Mixed Reality Human Media for Social and Physical Interaction

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Abstract: This paper outlines new facilities within ubiquitous human media spaces supporting embodied interaction between humans and computation both socially and physically. We believe that the current approach to developing electronic based design environments is lacking with regard to support for multi-person multi-modal design interactions. In this paper, we present an alternative ubiquitous computing environment based on an integrated design of real and virtual worlds. We implement three different research prototype systems: the Virtual Kyoto Garden, Touchy Internet, and the Human Pacman. The functional capabilities implemented in these systems include spatially-aware 3D navigation, tangible interaction, and ubiquitous human media spaces. Some of its details, benefits, and issues regarding design support are discussed.

Keywords: Ubiquitous Human Media, Augmented Reality, Tangible User Interface

1. Introduction

Ubiquitous computing is a new paradigm that outlines the vision of the next generation of computation[1)]. A lot of research efforts have been put in the human-computer interactions, as well as the integration of the computation world with the physical world. A major requirement of such integration has been the development of ubiquitous human media, allowing computational services to be pervasive throughout our work environments.

In this paper, we describe how 3-D images and graphical interactions using the principles of mixed reality support the creation of novel ubiquitous human media. This allows a new paradigm in human computer interaction to be explored by researchers, developers, and users.

We show in this research work that 3-D graphics and image analysis as applied to mixed reality allow ubiquitous human media to be implemented and expressed in action. Interaction with the computer can be designed in such a way that the environment and physical objects become the user interface. Additionally, we show that based on the mixed reality technology, the ubiquitous human media allows social and physical interactive concepts to be introduced, and where the interaction is not in a linear or rule-based manner, but instead can be improvised in real-time by the user both socially and physically. The structure of the remaining part of the paper is as follows: In the following section, we describe the theory and technical implementation of mixed reality, and the current state of ubiquitous computing research. In Section 3, 4, and 5 we detail examples of mixed reality for social and physical interaction. We discuss how each of these applications is an example of ubiquitous human media. Finally conclusions are drawn in Section 6.

2. Background

Mixed reality refers to the incorporation of virtual computer graphics objects into a real three dimensional scene, or alternatively the inclusion of real world elements into a virtual environment[2)]. The mixed reality approach is an exemplar of ubiquitous human media. Ubiquitous human media is the next generation computing paradigm that involves the elements of ubiquitous computing, tangible interfaces and interaction and social computing. In this way, it moves the computer interface away from the traditional keyboard and mouse and into the environment, supporting the more interactive behavior.

The three important research paradigms on which ubiquitous human media is founded, are Weiser's ubiquitous computing[1)], Ishii's tangible bits or "things that thinks"[3)], and Suchman's sociological reasoning to problems of interaction[4)].

It can be seen that ubiquitous computing deals with computing in the environment and with activities that take place in the context of the environment. Tangible interaction deals with using the physical world and physical object manipulation to interact with the digital world. Both share the views that interaction with computers should exploit our natural familiarity with the physical environment and physical objects. Both tie the computer interaction with physical activities in such a manner that the computer is embedded in the activity. In this way, the environment and physical objects become the computer interface.

For example, ubiquitous and tangible computing is based upon the idea of the computer being embedded

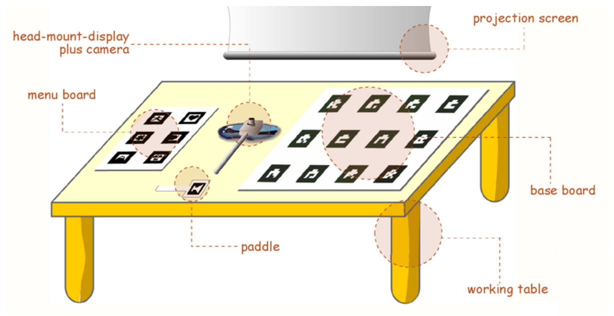

Figure 1: The layout of the Kyoto Garden system.

