WINDOW SEAT

Visual Experience with an Interactive Chair

YEONJOO OH, DOO YOUNG KWON, BABAK ZIRAKNEJAD, KEN CAMARATA, AND ELLEN YI-LUEN DO
Design Machine Group, University of Washington

A**bstract.** Window Seat is an interactive furniture piece ("chairware") that acts as a control mechanism for viewing and navigating remote or non-existent locations, such as a scale model of a building or virtual world. We built a rocking chair as an interface that controls the two axes of movement of a pan and tilt camera. A video projector and mirror are mounted on the chair to display the remote interior space onto the wall in the front of the chair for a virtual space immersion experience.

1. Introduction

Computational capabilities are increasingly becoming embedded into our built environment. The shift from using Graphical User Interface (GUI) – mouse and keyboard to ubiquitous, invisible, and tangible computing is apparent (Weiser 1991). User interface research is moving toward the integration of computation in product design.

Our “Window Seat” project, developed in the physical computing course (Camarata, Gross and Do 2003) whose topic was an interactive chair, investigates how a built environment can be perceived and navigated through a rocking chair interaction. We are interested in how such everyday devices or appliances can serve as devices for interacting with a computational process or virtual world. Window Seat would allow its user to visually navigate a remote location, an unoccupiable physical space such as architectural scale model, a virtual environment or a “nano space” under a microscope. This paper describes related work, motivation, an overview and the process of designing, as well as future work.

2. Related Work

2.1 VIRTUAL REALITY NAVIGATION

Virtual Reality (VR) interfaces provide users with computational visual simulation. Perhaps the best-known VR visual interface is the Head-Mounted Display (HMD). A tracking device in the HMD provides with the location and orientation of the users' head (Chung et al. 1990). Unfortunately HMD requires the user to wear bulky hardware that restricts contact with physical objects. Alternatively, a CAVE may be used to interact with virtual reality worlds. A CAVE is typically a cube-shaped space with five screens (three walls, a ceiling and a floor) that surrounds the users. When the user moves a tracking device helps the computer that is generating the imagery provide the correct perspective and stereo projections of screens on the surrounding screens (Cruz-Neira et al. 1992, Cruz-Neira, Sandin, and Defanti 1993). However, HMD and CAVE VR techniques have some problems providing a convincing and comfortable immersion experience: poor display resolution, display jitter, and lag time between head movement and the resulting change to the display. These problems are obstacles to giving the user a feeling of being immersed in the virtual spaces. An alternative VR interface is Desktop VR (Robertson, Czerwinski, and Dantzich 1997). It uses animated interactive 3D graphics to immerse virtual space with desktop display and no head-tracking device. Our Window Seat provides the user with a front screen display similar to desktop VR.

2.2 TANGIBLE MEDIA

Tangible media interfaces allow direct control of electronic or virtual objects through physical handles. Research on tangible media has progressed, but most research involving furniture has focused on computationally enhanced tables. Bricks (Fitzmaurice 1995), a graspable user interface, "metaDESK" (Ullmer and Ishii 1997) and "DigitalDesk" (Newman and Wellner 1992) both use the desk as an input device. In contrast we have taken the approach of using the affordances of a rocking chair as a means of input.

2.3 GESTURE INTERFACE

Traditionally, the keyboard and mouse have been used as input devices. However, arguably, gestural interfaces are more intuitive and provide users with a natural interaction that can take advantage of head and hand movement (Segen and Kumar 1998). We simplified the movement of a standard analog games joystick to the simple directional gestures of up, down, left and right. Besides head and hand movement, body position gesture interfaces were explored (Kikuo et al. 2002). In Kikuo's project, 3D positions of arms and head were tracked and used in controlling viewpoint. This body position interface can be compared with a joystick in that both these interfaces can control the viewpoint. Our Window Seat chair is a similar gestural interface that has been designed to support point-specific views into remote spaces. It is a gestural interface that engages the entire body rather than only the hand.

