Bumping Objects Together as a Semantically Rich Way of Forming Connections between Ubiquitous Devices

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ABSTRACT

This research explores the use of distributed sensors to form dedicated and semantically rich connections between devices. For example, by physically bumping together the displays of multiple tablet computers that are facing the same way, *dynamic display tiling* allows users to create a temporary larger display. If two users facing one another instead bump the tops of their tablets together, this creates a *collaborative face-to-face workspace* with a shared whiteboard application. Each tablet is augmented with sensors including a two-axis linear accelerometer, which provides sufficient information to determine the relationship between the two devices when they collide.

Keywords

Distributed sensors, context aware, multi-user interaction

INTRODUCTION

Establishing meaningful connections between devices is a problem of increasing practical concern for ubiquitous computing [3][4]. Wireless networking and location sensing can allow devices to communicate and may provide information about proximity of other devices. However, with many devices nearby, how does a user specify which devices to connect to? Furthermore, connections need semantics: What is the connection for? Is the user collaborating with another user? Is the user combining the input/output resources of multiple devices to provide increased capabilities? Users need techniques to intuitively form semantically rich connections between devices.

This research proposes physically bumping two devices together as a means to form privileged connections. Bumping introduces an explicit step of intentionality, which users have control over, that goes beyond mere proximity of the devices to form a specific type of connection. For example, dynamic display tiling [2] enables users to combine the displays of multiple devices by bumping a tablet into another one lying flat on a desk (Fig. 1). Users can also establish a collaborative face-to-face workspace [1] by bumping the tops of two tablets together (Fig. 2).

Bumping generates equal and opposite hard contact forces that are simultaneously sensed as brief spikes by an accelerometer on each tablet. The software synchronizes the data over an 802.11 wireless connection; two spikes are considered to be simultaneous if they occur within 50ms of one another.

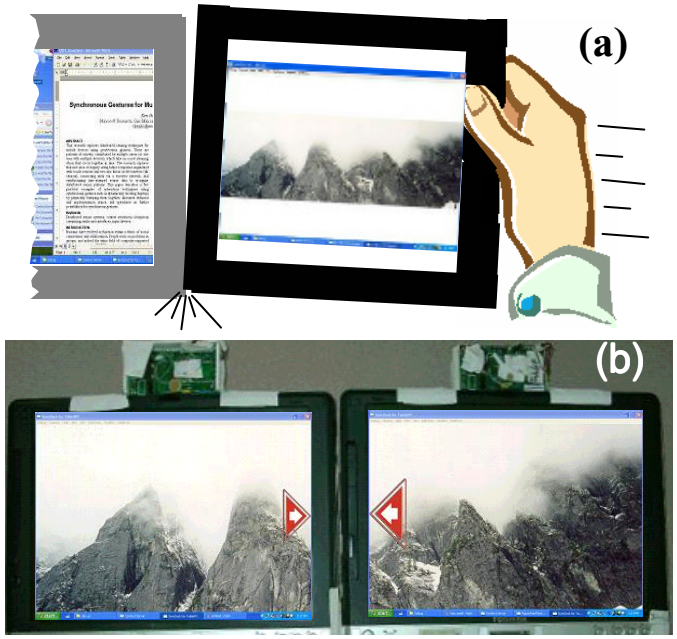

Fig. 1 (a) Dynamic display tiling by bumping together two tablets that are facing the same direction. (b) The tablets form a temporary larger display, with the image expanding across both screens. Small arrows provide feedback of the edges involved in the dynamic display connection.

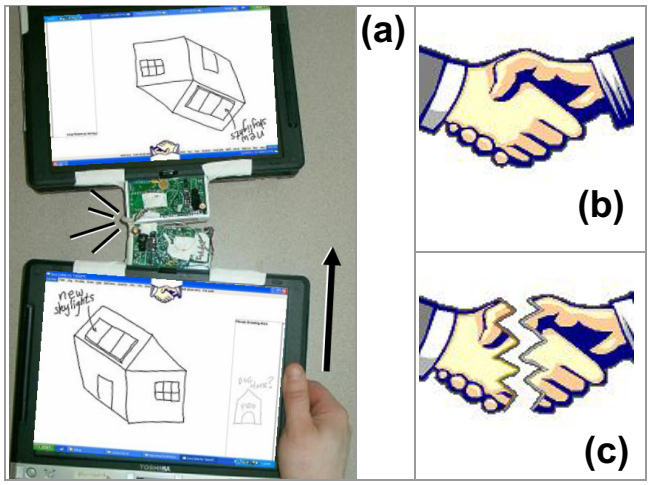

Fig. 2 (a) Face-to-face collaboration by bumping the tops of two tablets together. The sketch is shared with the other user for annotation. Also shown: feedback for (b) making or (c) breaking a collaboration connection.