Figure 2: The user holds the Head-mount-display, and point to one of the boards to view the virtual garden and menu.

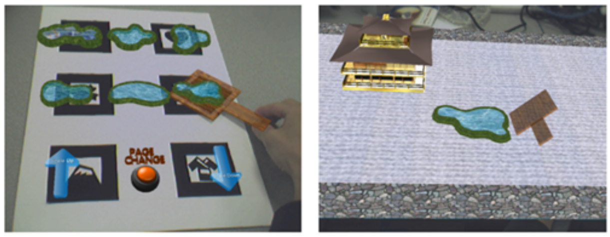

Figure 3: Picking up an virtual object from the menu, and drop it to the sand garden.

in our environment, in objects, and in the background. Thus the interaction is embodied in the physical environment, rather than on abstract representations on a computer system. Similarly social computing places the real-time and real-space activities of humans as social beings, or embodied actions, at primary importance. Ubiquitous human media ties all these ideas together, as a single research vision. Furthermore, ubiquitous human media foresees that the future of human-computer interaction will lie in an interface to computing that appears throughout our physical space and time. Thus, humans as physical beings now actually become situated inside the computational world.

Here we present three example systems developed in our lab. They are the Virtual Kyoto Garden, Touchy Internet, and Human Pacman. In the following sections, we will describe these systems in details.

3. Virtual Kyoto Garden

For years, Kyoto in Japan has beem famous for its unique garden art in the world. Recently, our research in Kyoto University also found out that, designing a mini sand garden can be a good aid for human mind therapy. However, designing a physical sand table is time consuming, and the white sand can be messy. To solve this problem, we come out with an novel idea of applying ubiquitous human media approach and develop an virtual garden designing system.

3.1 The System Design

The system was developed using the ARToolKit[5]. The layout is shown in Figure 1. On the table, there will be a base board consists of 12 different markers. The base board gives the position of the garden base. On the left, there is a menu board, where a catalogue of three dimensional garden object models is created and displayed on each page of the menu.

As shown in Figure 2, to view the virtual gardens and the objects inside, the user needs to hold the Head-mounted-display and camera, and point to one of the boards (menu board or base board). If she holds the paddle in front the camera, he will see a virtual wood paddle.

- **Picking up and Dropping.** By pointing the paddle closer to a virtual object on the menu board, the user can pick the object up. After moving the paddle with this virtual object on top to the base board (White Sand Garden), she can then drop the virtual object on the Table by tilting the paddle to a certain angle relative to the Table surface. (Figure 3)
- **Flipping pages of the menu.** At the left hand bottom of the menu page, there is a virtual button with virtual text "page change" on top. Using the paddle to "hit" the button gently will change the pages of the "menu". Then users can browse through different virtual objects on each page. (Figure 4)
- **Scaling of the virtual ponds in the Sand Table.** Pick up the "scale up" or "scale down" arrow from the menu and move the paddle horizontally closer to the center of the pond in the Sand Table, and then slowly move it away from the center. By doing this, users can easily increase or decrease the pond's size. (Figure 5)

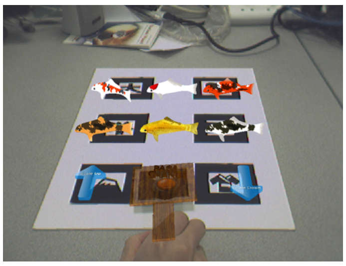

Figure 4: By hitting the virtual button using the paddle, users can change the pages of the menu.

