Tangible Design Media: Toward An Interactive CAD Platform

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This paper presents an interactive CAD platform that uses a tangible user interface to visualize and modify 3D geometry through manipulation of physical artifacts. The tangible user interface attempts to move away from the commonly used non-intuitive desktop CAD environment to a 3D CAD environment that more accurately mimics traditional desktop drawing and pin-up situations. An important goal is to reduce the apparent complexity of CAD user interfaces and reduce the cognitive load on designers. Opportunities for extending tangible design media toward an interactive CAD platform are discussed.

1. Introduction

Trends in ubiquitous computing are opening up new opportunities for weaving digital technology into the fabric of our everyday lives and throughout our entire environment [1]. Smart devices are becoming embedded in building elements such as doors, walls, floors, and furniture. Wireless network technologies allow these smart devices to be connected and coordinated, supporting knowledge-work at any place and time. Given inevitable growth in the range of interactive media and smart devices, interaction with computation is moving beyond the desktop, and more like the way humans interact with the physical world. Our design and work environments need to be changed to accommodate a new way of manifesting computation in physical space. These trends introduce new challenges for research in developing an off-the-desktop CAD platform involving physical interfaces, embedded sensors, mobile devices, and richer forms of multi-modal interaction.

This paper describes work in progress for developing tangible user interfaces supporting an interactive CAD platform in an integrated space that combines multiple interactive media and smart devices. There are many types of tangible user interfaces. Our interest is in the development of interactive CAD platforms, extending human-computer interaction interfaces beyond the mouse and keyboard to environmental support. An important goal is to integrate physical and digital representations intuitively and seamlessly.

This paper is organized as follows. First, we outline an interactive scenario as a motivating example. In section 2, we review the traditional value of physical interfaces typically used in design studios. In section 3, we present a media-rich ubiquitous computing environment for the interactive workspaces of the future. In section 4, we describe a rich set of tangible design media supporting design reviews and critiques. Some details of the tangible design media are illustrated based on the way that people have traditionally used in the design process. In sections 5, we describe the emerging interactive CAD platform, with special emphasis on the desirable simplicity, integrity, and affordances of the physical interaction in the interactive workspace of the future.

1.1. An Example Interaction Scenario

For the purpose of illustration in this paper, we will consider a set of desired capabilities, in a scenario of a design team in an interactive workspace, performing 3D navigation for design reviews and critiques. They organize digital drawings with multiple projections on tabletops, wall-sized displays, and handheld tablets. There may be a variety of interactive devices and modalities used in the workspace, but we will focus on tangible user interfaces for 3D visualization for purposes of discussion.

1. Jacky uses a physical plane to "cut" a section of 3D geometry projected on a digital desk. He moves the plane freely on the tabletop to visualize various section views from different positions in physical space.
2. Jacky rotates a physical ruler augmented by digital capability on a digital desk for viewpoint control. Rotating the augmented physical ruler changes the viewpoint of the 3D model on the wall display correspondingly.
3. Jacky moves a set of physical tokens on the vertical/horizontal surfaces to edit a parametric object in relation to the CAD model.

Recent advances in media technology have made this scenario feasible today. These tangible user interfaces offer opportunities for new user experiences beyond conventional desktop computers. In this paper, we define the appropriate physical interaction experience by providing the right navigational tools for 3D visualization in a physical-virtual integrated environment. The conventional physical design artefacts (e.g. planes, rulers, and tokens) will be augmented for pointing, manipulation, and annotation in design reviews and critiques. The augmented artefacts are integrated in an interactive CAD platform to enrich the design process.

Our research group in Information Architecture Lab in National Cheng Kung University in Taiwan is developing a media-rich multi-modal multi-device ubiquitous computing environment called *iCube*. *iCube* is a long-term project to develop the needed technologies supporting the media-rich interactive workspace of the future. An initial focus of this project has been developing a new form of human computer interaction beyond the mouse and keyboard, and more recently, for supporting an integrated (physical and digital) CAD platform. The work presented is part of the *iCube* project [2]. Some of its details, benefits, current status and some open questions are discussed in later sections.

