SPARK WALL

Control responsive environment by human behaviour

KUAN-YING WU and JUNE-HAO HOU
The Graduate Institute of Architecture, National Chiao-Tung University, Hshichu city, Taiwan
{rainage, jhou}@arch.nctu.edu.tw

Abstract. Responsive environment uses human computer interface (HCI) to improve how human experience their surrounding. Many research aimed at different kind of interactive environment modules with new digital tectonics or computation components. However, those new environments are sometimes could be manipulated by components which are less use-friendly and complex than traditional counterparts. In this paper, we implemented a real responsive interface – the Spark wall system, which use 160 actuator modules as our responsive feedback interface and depth camera as sensing input. We built up multi-modal interface for different operating purposes allowing user control responsive environment with their human behavior. User could change their body posture to change the pattern of the wall and moreover define touch-input area on any surface. For the user’s perspective, a responsive environment should be simply and understandable control. A responsive artifact should also be able to dynamically correspond to different methods of operation according to the user's intentions.

Keywords. Responsive environment; human computer interface; surface computing; multi-modal interface; depth sensing.

1. Introduction

In architecture, various new techniques have been developed to deal with dynamically changing demands on space. Responsive environments are composed of sensors, controllers, actuators, and materials to create a lot of new flexibility elements (Kroner, 1997). Interactive tectonics and skins can sense human movement by sensor network. It affects functional change to
the building construction. User cannot only control physical artefacts to display information and contents in digital environment, but also operate graphic user interface to affect the natural world. These developments point towards an architecture that can become more interactive with human and smarter (Aldrich, 2003; Anders and Phillips, 2004).

People interact with different artefacts by specific behaviour. The behaviour should be corresponded with particular purpose (Huang et al, 2013). We use our finger press the button to turn on a lamplight. Turn a knob to adjust the volume. When responsive environments adapt for different contents and sense through interactive technologies, people do need a new operate behaviour for those new interfaces.

In this paper we present Spark Wall, an implement system, which compose by a mechanical wall with a large number of actuators and 2 optional interactive modes. People can simply walk closely or move their body at different distance to change the display pattern of the physical pixels. Moreover, our system presented a new possibility to support this simpler creation of touch-base interface on everyday surface to control surrounding environment.

1.1. RESPONSIVE ENVIRONMENTS

Responsive environments include sensate space, enabled by spatially and socially triggered devices, intelligent and smart house, and sensor network environment. Nakajima (Nakajima et al., 2005) suggests that our daily lives will be more attractive when our surroundings become more intelligent. Fox (2012) indicated the potential role of robotics in architecture with decentralized control. A modular robotics and intelligent responsiveness are fundamental steps in the future of interactive architecture. Architects need to formulate the basis for physically dynamic architecture to carry out human needs.

1.2. SURFACE COMPUTING

Multi-touch has emerged as a new dominant paradigm on a wide range of device from phones and tablets to table tops and interactive wall. Together with multi-touch features and fast graphics capability, the direct touch aspect of these systems allows a more convincing simulation of the manipulation on physical objects than on mobile devices or laptops available previously.

Everywhere Display created ubiquitous graphic interface let displays on different surface in an environment (Pinhanez, 2001). Light Widget (Fails and Olsen, 2002) showed any visible surface that can be turned into an interactive widget that uses hand gestures. Wilson and Benko (2010) combine depth camera and projection to design the LightSpace prototype to provide
interactivity on and between surfaces in everyday environments. Those issues integrate graphic user interface and computation operator and allow user to “touch” the visual information on physical world.

2. Problem and objective

There are many researches aimed at different kinds of interactive environment modules. However, most existing of interactive environments was designed for three real-time responses by sensing human movement, and adaptive automatically by agent system or control by GUI on mobile device or computer. More and more complex responsive artefacts were created to adapt into real live space. But people who use those environments could not use their action to control those interactive artefacts. How to appropriately combine the HCI device and responsive environment into real space to enhance the human behaviour interaction? How can we solidify the links between people and spaces by using HCI technologies?

In order to create a responsive environment which can adequate feedback and strengthen the relationship between human and space, we present “Spark Wall” (Figure 1). This physical installation is activated by different degrees of tactile sensation that are determined from the user’s control behaviour. And it is implemented with 160 open-and-close modules to build up as 8x20 actuators with real-time computing system (Figure 2). The wall is the main component of our responsive environment.

After building the interactive wall, we design two different input modes of interface. One is location responsive mode. We use depth camera to capture spatial location and sense the human movement, then immediate re-
response to the interactive wall. The other is surface touching mode. We integrate virtual information of environment and graphic user interface as a tangible surface. Using this system, touch-based interactivity can be similar to any unmodified surface for sensing different degrees of touch and press to adapt for user’s control behaviours. User can interact with interactive wall with natural behaviours and be conscious of how to control the open-level of each unit.

Figure 2. Spark wall integrates 160 servos to achieve physical pixels.

