Unobtrusive Tabletops: Linking Personal Devices with Regular Tables

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Abstract
In this paper we argue that for wide deployment, interactive surfaces should be embedded in real environments as unobtrusively as possible. Rather than deploying dedicated interactive furniture, in environments such as pubs, cafés, or homes it is often more acceptable to augment existing tables with interactive functionality. One example is the use of robust camera-projector systems in real-world settings in combination with spatially tracked touch-enabled personal devices. This retains the normal usage of tabletop surfaces, solves privacy issues, and allows for storage of media items on the personal devices. Moreover, user input can easily be tracked with high precision and low latency and can be attributed to individual users.

Keywords
Tabletop, interactive surface, mobile device, multi-touch, touch screens, camera-projector system, collocated collaboration, smart environments

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces—*input devices and strategies, interaction styles*.

Introduction

Our vision of tabletop systems and interactive surfaces is one that relies on unobtrusive systems. By this, we imply that the interactive surface relies on the lowest possible amount of technology, which is set up in a way that it does not intrude on the user's experience. For example, we envisage the use of regular tables which are augmented by overhead cameras and projectors (which, for example, can be mounted inconspicuously in the room's ceiling directly above the table) to become interactive surfaces. Thus, the materials, the haptics, and also the durability of these interactive surfaces will appear to be that of a normal piece of furniture, which is typically carefully selected and to which users have an emotional binding. Indeed, whether or not the augmenting components are in use, the table can be used for its original purpose. In our vision of unobtrusive interactive tabletops we follow the idea of minimalism in ubiquitous interface design [8], which allows computational augmentations to coexist with unmodified artifacts and strives to preserve their aesthetics.

Advantages and Possibilities of Mobile Devices on Interactive Surfaces

Mobile devices—and mobile phones in particular—are increasingly used in collocated situations. We believe mobile phones to be an ideal input device for unobtrusive interactive surfaces. Mobile devices not only provide input capabilities through their keypads or their touch screens, they can also be used as a physical widget if they are spatially tracked. Fitting with our theme of unobtrusiveness, using mobile devices for input reduces the technological footprint of interactive surfaces, because additional tracking technologies, such as FTIR [3], are not required to enable interaction with the surface.

Moreover, the mobile phone provides a means for personal data storage. This can either be data the user intends to share with other users of the interactive surface or data that is generated by using applications on the interactive surface. The storage capabilities of mobile devices allow users to directly save the result of their work, or to continue their work at a later time. The security of the data is improved as the interactive surface is generally not required to store the data for use in a future session. Using a mobile device also permits the user to access online resources for use with the interactive surface in a private way.

The mobile device represents a private space for the user's data, as opposed to the public space of the interactive surface. This also applies to the mobile device's screen. As it can be tilted away from the view of other users, it can function as a private visualization area, for instance allowing the user of the mobile device to browse his photo collection for the photos he wants to share with the other users of the interactive surface.

A further advantage of using mobile devices on interactive surfaces is that they afford tangible interaction techniques, such as lifting, tilting and shaking gestures. Even more gestures can be detected by tracking the user's hand with the device's front camera (if the device is equipped with one). Such techniques can be used to manipulate and modify objects on the interactive surface, for example scaling images on the surface through tilt actions. Orientation changes of the device can also be mapped to actions on the interactive surface.

Using mobile devices on interactive surfaces also solves a common problem [2] which occurs with such interfaces—assigning a user identity to inputs on the surface. Using mobile devices for input on interactive surfaces allows the surface to imply the user identity from the device's identity.

A couple of projects use mobile devices in combination with large displays, including Remote Commander [1], which enables to use the touch screen on a PDA as a trackpad to control the relative position of a cursor on a remote display. Augmented Surfaces [6] tracks laptops on tables using printed 2D barcodes. BlueTable [7] tracks devices on a surface using IrDA.

Interaction Paradigms

In the following we detail interaction possibilities, which are enabled by personal devices that are tracked on tabletop surfaces. We differentiate between interactions based on device position and orientation on the table, interactions performed on the device itself (e.g., enabled by device touch screens), and rapid gestural interactions with the device (e.g., enabled by integrated accelerometers).

Spatial Interaction

We developed a camera-projector system that is able to spatially track dynamic markers displayed on the device screen [4] in order to identify devices present on the table. The marker is bar-shaped and thus only consumes very little screen real-estate (see Figure 1). One or more cameras observe the tabletop. The marker recognition system reports device positions and orientations (in a coordinate system defined relative to the table). Taking marker size into account, the system can also detect whether the device is placed on or lifted from the table. Device positions and orientations can be interpreted relative to other devices present on the table. This allows assigning specific application semantics to device configurations (such as proximity regions [4]). Marker recognition can be enhanced by optical flow detection to track devices during fast movement.