1.2. Related Work

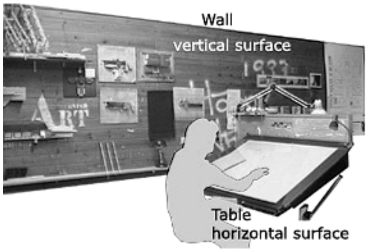
Until recently, the emphasis in human-computer interaction is shifting from the desktop to the environment [3, 4]. Our work was inspired by the vision of ubiquitous computing and the notion of tangible media. The vision of ubiquitous computing was proposed by Mark Weiser in 1991, illustrating a new computing paradigm which pushes computers into the background and attempts to make computational services ubiquitous [1]. With the ubiquitous computing approach, a variety of computational devices including tabs, pads, boards, are being developed along with the infrastructure that connects different devices [5]. The notion of tangible media was first proposed by Ishii, illustrating a way of integrating physical and virtual worlds in a seamless manner [6, 7]. The shift in focus from the desktop to the tangible user interface reflects the vision of ubiquitous computing. Another stream of research related to tangible user interface is the notion of augmented reality, allowing visual overlay of digital information onto real-world objects [8, 9]. In contrast to the current approach to augmented reality using head-mounted display devices, our approach focuses on direct manipulation of digital information in an intuitive manner without additional cost.

There are a number of efforts to develop ubiquitous computing environments for CAD applications that incorporates tangible user interfaces for CSCW (Computer Supported Collaborative Work), including augmented urban planning [10], navigational blocks [11], Aegis Hyposurface [12], etc. Our treatment of tangible media has similarities with the augmented urban planning system developed by Ishii et al. [10], whereby physical models and digital simulation are overlaid into a single information space. Unlike Ishii et al., our work focuses on the spatial mapping between various perspective views in physical space. We provide the user with the ability to directly interact with the physical artifacts through which a cognitive space is created between physical space and virtual space. The control and view of 3D geometry are directly mapped into physical space. Our tangible media allows interactive 3D visualization with a realistic amount of details, and without an excessive amount of manipulation.

2. Traditional use of physical interfaces

In order to determine if existing user interfaces could deal with tangible issues, it is first necessary to identify the functional requirements of physical interfaces in traditional design studios. Traditionally, design professionals rely on a range of physical models, various forms of analysis, and multiple representations to depict design ideas. Today designers must manipulate different forms of user interfaces (physical and digital), integrate multiple representations (model, drawings, and simulation), and manage varied design processes. In essence, traditional design architects have to transfer their considerable skills they have acquired from working with traditional media. Digital media has added distractions without helping interpret the media.

Our work is inspired by our previous empirical studies on the traditional architectural firm where a design group organizes their drawings on tabletops and walls in order to share, present, and critique a design. Our observations show that tabletops and walls are the primary media used for organizing external design representations, sharing information, and supporting shared awareness. Designers often draw their ideas on sheets of paper and address some issues on the drafting boards, which serves as a horizontal surface to create and share a design with team workers. In the meanwhile designers often pinup their drawings, photos, and sketches on a wall for design reviews and critiques. They get informal feedback from other co-workers by virtue of large displays in physical space. Spatial elements (e.g. tabletops and walls) provide large-format physical interfaces for information sharing and shared awareness. The conventional use of physical interface in traditional design studios is shown in Figure 1.



◀ Figure 1. Spatial elements (e.g. tabletops and walls) provide large-format physical interfaces for information sharing and shared awareness.

While people get used to the desktop setting, the personal experience through the use of the desktop computers has reduced the level of interactivity and social interaction. Design is a social process. Desktop computers in general have not been developed for multi-user multi-modal interaction in a social setting. Modeling and visualizing 3D information with a mouse on a pad while looking at a screen is an unnatural social process. It is argued that we should recapture the simplicity, interactivity, and affordances of physical user interfaces, which were lost in the desktop-based computer revolution. The computing environment should adapt to human designers, not the other way around. Human-computer interaction must be extended beyond desktop to environmental one.

