MIRROR ON THE WALL:
USING THE MIRROR AS A DESIGN PRINCIPLE TO ENGAGE USERS IN LARGE PUBLIC DISPLAYS

by

Lina Lee

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Approved by:

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Dr. Mary Lou Maher

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Professor Eric Sauda

ABSTRACT

LINA LEE. Mirror on the wall: using the mirror as a design principle to engage users in large public displays. (Under the direction of DR. MARY LOU MAHER)

With the advent of affordable large display screens and with the emergence of more sophisticated sensing technologies, Mid-air Interactive Information Display is becoming more common in physical public spaces. In the field of human computer interaction, Mid-air interaction has received great attention around the world and even is considered as the trend of future. The recognition of Mid-air gestures enables designers to create interfaces that enable explicit control of such systems. This Mid-air gestures undoubtedly makes public displays more attractive to passersby and easily make them to get involved with it, but still does not exploit the full capabilities of interactive displays that actively engage the user in public setting. One of the biggest challenges is interaction blindness. Despite holding important information or fun interaction, people fail to interact with a display because they can't discover that the system is interactive. I believe research is needed to design a discoverable interaction system, engaging enjoyable experience, learnable context to engage users, provoke their curiosity, and hold their attention longer for mid-air gestures in public space. In this thesis, I explore to identify characteristics of engaging visual feedback on public displays, identify design heuristics for discoverable mid-air gestures and develop a methodology for evaluation engagement in interactive systems.

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CHAPTER 1: INTRODUCTION

Due to falling display costs, the availability of large screens and the emergence of increasingly sophisticated sensing technologies, interactive displays are fast entering public spaces and beginning to support user interaction based on gestures. Mid-air interaction is an advanced and natural form of interaction wherein the user does not touch a display but interacts with it by performing bodily gestures to control a mirror image-like representation on the display.

Mid-air interaction has received great attention as an interaction modality for public displays. Mid-air interaction systems receive visual input and recognize users' gestures without requiring them to touch keys or screens. Mid-air gesture recognition enables designers to create interfaces that enable the explicit control of such systems. Mid-air gestures can undoubtedly make public displays more attractive to passers-by and get them easily and actively engaged with them in a public setting. Moreover, users do not have to make detours to approach the displays. Because the displays work without touch, they have decreased hygienic risks than touch-based systems. Therefore, users can expect to see progressively more interactive displays in public spaces.

Many challenges face current Gesture Interactive Information Systems. There have been many attempts to use mid-air interaction techniques, however, many displays fail to attract the attention of sufficient passers-by to exploit the full capabilities of interactions in public spaces (Alt et al. 2012). This thesis discusses public mid-air interactive displays, and specifically addresses how to design interactive user experiences that engage and captive users by providing effective visual feedback.

1.1 Motivation

One of challenges encountered by interactive displays is interaction blindness (Huang et al. 2008). People in front of interactive displays are generally unaware of their interactive capabilities, i.e., how they can interact with the displays, and whether gestural interaction is supported. Despite the fact that interactive displays possess important information and/or engage users, it is difficult to make people realize that they can explore them. In addition, users may give up if they do not immediately succeed with their interactions.

Because users expect to see increasingly interactive functionality in displays, gesture design for gesture input methods and real-time visual feedback to the user should be very cautiously considered. The creation of visual feedback and exploration of the interaction in gesture-based systems are challenging because little research to date has focused on characterizing interaction feedback for mid-air display platforms.

I am concerned with understanding how to engage people near public displays, including the ways they move towards them, congregate around them and transform from passive viewers into active users. Although Grace et al. (2013) pointed out that people are likely to assume that displays are non-interactive and often walk straight past them, I believe that by providing visual interaction feedback, interactive displays can become more effective at alerting users and inducing them to explore their interactive capabilities.

1.2 Research Requirements

I needed to explore the most appropriate methods of interaction with public interactive displays in order to give users the highest level of unique enjoyable experiences throughout the interaction period. The three main interaction requirements that I found are described below.

First, when users pass by a public display, the display must attract the attention of the user. People can quickly determine whether an interactive display is interesting or not. As Müller et al. (2010) pointed out, passers-by need to notice the display, understand that it is interactive, and be motivated to interact with it. Research is needed to determine how interactive displays can be designed to be more appealing and how designers can map interaction onto a screen with a particular focus on public engagement.

Second, when users try to interact with the system, they can lose interest or their sense of control without appropriate feedback. Without effective feedback, they cannot determine the connections between their actions and the results on the screen. The system should inform users that the system has detected their gestures and shown their progress on the screen. Research is needed on how to use interaction feedback to alert people to the display's interactivity and mechanisms.

