Everyday Objects as Interface: Collaborative MouseHaus Table, a Physical Interface for Urban Design

ABSTRACT

Computer visualization for urban information has provided opportunities to involve the public in the urban design process as never before. MouseHaus Table is a physical interface for urban pedestrian movement simulation in a group setting. The portable interface includes a video camera, colored paper, scissors, and a table with a projected display. With a registration process, users can employ color paper cutouts to represent building type, size, and location as input for the pedestrian movement simulation program. The interaction in MouseHaus Table leverages users' everyday knowledge and adds computational power to a face-to-face discussion of design issues. A preliminary study suggests that a paper interface engenders more conversation and gesture interaction among design collaboration.

KEYWORDS: tangible user interface, pedestrian simulation, urban design, collaboration.

SCENARIO

The XXX State Department of Transportation is in the very early stages of planning a multi-modal transportation center at XXX Street Station in the South Downtown area. The University of XXX College of Architecture and Urban Planning has been asked to hold a design charrette to generate ideas for how the new transit facilities can integrate with the South Downtown Neighborhood. Public participation is crucial to the success of this design effort. A visioning session with a public presentation and exhibition is planned to engage community members in discussing the neighborhood development.

One issue the charrette faces is how the street layout will affect the pedestrian movement. We provide a visioning tool, MouseHaus Table, to help collaborative stakeholders evaluate the pedestrian behavior of alternative street layouts. Three to five community members can work as a group around the table to create a street layout and evaluate the resulting pedestrian movement. They can use scissors to cut out paper rectangles to represent the buildings or parks and lay them on the MouseHaus Table. The embedded simulation program in the MouseHaus Table then provides pedestrian movement feedback using the resulting street layout.

Collaborating stakeholders can choose objects with different colors to represent buildings and parks. They register the objects with the Physical Object Register in the MouseHaus Table. When the colored paper is placed under the video camera, the Physical Object Register will read the RGB value of the colored paper and associate them with the corresponding urban elements in MouseHaus Table. After registration, whenever the user puts any red objects on the table, these objects will be recognized as urban buildings and the location and dimension information will be recorded and translated into the MouseHaus simulation program. Stakeholders can also discuss the arrangement of different urban elements on the table. When a specific street layout is arranged and activated, the pedestrian agents would start to appear on the table. These pedestrian agents perform behaviors such as moving between the buildings or resting in the parks on the table. Certain layout design may affect pedestrian movement pattern and impact density points in the urban space. The system can save these patterns for later discussion. Stakeholders may rearrange the street layout to produce the preferred movement pattern and density level for the urban space.

INTRODUCTION

Land-use planning and urban design decisions today must involve community participation. Providing urban information visualization for public participation may improve the quality of design process and enable the community to express design criteria and alternatives that designers might not anticipate. Interactive simulation can offer powerful tools to facilitate this discussion. Along these lines, MouseHaus Table is designed to provide a multi-user environment to engage discussion in the urban design context. MouseHaus Table provides a simple pedestrian movement simulation program to sample the complexity of urban design process. Its physical interface also enables participants without any previous computer experience to interact with the simulation.

The concept of physical interface follows a tradition of participatory design practice that became popular in the 1960s and 1970s. In this tradition, the design process was carried out with physical materials [2]. Community group stakeholders would be encouraged to manipulate these materials and to use them to comment on the relative merits of the design and to propose new alternatives. Recently, the concept of tangible user interfaces has become an active area of Human Computer Interaction (HCI) research. In a tangible user interface, a computer system detects a user's manipulation of physical objects and provides responsive feedback. The MouseHaus Table's physical interface, which uses everyday objects in the design process, is a proof of concept example of a tangible user interface for collaborative design. MouseHaus Table differs from many other tangible projects in that it enables users to employ ordinary materials as the interface. MouseHaus Table bridges physical objects manipulation, group activity, and computer simulation of pedestrian behavior.

SYSTEM ARCHITECTURE

In order to engage the discussion in the urban context, we developed a working prototype for a multi-user collaborative environment, MouseHaus Table and implemented the concept using everyday objects as interface. MouseHause Table has three components: (1) hardware setup - a table with a video camera 3 feet above the table to capture the image of the desktop that has a projection screen, (2) MouseHaus pedestrian simulation program, and (3) a physical interface – two image processing programs, a Physical Objects Register and an Object Detector, to register objects by color and recognize object type and locations in the simulation. We will explain the detail of these three components in the following paragraphs.

Hardware Setup

The hardware setup for MouseHaus Table consists of a custom-made table with a rear projection screen, a video camera and projector. We implemented the system with common and inexpensive computer peripherals that can easily be made available in any community meeting. We wanted to make MouseHaus Table easy to setup and portable.

