

# Seamless and Continuous User Identification for Interactive Tabletops Using Personal Device Handshaking and Body Tracking



Figure 1. An example of a user's personal device.

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## Abstract

Touch-based tabletops are a form of embedded device for group collaboration. This work tackles two key problems for effective use of such tabletops: there is currently no easy way for people to identify themselves to the table; and most current hardware does not link a person's touches to their identity. This paper presents a system which tackles these problems as it can identify users and keeps track of their actions around interactive tabletops. To start the user identification, a user puts their personal device onto the interactive surface. Once this is paired with the tabletop, linking the device owner's identity to the table, the system continuously tracks any touch by that user. The system seamlessly and continuously associates each user touch with an identity.

## Author Keywords

Context awareness; interactive surfaces; user tracking; user identification; collaboration; tabletops.

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## ACM Classification Keywords

H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces—collaborative computing.

## Introduction

Identifying user actions on the tabletop is important to allow users to share and keep track of their personal information, to associate individual contributions in collaborative activities and to provide personalised experiences. To date, there is no unobtrusive way to accomplish user identification and tracking at the tabletop. Previous systems, such as DiamondTouch [1] and Collaid [2] could track users but not identify them and HandsDown [3], which used hand biometrics, authenticated users but did not support walk up use. Previous systems for user identification have required users to manually associate their identity with specific gestures [3] or gadgets that they have to wear [1] which made them less seamless.

We explore the use of personal devices to provide a method for continuous user identification on tabletop surfaces. In this system, all users are tracked by a depth sensor placed above the tabletop. When a personal device is put down by a user, the tabletop locates it on the table, connects to the device, and associates the identity from the device to the tracked touches on the tabletop.

The personal device can support content sharing on the tabletop and controls for privacy. In our system, once identified, tracked users are only removed from the system

tracking after they are out of range of the overhead camera. This permits flexibility for users to move, change the position of their devices, pick it up and even place it in their pockets. It also allows monitoring of physical interactions around the tabletop even if users change seats or move around.

Our contribution is to provide a system that combines both user tracking and identification on the tabletop that is seamless and unobtrusive to the user. Furthermore we provide the means to log user's activity as a basis for contextually-aware tabletop applications and efficient data collection for the user.

### **Related Work**

There has been a significant amount of work on both user tracking and identification at a tabletop, but it has restricted users in various ways (e.g. by asking them to wear gloves, use pens, or remain seated at a specific spot). This section explores the two areas of our contribution: tracking users on a tabletop and ways that mobile phones can communicate with tabletops.

### **User Tracking**

One of the first commercially available tabletop systems that supported user tracking was the DiamondTouch [1]. This identifies every touch on the tabletop. It uses capacitive coupling on the tabletop with a pad that the user sits on. More recent systems such as Collaid [2] support user tracking using an overhead depth sensor device to follow user silhouettes and link touches to a user. Another approach tracked a user's location and arms through an array of proximity sensors around the table as in Medusa [4]. Dang et. al. [5] distinguished hands from the shape and angle of user touches on an FTIR table. What is common among these systems is that they allow for user tracking on the tabletop; however they do not provide the table with information on a user's identity.

A system that has authentication is HandsDown [3]. This provides a way to authenticate users by analysing hand contours. This allows a person to login by placing their hand on the tabletop – with an overhead camera scanning the surface to register the hand. It has the limitation of requiring users to pre-register biometric information on the tabletop, meaning it cannot support walk up use.

### **Mobile Phone Interaction**

Since so many people have personal mobile phones that they usually carry, it is natural to explore ways to make use of a mobile phone in conjunction with embedded tabletops. Previous work has explored mechanisms to track and connect multiple mobile phones with interactive surfaces with the purpose of sharing personal content. BlueTable [6] can establish a connection between phones and tabletops to identify the phone and to enable transfer of information. When a phone is placed on the tabletop, each available phone in Bluetooth range is asked by the system to flash its display or infrared light (if equipped). This change of light is tracked by an overhead camera which detects the phone position. PhoneTouch from Schmidt et al. [7] use phone accelerometers to identify which phone is in contact with a tabletop and use it to select targets on the surface, facilitating a pick and drop style transfer of objects between devices. By matching the accelerometer to the visual fingerprint of the phone, they demonstrated a quick and easy way to identify and use devices on a tabletop.

Our work goes beyond previous work, as it provides user identification and subsequent tracking of that user's actions at the table. Importantly, it operates in conjunction with a wide range of tabletop hardware and standard mobile phones. Its combination of identification and tracking can support: personalisation; context aware applications; and new services for users and researchers.