Third, a wide variety of rich data sets are visualized in public information displays, but oftentimes this content is unable to attract a users' attention. Users are often either overwhelmed by the display of too much information on the screen or not interested in the display at all. This can result in two scenarios: either the potential user does not approach the display, or he/she approaches the display but leaves in frustration after not being able to find any information of interest. Research is needed to determine how to design intriguing interactive visualizations that can hold the user's attention for longer time periods and persuade him/her to explore additional content with gestural interactions.

To this end, I designed three effective visual feedback prototypes using a mirror conceptual design principle to create enjoyable experiences with public interactive displays for users. It is necessary to design effective interactive visual feedback that not only provides useful information efficiently, but also engages people to look at the display. The display should be designed to show the information in an attractive and easy to understand manner, even from a distance. In addition, a 'fun' mode is predicted to trigger user interest in the display. It is necessary to find ways to maintain the user's attention. With interactive visual feedback, a display can convey the concept of gestural commands to users and show users how to use them in a compelling manner.

1.3 Research Goal

The goal of this thesis is to research new engaging ways of interacting with public displays through the development of effective visual prototypes to guide users and enable advanced dynamic interactions for navigating information. The objective is to lead users to realize how a simple interaction can benefit them greatly, giving them a playful and enjoyable experience and transforming them from mere bystanders into active participants who can purposefully interact with the display.

I considered three major goals for the design of applications for mid-air interactive public displays: the short term goal is to identify the characteristics (ontology) of engaging visual feedback in public displays, identify design heuristics for discoverable mid-air gestures and develop a methodology for evaluating user engagement in interactive systems.

1.4 Thesis Structure

This Master Thesis report is structured as follows: CHAPTER 2 describes the literature of several main areas of research, including public interactive displays, public engagement, gesture-based interaction, and precedent studies of mid-air interactive displays. CHAPTER 3 addresses three types of visual feedback prototype development using a mirror conceptual design principle as well as the associated design requirements. CHAPTER 4 covers the planning of the user studies and the methodology used in the research. Finally, CHAPTER 5 presents the conclusions of the work and contributions to the research field.

CHAPTER 2: BACKGROUND

Several related studies informed my thesis. In particular, I drew upon prior research in the domain of public interactive displays with a particular focus on public engagement, gesture-based interaction, and precedent studies in terms of playful and learnable displays that use mid-air interaction. In my thesis, I provide a summary of the relevant literature and identify its key concepts and issues.

2.1 Public Interactive Displays

Public interactive displays are becoming more commonplace in physical public spaces such as museums, libraries, plazas, and architectural facades, where they present information and enhance a user's experience in a highly visual and often interactive manner. Public settings have unique characteristics and therefore impose unique challenges. Public spaces attract diverse users, who differ in their age, interests, and levels of experience with technology, who engage in spontaneous and often unpredictable individual and group activities. In addition, the spatial layout, size, lighting conditions, and social connotations of a public setting affects which display technologies and interaction techniques are appropriate for the setting and how people will interact with and experience the installation (Hinrichs et al. 2013). A public interactive display presents different requirements and concerns regarding interface design and interaction techniques. A large body of research has been conducted on how to enable and evoke users to engage in mid-air interaction with public displays from a design perspective.

Hardy et al. (2011) describe the different interaction display types in terms of ambient displays, implicit interaction displays, subtle interaction displays, and personal interaction displays that are observed in many public interaction displays. Each interaction display type serves many purposes. Ten Koppel et al. (2008) describe different types of displays, such as flat, concave, and hexagonal formations, that impact how users notice the display and develop the motivation to interact with it. Akpan et al. (2013) describe installation locations. Because my thesis focuses on developing public interactive displays, the relevant interaction techniques I propose might differ based on how people engage with an identical interactive installation in different locations with varying spatial and social properties.

Memarovic et al. (2012) described how to enhance public engagement with public interactive displays based on in-depth observations of people interacting with them. When designing public interactive displays, it is important to keep the concept of public engagement in mind, and techniques are needed to encourage user interaction. In the past few decades, public interactive display researchers have emphasized the need to move beyond usability towards understanding how to design systems for more engaging user experiences (O'Brien and Toms 2008). O'Brien and Toms (2008) introduced a conceptual framework for defining user engagement with a comprehensive literature review coupled with a set of semi-structured interviews. Table 1 shows the definitions of public engagement that are found in the literature.