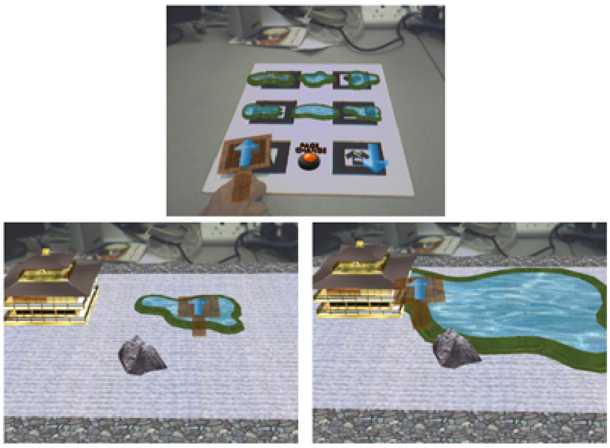

Figure 5: The paddle can also be used to scale the objects up and down in the garden.

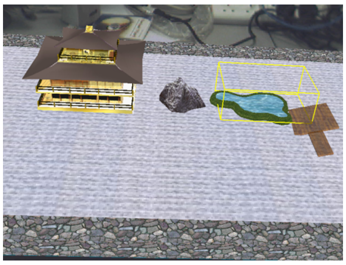

Figure 6: The paddle can be used to push the objects in the garden.

- **Moving of the virtual objects in the Sand Table.** Put the paddle parallel to the table surface and about the height of the virtual object which it's going to push. When the paddle is close to the object, a yellow box will appear around the object to indicate that it is in the"push" mode now. If the user continues to push the paddle, the object will be moved accordingly. (Figure 6)
- **Deleting of the virtual objects in the Sand Table.** Put the paddle parallel to the table surface and high on top of the virtual object which it's going to delete. Then use the paddle to "hit" the virtual object gently from above. (Figure 7)

Following the above steps, users can easily select the virtual objects that they are interested and design their own garden. This kind of human computer interaction is a radical departure from scrolling through a list of three-dimensional models on a computer screen. The interface now is the real-world object: a board and a paddle in this case, and thus it is a good example of ubiquitous human media space.

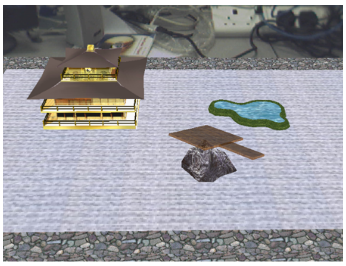

Figure 7: If the user "hit" the objects from above using the paddle, such objects will be deleted from the garden.

4. Human Pacman

4.1 Overview

Human Pacman is a novel interactive entertainment system that ventures to embed the natural physical world seamlessly with a fantasy virtual playground by capitalizing on mobile computing, wireless LAN, ubiquitous computing, and motion tracking technologies. It is a physical role-playing augmented-reality computer fantasy together with real human-social and mobile-gaming. It emphasizes collaboration and competition between players in a wide outdoor physical area which allows natural wide-area human-physical movements.

Human Pacman has some aspects derived from pioneering work that has been developed on ubiquitous gaming. Multi-player mobile gaming is demonstrated in 'Pirates!' [6]. However, visual and sound effects of game play are limited by the relatively low computing power of PDAs. The E3 project[7] examines the essential elements of free play, and multi-user social interaction. It focuses on human-to-physical interaction and human-to-human interaction. However it does not explore large-scale configuration where users walk around.

4.2 System Design

Human Pacman system features a centralized client-server architecture that is made up of four main entities, namely a central server, and client wearable computers, helper laptops, and Bluetooth embedded objects. Wireless LAN serves as a communication highway between the wearable computers, the helper computers (laptops), and the server desktop computer.