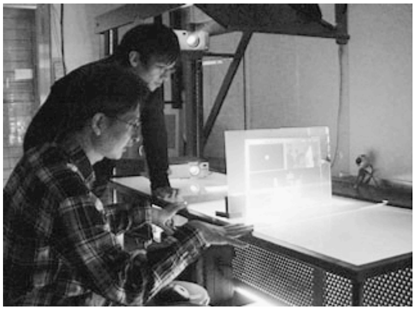
To increase the level of interactivity and social interaction we propose to extend CAD capabilities beyond a personal tool to environmental interaction support. We propose a digital tabletop as a horizontal display for shared awareness and details inspection, whereas the digital wall serves as a vertical display for directing the group's attention. In comparison with computer screens, the digital tabletop affords a large-format display that is easy to view, make annotations, organize and share ideas. We attempt to get away from the commonly used non-intuitive desktop CAD environment to a real-world 3D CAD environment that more accurately mimics the traditional desktop drawing and pin-up situation reducing the apparent complexity of user interface. Our response to the interface problem attempts to build a physical CAD platform within an interactive workspace that affords the desirable simplicity, integrity, and affordances of the physical interaction. Our work has been guided by the following principles:

- using physical space as an interface between humans and computation for embodied interaction,
- mapping views of 3D geometry to physical space for enhancing spatial mapping, and
- coupling action and perception (input and output) tightly based on an integrated design of physical and digital representations.

3. Interactive workspaces

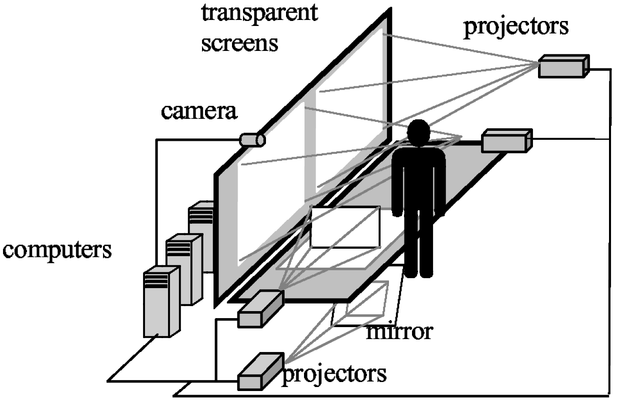
We have developed an interactive workspace that is a media-rich multi-device environment augmented with large displays, interactive whiteboards, wireless devices, and touch-sensitive tabletops. In the interactive workspace, we have two large wall-size displays augmented with interactive whiteboards (Mimio). We install another overhead projector on the ceiling with a mirror refracting projection light onto a table surface. An office table is transformed into a touch-sensitive interactive table by mounting a wireless interactive device. We design a spatially-aware tablet display by embedding a light-emitting diode (LED) device to track its position. The tablet is spatially-aware in a sense that the display reacts immediately in response to changes in its position. A set of web cameras are used for image recognition and motion detection within the workspace. The view of the prototype interactive workspace is shown in Figure 2.

► Figure 2. The view of the prototype interactive workspace



We have proposed three stages to develop new facilities within the interactive workspace toward an interactive CAD platform (Figure 3). The first stage is to embed the interaction interface into the physical space where the human is residing. There are already many available vision technologies that are capable of detecting real-world input such as gesture, motion, and touch. We choose to use the image processing techniques to detect hand gesture and the physical movement in space. This stage is accomplished by embedding existing computational devices (e.g. cameras, e-tags) in the spatial elements (e.g. doors, walls, and tables), making the computer aware of the physical artefacts as well as the user's hand gesture input. The second stage is to utilize existing authoring tools (e.g. Macromedia Director) connecting the web cameras to the server database.