Table 1: The definition of public engagement

O’Brien and Toms (2008)	Engagement is a quality of user experiences with technology that is characterized by challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest, and affect
Chapman (1997)	Engagement is something that draws in, that attracts and holds our attention
Overbeeke et al. (2005)	Engagement is a dimension of usability, and is influenced by users' first impression of an application and the enjoyment they derive from using it
Rogers (2006)	Engagement is the concept of engagement how people proactively use their capacities through technology, and how technology supports the use and extension of skills
Csikszentmihalyi (1997)	Engagement share some attributes with flow, such as focused attention, feedback, control, interactivity, and intrinsic motivation
Stephenson (1964)	Engagement encourages learning and creativity, develops and satisfies psychological and social needs, and involves aspects of competition and collaboration.
Toms (2002)	Engagement is interaction between users and systems operating within a specific context that facilitates an engaging experience

2.2 Gesture Based Interaction

Several advantages are associated with gesture-based interactive systems. Essentially, they provide a simple, usable and interesting user interface and satisfy the user’s need for more freedom in a human computer interaction environment (Cienki 2008). Gesture-based interaction technology provides people with pleasurable new experiences that traditional interaction technology cannot offer and makes the interactions between humans and computers more natural (Kaushik and Jain 2014).

One of the main motivations to transition from touch-based interaction to gesture-based interaction is that the traditional interaction technologies that were designed for desktop platforms, such as the mouse and keyboard, are not natural (Cao 2004). Users may prefer to interact with a system using natural channels of communication with gestures that they are familiar with in everyday life. Karam et al. (2009) suggests that freehand gesture interaction systems make use of intuitive gestures and hand movements that are familiar in users' everyday lives, particularly those that are used to communicate with people. Gestural interactive systems allow a user to operate systems through intuitive actions such as natural motions, movements, or gestures. Users can easily discover and understand how to control these types of systems.

Gestures have been a subject of research for many years. Gestures can take many forms, from simply using a hand to target something on the screen to specific continuous movement using the whole body. Implementing gestures in a real world system requires a careful consideration of the types of gestures that are applied in the system. Furthermore, it is important for the user to understand which gestures can interact with the display. Defining a set of gestures for interactive systems is needed in order to reduce any confusion on the part of the user. If the gesture is too circumscribed, unique, or complex, it will be difficult for the user to perform. If the gesture is too nonspecific or simple, it will be easier for the user to perform, but might conflict with other gestures (Seyed et al. 2012).

Many researchers have studied the taxonomy of gestures. Laurel and Mountford (1990) discuss the several classifications and taxonomies that have been proposed to categorize gestures. Karam (2005) presents a classification of gesture-based computer interaction motivated by a literature review of over 40 years of research in gesture based interaction. Karam's research presents a unique perspective on gesture-based interaction in terms of four key elements: gesture style, the application domains the gestures are applied to, and the input and output technologies used for the implementation of the interaction. Karam also gives an idea of which human gestures best enable a user to engage with interactive informational displays. In addition, gesture-based interaction is an exciting input method to explore, and hand gestures in particular are a popular way to interact with or control interactive systems. Many researchers have proposed various methods for dynamic hand gesture recognition. For example, the Fraunhofer Heinrich Hertz Institute has implemented an interactive Shop Window system that allows users to learn more about the products in a display with free-hand gestures using a Microsoft Kinect sensor.

2.3 Mid-air Interaction Precedent Study

Mid-air gestures have received attention as an interaction modality for public displays (Walter et al. 2013). Mid-air interactions allow ample room for creativity, giving designers a variety of options in designing the interactions. Several precedent studies have inspired me with their analyses of user interaction in order get a better understanding of engaging interaction. All of these studies suggest that successful designs that engage people in public displays must be playful, easy to use and novel.

2.3.1 Playful Displays

A number of public displays have used mirror images to motivate users to play with them. For example, Magical Mirrors (Michelis and Müller 2011) is an installation of four large public displays that show a mirror image of the environment and apply optical effects to react to the gestures of the audience. Magical Mirrors incorporates the phases of users passing by a display, viewing and reacting to the display, subtle interactions, direct interactions, multiple interactions and follow-up actions. StrikeAPose (Walter et al. 2013) is designed to be a simple but engaging game based on physics simulation that motivates passers-by to interact with it. Passers-by see their mirror images on the screen and can use them to play with virtual cubes. The gesture used in StrikeAPose can be described as a full-body version of the pinch gesture, wherein users touch their hips with their arms to enclose distinct inner areas in their contour images (See Figure 1).

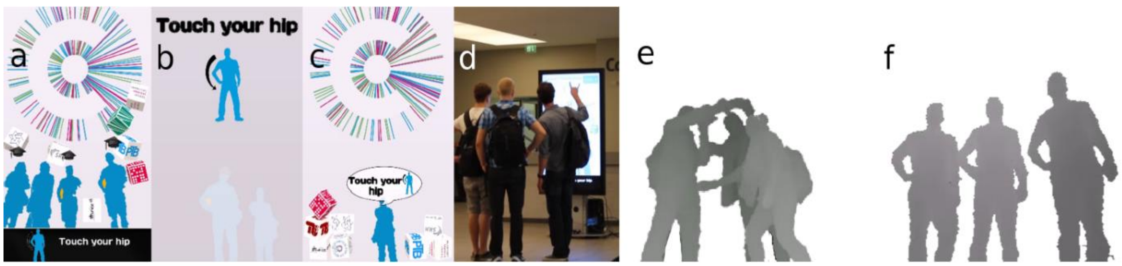


Figure 1: StrikeAPose, Revealing an initial mid-air gestures (Walter et al. 2013)