3. Motivation and Demonstration Scenario

Window Seat is an ordinary person's virtual reality interface. Unlike a HMD or CAVE, Window Seat does not require expensive special equipment. It is built from easy-to-obtain parts. We built the Window Seat to explore how an everyday artifact such as a rocking chair can be used to mediate the visual experience of a remote location. A rocking chair has the advantage in that the simplified body behaviors such as up, down, left and right can be translated easily to the movement of a rocking chair. While sitting in the chair, the Window Seat user can inhabit a scale model and watch the video in front of them, as in a CAVE. The image provides a sense of being inside an otherwise unoccupiable space. The Window Seat can also be used to experience full-scale remote locations, or models (or other data) at other scales.

Making scale models of designs is common practice in architectural design. These models provide clients and other stakeholders with a better understanding of the design's spatial and architectural qualities (Sanoff 1991). Unfortunately, unless they are trained as an architect or possess strong spatial understanding, it is difficult for people to understand the relative scale of a model. Computer graphic models do provide a way for ordinary people to view architectural space but many architects will continue to build physical scale models. People cannot really 'get inside' the model to perceive what the interior space is like. Even with a scale model, it is difficult for people to imagine and perceive what it is like to be inside the model. Therefore, we designed Window Seat with a camera inside a scale model to provide interior views of the space.

In our Window Seat design, we paid careful attention to configure the camera movement to correspond to the user's viewing height. In order to make users feel that they are immersed in a real space, the viewpoint of the camera has to be mapped to the relative human height in the scale model. We developed a mapping scheme for motion translation inside an architectural scale model. In our demonstration, a simple camera is located inside a scale model of Steven Holl's St. Ignatius Chapel in Seattle.

4. Design Schematic and Diagram

We designed Window Seat chair to be a virtual joystick-like input device. The movement of the chair used two kinds of sensors to control the camera movement in the scale model: an infrared sensor below the seat and two pressure sensors on the arms. As Figure 1 illustrates, Window Seat has 5 major components: physical chair as input device, Handyboard as control device like a 'brain', camera as 'eye', projector as display device, and images on the wall for the simulated immersive environment. The camera is located in a remote place, in our demonstration inside an architectural scale model.

Figure 1. *Information Flow in the Window Seat*

Figure 1 shows the flow of information in the Window Seat. When users rock the chair and press the armrests, sensors transmit information to the Handyboard. The Handyboard processes the sensor information and uses it to drive the two servo motors that control the camera. The image (current remote viewpoint) from the camera is then projected on the screen by a video projector housed inside the back of the seat. We set up the screen on the wall to serve as a projection screen in front of the chair. We used as easy-to-obtain white shower curtain (Figure 2).

Figure 2. *Chairware Components; (1) Physical chair; (2) Handyboard; (3) Remote Camera; (4) Projector; (5) Wall as Display Device*

4.1 CHAIRWARE AS GESTURE INTERFACE

Our chair design is similar to a joystick. The user interacts with the chair to navigate the virtual space. In Window Seat the chair controls two axes of movement of the camera (up/down and left/right). When the user rocks the chair up and down, the interpreted gesture of camera movement is also up and down. The “up” gesture is produced by tilting, increasing the camera’s angle of pitch. The “down” gesture is produced by pitching forward. The “left” and “right” gestures are generated by rotating in those directions. The camera is designed to pan and tilt to show the interior space to the user of the chair.

Imagine what effects the camera movements provide users for immersion into virtual space. As mentioned, the camera acts as an “eye” in the Window Seat. The “up” gesture of the camera means that users tilt the head backwards, the “down” gesture means that users tilt the head towards the chest. “Right” and “left” gestures occur when users turn their head to left and right direction. In our demonstration, the camera as “eye” is fixed on the specific point in the architectural scale model, thus users can experience being inside the model. In Window Seat, directional gestures are transmitted directly to images that users can see on the front wall.

