Towards Personalized Surface Computing

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ABSTRACT
With recent progress in the field of surface computing it becomes foreseeable that interactive surfaces will turn into a commodity in the future, ubiquitously integrated into our everyday environments. At the same time, we can observe a trend towards personal data and whole applications being accessible over the Internet, anytime from anywhere. We envision a future where interactive surfaces surrounding us serve as powerful portals to access these kinds of data and services. In this paper, we contribute two novel interaction techniques supporting parts of this vision: First, HandsDown, a biometric user identification approach based on hand contours and, second, PhoneTouch, a novel technique for using mobile phones in conjunction with interactive surfaces.

Keywords: Surface computing, user identification, mobile devices

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. – Input devices and strategies

General terms: Design, Human Factors, Algorithms

INTRODUCTION

Multi-touch surfaces support direct and natural use of both hands and greatly expand the range of gestural input, while offering a compelling platform for collocated collaboration. Recent advances in this field indicate that interactive surfaces might become an integral part of our everyday environments. Already, a steadily growing number of screens also double as multi-touch input devices, display sizes in general are increasing, devices are getting cheaper, and new form factors such as tabletops become commercially available.

Given this development, it is imaginable that interactive surfaces will turn into a commodity. We envision that wherever there is just a screen delivering output at the moment, this screen will also serve as input device in the future, hence allowing for direct interactions (e.g., large screens used for advertising at bus stops or airports will also offer the possibility to interact with them). In addition, we expect the mere number of interactive surface installations to grow; more and more regular surfaces will become interactive in home and office environments as well as in public spaces (e.g., furniture [12], wallpapers [3], or floors [2]).

UIST'10, October 3-6, 2010, New York City, New York, USA.

In an independent development, Internet access is already widespread and readily available, stationary as well as on the go. In this context, we can observe that a growing number of services and applications become available over the Internet. Instead of having applications installed or personal data stored on a local machine, they are easily accessible from anywhere online (e.g., webmail, distributed data storage and synchronization tools such as Live Mesh[1], or office applications such as Google Docs[2]). Consequently, users can access and work with personal information wherever and whenever they wish to, commonly by using their personal mobile devices these days.

We believe that a ubiquitous presence of interactive surfaces as outlined before has the potential of providing alternative, convenient, and more powerful points of access to services and data available online. Acting as portals to personal data, interactive surfaces offer large, high-resolution visualization capabilities as well as direct and natural ways of manipulation by means of multi-touch input. However, we do *not* foresee personal mobile devices to vanish due to their distinct characteristics (e.g., highly private devices, always at hand independent of building infrastructures). Rather, we envision a co-existence of personal mobile devices, complementing large and stationary interactive surfaces.

CONTRIBUTION

In my dissertation, I am taking first steps towards exploring this vision of ubiquitously present interactive surfaces. Specifically, I am designing and implementing novel technologies and interaction concepts to support instantaneous and fluid access to personal data on interactive surfaces.

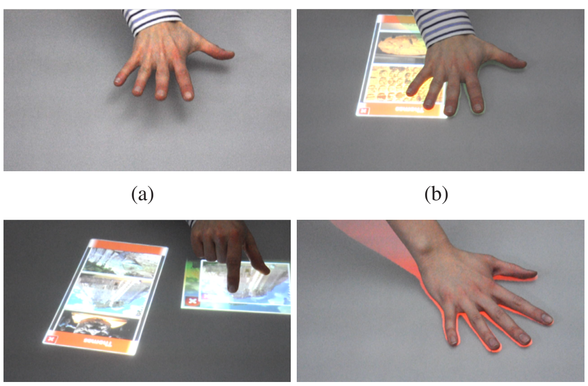
In doing so, my current approach is twofold: First, I am investigating techniques for user identification on interactive surfaces to address the issues of personalization and authenticated access to protected data on shared interfaces. Second, I am researching how to realize a fluid interplay between surfaces and mobile personal devices, for example to allow for data transfer between the personal and the shared context, or to act as a proxy for their user.