There is some evidence that systems that employ emotional connection with natural gestures help encourage users to view interactive displays for longer time periods. The Sniff system (2009) was created with the Unity3d Game Engine, and renders a dog in real time and allows for dynamically changing behavior based on video tracking data. The dog keeps track of the attitude of the user and forms a relationship with him/her over time based on the history of their interaction (See Figure 2). It's You (2009) is an interactive storefront-window projection. When the user enters the interaction area in front of the window, projected figures turn their heads to glance at him/her. After the user has been in the interaction area for a certain period of time, the projected figures react to the user by clapping, applauding and clarifying the role of the user. Throughout the process of interaction design, these systems are built on the idea that target users will engage with interactive displays that trigger an emotional response.

Figure 2: Sniff (2009)

A number of public displays have used games as a means to attract people. Chained displays (Ten Koppel et al. 2012) can be used to present a space-invaders game that can be played by users with full body gestures. Imitation behavior is a very strong factor in teaching people how to play the game. Because the contours of the player are shown on the screen, the players imitate what they see the contours of other players do. Connecting displays at different locations in a media space, as proposed in this paper, multiplies such opportunities for imitation and learning. In the arts, community public displays have been used for a long time to encourage user interaction and reflection in playful ways. Beginning with Myron Kruger's seminal work with VideoWall (Krueger et al. 1985), several other systems have also used silhouettes in a similar way to chained displays.

2.3.2 Learnable Displays

Several public interactive displays guide users on how to use the displays in fun ways. Media Ribbon (Grace et al. 2013) is designed to provide a simple and intuitive user interface to allow people to quickly navigate and view content. A real time representation of the user's skeleton is rendered on the bottom of the displayed content along with a help bar that displays icons representing the four gestures available to the user. The successful recognition of a particular gesture by the system is indicated by a change in the color of the visual gesture icons (See Figure 3).

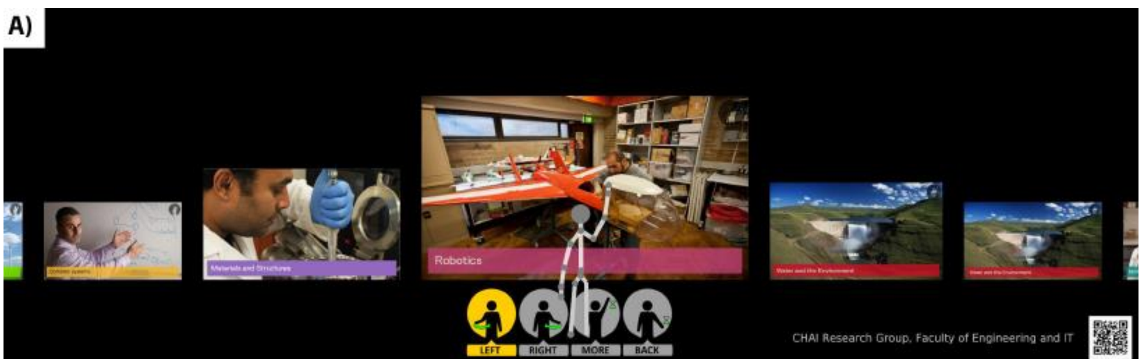


Figure 3: The media ribbon tutorial UI showing research clusters content (Grace et al. 2013)

Similar examples include Explore UNCC (Lee et al. 2014) and Cuenesics (Walter et al. 2014). Walter et al. (2014) proposed a design space for hand-gesture based mid-air selection techniques in interactive public displays. Their system used two selection techniques to improve its immediate usability. The left image in Figure 4 shows a cursor representation and a two-dimensional layout consisting of a real-time mirror image representation of the user shown in the bottom right corner, with the hands highlighted. The right image shows a mirror image representation and the information layout surrounding the mirror images.

