An Interactive Belt-worn Badge with a Retractable String-based Input Mechanism

Norman Pohl[1,2], Steve Hodges[1], John Helmes[1], Nicolas Villar[1], Tim Paek[3]

[1] Microsoft Research
Cambridge, UK

[2] Institute for Visualization & Interactive Systems
University of Stuttgart, Germany

[3] Microsoft Research
Redmond, WA

norman.pohl@vis.uni-stuttgart.de {shodges,v-johelm,nvillar,timpaek}@microsoft.com

ABSTRACT

In this paper we explore a new type of wearable computing device, an interactive identity badge. An embedded LCD presents dynamic information to the wearer and interaction is facilitated by sensing movement of the retractable string which attaches the unit to the wearer's belt. This form-factor makes it possible to interact using a single hand, providing lightweight and immediate access to a variety of information when it's not convenient to pick up, unlock and interact directly with a device like a smartphone. In this paper we present our prototype interactive badge, demonstrate the underlying technology and describe a number of usage scenarios and interaction techniques.

Author Keywords

Smart interactive badge; memory LCD; retractable string; interaction techniques.

ACM Classification Keywords

B.4.2 Input/output and data comms: Input/Output devices.
H.4.1 Information systems applications: Office Automation.
H.5.2. Information interfaces (e.g., HCI): User interfaces.

General Terms

Human Factors; Design.

Figure 1. Prototype interactive badge and associated belt clip.

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INTRODUCTION

We present a new type of wearable computing device in the form of an interactive belt-worn identity (ID) badge. ID badges are common in the workplace and they offer some interesting possibilities from an interaction perspective. In particular, we propose embedding a display in the badge to facilitate the presentation of nuggets of information in a manner which is very accessible to the wearer. By being on-hand and instantly available at all times, the badge may provide a quicker and easier way to access information than established mobile devices such as phones and slates. In addition, it can still fulfill its role as an identity badge.

Using a relatively small display to present a useful range of information either means displaying the information in a highly compressed manner or providing some way for the user to select a specific subset of content. We therefore propose a second key element to complement the LCD, a sensor embedded in the retractable string mechanism which detects movement of the string itself. In this way the extent to which the display is pulled away from the belt and its direction can be manipulated by the wearer to provide input, facilitating an immediate interactive experience.

In our experience, accessing and navigating information in this way can be quicker, require less attention and be more convenient than it is with conventional devices. Unlike a smartphone, the badge does not need to be retrieved from a pocket or bag, switched on and unlocked before interaction. It supports glanceable information consumption with single-handed operation, and simply 'letting go' of the device ends the interaction. Unlike touch-based interaction, the retractable string avoids occlusion of the display without unduly restricting the range of input in the way that physical buttons would.

We imagine that our interactive badge could be used to support short, lightweight interactions with applications and information throughout the day without unduly distracting the user. For example, the wearer can quickly manipulate the display in 3D space to navigate information intuitively, even when only a couple of seconds of interaction are desirable. Scenarios include access to email, social networking, calendar appointments and online services such as search, mapping, weather forecasting and traffic updates. Furthermore, this approach could provide an alternative to active notifications in some scenarios by displaying information in a more passive, glanceable manner.

In the remainder of this paper we first review related prior work, then we describe our prototype system in more detail before presenting an overview of the interactive possibilities and scenarios it affords. We do not quantitatively evaluate this new mobile device accessory but rather we aim to establish the concept, explore the interaction techniques it might afford and thereby demonstrate its potential. We end with a number of areas of future work which we think are important next steps.

RELATED WORK

The concept of a corporate identity badge as a wearable electronic device was explored by Want et al. in the form of the Active Badge [12]. This battery-powered device periodically transmitted a unique infrared signature which was detected by a network of infrared receivers to pinpoint in which room the wearer was located. Later iterations of the Active Badge included a buzzer and LEDs for user feedback plus two push buttons for input. The Active Bat developed subsequently used ultrasonic ranging technology to track location much more accurately [1]. Not only could the wearer be located in 3D space, but if they temporarily removed the Bat device from its clip or lanyard it could be used for handheld interaction in conjunction with both static posters and computer displays situated in the environment.