4.2 PHYSICAL DESIGN OF CHAIRWARE

The rocking chair makes handling easy in one axis - the chair can easily rock back and forth to control the camera. The control of another axis is achieved by pressing the armrests. The two buttons (pressure sensors) are inside the arms of the chair. Each sensor corresponds to one direction; if the user pushes the left sensor, the camera will turn left.

The use of pressure sensors instead of a swivel to pan the camera allows the projected viewpoint to easily be displayed on a wall surface. If the chair also swiveled, a wrap around screen would be required.

In the design process we also considered the ergonomic aspects of sitting comfort, using chair design standards for length and width of the seat and back (Cranz 1998).

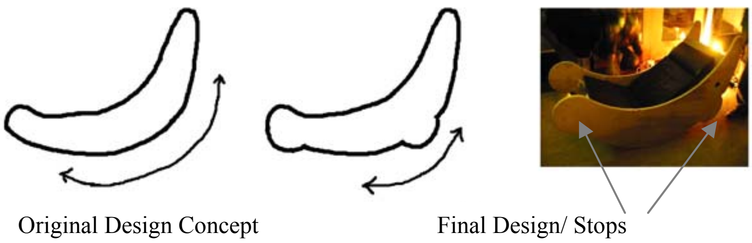

Figure 3. *Stops for Chair Balance*

The basic shape of the chair is a crescent-like simple curve (Hennessey and Papanek 1973) made of plywood. We designed the chair to balance easily with stops, which we placed in the middle and the end of the chair curve (Figure 3). Without these stops, the crescent shaped chair could fall backwards because of the heavy weight of the video projector.

Our original design considered the alternatives of a screen connected to the rocking chair from either the top or the bottom of the chair. (Figure 4 (a))

These alternatives have the strong merit that the projected images move simultaneously with users, because the screen attached to the chair is moving with chair at the same time. That, in turn, would allow the user to control the camera pan simply by swiveling the chair. However, we encountered some problems with that alternative. Attaching the screen on the chair top makes the chair unbalanced. Mounting the screen on the bottom of the chair makes it hard to sit comfortably. In spite of these difficulties, these design alternatives have the potential in a future version of the Window Seat.

In order to project the images onto the front wall, we mounted the projector inside the back of the chair. The heavy weight of the video projector might give the user a difficulty to rock the chair. We designed a book shelf on the bottom of chair to act as counter balance for the chair so that this book shelf helps the user rock easily, and which also serves a book storage place (Figure 4 (b)).

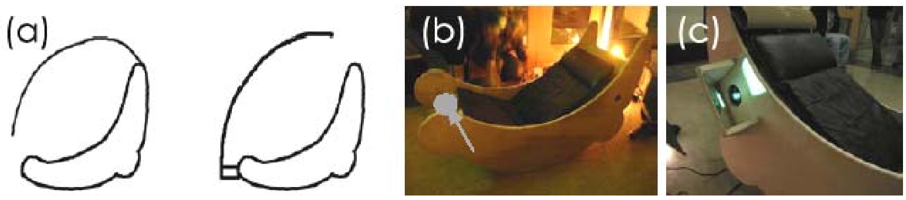

Figure 4. *(a) Screen Design Alternatives (b) Bookshelf for Chair Balance (c) Projector and Mirror Placement*

4.3 PLACEMENT OF PROJECTOR AND MIRROR HOUSING

We used a video projector to display interior space images onto the wall to create an immersive illusion for the users. We considered several different design alternatives and made several attempts to position the projector. We first tried to put the projector on the top of the chair, but discovered that the placement of the projector has to be different depending on the user's height and body shape. Therefore we decided to put the projector inside the back of the chair and used a mirror to reflect the image (see Figure 4 (c)). A visual image from the projector is projected to the mirror, and then reflected out to the front screen.

4.4 PLACEMENT OF SENSORS

Two kinds of sensors were used in the design: an infrared sensor and pressure sensors. A single infrared sensor is used to find the distance from the floor; the pressure sensors act as variable resistors. The infrared sensor is located under the seat and senses the changing value range from the floor. It is placed beneath the rocking chair for sensitive distance measurement.