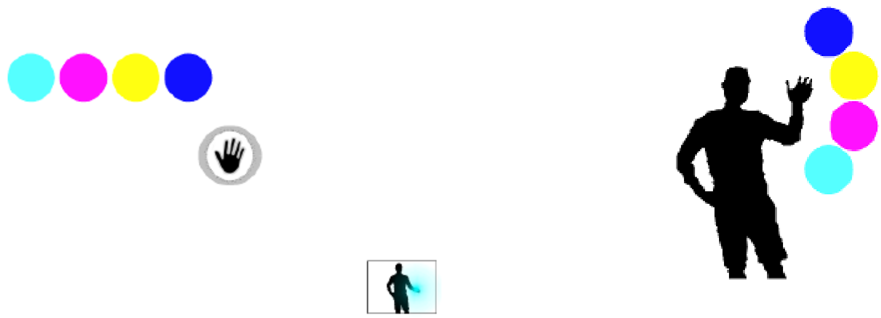


Figure 4: Left: Hand cursor representation, Right: Mirror representation (Walter et al. 2014)

A number of public displays have used skeleton based interaction to guide user performance. For example, the Rehabilitation Exercise Monitoring and Guidance System (Zhou and Hu 2008) involved the design and implementation of a Kinect-based system for rehabilitation exercise monitoring and guidance. The system demonstrates the correct way to perform an exercise via a 3D avatar on one side of the screen using pre-recorded motion data. On the other side of the screen, another avatar is shown that reflects the actual patient's movement. Furthermore, the system implements a set of correctness rules for each exercise and assesses the patient's movement in real-time. The assessment results are incorporated into the patient avatar in the form of visual guides to help the patient perform the exercise correctly. The system also records vital data that are pertinent to the quality and quantity of the exercises such as the number of correct iterations as well as detailed motion data for real-time feedback and post-analysis. YouMove (Anderson et al. 2013) is a novel system that allows users to record and learn physical movement sequences. The recording system is designed to be simple, allowing anyone to create and share training content. The training system uses recorded data to train the user using a large-scale augmented reality mirror (See Figure 5). The system trains the user through a series of stages that gradually reduce the user's reliance on its guidance and feedback.

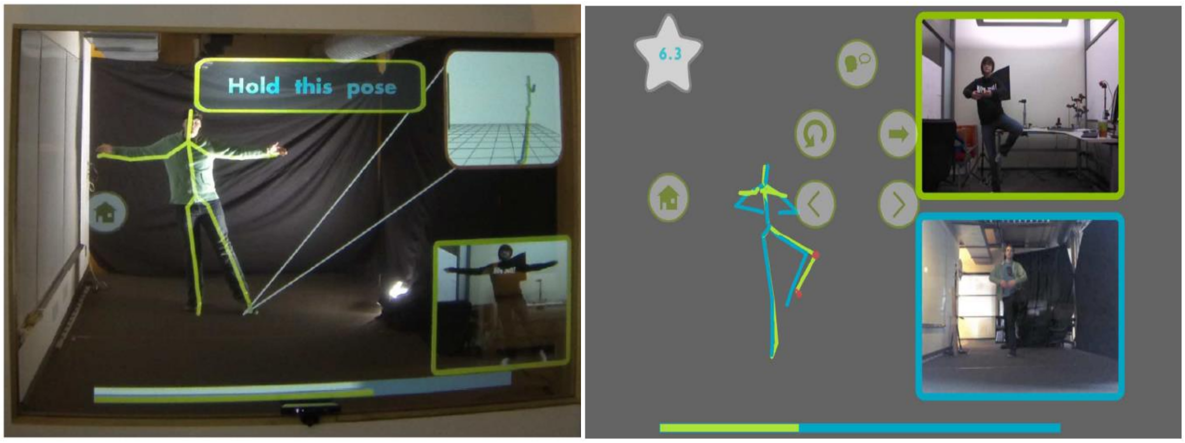


Figure 5: YouMove, Physical movement guidance system (Anderson et al. 2013)

CHAPTER 3: PROTOTYPE DESIGN

3.1 Design Goal

I designed interactive visual feedback to encourage users to enhance their experience with and engage in public mid-air displays. My design goal was to design a discoverable interaction system for mid-air gestures.

Users can lose interest in a display very quickly and abandon further attempts to interact with it if they see no immediate system response resulting from their first actions. Real-time and interaction feedback needs to be designed for discoverable interaction systems. The important design rule of an interactive system is visibility. All of the controlling gestures should be visible and therefore easily discoverable. Creating an engaging experience for the user is also important. The user should feel as if he/she is in control of the experience at all times; he/she must constantly feel like he/she is achieving something and be able to view the well-designed results of their interaction. An engaging interaction with a mid-air interactive system is not only more enjoyable, but also easier to use and more learnable than other types of systems. The layout and user interactions of the system should be consistent throughout the interaction. By maintaining the consistency of a system, users are able to learn how to use it relatively quickly.

To achieve the design goals of this thesis, a mirror concept is used as an effective method for positioning users and providing them with a real-time reference. The mirror concept is described in section 3.3.