Falk and Björk described a different kind of wearable badge [4]. Their BubbleBadge was primarily designed to present visual information to those around the wearer and as such did not support dynamic interactions. Several researchers at MIT have also explored wearable display badges, for example the Uber-Badge [9] which supported peer-to-peer communication, resulting in dynamic information display.

Rantanen et al. described a self-contained smart clothing system developed for the Arctic environment [6, 7]. Their design included a 128x64 pixel monochrome display mounted on a retractable string which could sense the distance of the device from the user's body. The wearer could pull the device away from them to scroll through a 1D menu list and squeeze it to make a selection. No further details of interaction techniques or thoughts towards other potential application areas were given. The DistScroll system [8] enabled similar interactions and explored potential applications a little further.

Koch and Witt [10] proposed a richer retractable string sensor with 3D sensing. Their chest-worn input device monitored the extent and direction of pull. They evaluated this using a simple task where users selected 'voxels' displayed in a 3x3x3 grid on a computer monitor by moving the end of the retractable string to the corresponding 3D location and pressing a button. The study highlighted limitations of the hardware design – users found the trigger button cumbersome and the prototype was bulky – but showed that users could be more accurate in making selections with the retractable string. The authors suggested this is due to the natural mapping between the on-screen target and the physical 3D space used for interaction.

In another piece of related work [2], Blaskó et al. presented and discussed a retractable string built into a watch or other small device. The motivation was to provide an alternative to dedicated physical controls for immediate and atomic access to a portfolio of information sources, especially when device real estate is limited. The idea of incorporating display pixels within the retracting string was also presented. We imagine an interactive ID badge providing a similar role in terms of lightweight and immediate access to information but with a bit mapped display and single-handed operation.

PROTOTYPE HARDWARE IMPLEMENTATION

Our interactive badge prototype consists of two key elements: the belt-worn retractable string sensor and the attached badge display. Each includes a radio, embedded processor and battery; they connect wirelessly to a paired mobile device following a thin client architecture. This approach was chose to maximize flexibility although it relies on a nearby host such as a smartphone or slate.

We wanted the display to operate continuously so that it could be a substitute for a standard ID badge when not being used for interactive content. Our initial thought was to use a bistable display technology such as electrophoretic E-ink [3] or a zenithal bistable display [5] because these both maintain an image when power is removed. Unfortunately neither is suitable for an interactive display because they don't yet support the fast update rate required.

As an alternative we chose to use a 400x240 pixel monochrome Sharp LS027B7DH01 Memory LCD [11] for our prototype. This reflective LCD technology delivers a good contrast and resolution and is fast enough to support scrolling text and images. No polarizer is required resulting in a wide viewing angle and high optical efficiency, providing outdoor readability. A 1-bit memory element embedded in every pixel enables the display state to be held with very little operating current, meaning that always-on operation is realistic.

For the badge display we use an NXP ARM Cortex M3 processor with 32kB embedded SRAM and 512kB Flash memory, in conjunction with a standard Bluetooth 2.1 communication module (KC22 from KC Wirefree). Although the badge display is always-on, the processor and wireless module only need to operate during interaction. Our prototype, which does not include any power optimizations, draws around 60mA while communicating, allowing 4 hours of continuous interaction. When only the badge display is powered consumption is less than 1mA. We added 15 buttons around the bezel of the device to facilitate additional interactive possibilities. Figure 2 shows the badge display hardware.

The belt-worn string sensor contains an NXP ARM Cortex M0 processor, a KC22 Bluetooth module and a battery. Interaction with the badge display is sensed using a continuously-rotating potentiometer from Alps. The M0 processor contains a built-in analog-to-digital converter which we use to sample the two wiper positions with an 8 bit resolution. Pulling out the entire 60cm of string results in 8 complete rotations giving a sensed resolution of around 0.3mm. In practice there is a small non-linearity because the diameter of the coiled string decreases as it is pulled out, and there is also a slight variation depending on exactly how the string retracts. Coupled with sensor noise we get around 1mm resolution in practice. The angular sensing is achieved by threading the string through the center of a small analog joystick; an 8 bit analog-to-digital conversion process results in around 1° resolution across a total of 50°.