The pressure sensors act as variable resistors. We had contemplated several options. The first option was to set them up on the seat cushion so that when the user's center of gravity moves toward to the right, the camera will pan to the right. However, this interaction seemed unnatural. Furthermore, it was different to calibrate the camera movement related with the value of pressure sensors. Another idea was to install pressure sensors on the chair base so that the buttons will be pressed when the user sits up. The location of the buttons would be close to the location of the user's legs. However, if the user leans back or lies down on the rocking chair, it would become difficult to press the pressure sensors. Therefore, we decided the proper place for the pressure sensors is on the armrest. This setup makes it easy for the user to press them regardless of the user's position on the chair (See Figure 5).

4.5 MOVEMENT CONTROL: CAMERA AND HANDYBOARD

A digital camera is located in a remote place to show interior space images (see Figure 1). In our demonstration, we placed a digital camera in the architectural scale model. The camera is attached with two servo motors for two axis movement control.

We used a Handyboard for controlling the two servo motors, infrared sensor, and pressure sensors. The Handyboard is a microcontroller system with sensor and motor ports. It is designed for experimental mobile robotics work (Martin 2001). Our interactive C program running on the Handyboard translated the sensor values to corresponding actions (Leider 2003, Martin 2003). The values of the two kinds of sensors are transmitted to the Handyboard and then the Handyboard controls the servo motors to tilt and pan the camera.

5. Electronic System: Two Kinds of Sensors

5.1 INFRARED SENSOR AND PRESSURE SENSOR

We used two kinds of sensors; an infrared sensor and two pressure sensors. The infrared sensor is located beneath the seat (Figure 5), it senses the distance from the floor to the chair. When the rocking chair moves, the value of the sensor is changed. This change makes the camera tilt.

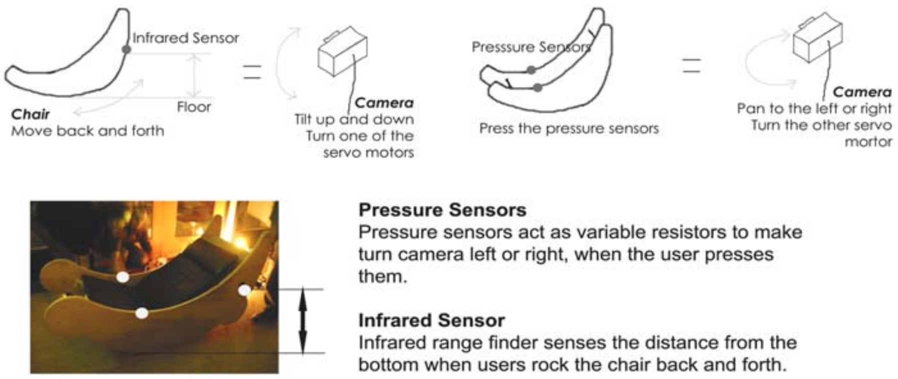

Figure 5. *Camera movement and Sensors Placements*

As shown in Figure 6, the pressure sensors are wrapped by conductive foam, and sandwiched between two washers. These pressure sensors act as variable resistors. When the user pushes the left pressure sensor, the camera pans left, because the Handyboard makes one of servo motors rotate. The camera returns to reset default, if the user pushes both pressure sensors at the same time.

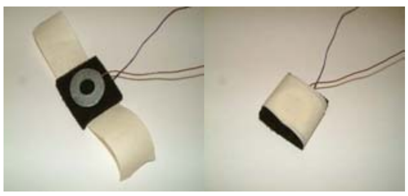

Figure 6. *Pressure Sensor with Washers and Conductive Foam*

6. Mechanical System

6.1 MOVEMENT OF CAMERA: SERVO MOTORS

We used two servo motors to control the pan and tilt of the camera. For these two axes movements, two servo motors are attached at a right angle, and then we put together camera and two attached servo motors (Figure 7). If the user controls the chair to move back and forth, the value of the infrared sensor is changed, and one of servo motors would tilt up and down. Similarly, if the user pushes one of the pressure sensors, the value of the direction is sensed to cause the other motor to pan.