The table surface is made of wood with a translucent plastic surface in the center. The tabletop is the surface for users to place pieces of colored paper to indicate or propose the location of urban elements such as buildings and parks. A mirror mounted under the table reflects the image from the projector to the translucent plastic display screen. Figure 1 (Left) shows the hardware setup and Figure 1(Right) shows the interaction of the MouseHaus Table. The screen of the MouseHaus simulation that was originally displayed on a computer monitor is displayed on the MouseHaus Table. The captured image from the camera above the table is sent to the image processing program (described below) to identify physical object placements and create objects in the MouseHaus simulation program. Collaborating stakeholders thus can use physical objects on the table as input and have the corresponding image of simulation overlaid on the same table.

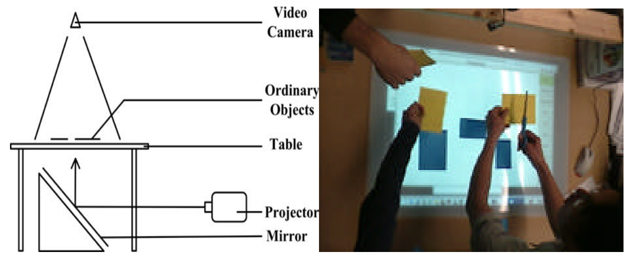

Figure 1 (Left) Hardware Setup, (Right) Interaction in the MouseHaus Table

The table is modified from a normal workbench. We replaced the top with a 50" by 35" chip board, cut a 32" by 24" rectangle in the center and place a 32" by 24" size translucent plastic plate. We set a mirror at 45 degree under the translucent plastic plate and a Sony LCD Projector VPL-V800 facing the mirror to produce a rear projected image on the table. We positioned an Intel CS-110 web cam 3 feet above the table. Both the projector and web cam are connected to an IBM ThinkPad X20 notebook running the image processing and the simulation program

MouseHaus

MouseHaus is a simple pedestrian simulation program implemented in Java by XXX, a former member in our group [5]. The MouseHaus was inspired by a traditional Thai-Chinese toy, "Mouse Palace". Mouse Palace consists of a set of wooden house-like blocks for children to construct an environment to observe the behavior of mice. MouseHaus is hence a simulation program to enable designers to project the impact of a physical environment on pedestrian behavior.

In the simple MouseHaus simulation, pedestrian movement is based on the concept of artificial life [5]. Each "Mouse" agent has both an internal and external state. For example, when the simulation starts, one type of agent in this model select a random destination as the initial internal state. At each time step, the agent accumulates external stimuli on its way in the form of the urban element layout that has been constructed by the user and decides on a course of action - to move forward, turn, pass or stop. The combination of all the individual motion paths produce a pedestrian pattern. Because we simplify the complexity of human behavior in the agent simulation, we call the agent in the simulation "Mouse" rather than a "pedestrian".

The color of each pixel passed by a pedestrian agent will turn from green to yellow, to orange- the more the pedestrian agent passes through a certain point, the more saturated the color becomes. Figure 2 (Left) shows an example of the pedestrian movement pattern. The saturated color is where the pedestrian agent tends to gather. The white rectangle indicates where the orange color emerges.

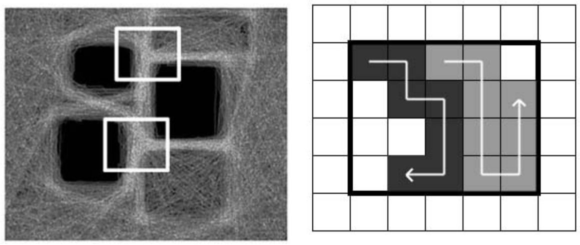

Figure 2 (Left) A sample pedestrian movement pattern, (Right) Search path of Object Detector.

MouseHaus Table

MouseHaus Table is a physical interface for the MouseHaus pedestrian simulation. The physical interface is driven by an image processing program employing Java Media Framework to capture and analyze an image. We wrote a Java application to capture individual frames from the real time image and process the image. The image processing program has two parts: a physical objects register and an object detector.

Physical Objects Register. MouseHaus Table uses the color of the objects to distinguish different objects from one another. Users must put the objects that they want to use as urban elements under the video camera and the Physical Objects Register program will complete the registration process. Different colored objects are then associated with different elements types in the MouseHaus simulation.

Object Detector. When users place previously registered objects on the table, the object detector program scans the screen image from the top left to lower right, row by row. Each time the object detector finds a non-empty pixel, it calls a flood function to determine the boundary box of adjacent pixels of same color. Figure 2 (Right) shows the searching path of a black object and a grey object. The boundary box search process finds the diagonal top left pixel and bottom right pixels and draws the rectangle.

Based on the physical objects register and the object detector, the arrangement of the colored paper on the MouseHaus Table is then transferred to the street layout of the simulation program. The mapping between urban block and tangible user interface is accomplished through the color image recognition.

PRELIMINARY USABILITY TEST

To observer how MouseHaus Table enables users to collaboratively discuss the impact of street layout on pedestrian flow with everyday objects as interface, we conducted a preliminary usability testing. The focus of the test was to find out how the application affects user collaborative behavior rather than how efficiently they use the application. Thus, we created three tasks: hand-on task for MouseHaus Table, paper interface task, and the traditional mouse interface task. All tasks were carried out on the table. We also administered post-test questionnaires and conducted user interviews which addressed participants feeling on these two interfaces.