3. Design Process

In this paper, we focus on the development of multi-modal operators to link with responsiveness, which could not apply conventional control method as traditional artefact in our home. Therefore, We need to design an output interface with HCI technology for future smart space where human can communicate with environment intuitively and naturally. The new responsive interface in our concept is a dynamic wall. We reference the characteristics of responsive environment system (Table 1), which proposed by Lino et al (2010) to describe the characteristics of spark wall. For good contextual resolution, we choose physical pixel display and allow people on both sides changing the transmittance to interact with each other.

Table 1. The characteristics of spark wall system.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>User-Centred Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>Easy to assemble and replace, self driver</td>
</tr>
<tr>
<td>Interaction</td>
<td>Resulting in interaction models that are non-invasive and non-obtrusive, and</td>
</tr>
</tbody>
</table>
interface need to reflect the user's subtle movements

<table>
<thead>
<tr>
<th>Context awareness</th>
<th>Play a role as physical pixels and intelligent façade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptation</td>
<td>Multi-modal control by body movement and surface touch</td>
</tr>
<tr>
<td>User Experience</td>
<td>Responsive according user control mode, relative relationship, duration, and self-define interface</td>
</tr>
</tbody>
</table>

3.1. HARDWARE

- **Open-and-close module**: The core hardware is the open-and-close module that included four blades and motion mechanisms drive by one servo. Each module can be independently controlled to adjust the degree of opening and closing, to achieve transparency of the physical pixels (Figure 3).
• **Actuator group:** In order to facilitate maintenance and cost considerations, we put 16 open-and-close modules as a group (Figure 4, c). Each group used a 16-channel servo driver board as self-management agency to independently manage the movement of each motor. Therefore we have 10 individual actuator groups could self-handle the number of large and complex motion control.

• **Sever-Slave control:** The whole control hardware system used I2C protocol, which is a very simple communication way. Let device make with few connected wires and unique ID for each servo driver as slave-unit. When servo unit is working, we use Arduino board to sent out the control message by broadcast to make the request that the slave unit needed.

### 3.2. SYSTEM SETUP

The Spark Wall system consists of three main components, as shown in Fig. 4 top: the responsive wall, movement-aware interface, surface touching interface. The responsive wall is hanging from the ceiling and the maximum height is about 230 cm. We integrate this wall and movement-aware system into one server computer (PC1) to get depth data through processing camera’s image and send actuator control signal via comport to responsive wall. There is the other server computer (PC2) connected depth camera and projector as surface touch interaction system to capture signals when user is touching on different surface then send actuator control signal via wireless network to PC1.

![Image](image.png)

*Figure 5. The wall is in the standby mode while sensing distance > 300cm (a). Motion detection mode: The wall unit is triggered by sensing user movement shift when user is enter in between 80cm to 300cm. (b, c, and d). Immediately interactive mode (e, f).*
3.3. INTERACTION

For the current implementation, we develop two main operator modes, allowing people interactive with Spark Wall, based on two different concepts of user experience:

- **Movement-aware**: Common concept allows people make connection with interactive wall (Figure 4, f). We use depth camera as input device to get two kind of information. One is the distance between people and this wall. The other is bounding region that we capture user’s image and map on the wall. We design several patterns when users stay in different areas. In this scenario, we turn Spark Wall as a contextual display. The transparency of the physical...
pixels reflects the distance between human and the wall. In default mode, if no user into the sensing area, distance > 300cm, pattern will be in the standby mode with slight opening and closing regularly (Figure 5, a). In this mode, each wall unit is triggered by sensing user movement shift when user is entering between 80cm to 300cm (Figure 5, b-d). The immediately interactive mode is an additional mode in our interact scenarios. If users in the double sides of the wall are entering between 50cm to 80cm (Figure 5, e, f), they can interact with each other. This responsive wall is kind of social interface if there are two persons on different sides. The physical pixels those between them will change the transmittance from blur to clear allowing them meet each other and say hello (Figure 5, f and Figure 6).

- **Surface touching:** The core objective of this mode is to make user simply define control interface quickly and easily, such that they could feasibly customize an interactive area each time they need (Figure 4, e). Users define their interactive area though moving their hand over the target surface. To achieve this, we combine the depth camera and projector to provide user touching surface as a sensing interface tool. First, when the system starts up, we capture 20 consecutive depth frames and average them to produce a depth background profile (Figure 7, a). It is important that the scene must be stationary and in a background configuration when system is initialized. Within this background image, we can separate object pixels from depth pixels as significant pixels. Significant pixels differ from background surface by at least 5 mm and at most 50 mm are considered touch pixels. Then we use blob detection to turn touch pixels into touch blob image (Figure 7, b). That indicates user to touch on the surface. The system will record the touched paint until users lift their hand. The paint image is defined as interactive area and the control interface is done (Figure 7, c).

### 4. Conclusion

In summary, this work outlines some ways in which spaces can get physical activity and social data through some peoples’ behaviours and realise patterns in real time responsive environments. We implement two operator systems for the same responsiveness to handle different interactive purposes. The wall patterns can be changed more roughly by movement aware or more precisely by surface touching. There are several areas for future work. First, we want to make the wall actuator module as a self-independent one. We can put it all over the space that will have more potential to design responsive environments. Second, we want to integrate the gaze-interaction and surface touching. It allows environments have more ability to detect the user's intention.
References