Sensed data is streamed from the belt clip to a mobile device such as a phone using the Bluetooth Serial Port Profile; graphical data passes from that device to the badge display in a similar manner. In practice we have found the latency associated with this architecture to be acceptable. Both the badge display and the belt-worn string sensor components incorporate lithium ion cells which can be recharged over USB. The badge display includes a DC-DC converter to generate a 5V supply for the memory LCD.

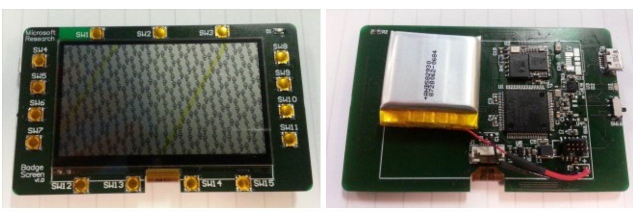

Figure 2. Interactive badge display hardware.

Whilst it did not make sense to overly miniaturize our first prototype, we wanted the hardware to be as compact as possible. The belt-clip houses the battery on the inside of the wearer's belt in order to reduce the extent to which the other side of the clip protrudes, see Figure 1. The display case itself is no larger than a standard corporate ID badge holder with dimensions of 90 x 55 x 8mm, see Figure 1 and 3. In particular, the depth of the badge is less than the Active Badge which was worn daily for many years [12].

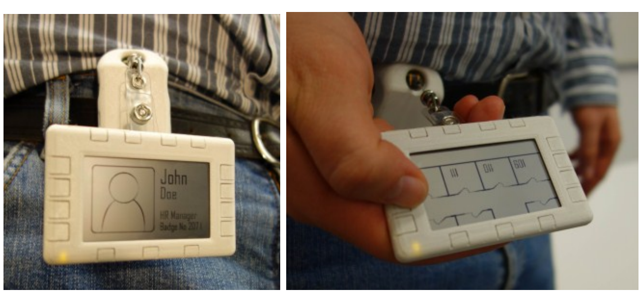

Figure 3. Prototype in 'identity' mode and showing a map.

INTERACTION TECHNIQUES

Although our prototype included several bezel-mounted buttons, informal evaluation quickly revealed that these afford much less natural interaction than the retractable string. For any given user and grip it is hard to comfortably manipulate more than 3 of the buttons when operating the badge single-handed, and even this can require re-grasping. Also, reaching some button locations occludes the display.

Whilst previous systems proposed that a retractable string sensor be used to split the 3D space into discrete zones [2, 7], the increased sensing resolution of our device (around 1mm as opposed to 3cm mentioned in the literature) allows us to complement this 'voxel' approach with a more continuous but layered conceptual model, see Figure 4. These complementary approaches are analogous to two of the Active Bat system interaction metaphors (virtual buttons and mice [1]) but our system imposes no location system infrastructure requirements. It also naturally creates an interaction space which is 'pinned' to the wearer; following them as they move around. If the belt clip is worn in a consistent position this allows the user to develop a clear spatial model of the interaction zones and layers. For example, holding the display directly in front of you at waist height could show a particular type of information such as calendar appointments.

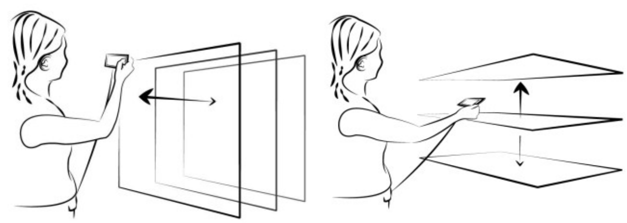

Figure 4. Layered interaction spaces in front of the user.