As shown in Figure 8, the heart of the wearble computer system used in Human Pacman is a Desknote A980 system, with a 3GHz processor and a NVidia GeForce4 video card. Twiddler2 acts as handheld keyboard and mouse inputting device for the system. Video input of the surroundings is obtained from Firefly digital firewire camera. The Cy-Visor video see-through Head Mounted Display (HMD) displays the processed video. Data from the InertiaCube2 (which has been fastened on the HMD) is obtained and used to track the user's head motion with a dynamic accuracy of 3 degrees. Data obtained from Point Research's DRM-III module helps in determining the position of the user through direct usage of its GPS data, or indirect estimation with the dead-reckoning method using its step-counting data, which has an accuracy of 2% to 5% of the total distance travelled. Bluetooth communication is made with the TDK Bluetooth USB Adaptor. A

Figure 8: Detailed configuration of research wearable computer system

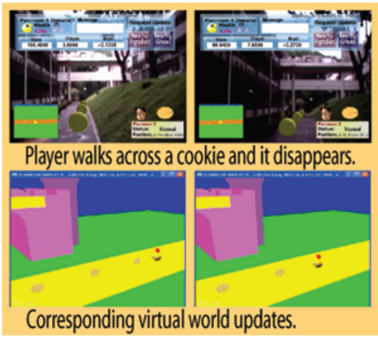

Figure 9: Pacman collecting cookies.

Figure 10: Sequence of pictures showing the collection of a special cookie.

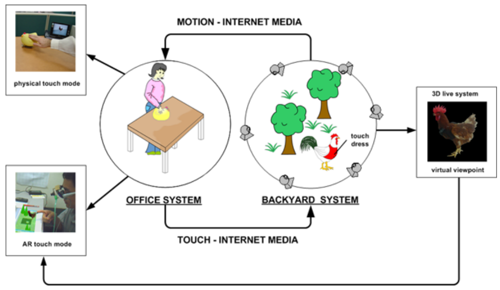

Figure 11: The general schematic of our system

touch-sensor circuit designed and built in our laboratory using capacitive touch sensors QT160 is used to sense the touching of the backpack by the enemy player or the touching of Bluetooth embedded objects by Pacmen.

4.3 Game Play

The players are assigned to two opposing teams, namely the Pacman team and the Ghost team. The former consists of two Pacmen and two Helpers; correspondingly, the latter consists of two Ghosts and two Helpers. Each Pacman\Ghost is in coalition with one Helper, promoting collaboration and interaction between the users. Pacman collects a cookie by walking through it. Such physical action is reflected visually in Pac-World through the disappearing of the cookie in both the AR and VR mode. In Figure 9, the top images show the HMD view of the Pacman player as she collects a cookie. When she walks through the cookie, the cookie disappears. This collection is also reflected real time in the virtual Pac-World (seen by Helpers) and Pac-World map (seen by both Pacmen and Ghosts) through the disappearing of the cookie in the corresponding location.

In Figure 10, a sequence of pictures shows a Pacman collecting a special cookie. When the Pacman is within range of the Bluetooth object (about a distance of 10 meters), communication takes place between the wearable computer and the Bluetooth device. The wearable computer sends the unique address of the Bluetooth device to the server. Upon receiving it, the server will then decide if the player is eligible to collect the special cookie that is associated with the physical Bluetooth object.

5. Touchy Internet

The another system we have developed in our lab is the Touchy Internet — A Mobile Pet Wearable Computer and Mixed Reality System for Human - Poultry Interaction through the Internet.

5.1 System Overview

This system is a human-computer-pet interaction system that transfers the human physical body fondling through the internet to the pet and at the same time transfers the pet motion in real time with a physical doll movement on our low cost X-Y positioning table or as a real time 3d live[8] view of the pet in a virtual garden augmented on the owner's desk. Figure 11 depicts the general schematic view of the system. As can be seen in this figure, our system consists of two physical entities. We define the *Office System* as the space and setup at the owner's office premise; it is where the owner fondles with the doll (or virtual 3d live view of the pet) and sees its physical movement that follows the pet motion. This in fact can be anywhere and not just an office. We also define the *Backyard System* as the space and setup where the real pet is reared. The Office System and Backyard System are separated by any distance, as they are both connected to the internet. The pet wears a special dress with some vibrators and whenever the doll (or the virtual 3d Live view) is touched the action goes through the Internet to the pet dress and the vibrators are activated and the pet feels the fondling sense.

