A disadvantage of Bluetooth is the impossibility to determine the exact distance from one device to another. Therefore, the ALM prototype transmits an audio signal through a loudspeaker towards which the user has to navigate by acoustically locating the source of the signal.

The ALM prototype (which is attached to a POI) performs the following steps:

1. Scan for Bluetooth devices, store their BD_ADDR
2. For each BD_ADDR, perform a HCI_INQUIRY to determine its name
3. If a predefined name is found, begin transmitting an audible signal, otherwise stop the signal.
4. Start again with 1.

6.2 Implementation

Our current implementation of the ALM prototype consists of a standard 14.1" laptop with an attached class-2 Bluetooth dongle. We use a small loudspeaker connected to the audio jack of the laptop to transmit the audible signal. A passive NFC tag is attached onto the front of the loudspeaker, representing a POI. The ALM prototype runs a program, which continuously scans for Bluetooth devices with a predefined device name. Figure 2 shows the setup of the ALM prototype for the user evaluation.

The mobile device (a Nokia 6131 NFC mobile phone) runs a Java-MIDlet and features a predetermined broadcast name. This allows the ALM prototype to detect the presence of a user. It consequently starts transmitting an audible signal to promote the location of the POI. The signal starts at a low sound level, which increases over time, reaching its maximum value after 10 seconds. Once the user touches the POI with the mobile handset and the NFC tag is discovered, the MIDlet plays a short audio stream to inform the users that they have finished the task. Additionally it stops the transmission of the audible signal. If another user has activated the MIDlet on his/her phone in the meantime, the audible signal of the ALM prototype will not be deactivated.

Figure 2. The ALM prototype used for the evaluations, which consisted of a laptop, a speaker, and an NFC tag. The picture also shows the mobile phone interaction with the prototype.

6.3 Results from a preliminary evaluation

The goal of the preliminary user evaluation was to determine the applicability of our approach with blindfolded users, before conducting formal evaluations with real users. We recruited four users in total (between 20 and 30 years, 2 male/2 female), who voluntarily took part in the study. The task was to locate the ALM and to touch the attached NFC tag with a mobile phone. The evaluation was conducted in a medium sized (about 30m²) furnished room, which represented a quiet environment in order to minimize possible distractions.

Before the evaluations, we introduced each participant to the subject in general and demonstrated the ALM prototype. Since the focus was on locating the ALM, not on tactile identification, the participants received information about the test set-up (the location of the NFC tag on the ALM prototype). They also had to activate the NFC tag once before starting the actual evaluation to learn how to use the technology. After the introduction, the participant had to leave the room and the ALM prototype was placed at a random location in a height between 1.20 and 1.70m. The blindfolded participant was then led into the room. During the evaluation, one researcher followed the participant to prevent possible injuries. This procedure was repeated two times for every participant. After the evaluation we conducted a short structured interview to receive qualitative feedback about the difficulty of the task, the suitability of the audio signal used for locating the ALM, and suggestions for improvement.

All participants were able to locate the ALM prototype within 33 seconds or faster. No false attempts to touch the NFC tag (i.e. false positioning of the mobile phone) occurred. Overall, the feedback from the participants was very positive. They stated that they found it surprisingly easy to locate the ALM prototype by simply relying on their auditory-cognitive abilities. The average rating on a 6-point Likert scale was 1.5 (1 being very easy). One participant expressed concerns about the applied sound signal because of its similarity to the ticking sound of pedestrian traffic lights. We will further investigate this during evaluation sessions with blind and visually impaired users.

7. DISCUSSION

Our current approach has two limitations. Firstly, it is only applicable for environments with a low density of POIs. However, our hypothesis is that POIs according to the second and third categories of our model will not appear in high densities. We will conduct further interviews to verify this assumption. Secondly, it relies on the users' perceptual and cognitive abilities for the task of determining the location of the signal [4]. Our preliminary evaluations have shown that our approach of transmitting a ticking audible signal is sufficient for this task. Since we will conduct further evaluations with an extended version of the ALM prototype, we will get additional insights on the applicability of this approach.

While our research goal was to make existing real-world tags accessible, ALMs may also be used to develop assistive applications for blind and visually impaired people, who generally suffer from a deficiency of information. It is therefore important to provide them with information on their environment and objects in their vicinity, e.g. list of ingredients or the expiration date on products. The integration of tags in the physical world creates interfaces that can be used for specific data-feeds, which can provide crucial assistance in everyday scenarios. Ideally, these data-feeds should be: (1) easy to use, (2) easy to find, (3) customizable and configurable, and (4) unobtrusive for people in the vicinity. NFC tags are designed to operate within a low range and therefore have to be touched with the NFC device in order to be read. This method is a straightforward transformation of natural human behavior to the digital world: blind people rely on their sense of touch for exploring the world. Touching a tag with a device is therefore compliant with their current way of accessing information that is physically encoded in the world. NFC tags are small and can be integrated into almost any object. If they are provided as self-adhesive tags, users can easily attach them onto their personal belongings.

8. CONCLUSION AND FUTURE WORK

Based on the results from an expert interview with a blind employee at a federal institution we developed a working prototype that implements the concept of ALMs. At the current stage, the prototype supports locating real-world tags. It is based on NFC technology and transmits an audible ticking signal that leads the users to the POI. Our preliminary evaluation with four blindfolded users showed that our approach works well for locating the POI.

In a next step we will extend the prototype to also cover the identification of real-world tags (which are attached to POIs). We will develop a tactile language for different classes of actions that can be initiated through tags, such as payment or downloading content. This tactile interface will be developed together with users from the target group and the entire prototype will be subject of an evaluation with real users. The project's long-term goal is to develop stand-alone signaling devices that allow the application of ALMs in real contexts.

We also suggest the application of ALMs for developing assistive technologies based on real-world tags. While the personal computer has established itself as an interface to the virtual world for blind users, we believe that the mobile phone has similar potential for serving as an interface to digital information within the physical world.

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