[1] http://www.mesh.com
[2] http://docs.google.com

USER IDENTIFICATION: HANDSDOWN

Although most interactive surface systems can track multiple points of contact, only few can distinguish between different users. Without this identification ability, all touches essentially look the same. Therefore, it is impossible to identify users, or tell apart input from different users interacting simultaneously. User identification enables a whole new set of interaction possibilities, such as complex gestures [5], multiuser-aware widgets [7], and access control [11]; users can instantaneously access personal data or customize interactions. For example, starting a browser application will bring up the user's personal start page, or touching the "My Documents" folder will show documents of the user who invoked the action.

To enable user identification for interactive surfaces, we developed HandsDown [9], a biometric approach based on hand contour analysis. The technique allows for instantaneous and fluid interactions; no user instrumentation or external devices are required.



(a) (b) (c) (d)

Figure 1: Here, HandsDown is used to identify users and access personal picture collections.

To identify, users put down their hand flat onto the surface, the fingers spread clearly apart (Figure 1(a)). For example, a personal picture collection can be retrieved and displayed in front of the user, once successfully identified (Figure 1(b)). HandsDown seamlessly extends conventional multi-touch on interactive surfaces: Users can manipulate elements using common multi-touch gestures, such as pinching to resize (Figure 1(c)). Appropriate feedback is displayed if an unregistered user attempts to identify (Figure 1(d)).

System

HandsDown is designed for interactive surfaces which can detect arbitrarily shaped objects in addition to finger touches (e.g., Microsoft Surface). After a hand has been put down flat onto the surface, we analyze its contour to localize hand extremities (i.e., finger tips and valleys). For each finger, we select a set of features, including finger lengths and widths. Support Vector Machines (SVM) are used for registering and identifying users based on the collected features.

To evaluate our approach, we collected 544 hand images of 17 different subjects and tested its performance using Receiver Operating Characteristics (ROC). We simulated six

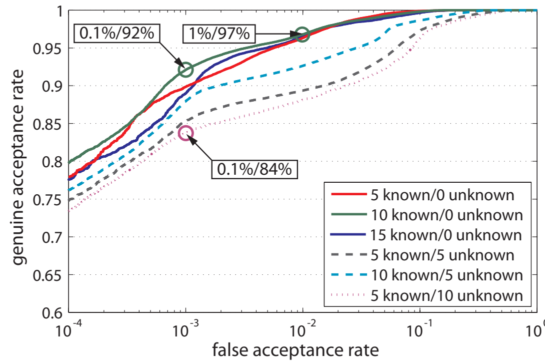


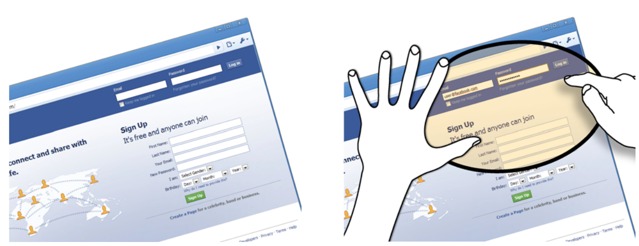
Figure 2: ROC comparison (tradeoffs between genuine and false acceptance rates as a function of classifier threshold). Three example rates are pointed out.

scenarios, differing in the numbers of known and unknown users. Here, a known user is someone which has registered with the system; an unknown user is someone who has not provided any hand contour information before. Ideally, a known user is identified correctly while an unknown user is rejected. Figure 2 combines the resulting ROC curves into a single diagram for comparison. Depending on application domains, the classifier's threshold can be adjusted to meet different security requirements, or rather tradeoffs between genuine and false acceptance rates.

Interactions

Using HandsDown as enabling technique, we propose IdLenses [10] as a novel interaction concept for dynamic interface personalization. On the lines of Toolglass and Magic Lenses [1], IdLenses exist on a transparent layer between applications and user input. In contrast to previous Magic Lens approaches [4], each user has its own personal lens. In other words, the users identity is always attached to a lens, hence enabling the dynamic customization of input and output.