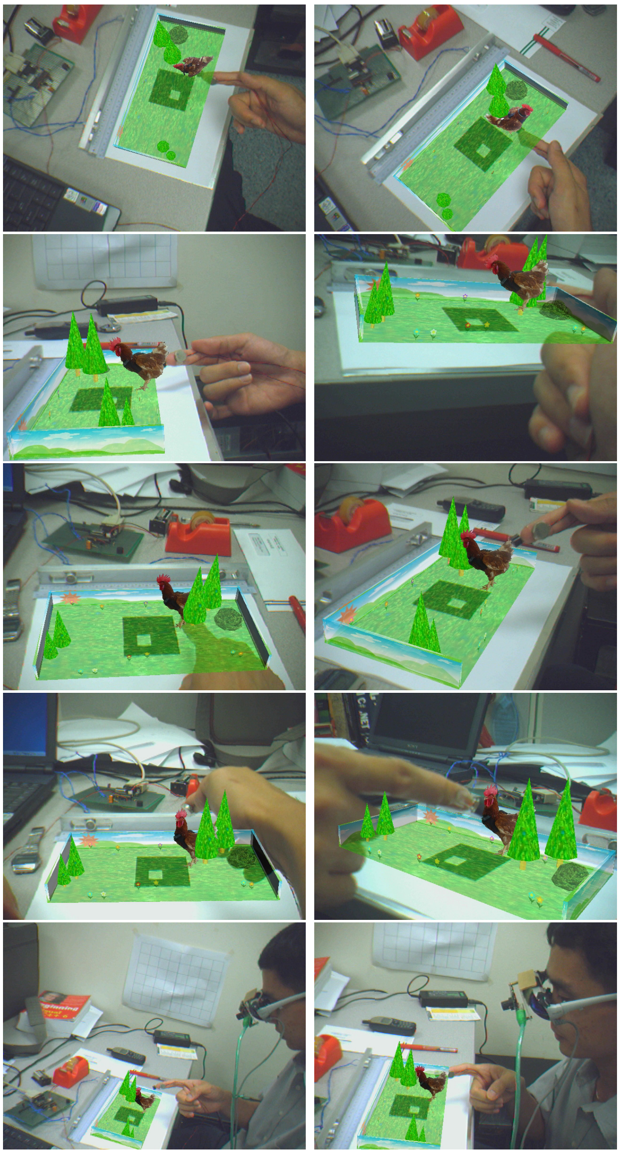

Figure 12: 3d live AR touch mode examples with virtual touching of the pet. Note that the pet is not a pre-animated or created 3d model but a live 3d viewpoint. Occlusion between the live pet and virtual objects such as trees can be achieved.

5.2 Multi-Modal Office system

To represent the pet for the owner in her office, we have realized a multi-modal interaction system with the pet which has two related parts. The first one is representation as a real time live captured 3d object augmented on the owners desk that we call *3d Live AR touch mode*. The second method is representation by a doll which we can have a real physical interaction with, which we call the *Physical touch mode*.

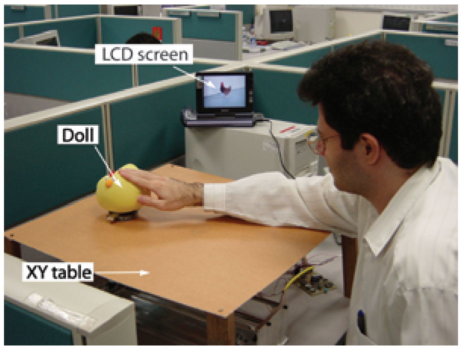

Figure 13: The pet owner fondles with the doll, which has touch sensors, and moves according to the remote located real pet.