► Figure 3. Facilities are developed within the interactive workspace toward an interactive CAD platform.



The authoring tools couple input and output with interactive media that map the views of 3D geometry to physical space. The third stage is to program software agents to interpret the input from the web cameras and e-tag readers and exchange message with the server database. The software agents send signals to actuators so as to produce real world actions in a proactive computing environment.

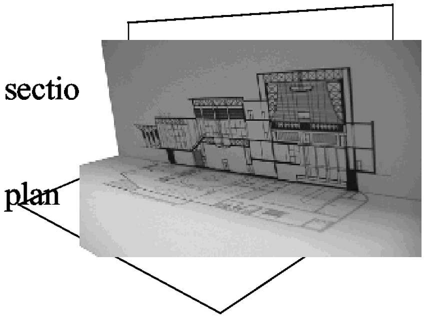
Consider a design team in our interactive workspace performing reviews and critiques with a variety of tangible design media. The designer uses tangible user interfaces to inspect and modify 3D geometry by manipulating physical artifacts. Major questions about the practical use of such an interactive workspace include: How can we utilize these facilities for interactive 3D navigation? How can we control viewpoints through embodied interaction? How can we augment physical artefacts for 3D geometric editing? What are the non-desktop interface metaphors appropriate to the design reviews and critiques? These questions are fundamental to the design of tangible design media and will be addressed in next sections.

4. Tangible design media

We have implemented a set of tangible design media, including the orthographic multiple projections system for interactive 3D navigation, the augmented physical rulers for viewpoint control, and the augmented physical tokens for direct manipulation. Each of them serves different tangible interface aspects for constructing meaningful actions in the design process. Together, the different kind of tangible user interfaces that are potentially applicable to define a new set of facilities for interactive CAD platforms.

4.1. Multiple Projections for Interactive 3D Navigation

Designers often need to check the coherent relationships between plans and sections in order to inspect the details and maintain spatial integrity. The most common architectural design convention is to make a plan coincide with a section in a horizontal and vertical setting. This yields a simultaneous orthographic view, as depicted in Figure 4.



◀ Figure 4. A plan coincides with a section in an orthographic setting.

To mimic such a traditional design setting, we develop an interactive CAD platform that maps a simultaneous orthographic view to physical space. The interactive CAD platform is composed of three elements: an orthographic multiple projections system, a digital tabletop, and a physical plane perpendicular to and coincide with the tabletop. The physical plane is a tablet made up of acrylic fiber for projected image display. In the interactive tabletop environment, we use the physical plane as a vertical projected screen and the tabletop surface as a horizontal projected screen. In the course of 3D navigation process, a section image is projected on the physical plane whereas a plan image is projected on the tabletop. The interactive CAD platform provides a simultaneous orthographic view with multiple simultaneous projections for interactive 3D navigation, while at the same time preserves the simplicity of physical interaction.

The orthographic multiple projections system is controlled by two parameters. One is the position where the section plane coincides with the plan on the tabletop. We mount a Light Emitting Diode (LED) on the physical tablet to track its position. All section views are real-time rendered images that can be displayed on the "cutting" plane as the LED position is detected by the web camera. The other parameter is the variation of velocity at which the LED-mounted tablet moves. When the tablet is moved at a sufficiently rapid rate, it generates a sequence of projected section views in physical space in a coherent manner. If the motion rate is sufficient to achieve spatial coherence, the user can perceive an animated model made up of a sequence of projected images in physical space. This produces a rich flow of visual information in physical space in terms of simple embodied interaction.

► Figure 5. The user uses a LED-mounted tablet as "the cutting plane" to obtain a sequence of projected section images for interactive 3D navigation.

This orthographic multiple projections system mimics the user experience of "cutting" a physical model while offering the advantage of working with digital models. The orthographic multiple projections system can provide a real-time view of the section image based on the position with which horizontal and vertical projection surfaces coincide. The user controls and moves the physical plane in reference to the plan geometry projected on the tabletop. Whenever the position of the physical plane is altered, the projected section image is updated correspondingly. The orthographic multiple projections system is shown in Figure 5.