As an initial exploration of these interaction ideas we implemented an indoor map display system. When not in use, the badge display defaults to an image which represents the corporate ID badge it replaces. However, as soon as the badge is pulled away from the belt, the system activates a building floor plan display application. The premise of this is a virtual map of the entire floor of a building laid out in front of the user at waist height. The user can immediately reveal any part by moving the display to the associated point in virtual space and pressing a button on the display bezel. If the button is held down, the map can be panned across the display and it's also possible to move the display up and down to change to a different floor in the building. If part of the map needs to be consulted for longer, letting go of the button will freeze the display. When the wearer wants to finish the interaction, releasing the display will allow it to retract back to the belt clip whereupon the ID badge image is displayed once again and the badge can return to a very low power mode.

We evaluated the indoor map application informally with half-a-dozen work colleagues to get an early feel for its appeal and ease of use. Feedback was positive, several people commented that they found the interaction paradigm intuitive and one user was keen to evaluate it for longer (which has not been possible to date). Another user said that it would be better if the display update rate was faster.

During the development of this system we found that the choice of a fixed gain is not ideal in all cases. For example, when a user is in a situation where large movements would not be appropriate, e.g. seated at a desk or table, they may want a high gain so that they can navigate a relatively large virtual canvas easily. In such cases we can leverage the natural increase in resolution of sensed lateral position which results when the display is closer to the belt clip to support finer interaction movements.

We have also explored a number of additional interaction techniques such as a traditional clutching model using one of the bezel buttons. This allows the user to pan around an infinitely large virtual canvas and to compensate for any variations in the relative position of the display and belt clip. To make navigation more convenient we also explored a 'semantic zoom' mode. Here, a classic 'zoom' interaction where the image is magnified as the display is moved towards the eye is augmented by adding more details to the image at certain magnification thresholds.

DISCUSSION AND FUTURE WORK

During the construction of our prototype interactive badge and the subsequent development of the interaction techniques as described above, a number of new directions for this work came to light. From a technology point of view, a variety of enhancements could potentially extend the interactive possibilities afforded. Examples include a larger display with no significant bezel, a single 'squeeze' sensor which works using any reasonable grasp position and inclusion of an accelerometer, gyrometer and/or magnetometer in the badge. A view-angle dependent display could be used either to restrict visibility to viewers other than the wearer, or possibly to present different images to the wearer and to others. Exploring a colour display based on Mirasol technology would be interesting. We would also like to move to a Bluetooth Low Energy radio to support continuous low power connectivity which would allow a remote 'push' mechanism for image updates. Finally, we feel that touch sensing – either on the display or on the rear of the badge – would be useful. However, this wouldn't in itself substitute for the retractable string sensor because of ergonomics, occlusion and the smaller sensing region of the display as compared to the region over which the badge can be physically moved.

In addition to the above potential features uncovered during the course of this work, Koch and Witt [7] report on two interesting directions. Firstly, they used a conductor as their retractable string so they could pass data along it, a technique that we would like to leverage to enable both data and power to be transferred from the belt clip to the display element, thereby reducing the size of both. Secondly, they mention the use of force-feedback to provide feedback to the user during interactions, and we think this would be a useful way to assist an "eyes-free selection" stage which could precede a quick glance by the wearer.

We also want to deepen our experience of the interactive badge in use. We plan to do this in two ways: firstly there are a number of objective studies we have in mind, such as an evaluation of the number of discrete locations which users find useful and the repeatability with which they can return to them. Secondly we would like to deploy additional content and applications, like those mentioned in the introduction, with users for a meaningful period and get more realistic feedback about the merits and limitations of the device than our ad-hoc user feedback to date. Candidate scenarios include offering calendaring and contact information, access to social networks, traffic updates and so on. One idea we are excited to explore is the notion of a long-lived desktop GUI 'clipboard' where clipped content is associated with specific badge locations and may be retrieved by holding the badge in the relevant position before selecting 'paste' on the desktop. It would also be interesting to explore text entry using the badge (suggested by [7]) and gestural input – for control of displayed content and also for security applications such as access control.

Our ultimate goal is to further explore the design space of devices and techniques for mobile interaction. As we do this we hope to inform other practitioners working in related fields by sharing our experiences.

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