3.2 Basic Design

3.2.1 System Description

Explore SIS is a mid-air interactive information system featuring a “Walk-Up-And-Use” interface that utilizes gesture recognition via Microsoft Kinect and is designed for use with multiple users. Explore SIS displays course information for the Software and Information Systems (SIS) department for the 2015 spring semester. Five clusters of SIS courses, namely, HCI, Health Informatics, Intelligent Systems, Security, and Software Systems, are distinguished with different colors. Course information is presented to users in the form of the course number, course name, instructor and a brief description of the course.

Explore SIS, which was a subject of independent study under the guidance of Professor Mary Lou Maher during the fall semester of 2014, will be used to test the prototypes. It has proven to be an effective system that either attracts users on its own or through word of mouth. Although Explore SIS has usability issues, these issues can be resolved iteratively during the implementation of the design concept. Since very little feedback is given by Explore SIS, users had a difficult time figuring out how to use the system.

Using this basic system, three visual feedback prototypes were added to explore ways for users to interact effectively with the system: 1) Emotional Avatar, 2) Shadow, and 3) Skeleton. The three additional types of visual feedback help users to notice the display, understand that the system is interactive, understand how to interact with it, and finally be motivated to interact with it. In order to define which types of visual feedback help to guide users and enable advanced dynamic interactions such as navigating information, I sought to carry out several experiments under identical conditions. For gestures, the results of the gesture elicitation study of the Explore SIS project were applied, and a think aloud gesture elicitation study was conducted to elicit common user-defined intuitive gestures. The swipe, zoom and point gestures were the most common gestures used by the study participants. The software system that implements the gesture interaction is responsible for recognizing the users' gestures and mapping them onto the appropriate corresponding actions. The Microsoft Kinect SDK was used to capture users' skeleton-stream data from a Kinect camera.

3.2.2 Data Structure

The data structure of basic system represents information about five course categories within the SIS department for 2015 spring semester at University of North Carolina Charlotte (UNCC). To provide clarity as well as a visual hierarchy of information, the system uses color to differentiate the five clusters of courses: HCI, Health Informatics, Intelligent Systems, Security, and Software Systems (See Figure 6). This information can be arranged by information type into entity-relationship data structures in order to provide users with multiple ways of exploring the system. This information is presented to the user in the form of course number, name, instructor and brief description.

Code	Course	Title	Topic Area
ITIS	3130	HCI Foundations	HCI Design
ITIS	4412	HCI User Centered Design and Evaluation	HCI Design
ITIS	4420/6420	Usable Security and Privacy	HCI Design
ITIS	3150/6450/8450	Rapid Prototyping Design Patterns	HCI Design
ITIS	4011/6011/8011	Interaction Deesign Studio	HCI Design
ITIS	4430/6430/8430	Ubiquitous Computing	HCI Design
ITIS	6400/8400	Principles of HCI	HCI Design
HCIP	5375	Computer Vocabularies and Programming Systems	Health Informatics
HCIP	5376	Intro. Programming for HI	Health Informatics
HCIP	6392	Enterprise Health Info Sys	Health Informatics
HCIP	6070	Current Issues in Health Informatics: Text Mining in Biomedicine	Health Informatics
HCIP	6070	Current Issues in Health Informatics: Clinical Decision Support	Health Informatics
HCIP	6201	Computer Security, Privacy and Legal Issues	Health Informatics
ITIS	1350	eScience	Intelligent Systems
ITIS	4110/5110	Introduction to Agent-Based Models and Simulations	Intelligent Systems
ITIS	6010/8010	Network Science	Intelligent Systems
ITIS	6410	Personlztn & Recmmndr Sys	Intelligent Systems
ITIS	6500	Complex Adaptive Science	Intelligent Systems
ITIS	6510	Software Agent Systems	Intelligent Systems

Code	Course	Title	Topic Area
ITIS	3200	Intro to Info Security & Priv	Security
ITIS	4221/5221	Secure Programming and Penetration Testing	Security
ITIS	4250/5250	Computer Forensics	Security
ITIS	6150/8150	Software Assurance	Security
ITIS	6167/8167	Network & Information Security	Security
ITIS	6200/8200	Prin Info Security & Privacy	Security
ITIS	6210/8210	Access Control & Security Arch	Security
ITIS	6230/8230	Info Infrastructure Protection	Security
ITIS	6240	Applied Cryptography	Security
ITIS	6362	Info Tech Eth, Pol & Secur	Security
ITIS	6999	SFS Research	Security
ITIS	3320	Intro Software Testing & Assur	Security
ITIS	1212	Intro to Media Programming	Software Systems
ITIIS	1213	Media Programming	Software Systems
ITIS	2110	IT Infrastructure I: Design and Practice	Software Systems
ITIS	2300	Web Based Application Dvlpment	Software Systems
ITIS	3105	Server-Side Applications and Data Management	Software Systems
ITIS	3110	IT Infrastructure II: Design and Practice	Software Systems
ITIS	3300	Software Req & Project Mgmt	Software Systems
ITIS	3310	Software Arch & Design	Software Systems
ITIS	4166/5166	Network Based App Dvlpment	Software Systems
ITIS	4180/5180	Mobile Application Development	Software Systems
ITIS	6112/8112	Software Syst Des & Impl	Software Systems
ITIS	6177	System Integration	Software Systems
ITIS	6320	Cloud Data Storage	Software Systems
ITIS	6342	Info Tech Project Mgmt	Software Systems

