INTERACTION AND SOCIAL ISSUES IN A HUMAN-CENTERED REACTIVE ENVIRONMENT

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Abstract. In the last decade, the ubiquitous computing paradigm has pushed computation out of desktop and made computational services pervasive throughout a physical environment. In this paper, we describe the work in progress in developing ubiquitous/pervasive applications supporting digital design media presentation. The result of the experimental study in various spatial settings is reported. Finally, we present a model of interaction towards a human-centered reactive environment, and discuss some interaction and social issues that must be addressed in implementation.

1. Introduction

As ubiquitous computing (Weiser, 1991) provides new ways of manifesting computation in the physical world, the style of interaction is moving beyond the desktop and into architectural space where we live and act. A new paradigm for multi-user multi-modal interactions in an integrated space is emerging, based on several related research such as “cooperative buildings” (Streit et al., 1998), “tangible interface” (Ishii, 1997), “augmented reality” (Buxton, 1997), “wearable computers” (Bass et al., 1997), and so on. It is also recognized that the conventional model of interaction will have to evolve towards human-centered interaction (Dertouzos, 2001).

Interacting with computation opens up a new set of research issues in an integrated design of physical and virtual worlds. This paper describes the work in progress in developing ubiquitous/pervasive applications supporting digital design media presentation. The result of the experimental study in various spatial settings is reported. Subsequent sections provide a model of interaction towards a human-centered reactive environment, and discuss some interaction and social issues that must be addressed in implementation.
2. The $I^3$ Environment

Our research group in Information Architecture at National Cheng Kung university in Taiwan is developing “the $I^3$ environment” (Intelligent, Interactive, and Informative) based on an integrated design of physical and virtual spaces. We have installed a variety of touch-sensitive displays and computational devices in a physical environment, including large-display interactive whiteboards, touch-sensitive tabletop, tablet computers, PDAs, and other environmental sensors. We are motivated to re-design a hallway supporting digital design media presentation, informal group discussion, and asynchronous multimedia annotation.

In order to get this research work in practice, we begin with the development of Tangible Media for presentation and exhibition of digital design studio work. An experimental study was performed by placing a wall-sized interactive whiteboard, an interactive electronic table, along with cameras and VCRs into the hallway. The setting allows students to draw annotations on wall-sized displays and interact with other digital equivalents using fingers, electronic pens, and voices when they engaged in design jury activities in a digital design studio.

![Figure 1](image-url)

*Figure 1.* The prototype of the $I^3$ environment includes iTable (on the left), Tangible Media (in the middle), and Intelligent Corner (on the right).

For the purposes of illustration in this paper, we will discuss a small subset of the capabilities of the $I^3$ environment, in a scenario of students in a digital design studio, presenting and exhibiting their work in the hallway. Here we list three key components that have been implemented in the $I^3$ environment, as shown in Figure 1.

1. **iTable** is an interactive electronic table that contains a touch-sensitive display surface and a built-in computational device coupling with a palm-sized physical building model. The iTable is placed in a public space for display, communication, and annotation of students’ design work. People can write and draw on the display surface with a pen and interact via finger with digital information. The physical model is useful for directly controlling the perspective viewpoint of digital
three-dimensional models. Moving the physical model correspondingly alters the orientation of perspective geometry.

2. **Tangible Media** provide multiple touch-sensitive monitors and an optical device, pointing the user’s current location on a paper-based floor plan. The display is bound to the movement of the pointer device. Relocating the pointer to a new position correspondingly resets the view of a virtual space. As the user touches a virtual space on the first monitor, digital information is conveyed from one monitor to another, triggering a built-in walk-through animation to be displayed on the second monitor. The objective is to examine how people deal with information with multiple views in a same display space.

3. **Intelligent Corner** is a project for presentation and dynamic exhibition of digital design studio work in an integrated space. In our initial prototype, two large wall-sized interactive whiteboards are mounted in parallel. An iTable is placed in a corner of the corridor. The whiteboards simultaneously display different views of design, such as design plan, perspective, and three-dimensional animation. As the user clicks the electronic pen over the first interactive whiteboard, it triggers an internal operation that activates playback of a multimedia movie in the second whiteboard accordingly. We attempt to explore a particular style of human-centered multi-modal interaction in an integrated space as input channels, and develop physical representation for output channels of digital information. The objective is to develop a reactive environment with a certain degree of ubiquity, tangibility, and in particular, context awareness.