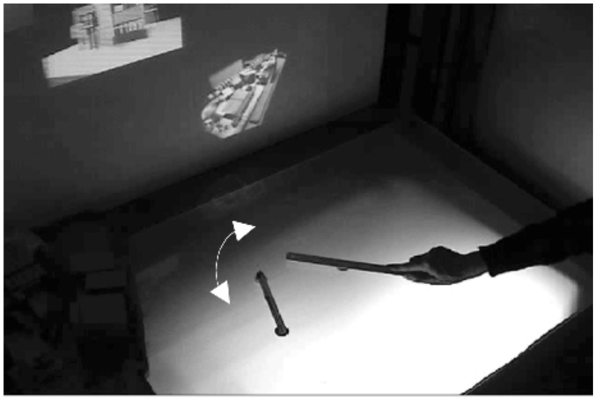
The simultaneous orthographic view enhances the cognitive skills in spatial mapping between various perspective views of 3D geometry in mental construct. We use "cutting plane in hand" metaphor to provide a physical interface for interactive 3D navigation. From the user's perspective, the physical tablet is served as "a cutting plane" to obtain a snapshot of building section views in physical space. A "section" view of the 3D model is superimposed on the tablet display immediately after the tablet is activated and well placed on the tabletop surface. The user can relocate the physical tablet to a new position, which automatically resets the 3D model's section image related to its corresponding coordinates of the plan geometry. By acting through the system with embodied interaction, the user can create a sense of cognitive space between physical space and virtual space. The orthographic multiple projections system is spatially-aware, allowing the user to perceive a 3D model in his/her mental construct as if the model is really there in the physical locale.

4.2. Augmenting Physical Rulers for Viewpoint Control

After developing an interactive CAD platform for multiple projections 3D navigation, we start to augment physical rulers for viewpoint control. Rather than a two-handed manipulation for one model, each augmented ruler is currently implemented for controlling one 3D model. Often an architect needs to critique the design from various viewpoints of the 3D model. Moving the viewpoints reveals different aspects of an object's geometry for group discussion. While most architects get used to desktop computers, a common problem is that they often feel frustrated by the complex desktop user interfaces. Most architects wish they could directly control the viewpoint of digital models in the same way they move and rotate the physical model.

To facilitate viewpoint control, we augment a physical ruler for use in real-time viewing operations. The physical ruler is an input device augmented with digital capabilities to execute various viewing commands, such as translation, rotation, zoom-In, and zoom-Out. We choose to augment a ruler because it is an often-used physical artifact in traditional design studios for measuring the scale of 2D geometry. With an augmented physical ruler, a designer can directly control the viewpoint by rotating the physical ruler without remembering different kinds of execution commands, as shown in Figure 6.

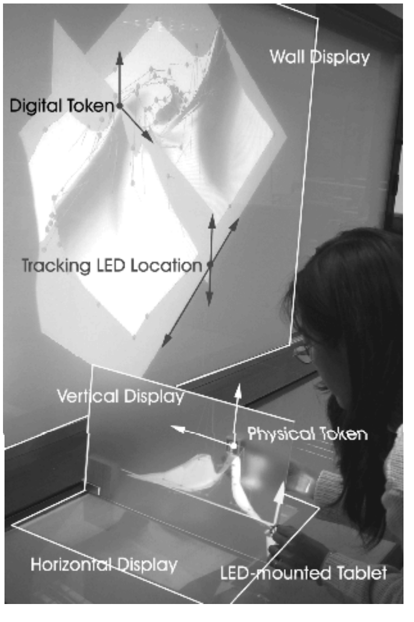
► Figure 6. Rotating an augmented physical ruler on the tabletop changes the viewpoint of the 3D model on the wall display correspondingly.