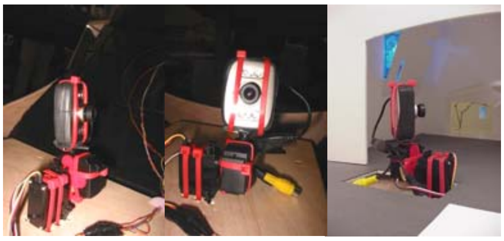

Figure 7. *Camera and Servo Motors*

7. Immersing Experience

In the demonstration Window Seat was used by over 20 people. At first they just sat and rocked the chair. After that, they realized that they can control the viewpoint by rocking the chair and pressing the buttons on the armrests. User can see visual images on the screen in front of the chair without any motion sickness. The projected visual images move as the user rocks, because the video projector is located on the chair and it is moving with chair at the same time. For example, when the user rocks the chair backwards, the images move upward (Figure 8).

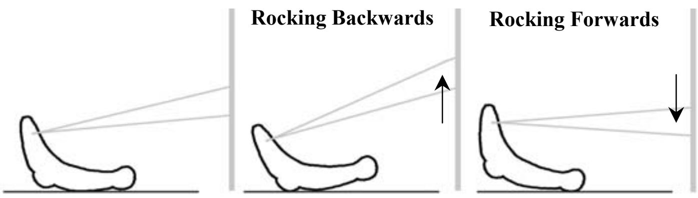

Figure 8. *Moving Image on the Screen*

In our demonstration we place a small digital camera inside an architectural model. The scene the camera "sees" is projected on the wall in the viewing spaces. With the chair the user controls the camera tilt and pan to look in different directions within the model. Our scale model is the Chapel of St. Ignatius by Steven Holl. Our model was rough but included characteristic features of the chapel. Therefore, most people got to know what they saw and where they navigate. As shown in Figure 9, user can get images similar to what they might experience immersed in the real chapel. The second and the last images are views inside the model, and the other images are real photos of the chapel. Navigating in the scale model by simple controls gave people pleasure as well as a chance to experience this visual illusion.

Figure 9. *Images on the Screen at the Demonstration; the second and fifth pictures are the projected images on the screen. The rests are real photos.*

8. Discussion and Future Work

We look forward to developing this research in a variety of respects: design alternatives, immersion experience, and the potential remote space. First, we chose to restrict the chair movement to correspond to only one axis movement of the camera (tilt) in our chair design. The other axis movement (pan) used the pressure sensors as variable resistors instead of swiveling the chair. The swiveling chair design gives the user a better experience of virtual space. However to accomplish this visual experience, we need to build the screen in all directions in order to create an immersive environment. If the chair can turn to the left and the right, the screen would be have to be set up on at least the walls in the whole space where chair is placed like a CAVE. We decided to allow the chair to only move in one axis so that only one screen is required. In the current demonstration, projected images move up and down on the front wall according to the chair movement. The screen remains static, because the video projector is mounted in the back of a rocking chair.

Our project is simple, but it works. In the future, we would like to further explore the potential or creating real immersion sensation of remote location. One direction is to employ a mobile camera. The current camera is fixed at a specific position. If we put the camera on a mobile device inside the model, then 'drive-through' experience through the space instead of 'head movement only' in a fixed location. The camera can be moved in the space, and users can have more realistic visual experiences.

We use an architectural model as the remote location for our demonstration. However, the remote location can be a geographically remote place, an unoccupiable space such as a molecular scale space, or a distant space like a space trip. Perhaps more relevant to architectural application, the remote location can be a real, physical environment such as a historical building in another city, or a construction site.

Acknowledgements

We thank Professor Mark D. Gross who gave us helpful comments. We are also grateful to another WINDOW SEAT team member, Jennifer Lewis who cooperated with us.

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