*iTable, Tangible Media, and Intelligent Corner* are a sequence of increasingly developed systems for the I3 environment, moving towards human-centered interaction. Rather than conceiving of interactive systems as a network of computational devices, we take a human-centered approach to developing a reactive environment supporting digital design media presentation. There may be a variety of approaches to developing reactive environments [Cooperstock, et al., 1997], but we will focus on the interaction and social issues based on an integrated design of physical and virtual spaces.

### 3. Human-Centered Interaction Model

Having briefly outlined the components of the I3 environment, we can see an emerging model of human-centered interaction for characterizing an integrated space. An integrated space has three fundamental levels of abstraction: *cognitive space, physical space, and virtual space*. Here we
identify some key characteristics generally applied to an integrated space, as illustrated in Figure 2.

The human-centered interaction model being proposed here is based on five key elements of interactive systems: human, control, representation, event, and model. In a reactive environment, human can be considered as an entity without independent sets of input and output channels. There are two fundamental levels of representation: physical representation and digital representation. Human perception comes from physical representation coupling with the state of digital representation. Underlying digital representation are digital models that map onto physical representation in varied application domains. Physical representation is perceptually coupled to digital representation of digital models. Changing the physical representation triggers an event, yielding digital representation that is computationally mediated.

Physical representation embodies interaction with digital information, making computation ubiquitous, yet invisible. For example, the iTable serves as a computational artifact with physical representation and control for direct manipulation of underlying digital 3D models. The iTable also uses a physical building model as physical representation of an actual building. Moving or rotating the physical building model (i.e. physical representation) changes the perspective geometry (i.e. the digital representation) of a virtual space (i.e. digital models).
4. Interaction and Social Issues

Having established a human-centered interaction model, we can now further discuss some research issues in accordance with interaction and social perspective. We set out to identify a set of research issues based on the implementation of the I3 environment. Those issues include human factors, embodiment, coupling, ontology, metaphors, media space, and context awareness.

**Issue 1: Human factors**

While the ubiquitous/pervasive computing technology is truly promising, we believe that this approach will succeed only if we take into account the human factors governing the use of these systems. Our study shows that a reactive environment demands new interaction techniques to cope with human factors. For example, “pull-down menus” in a wall-sized large display are hardly to reach especially for a short person. We often re-configure the boundary of the display area in order to cope with different scale of human body. “Drag-and-Drop” user interface cannot be used effectively because few people have been able to touch multiple “windows” by standing at the same physical location.

Cognition is another human factor that demands careful consideration. To some degree the user’s focus on a wall-sized display is episodic because he/she is often engaged in a conversation with other people in public space. The user does not have additional cognitive capacity to detect slight change in a single large display, not to mention to perceive simultaneous changes in multiple large displays.

There are some other social interaction issues to be addressed. Synchronization is a problem in the development of Intelligent Corner when many people want to make annotations on the same drawing. In a physical space, two people are hardly able to write in the same area at the same time. One may unconsciously block part of the display. It would be also useful to support awareness of external events occurred in some other spaces. However, information overload is a major concern. We need an efficient way to partition a media display space supporting peripheral awareness.

**Issue 2: Embodiment**

The second issue is embodying the control and representational aspect of tangible interfaces. From a design viewpoint, it is appropriate to question what makes for good tangible interface design. Most tangible interfaces are so far developed by technological practices. Many practices are driven by the availability of sensor technology and the emergence of new control devices. Due to the lack of theory in understanding of physicality in interaction, new forms of tangible interfaces rely on system designers’
experiences of an interaction system. It is needed to uncover the philosophical assumptions that run throughout engaged practices of embodied technology, so that we can understand more about what kind of physical representation can be made for tangible interface. A foundational study of embodied interaction is provided in (Dourish, 2001).