The first task was designed to familiarize participants with the system. Participants were given a print-out pattern and asked to construct the layout pattern of pedestrian behavior. The second and third task started with the street layout of the first task. With the existing blocks in the first task, the second task was to decrease the overall pedestrian density with paper interface and the third task was to increase the overall density using a mouse interface. Participants repeat the second and third task three times in order to create several design alternatives and then select a preferred layout at the end of each task. Thus we have results named Paper Trial #1-#3 (P1-P3) and Mouse Trial #1-#3 (M1-M3).

Table1 Number of layout change

ID	Paper Trial			Mouse Trial		
	P1	P2	P3	M1	M2	M3
A	9	9	7	6	0	0
B	14	14	17	9	0	7
C	7	7	17	0	7	5

We recruited three participants for the preliminary test: two architecture graduates and one undergraduate with an architecture minor. Results showed that people had more conversation and gesture interaction in the paper interface than in the mouse interface (Figure 3). Moreover, in the mouse trial #2, one person seemed to dominate the change of the layout while the other two participants acted as bystanders. Table 1 shows that the number of layout changes is higher in the paper interface. For example, participant A did not engage any layout arrangement in M2, and M3, but he changed the layout 11 times in P3. We did not report any statistics significance due to the small number sample.

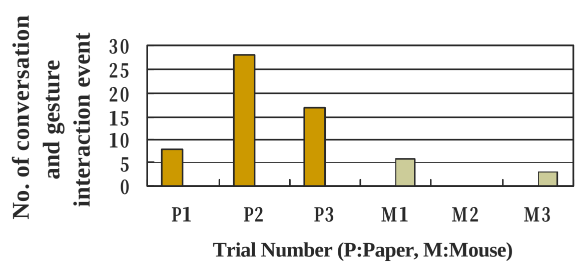

Figure 3: Number of conversation and gesture interaction event

The post-test questionnaire revealed that the paper and table input makes it slightly easier to contribute to the layout and facilitates more group interaction. When using the mouse, people felt that one person should be in charge of the layout configuration.

PRELIMINARY USABILITY TEST

A tabletop workspace has long been an appealing topic for HCI researchers. DigitalDesk, Tangible Geospace, metaDESK, Sensetable, etc are few examples that apply either a computer-vision-based approach or a sensor-embedded presentation [3, 6, 7, 9]. Many projects such as Envisionment and Discovery Collaboratory (EDC), Urp, Illuminating Clay, further applied the tabletop digital media into an urban design or landscape planning context [1, 4, 8]. In the EDC project [1], Arias et al. use an electronic whiteboard and an antenna-embedded board as workspaces for design collaboration. The electronic whiteboard has a single-user limitation similar to a standard mouse. In the antenna-embedded board, the tokens provided for information gathering must be pre made. Urp provides shadows cast, wind simulation and other digital information as system functions and uses physical objects to activate these functions [8]. Illuminating Clay provides moist porcelain clay for users to shape terrains while a laser scanner mounted on the ceiling captures the geometry of the model and processes data to project back on the clay model [4].

The physical interaction of MouseHaus Table is similar to DigitalDesk. A video camera is used to capture physical input from users and overlay computer generated feedback onto the table with a projector. However, unlike other tangible user interface projects, MouseHaus Table works with ordinary objects that don't reauire advance preparation. EDC depends on pre-configured coils in the token. To recognize the physical objects in Urp, a pattern of actual colored dots must be affixed to each object. In the Illuminating Clay, users can form landscape models and see images cast back onto the model, but the porcelain clay and laser scanner are both specific and costly requirements. Unlike other tangible user interface projects having to depend on pre-configured gadgets, MouseHaus Table enable users to register everyday objects and assign them specific meanings for later application use. There is no need for users to have any professional skill to work with the dynamic digital simulation.

DISCUSSIONS

We found from the user interviews that participant appreciated the paper and table interaction with the computer simulation. Two of the participants mentioned that the paper interface created a "dialogue" between humans and computer. They emphasized the value of hand movement in the design process. We also found that the tabletop affected participants' response to the simulated pedestrian agent. We explained to the participants that the behavior of the pedestrian agents is totally random and different from real human behavior. However, when the participants finished the first hand-on task and started to place papers on the table, they referred to the agent as "people," or "guys." Both above examples showed how the design process can be enhanced by a physical interface with digital simulation.

We are only using color information to connect everyday objects with a computer simulation program. In the computer vision research field, there are many other detection and pattern recognition techniques which can be used to augment everyday objects. However, from the user feedback, we found that participants especially like the interaction between them and tabletop in the layout task and they appreciated the paper interface. One important design principle suggested here is that the interaction between human and computer can be enhanced with a physical interface. We believe that tangible user interfaces have the potential to live outside the research laboratory. We suggest that integrating a better defined user task while designing a tangible user interface and having more careful evaluation work could lead to insights that may ultimately improve the computer supported design process.

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