In the tabletop setting, we mount two tokens with different color (i.e. red and green) on a commonly used physical ruler. The color tokens are used for motion detection when the user moves or rotates the ruler. The viewing commands include pan, zoom-In, zoom-out, and rotate. By shifting the physical ruler bar in different directions on the tabletop, the user can change the viewpoint of the digital building model on the wall display correspondingly. The user can continuously adjust the viewpoint by rotating or shifting the physical ruler. Furthermore, the user can bring the image from the wall display to the tabletop in a fluid manner by moving the physical ruler downwardly in a larger scale.

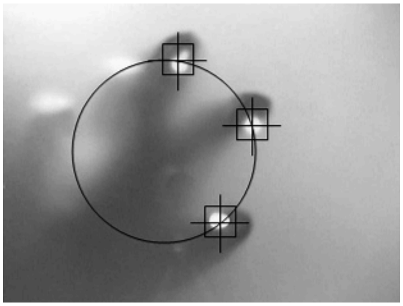
4.3. Augmenting Physical Tokens for Direct Manipulation

► Figure 7. The user moves physical tokens to perform topological editing of 3D geometry.



A variant of the same idea, physical interaction can be achieved by augmenting physical tokens in relation to the control points of 3D geometry. To support easy modification, we choose a set of general-purpose physical tokens for direct manipulation. We construct a free-from 3D landscape model with designated control points that are formerly produced by CAD software. Then we translate the 3D model to an authoring tool which can further link to the orthographic multiple projections system as we presented in Section 4.1. In the interactive tabletop environment, we attach a set of physical tokens on the vertical projection plane to adjust the form of the 3D landscape, as shown in Figure 7.

A much more powerful facility for quick modification of the 3D model can be provided by augmenting a set of general-purpose physical tokens. Tokens are physical objects augmented with digital capabilities for representing execution commands. Users can attach red or blue tokens to the control points to execute topological editing commands such as insert, move, stretch, and delete points of the 3D object. The image processing technique that we used to recognize the hand gesture in relation to the positions of the tokens is illustrated in Figure 5 (right).



◀ Figure 8. A video camera recognizes the hand gesture in terms of a pre-defined image pattern.

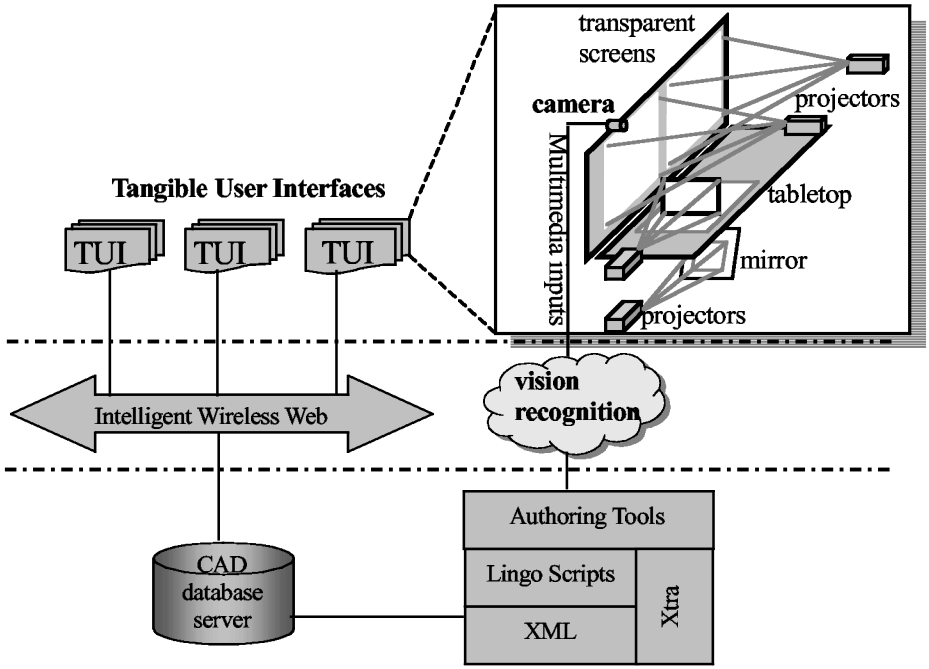
5. The implementation

In the current implementation, we use a combination of multiple (front and back) video projectors and camera-based vision recognition technology to develop the tangible design media. The tangible design media are placed in our interactive workspace that maps to a ubiquitous computing infrastructure. The system infrastructure consists of three tiers:

1. *Tangible User Interface Tier* The first tier integrates the cameras and the multiple projections system to capture the real-world images and the multimodal inputs. Macromedia Director is used for gesture-based interaction with interactive whiteboards. Flash movies are used to integrate 3D models, interactive movie clips, graphical display, and music. The multimedia inputs (e.g. video stream) are sent to the application tier for vision recognition.
2. *Logical Application Tier* The middle tier performs the mapping operations that transform the 3D real-world coordinates to screen-based 2D coordinates. We use Macromedia Director with Lingo scripts to perform the logical mapping operations and detect the targets. When a target image is detected, this tier performs a remote procedure call, generates service events, and transfers XML to remote server. Each interactive devices using XML as communication protocol in a client-server relationship.
3. *Service Tier* The third tier manages a variety of service events in the event network. The server captures the interaction events in XML and stores them in the databases.

Our system has been implemented by C# for deploying and performing computational tasks in a server. Each tangible interface deals with XML I/O as service events. Interaction and service events can be represented as XML tags with extensibility and structural representation. The system architecture is depicted in Figure 9.

► Figure 9. The system architecture.



6. The emerging interactive CAD platform

In order to evaluate prototype experiences and user responses, we held an exhibition of interactive media spaces called "Digital Media and Architecture". The exhibit was open in the Art Center of National Cheng Kung University in Taiwan for a week in April 2003. In the exhibition space, we adapted the original setup for tangible design media in a larger context of interactive workspace. Six hundred people from various backgrounds visited the exhibition. We distributed questionnaires to the visiting public. The exhibit received enthusiastic feedback from architects, engineers, artists, and students. Our main goal on this exhibition was to understand the strengths and limitations of tangible interfaces while presenting our research work for interactive museum exhibition, entertainment, and education. A view of the Digital Media and Architecture exhibition is shown in Figure 10.

We observed that the exhibit did attract and maintain interest. People showed great interests in using gesture, touch, and pointing to navigate 3D models and control CAD models by interacting with their surroundings. One of the most significant parts of the exhibit space is the capability of embodied interaction, allowing users to move across physical space and

▲ Figure 10. A corner of the Digital Media and Architecture 2003 Exhibition in Taiwan.

virtual space. Most visitors reported that using tangible interfaces to view and control 3D virtual models was cute and potential useful for future practice. The cognitive and presentation skills could be enhanced for entry level architects. However, traditional architects are concerned with adaptability and portability of tangible design media in practice. For example, some architects wish to use any CAD files in the interactive 3D navigation system without additional cost. The existing cost of our system is the process of translating the CAD files to Flash movies with specialized coding. Currently, our system installation involves many tedious calibration processes and procedures before the system can be used. Another concern is the portability of the interactive CAD platform of using a movable panel to display cut sections. Most architects are reluctant to change their practices from desktops to tangible media due to a large amount of specialized setup was required to achieve the desired results.

The challenging problem before us is to facilitate the integration of tangible design media and reduce the complexity of system installation. The future CAD environment will be justified by its support of more significant changes in current practice in terms of the desirable simplicity, integrity, and affordances of the tangible interaction in physical space. Given growing diversity of embedded devices and interactive computers, the CAD working environment will become increasingly characterized by the use of different specialized tangible design media and its support for multiple interaction modalities. We need to develop a common design platform for integrating implicit input and distributed output in our surrounding environment.