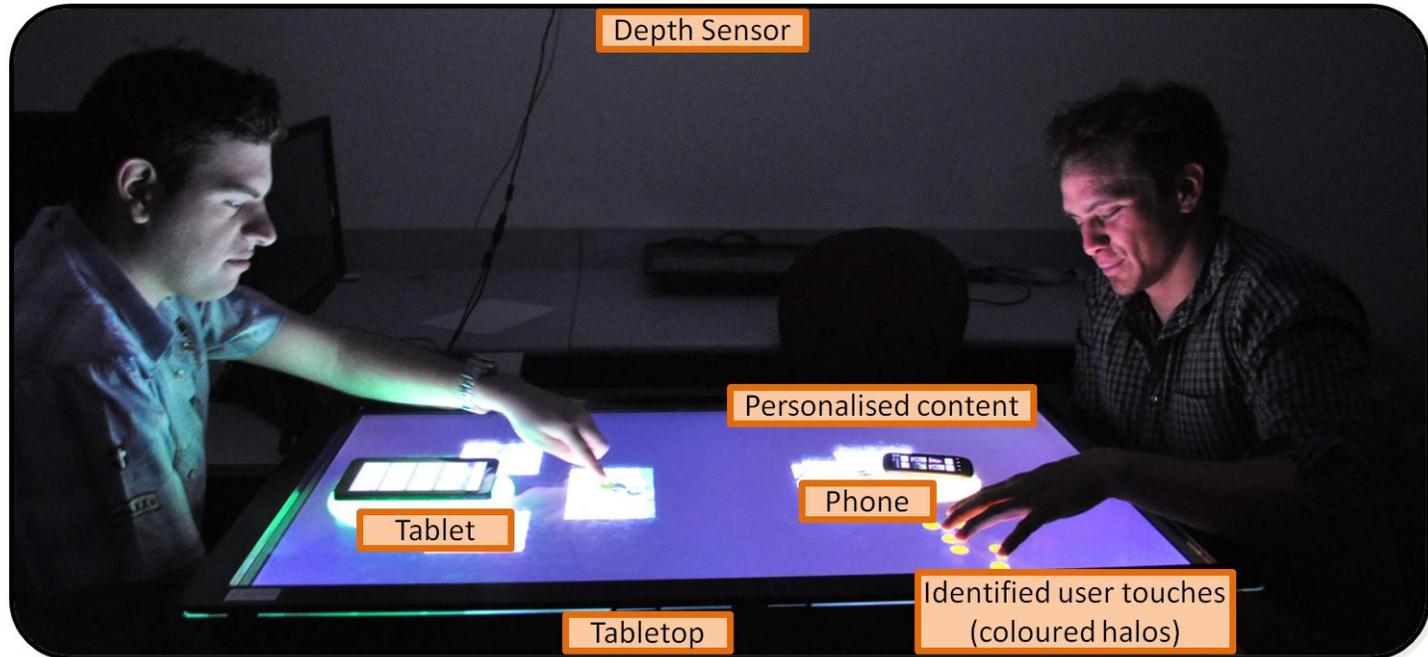


Figure 2. The Tracking System. On top – a high level overview. On the right – the real-life system.

In this scenario there are two users. Both have been identified by the system – indicated by green halos on the left user’s touches and yellow halos for the user on the right.

The system consists of:

- 1) A depth sensor mounted above the tabletop.
- 2) A tabletop. We use an off the shelf multi-touch screen.
- 3) Personal devices. For example a tablet or phone.

The system allows:

- 1) Identified user touches.
- 2) Personalised content to be sent from the device to the tabletop.

### System Overview

The system integrates an interactive tabletop and personal devices, using a depth sensor for continuous tracking of touches that are linked to an identified user. Figure 2 shows the system in use. We now discuss its architecture, with an overview in Figure 3. The system operates in the following steps labelled in Figure 2 and 3:

1. The Depth Sensor sends data about people and objects to Collaid and the Tabletop sends touch and object information to the system.
2. The System Application forwards received data from the tabletop to Collaid.
3. Collaid determines the users and objects and starts to track them anonymously.
4. The System application upon receiving object data (from Step 1) sets a colour under the object to initiate a handshaking protocol for establishing an identity.
5. The phone detects the colour with its camera (when instructed by a request) and sends it to the system application to be processed.
6. The system application matches the processed data from Collaid to the data from the tabletop and displays feedback on the tabletop.