**Issue 3: Coupling**

Another important issue is coupling physical artifacts with digital information. To develop tangible interface, physical artifacts must be \textit{statically} coupled with or \textit{dynamically} bound to digital information. As illustrated in the \textit{i} environment, the iTable affords a variety of association relationships between physical artifacts and digital information. In the Intelligent Corner, the user is presented within a reactive environment where he/she can manipulate digital information through a chain of remote action. A local action on the iTable can have a remote effect through a sequence of couplings, including associations of digital media and physical properties. By coupling, we can build up and maintain association relationships between digital and physical representations.

**Issue 4: Ontology**

Ontology is concerned with the nature of existence and relations between computational artifacts. We use ontology to refer to a user’s cognitive model. Ontology provides the structure from which meaning can be constructed. In the Intelligent Corner, for example, different modes of interaction and settings of practices (e.g. digital media presentation) will result in different ways of understanding the ontology of a reactive environment. If we look at Tangible Media, the user moves his/her arm along with a physical model to perceive the building’s interior spatial extensity in a virtual form. The user perceives what he/she moves and interprets the meaning that may be conveyed though a sequence of image displays. Based on our observations, the user’s action controls his/her perception in accordance with an ontological structure. On one hand, ontology is a \textit{consequence} of interaction. The user’s ontology arises from his/her engaged action in the physical world. On the other hand, ontology is an \textit{internal phenomenon} created by the user of an interactive system. A reactive environment should provide a certain degree of flexibility in dealing with an evolving ontological structure, rather than statically embedded in some computational artifacts.

**Issue 5: Metaphors**

A new interaction metaphor is emerging in understanding an interactive space. Here we are not talking about “desktop”, “menus”, “dialogs” user interface metaphors in personal workstations. Rather we are concerned with
the use of the real world as a metaphor to conceive and interpret, and understand a reactive environment. For example, a metaphorical physical model in the iTable represents an actual building, which incorporates the sense of physical presence from the real world. We use the metaphorical model as a tangible interface for interaction. The Intelligent Corner is largely concerned with metaphorical physical properties (e.g. the iTables and interactive walls) for embodied interaction. Interaction metaphors can be used to extend the sense of familiarity into a broader range of embodied phenomena.

**Issue 6: Space as Medium**

As digital information takes physical form and is mapped onto artifacts, the distinction between physicality and virtuality is blurring. Architectural space becomes a medium for interaction. To explore this idea, let us take the example of Intelligent Corner. A wall becomes a medium for the expression of digital information. The essence of Intelligent Corner is in the way in which digital information moves from one wall to another through social interaction in the presence of the iTable. An interactive wall must provide more functionality than a whiteboard. Taking a broader view, media space provides an opportunity to cut across conventional device boundaries and offers a way of interacting with our surroundings.

**Issue 7: Context awareness**

Context refers to implicit situational information embedded in computational devices for interaction. An interactive system is context-aware if it can interpret explicit acts and react to implicit situations or settings. Dey refers to context as any information that can be used to characterize the situation of a person, place, or an object between a user and an application (Dey, 2001). In a reactive environment, it is appropriate to question what sort of context in which an action may arise.

In a building space, however, context may change over time. A corridor is a walk-through space that might be occasionally used for design jury activities. Group discussion often occurs when people meet in the corridor. Collaborative mark-up can be made in the course of discussion when interactive whiteboard is provided. An important aspect of context awareness is to take into account evolving contexts in a reactive environment, providing computational services that are appropriate to the particular user, situation, and spatial setting.
5. Conclusion

This paper sets out to identify a set of issues that are at work in some major components of our current research in an integrated design of physical and virtual spaces. We present several interactive prototype systems in terms of the implementation of the $I^3$ environment. In the light of these prototype investigations, we propose a human-centered interaction model in such a way to set out some basic foundations for emerging new forms of multi-user multi-modal interactions in the physical world.

Ubiquitous computing has encouraged us to explore various aspects of a reactive environment, incorporating tangible interfaces into architectural space and into fabric of work and design practice. The experimental study shows that research in developing interactive systems and a reactive environment is inherently empirical. It relies on a prototyping development cycle that can react to feedback from user evaluation. Future work is to develop perceptional capabilities through embodied interaction supporting context awareness in an integrated space, catching up to the vision of “Form follows function. Function follows code.” (Mitchell, 1999).

References


Research of the $I^3$ environment can be found at http://www.arch.ncku.edu.tw/ialab