3d live AR touch mode In the 3d live AR touch mode the user can see through the head mounted display (HMD) a virtual garden and real time 3d view of the pet which is augmented on her table. Figure 12 shows example of what a user can see in this mode. Here the user has a real time 3d realistic representation of her pet in visual form. The person will see live and in real time the actual 3d image of the remotely located pet. It should be noted that the pet is not animated or a pre-created 3d object, but an actual live 3d viewpoint.

To have the sense of touching, the user finger must be tracked to detect when it touches the virtual pet and then the touching event must be sent to the pet. For this we developed an ultrasound tracking to detect the finger position. Also we have put a vibrator together with the transmitter on the user's finger. It will be activated whenever the user finger meets the virtual pet. Therefore the user can have haptic feedback when she touches the virtual pet.

Physical touch mode Figure 13 shows the office system in physical touch mode. As can be seen in this figure, the user is touching the doll and at the same time she can see the pet in the LCD screen. The doll follows the real pet motion in 2D by moving on an XY positioning system. When she touches the doll, data is transferred to the pet dress and vibrates one of the vibrators on the pet dress according to the part of the doll which is being touched.

The physical touch mode contains two major parts which are described here: The doll which detects the user's touch and transfers it to the PC, and the XY positioning system which controls the doll movements based on the pet motion in the backyard.

5.3 Backyard system with Wearable Computer on Poultry

In the backyard we have set up the 3d live system containing six cameras mounted around the subject (the poultry in this application) to provide real time 3d live data of the pet from any arbitrary view point. If we do not want to use 3d live AR mode in the office system, we can have only two cameras: one on the ceiling for

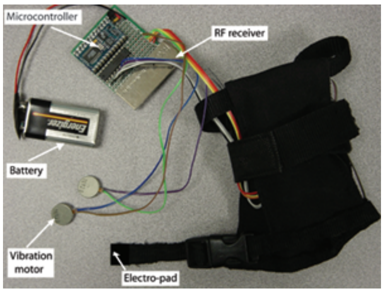

Figure 14: The dress of the pet with micro-controller, electodes and vibrators

Figure 15: The rooster wearing the pet-dress

tracking of the pet based on computer vision algorithms and another one for the front view imaging.

We have also provided a special pet dress for transferring the user's touch to the pet. Therefore the pet can feel whenever its owner touches its avatar on the office. In the rest of this section, we describe the design details of our pet dress, our vision-based tracking algorithm for 2D detection of the pet and its orientation and finally we describe the 3d live system that we used in the backyard to provide a real time realistic view of the pet.

Figure 14 shows the hardware system and the pet dress. Here we put five vibration motors on neck, back, left, right and breast of the pet. The total weight of our dress with hardware and battery is just 127 grams. Figure 15 depicts our pet (a rooster in this application) wearing the dress. Many tests on our pet rooster showed that it did not make any problem or discomfort for the pet to wear it (as will be detailed below).

6. Conclusion

In this paper, it was proposed that 3-D images and graphical interaction using the principles of mixed reality allows the new methodology of ubiquitous human media to be implemented and expressed in action. Ubiquitous human media is a computing paradigm that involves the elements of ubiquitous computing, tangible interfaces and interaction, as well as social computing. It brings the opportunity of placing computation and interaction through and with the environment, rather than only on a desktop computer with keyboard and mouse, in addition to incorporating the sociological organization of interactive behavior. Thus, using ubiquitous human media, a new paradigm in human computer interaction can be explored by researchers, developers, and users. Essentially, humans as physical beings now actually become situated inside the computational world.

The technical background of ubiquitous human media was discussed, and then application examples where shown where ubiquitous human media allowed computing within the physical environment and supports interactions both socially and physically. Moreover, these activities take place in the context of the environment. Using 3D graphical objects, tangible interaction, and 3D sound, it was shown that ubiquitous human media allows the manipulation of objects in physical space to interact with 3D digital information. For these systems, the computer is embedded in the activity in such a way that the user interacts with the environment, and physical objects themselves become the interface.

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