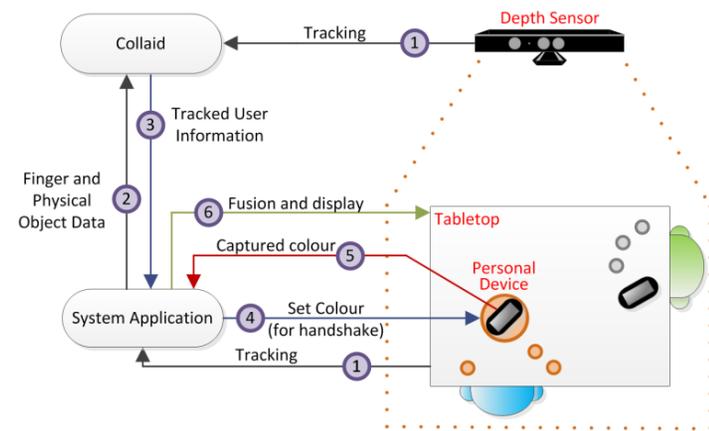


Figure 3. Architectural View of the System.

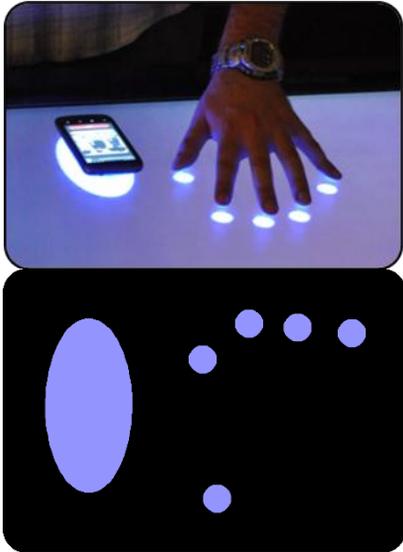


Figure 4: The tabletop distinguishing between fingers and devices.

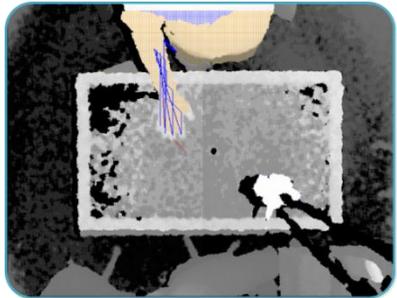


Figure 5: Depth information captured by the overhead mounted sensor used to track hands and bodies above the surface.

This architecture makes it possible to identify and tracker users on general tabletop hardware inexpensively. Its features are summarised in Table 1.

Feature	Explanation
Multi-touch	Can be integrated with arbitrary multi-touch hardware.
Multi-user	Can deal with many users, limited by tabletop size.
Tracking	Follows user movement and touch interactions on the tabletop.
Identification	Links touches and user objects to an identified user.
Personal devices	Devices allow for user identification and permit sharing of digital resources.
Inexpensive	The system uses off the shelf items, thereby allowing other systems to easily integrate.

Table 1: Features of the System

#### Tabletop Hardware

Our current implementation uses a 42 inch commercial LCD display with a multi-touch overlay<sup>1</sup> that detects touches and rudimentary objects (Figure 4). Information is sent using a custom TUIO<sup>2</sup> server. Our system is flexible to accommodate other types of tabletop hardware as well.

#### User Tracking (with a depth sensor)

Continuous user tracking is performed by a tracking environment called Collaid [2]. The Collaid system can plug into various available tabletop hardware to capture information around the touches and objects on the interactive surface. It makes use of an overhead depth

<sup>1</sup> PQLabs: <http://multi-touch-screen.com/>

<sup>2</sup> TUIO protocol: <http://www.tuio.org/>

sensor<sup>3</sup> that captures each user's body and arm positions of a number of users above the interactive surface. We pair the depth images generated by the depth sensor with each touch performed on the interactive tabletop identifying the finger that is touching the table in that position, at that precise moment.

When a user's fingertip touches the tabletop, the system pairs the contact spot with the closest finger to that zone. Next, using a modified greedy search algorithm, the system follows the shape of the hand and body detecting the arm span of the user. Figure 5 shows a visual representation of the algorithm process when a user places their fingers on the tabletop. The system recognises the owner of the touches according to their position around the table. In this way, any direct manipulation on the tabletop is associated with a specific user in a non-intrusive manner and in real time.

#### Personal Devices

A personal device, such as a mobile phone or tablet (with equipped camera), provides the means to associate an identity with a tracked user. We used a HTC Nexus One and a Samsung Galaxy Tab both running Android 2.3. We created a plain mobile phone application that stores a unique user-id and communicates it with the tabletop (Figure 1).

