Mobile instruments for multi-surface interaction

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Abstract
Increasingly portable and wearable computing devices offer a rich interactional capability for multi-surface environments. We argue that these environments offer an exciting opportunity for collaborative and dynamic interactions that will require us to develop new interaction models. We use instrumental interaction as a framework to guide our approach to allowing users to express interaction using a blend of personal devices and shared multi-surface environments.

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multi-surface interaction, instrumental interaction, collaboration, wall-sized displays

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H.5.m [Information interfaces and presentation (*e. g.*, HCI)]: Misc.

Introduction
With recent advances in technology, general computing users are beginning to realize the ubiquitous computing dream [12] of personal, portable computing devices. People increasingly carry with them not just nomadic devices such as laptop computers or tablets, but also may always have a smartphone in the pocket or purse. Furthermore, more personal "devices" such as watches,

jewelry, and clothing are become computational or interactive devices.

We imagine a not-so-distant future in which the things that people carry with them, such as some subset of rings, bracelets, watches, necklaces, clothing, and smartphones, may offer a rich set of personal and personalized interactional capabilities. The personal nature of these devices may be in the form of merely containing personal data or a personal profile of the user, or perhaps a rich understanding of the user gained through the sensor capabilities of the device.

Beyond this intimate understanding of the user, these devices may also present a collection of rich interactions. For example, a ring may enable the user to perform in-air gestures [1] or very precise movements as with the knob of a fine stereo. A bracelet may provide for simple sliding or contact gestures around the wrist [8], while a smartphone might allow for the user to extend the capabilities of the environment with a high-quality camera. Just as these devices may be able to extend the interactional capabilities of the environment, such as by leveraging the proprioception of the user to interact with on-the-body objects, these devices can further extend their capabilities by taking advantage of the capabilities of the environment:

- A motion capture system (such as through Kinect, Vicon, or AirTrack) might enable the user to interact with objects at a distance.
- A high-speed network connection may enable low-latency, high-bandwidth connectivity with high-resolution data, such as medical scanner imagery.
- A computing cluster may enable powerful calculations on data in the user's possession.

Multi-surface environments

Our work focuses on multi-surface environments, wherein a user interacts with multiple heterogenous interactive surfaces. Such interaction may take the form of an environment with specialized infrastructure. This type of environment, such as WILD [4] offers dedicated capabilities that might not be available elsewhere, and has been used in work with extreme users such as microbiologists, astrophysics researchers or neuroscientists. Other multi-surface environments may be less extreme and focus on taking advantage of multi-device interactions to create a kind of user-centered ecosystem in which collaboration is more spontaneous and opportunistic between common devices, as in Apple's Handoff or in Hamilton & Wigdor's Conductor [7]. Much of the work in this space to date has focused primarily on smartphones and tablets, but as wearable devices become increasingly capable and affordable, users will demand the expressiveness such devices may permit.

Mobility

Mobile interaction can take a variety of roles. It is common to think of mobile interaction as that which takes place while a person is on-the-go, such as for micro-interactions throughout the day [2] or during one's commute; or in the context of nomadic computing, such as when a user carries her digital home to a new coffee shop.

We consider primarily the context of a user appropriating a fixed physical computing infrastructure. This appropriation may be in the form of walking down the hallway in the way that one might use a conference room,

or the context of a traveler using a business suite in an airport or hotel, or simply someone who interacts with a digital ad in a mall or an interactive metro map in a subway station. Regardless of the form, these interactions can all be characterized by a user appropriating some fixed capabilities of a *public* or *shared private* environment paired with the capabilities of her own *personal* devices.

Collaboration
Multi-surface environments offer a natural context for collaboration. Dedicated spaces may provide the room in which multiple people may gather to interact, as in WILD. These environments may give users a shared vector for information-sharing in independent tasks, such as for intelligence analysts in a collaborative sense-making task [10], or as a more tightly-coupled team [11].

Alternatively, multiple people may spontaneously create a shared interaction, as two students might in pushing project sketches from one tablet to another, such as with a pick 'n' drop [9] interaction. The prevalence of miniaturized rich computation, sensing, and communication, opens the possibility for interactive systems to maintain a richer awareness of the relationships and physiological state of users and to leverage that as a part of collaboration, such as by identifying proxemic relationships between users.

Instrumental Interaction

Our principal challenge for interaction in such environments how to model interaction. Much of the way we think of building software today is oriented around applications or documents. Even web-based application models reflect an implicit assumption of a single user at a single web browser. Multi-surface and multi-device environments break these assumptions, forcing us to re-think the role of applications and of interaction in multi-surface environments [6], where interaction, computation, and data may all take place on different devices with heterogeneous capabilities.

The instrumental interaction model seems particularly well-suited as a design tool for both interactions and for their underlying software implementations in a post-WIMP world [3]. Instrumental interaction is essentially an extension to direct manipulation, taking into account that not only to people directly act on objects, but also they may perform actions on objects as mediated through tools, called instruments. Key concepts involve *reifying* software functions and objects as user-visible concepts on which the user can interact through *polymorphic* instruments and allowing for the *reuse* of such actions [5]. Software designed around these principles should provide for a manageable flexibility both in terms of the kinds of interactions that a user can perform, but also in how the devices interact with each other in a dynamic system.

We are currently exploring the use of instrumental interaction as a model for the design of collaborative multi-surface visualization environments. These environments provide a combination of a computation cluster with a wall-sized interactive display environment to extend the user's interaction with data on her own personal device. Carried and worn devices can enable rich collaborations with data by extending the user's interaction vocabulary and by helping to create a smooth transition between individual and shared information spaces.

Challenges

Ultimately, we see two primary challenges facing designers of collaborative multi-surface systems: what should the

interaction look like, and how can we give software developers the tools they need to reason and implement it.

Interaction
How does a user appropriate multiple devices? Even for simple interactions, making them work across heterogeneous devices is not obvious, and entails a tangled mess of infrastructure and coordination. Even 16 years later, Rekimoto's pick 'n' drop has yet to become mainstream. Simpler interactions still, such as cross-device communication within a single manufacturer's device, still remains awkward.

Software
How can we provide the appropriate tools to software developers to help them easily write software that respects and embodies appropriate multi-surface interactions and collaborations. Standard WIMP toolboxes help developers to reason about interactive widgets in a way that makes implementing functional interfaces straight-forward. No such toolbox really exists to help guide multi-surface application developers.

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