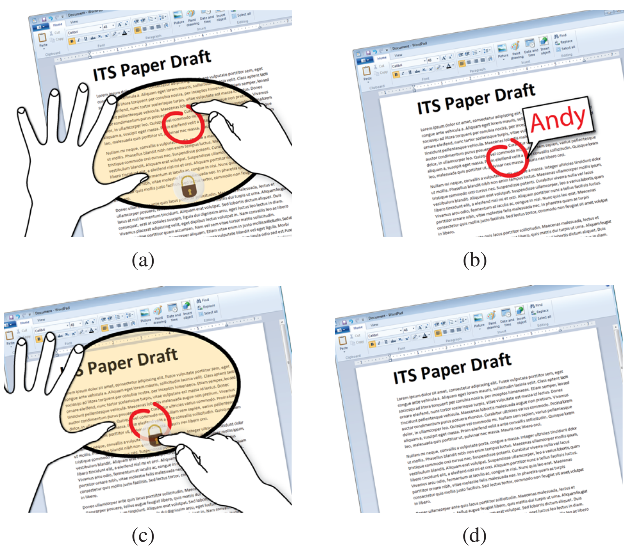
To open up a lens, the user puts down their hand on the surface. Once identified, the surface displays a personal virtual lens next to the hand. All touches made through the lens are associated with the users' identity, while touches outside remain anonymous. Further, content displayed through the lens can be personalized.



(a) (b)

Figure 3: (a) A protected web page requiring login. (b) Moving the lens over the login area automatically fills in credentials and enables login by simple touch.

So far, we developed a set of application scenarios for IdLenses using sketches and mock-ups. For example, while browsing the web, a click on "Login" on a protected web page such as Facebook or GMail would log in the user if performed through a lens (Figure 3). Appropriate login credentials are automatically retrieved, hence rendering unnecessary the input of a password on a public surface. In another example, IdLenses allows to access personal data attached to public objects. Moving the lens over a private or hidden piece of information makes it visible. In Figure 4, personal annotations attached to a document are revealed when moving the lens over it.



(a) (b) (c) (d)

Figure 4: (a) Adding a personal annotation to a document. (b) As entered through the IdLens, the annotation's author is known. (c) To make it private, the annotation is selected through a lock button. (d) Only the author can now see the annotation through their lens.

PERSONAL DEVICES: PHONETOUCH

When people interact with interactive surfaces, the question arises as to how their personal devices can be brought into play. The purpose of using personal devices might be to act as a proxy for their user (such that input events can be associated with different users), to affect control on the shared device, or to transfer data between the personal and the shared context.

Recent work has specifically investigated use of mobile phones in conjunction with interactive surfaces. Techniques have been presented for pairing of phones by placing them on a surface [13], and for localization of phones such that their position and orientation can serve as input. In both cases, interaction is affected by placing a phone on the surface, much like a token. In contrast, we propose a novel technique, PhoneTouch [8], for direct phone interaction on surfaces, where the phone is used like a stylus. This affords fast and fluid interactions on the surface, such as pointing and selection of targets, or copying of objects from the surface to the phone and vice versa.

System

The system design for PhoneTouch is illustrated in Figure 5. The principal idea is that all involved devices, the surface

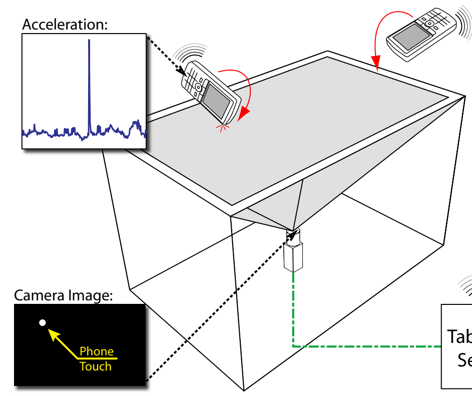


Figure 5: Surface and phones detect touch events independently. The device-level observations are communicated over a wireless network, correlated in time, and combined to associate a touch with both surface position and phone identity.