We implemented a handshaking protocol based on colour detection. Colour detection was chosen as it is a method that works when the phone is placed down, not requiring special tags or bar-codes to be generated, or the device to be picked up again such as with an accelerometer. Each colour is paired to a user detected by Collaid, and is recycled when a user walks out of the field of view.

<sup>3</sup> Kinect sensor device: <http://www.xbox.com/kinect>



Figure 6: Sharing content from the personal device to the tabletop. In this scenario, the user selects the gorilla picture from the phone and this appears on the tabletop.



Figure 7: The user's device and their touches are tracked and identified. The phone's region has turned from an oval to a circle halo, as have the user's touches.

The steps of the handshaking protocol are as follows:

- 1 **Register the device with the application (Figure 1).**  
*The device connects to the tabletop through a wireless network and its unique hardware identifier.*
- 2 **Place the device on the tabletop (Figure 4).**  
*The tabletop recognises a physical object has been placed by a user, it displays a coloured oval (associated to the tracker user) around the object and broadcasts a handshaking request to all registered un-paired devices.*
- 3 **The device sends back a colour.**  
*Upon receiving the handshaking request, the device uses the camera to capture the colour, resolves it and sends it back to the tabletop.*
- 4 **The system fuses the sensor inputs together (Figure 7).**  
*The system uses the information to figure out which registered device was placed down, and links the identity with the appropriate tracker user.*

After initial setup of installing and launching the application, it takes a short period for the device to be paired to a tracked user. Once a device has been identified and paired with a user, the system will continuously track the touches of that user even if the device is removed from the tabletop. The device need not be tied to the tabletop and can be used for other purposes, such as viewing personal content or selecting files to share with other users. Removing it from the table may also be desirable to avoid clutter, freeing up the interface for collaboration, or alternatively be used as a private space.

### User View

We created a photo sharing application. It enables users to share photos that are on their phones at the tabletop. When a user places their phone on the tabletop the system performs the identification process described earlier. The phone loads appropriate data from its library as shown in

Figure 6, where the phone has a yellow halo and all touches create small yellow halos, as in Figure 7.

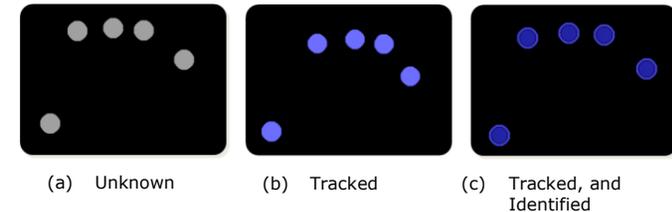


Figure 8: Real-time system feedback to the user.

The actual colour each user sees gives visual feedback about the current state of the system as shown in Figure 8. Unidentified touches have grey halos. When a person has been detected, their touches are tracked and associated with them, and the associated colour used, shown here as light blue. Once the person has also been identified, the colour becomes a deeper coloured halo.

### Discussion and Further Work

This paper introduces a system for seamlessly and continuously tracking the interactions of groups of users using a multi-touch interactive tabletop. Our approach relies on the integration of readily available technology to support user identification and capture actions that occur on and around the interactive surface.

The purpose of this system is to make the surface into a digital environment that is aware of users' interactions with the tabletop, their physical position and their activity over the surface. Combining user identification and user tracking on a shared tabletop surface permits the tabletop to become more aware of its users as they interact on the tabletop, near it and with each other. This allows for elements of personalisation of content or activities, privacy control and proxemic interaction.

This is useful, for example, when two people walk up to a tabletop in a workplace meeting room. They each place their device on the tabletop. It identifies them, and then offers projects this group works on at that table and as it is in a meeting room, automatically loads and makes accessible files and resources needed for an impromptu meeting. This could also facilitate multiple personas on the device – each representing a different role or profile for different projects a person works on.

Another example concerns privacy. This involves being able to share information as one wishes [8]. The user may be presented with a tiered privacy control when they walk up to a tabletop to use it with their private device. They can then share private material and ensure that only they can interact with it. In addition, if a device is removed from the tabletop, the system could automatically remove private content. There could also be mechanisms to leave less private material on the table until they move away from the table.

One other valuable use for our system is to create new ways to capture the digital footprints of users without impacting the main task. This rich information can be exploited by statistical analysis tools or data mining algorithms to find useful patterns in the collaborative interactions and model the processes of communication and the group activity [2].

The next steps in this research project include the evaluation of the system by integrating it into a number of collaborative applications. We aim to support regular collocated meetings in which users can share personal information. We will also apply user identification to provide adapted support through collaborative tabletop learning applications and the

use of tools to investigate patterns of interactions that can help learning.

### Acknowledgements

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