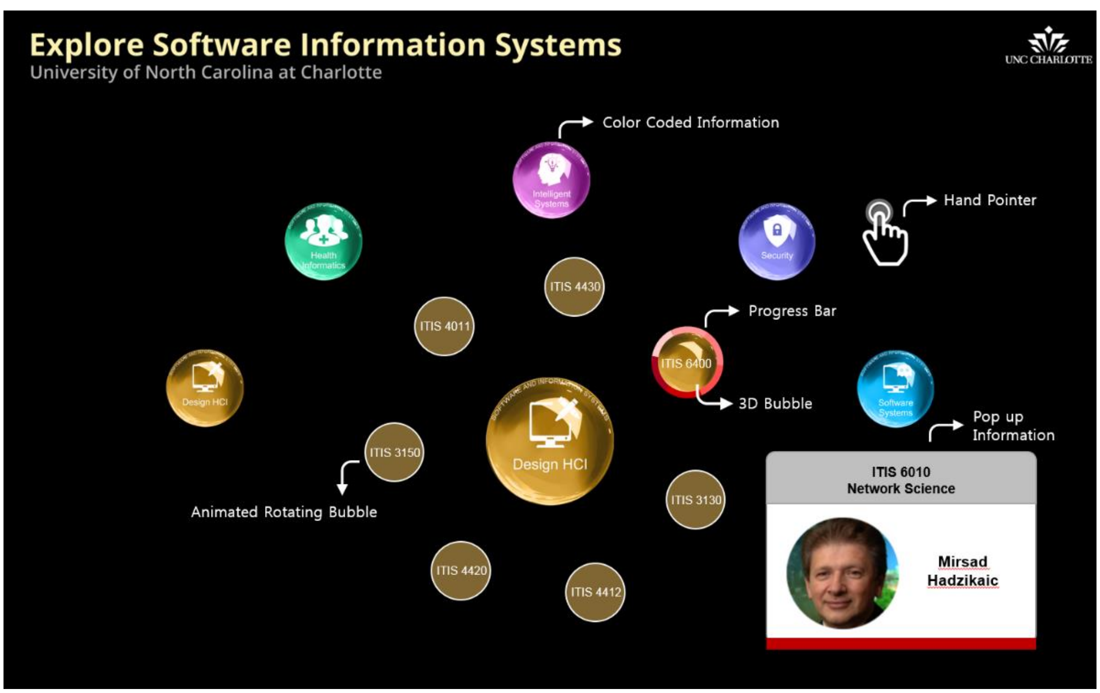
Figure 6: 2015 Spring semester courses data

3.2.3 System Design

When the system is activated by the user, the user is presented with a screen displaying the course information clustered by department. Users can use their hands to interact with the system. Hand movement plays the role of a cursor, allowing the user to delve into the cluster and explore the information presented in greater detail. When one of the clusters is selected, the selected cluster appears at the center of the screen and rotating animated nodes are displayed within the cluster. The user can use a similar method to gain more detailed information about specific types of related information. Detailed pop-up information is also displayed on the screen.

Table 2: Basic system characteristics

Color	Each cluster and relation is assigned a color based on the type of information it contains
Animated Rotating Bubble	Eye-catching content, such as colorful animated particles moving against a contrasting background, attracts more attention than static information displays
Progress Bar	A progress bar conveys information to the user about his/her current status or progress and how the user's interaction will be controlled and represented within the system
3D Bubble	When one of the bubbles is selected by moving the hand cursor, it changes from a 2D bubble into a 3D bubble to inform the user that their gesture has been recognized by the system
Hand Pointer	To help the user locate his/her hand position relative to the screen, the interacting hand's position is indicated by a hand cursor
Pop-up Information	When related information is selected, a pop-up displays on the screen to show more detailed information



3.3 Mirror Design Principle

The mirror image is an effective method for positioning users and provides for a real-time representation of users. People observe their mirror images with great curiosity and can use them to experience themselves and their surroundings from new perspectives. Schönböck et al. (2008) stated that making users a part of the display has a strong potential to catch a user's attention as they pass by.