Now, we are in the transitional state where efforts are being made to develop the cutting-edge media technology inherent in ubiquitous computing for future practices. A new CAD platform for a new form of human computer interaction has emerged from the appropriate physical interaction experiences that reflect the natural structure of design tasks performed in various physical settings. While we are shifting away from the desktop user interface, we argue that the focus will inevitably broaden to address the issues of continuous tangible interaction with a CAD platform. In such a CAD platform, users can continuously write, gesture, and interact with physical artefacts in order to communicate with other designers, involving possibly multi-user multi-device multimodal interactions and unique sets of criteria across multi-disciplinary domains. It requires a shift in the way we think about interaction with computation from the user interface to a new system infrastructure of physical computing. The new system infrastructure could directly map to those aspects of environmental functions and services. That is, developing a future CAD platform requires a new way of mapping a physical space to a ubiquitous computing infrastructure and a corresponding model of interaction.

7. Conclusion

In this paper, we have presented a CAD platform within the interactive workspace where designers can use a rich set of tangible design media to navigate 3D models, control viewpoints, and perform topological editing operations. While our work remains at the level of demonstrational prototypes, we are gaining some physical interaction experience and a richer understanding of physical and social settings inherent in ubiquitous computing. Meanwhile, we are also starting to bring tangible design media to other locations, including digital media exhibitions in interactive museums where the tangible user interfaces are used to support interactive entertainment and education. Future work will create more living laboratories in the real world for ubiquitous computing research and conduct more formal user studies of the prototypes for architectural practices.

Acknowledgement

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References

1. Weiser, M., The Computer for the 21st Century, *Scientific American*, 1991, Vol. 265, No. 3, pp. 94-104.
2. Jeng T. and Lee, C., iCube: Ubiquitous Media Spaces for Embodied Interaction", in: Chiu, M. L., ed., *Proceedings of CAADFutures2003*, Kluwer Publishers, Taiwan, 2003.

3. Carroll, J. M. (ed.), *Human-Computer Interaction in the New Millennium*, Addison Wesley, New York, 2001.

4. Dourish, P., *Where the Action is: The Foundations of Embodied Interaction*, The MIT Press, Cambridge, Massachusetts, 2001.

5. Johanson, B., Fox, A., and Winograd, T., The Interactive Workspaces Project: Experiences with Ubiquitous Computing Rooms, *IEEE Pervasive Computing*, 2002, Vol. 2, pp. 71-78.

6. Ishii, H. and Ullmer, B., Tangible Bits: Towards Seamless Interfaces between People, Bits, and Atoms, *Proceedings of Computer-Human Interaction (CHI97)*, 1997, ACM Press, pp. 234-241.

7. Ullmer, B. and Ishii, H., Emerging Frameworks for Tangible User Interfaces, *Human-Computer Interaction in the New Millennium*, ed. J. M. Carroll, Addison Wesley, New York, 2001.

8. Wellner, P., Mackay, W., and Gold, R., Computer Augmented Environments: Back to the Real World, *Communication of the ACM*, 1993, Vol. 36, No. 7, 1993, pp. 24-26.

9. Feiner, S., MacIntyre, B. and Seligmann, D., Knowledge-Based Augmented Reality, *Communication of the ACM*, 1993, Vol. 36, No. 7, pp. 52-62.

10. Ishii, H., Underkoffler, J., Chak, D., Piper, B., Ben-Joseph, E., Yeung, L., and Kanji, Z., Augmented Urban Planning Workbench: Overlaying Drawings, Physical Models, and Digital Simulation, *Proceedings of IEEE & ACM International Symposium on Mixed and Augmented Reality*, ACM Press, 2002, pp. 386-393.

11. Camarata, K., Do, E., Johnson, B., and Gross, M., Navigational Blocks: Navigating Information Space with Tangible Media, *Intelligent User Interface*, 2002.

12. Goulthorpe, M. (dECOi Architects) and Burry, M. (Spatial Information Architecture Laboratory, RMIT), *Aegis Hyposurface*, http://www. hyposurface.com.

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