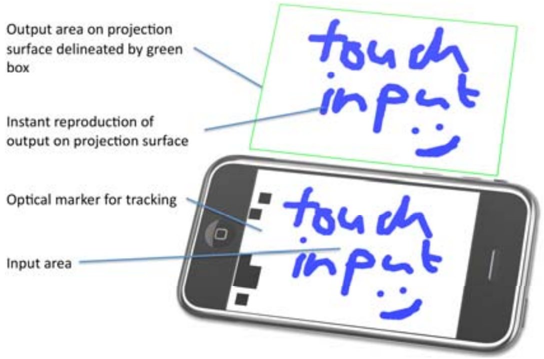

Figure 1. Touch screen-enabled graffiti projection.

Device-bound Interaction

Current devices provide a wide range of features to capture interactions, such as buttons, (multi-)touch screens, front-side cameras, and integrated sensors. On the output side built-in projectors can project onto the table and enrich fixed ceiling-mounted projection. Device-based audio output can generate local audio to augment movies projected onto the tabletop. A general problem of device-enabled interactions is that the feature sets of mobile devices are very diverse. For a more general system designers would therefore need to either agree on “lowest common denominator” or the system would have to discover the available features and adapt the interactions accordingly.

Visually tracking fingers or hands on the table is usually difficult to do robustly. Precision and speed are limited by the resolution and frame rate of the camera. Moreover finger-tracking systems typically cannot distinguish between users. This is problematic in multi-user situations. Therefore, we use the touch-screens of spatially tracked personal devices for reliable high-resolution multi-touch input and simultaneous user identification. Each input action can thus be attributed to a particular user.

Gestural Interaction
With integrated accelerometers device tilts and fast movements can be tracked. Changing the tilting angle can be used for obtaining a better reading angle compared to looking at the table directly. Tilting can also be used for driving interactions, such as dropping information from the device onto the table [1]. Tilting angle can be mapped to continuous parameters, such as zooming. Moreover shake gestures can trigger discrete events.

Scenarios

A first scenario for unobtrusive interactive surfaces is to place them in public spaces, such as pubs. Standard pub tables could be augmented to become interactive surfaces, allowing interesting interactive applications adapted to the setting. Apart from allowing the pub’s patrons to order meals and drinks via the interactive table, videos could be displayed on demand or collaborative games could be played using the system. Additionally, an interactive pub table could allow for anonymous inter-table communication, or also the exchange of personal media such as photos. Applications of this kind are likely to be desirable and fun in social settings such as pubs.

An unobtrusive tabletop could also be used in a more secluded setting such as a conference room. Here, the tabletop could be used to synchronize the calendar items of meeting attendees or to record and share meeting notes. Note-taking or mind-mapping applications could use OCR to generate text from strokes entered on the devices’ touch screens. The advantage here is that every meeting participant would not only see the entire mind map on the interactive surface, but also have a local copy on his device to take away at the end of the meeting.

Prototype

We have implemented a prototype of an unobtrusive tabletop system. A projector provides output for the interactive surface, which is set up on a normal office table. iPhones, which display a visual marker, are tracked using an overhead camera mounted next to the projector. To place a note, users connect their mobile devices to the interactive surface via WiFi. The interactive surface then assigns a marker ID to be displayed by the user’s device. Thus, the input of a specific device can be mapped to its current location which is provided by the marker tracking. The users can enter notes or drawings (“graffitis”) on the interactive surface by using the device’s touch screen. A rectangle is displayed on the surface to indicate where the user’s note will be placed on the surface. This rectangle can also used as a cursor to select and modify a note at a later time (see Figure 1).

Summary and Challenges

We have argued that linking mobile devices with tabletop displays has lots of benefits with regard to unobtrusiveness. Mobile devices can be spatially tracked, can store personal data, can access online resources, can provide high-fidelity (multi-)touch input, and enable accelerometer-based gestural interactions. They increase display flexibility in that they can be lifted from the tabletop surface for better reading angle or reading distance and provide a private information display.

Unobtrusive tabletop systems, such as the one we have proposed have several limitations, which must be improved on in the future. For optical tracking a high frame rate is desirable to allow for fluid interactions. The input capabilities depend on the characteristics of the devices used with it. Due to the large variety and differing capabilities of mobile devices, it may be difficult to create a system that supports and adapts to a wide range of devices. Obviously, a more general system can only offer a very limited set of input methods compared to a system tailored towards a single device.

Using mobile devices as physical widgets also has some limits. For one, the effectiveness of tilt-interaction with mobile devices depends for a great part on the reading angle of the tilted display. For another, there are size constraints to spatial interaction, as the users will face reachability problems if the distances become too large. In effect, this constrains the size of the interactive surface if spatial interaction is used. However, such reachability issues are a general problem of large display surfaces and mobile devices can potentially provide interaction techniques to help solve them.

Beyond these technical challenges it is important to explore user acceptance in real settings. We need to investigate how social processes of collocated users are affected by such systems and whether they are perceived as useful.

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