and the phones, independently detect touch events. Detected device-level events are time-stamped and communicated in real-time to a server, over a wireless link. The individual surface and phone events are matched based on their time-stamps, in order to determine PhoneTouch events. The PhoneTouch events combine complementary information contributed by surface and mobile device: location of the touch and identity and state of the phone. As the matching is based exclusively on synchronous timing, there is no requirement for use of specific sensors. This principle of using co-occurrence of events in abstraction of sensors has precedents in a variety of works such as *SyncTap* [6]. As the technique is based on event correlation in time, the system clocks of the surface and the phones need to be pairwise synchronized.

We implemented a prototype, using our custom built interactive tabletop based on frustrated total internal reflection (FTIR). Phone and finger touches are easily distinguishable by contact area size. On the phones (we used Nokia 5800 with external WiTilt V3 wireless sensors), we run a threshold based detection algorithm which identifies narrow, sharp peaks characteristic for touches.

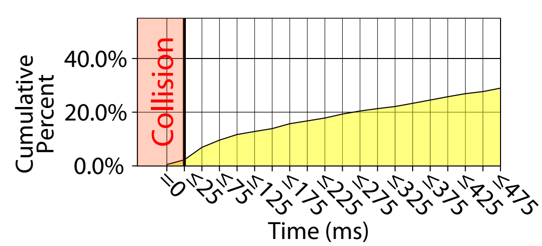


Figure 6: Temporal distribution of phone touches (time differences accumulated in intervals of 25ms).

An experiment with 12 participants (7 female) was conducted to first, verify finger versus phone classification performance on the surface and, second, analyze the temporal distribution of phone touches in a multi-user task. Participants in groups of three were asked to perform a series of selection tasks, some of them to be carried out using fingers and some using phones. The system achieved a correct phone classification rate of 99.99% while miss-classifying 5.66% of fingers as phones. Measuring time differences between successive phone touches, 97.7% of phone events could be detected without collision; Figure 6 shows a temporal distribution of phone touches. These results suggest the suitability of PhoneTouch for parallel use in small groups.

Interactions

Figure 7 illustrates the use of PhoneTouch in a scenario. Andy, Bart and Chris meet around an interactive tabletop. One of the friends, Andy, wishes to share a collection of photos he has taken on a recent trip. He takes out his phone, starts the picture sharing application, selects the photos, and then touches the tabletop. The selected photos immediately appear on the table, spread out around the point of contact (Figure 7(a)). He pockets his phone and the three friends start browsing the photos, using their fingers on the multi-touch table (Figure 7(b)). The friends enlarge several of the photos for a closer look at them and arrange them by interest. Bart and Chris take out their phones, also start the picture application, and pick up photos they would like to take home by touching them with their phones (Figure 7(c)).

(a) (b) (c)

Figure 7: A scenario of PhoneTouch interaction: (a) Andy transfers a collection of photos onto the surface. (b) With his friends he is browsing the collection. (c) Chris copies a photo to his phone by touching it.

CONCLUSION AND FUTURE WORK

Up to this point, I designed, implemented, and evaluated two novel interaction techniques for personalized surface computing: HandsDown, a hand contour based biometric user identification approach, and PhoneTouch, a technique for integrating mobile phones with interactive surfaces. Further, I started exploring the respective design spaces by sketching usage scenarios and implementing interactive mock-ups, based on HandsDown as well as PhoneTouch.

For future work, I first plan to investigate alternative sensing strategies for PhoneTouch (e.g., using an array of contact microphones on the table or employing the phone's built-in microphone for hit detection) in order to gain a better understanding of suitable sensor setups for a wider field of surface systems. Second, I intend to investigate the interaction design spaces of HandsDown and PhoneTouch in greater depth. In particular, I aim at implementing a set of the proposed application scenarios as working prototypes in order to further refine them based on feedback to be collected in user studies.

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