The two orthogonal sensing axes of each accelerometer provide enough information to determine which edges of the tablets have collided, allowing tiling of displays along any edge (left, right, top, or bottom) or sensing that the tablets are facing one another when bumped together in the case of face-to-face collaboration. Example accelerometer data from bumping two devices together is shown in Fig. 3, as well as simultaneous but incidental handling of the devices. The software can ignore most such sources of false-positive signals. Details of synchronization and gesture recognition appear in [2].

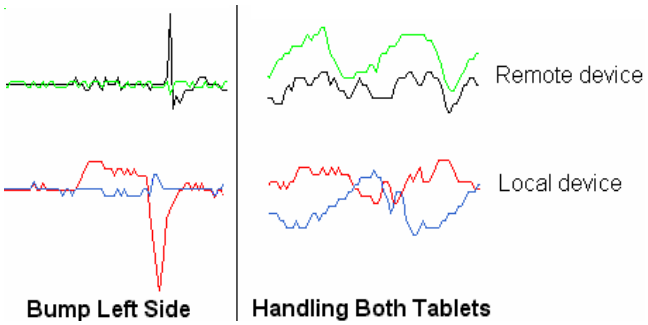

Fig. 3 **Left:** Example accelerometer signature for bumping two tablets together, with forward-back and left-right accelerometer axes for the local and remote devices. **Right:** Incidental handling of both tablets at the same time results in signals that are distinct from intentional bumping.

For dynamic display tiling, one tablet (the *base tablet*) rests flat on a desk surface, and a second tablet (the *connecting tablet*) is held by a user and bumped into the base tablet along one of the four edges of its screen bezel. Note that this creates a hierarchy in the connection. The connecting tablet temporarily annexes the screen real estate of the base tablet. The software currently distinguishes the connecting tablet from the base tablet using capacitive touch sensors to determine which of the two tablets is being held.

Appropriate feedback confirming that a connection has been established is crucial to the techniques. Users are shown the type of connection being formed using overlaid icons on the screen as shown in Fig. 2 (*b, c*) for face-to-face collaboration; analogous "connection arrow" icons for dynamic display docking can be seen in the video. Furthermore, because the techniques involve two users, one user's attention may not be focused on the tablets; hence it is important to provide audio feedback as well. Tiling two displays together makes a short metallic clicking sound suggestive of a connection snapping together. A different sound reminiscent of slapping two hands together occurs when users establish face-to-face collaboration.

For display tiling, picking up a tablet removes it from the shared display. By contrast, for face-to-face collaboration, users may want to move their tablets apart but continue collaborating; hence moving the tablets apart does not break the connection in this case. Instead, users can explicitly break the connection by drawing a slash across the handshake icon (*Fig. 2b*), or the system automatically breaks the face-to-face connection if one of the users walks away (walking can be sensed using the accelerometer [1]).

Users can also exchange information by bumping tablets together just as people at a dinner table might clink glasses together for a toast. This is distinguished from display tiling by sensing that both tablets are being held (as opposed to one being stationary on a desk). Finally, one user can "pour" data from his tablet into that of another user by angling the tablet down when the users bump their tablets together [2]. These variations shown in the video suggest additional ways to enrich the semantics of connections that can be formed based upon bumping objects together.

RELATED WORK

Smart-Its Friends and ConnecTables form distinguished connections between multiple devices. Smart-Its Friends infers a connection when two devices are held together and shaken. ConnecTables [4] are wheeled tables with mounted LCD displays that can be rolled together so that the top edges of two LCD's meet, forming a connection similar to the collaborative face-to-face workspace proposed here. Both [3] and [4] can form only one type of connection, whereas bumping two objects together can support multiple types of connections. Furthermore, bumping can specify additional parameters, such as which edges of two separate displays to join, or determining which tablet is the connecting tablet (as opposed to the base tablet) to provide a direction (hierarchy) to the connection.

CONCLUSION

This work contributes a novel and intuitive mechanism to form specific types of connections between mobile devices. When bumping two tablets together, a connection is formed in the physical world by manipulating the actual objects of concern, so no naming or selection of devices from a list is needed. Bumping can support several different types of connections, including dynamic display tiling, face-to-face collaboration, or "pouring" data between tablets. Here we focus on multiple Tablet PC's, but in the future, dynamically combining multiple heterogeneous devices could lead to compelling new capabilities for mobile users.

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