Grace et al. (2013) pointed out that conveying public display interactivity has found that user mirror image are more effective in order to motivate users to interact with the system. They verified that user made interaction immediately when they found their own reflective representation on screen and could aware more quickly and more accurately notice interactivity when passing by a display. Several research projects follow the metaphor of a mirror to encourage interaction. For example, Magical Mirrors (Michelis 2009) presented a mirror image of the audience and augmented that image with optical effects, like a ribbon following the user's hands. The digital mirror of the ALIVE project of the MIT Media Lab (Maes et al. 1995) is the interface that reflects the picture of the user in a virtual world. ALIVE project embed users within a different context, a scene at the beach or on top of a mountain. The other function is supported to enhance engaging experiences as recording the picture and the screen that visualizes the user next to the comic figure. It awakens the curiosity of the viewer and invites him or her on a trip into virtual worlds.

Interactive displays for public spaces based on the mirror concept are enjoyed by many people because their design principle is intuitive and encourages playful interactions with whole-body gestures. These systems are considered to possess potentially engaging interaction components for users. For example, as a passer-by looks at the display, attracted by its movement, his/her curiosity may be raised by the mirror image. He/she may start to wave a hand in a subtle interaction to see how the display reacts. If his/her curiosity remains sufficiently elevated, he/she may start to directly interact with the display with gestures and explore their effects. Ideally, at this point, deeper interaction that challenges and engages the passer-by for a prolonged period should be made available to him/her (Müller et al. 2010).

The mirror design concept uses reflection as a subtle but effective trigger to catch the user's attention, but this is only step one of the interaction. Reflection exists in several forms. I suggest three ways of using mirror interaction, i.e., an emotional avatar, shadow, and skeleton. Different visual feedback techniques explore the consequences of using the best reflective trigger and what the interaction really needs to be in order to get people to interact with the system, as well as maintain a positive and curious awareness of the system by routine users. The three ways to implement the mirror concept are discussed in the next section.

3.4 Three Ways to Implement the Mirror

3.4.1 Emotional Avatar

The goal of this design concept is to explore emotional responses to the human body through a dialogue between the user and another human shaped avatar inside the screen. This avatar creates a sequence of gestures that provoke and respond to the gestures of the people in front of the screen. This avatar must act as provocateur to engage the users. Once engaged, the users continue to interact with the system, and to provoke the avatar's movements, the reactions of the avatar may be used to evoke an emotional response in the users.

Donald Norman (Norman 2004) explains that emotion is a fundamental aspect of our cognition, perception, memory, and learning. Emotional value is important in design for enhancing the user's experience. Emotional avatars engage in interaction involving human communication, such as waving to indicate 'goodbye.' This interaction technique employs natural interactions that are as close as possible to natural everyday human behavior. Emotional response designers use natural methods of human communication such as using gestures as a means to get users to interact with the system. Because emotional design provides engaging user interaction, I assume that an emotionally satisfying experience using body movement would enhance the user's interaction and positive behavior in a mid-air interactive environment. I seek to understand how users feel, and discover which emotional factors affect a user's feelings in order to provide a remarkable experience for users.

In order to understand the relationship between emotions and the physical movement, I examined several research studies that formulated framework models of emotional interaction through human movement. Human movement is an emotionally expressive form of communication. Thus, it would be natural to employ physical human movement within an effective system to augment emotion during an interaction.

Fagerberg et al. (2003) studied various theories of emotion and movements and designed a language of emotional expressions using a combination of shape (changing forms of the body in space), effort (space, weight, time, and space) and valence (pleasure and displeasure) for affective interaction. Lhommet and Marsella (2014) studied the ways our body conveys emotional information, such as adopting a collapsed posture when depressed or leaning forward to show interest. This thesis shows how people communicate emotion through body posture and gesturing, and explores how people make inferences about avatar's emotional state based on perceived postures and gestures.

1) Emotion Category

The system gestures are divided into the following four categories based on the purpose of the gestures.

I. Greeting Emotion

Greeting is an act of communication in which human beings intentionally make their presence known to each other to show attention to each other and to suggest the types of relationships that exist between individuals or groups of people that come into contact with one another. Greeting gestures are intended to grab a user's attention.

II. Positive Emotion

Positive gestures can be defined as nonverbal movements and gestures that communicate interest, enthusiasm, and positive reactions based on what someone is saying. Positive gestures are intended to encourage people to continue interacting with the system.

III. Negative Emotion

This category of gestures is used to directly respond to participants' movements. If they engage in an incorrect interaction, the system avatar presents negative gestures.

IV. Goodbye Emotion

These gestures intend to show expressions of sadness to users.

2) Interaction Phase

The system adapts to the user in four interaction phases. If there is no user nearby, the display remains in ambient mode to enable users to get a general overview of the information at a quick glance. When users first look at the displays, they might move their arms to get a reaction from the displays. Later, they might change their location to the center of the displays to interact more with the system. If users approach the display, they can interact with it using gestures in subtle interactions. If users are interested in interacting further with the system, they can actively interact with it by producing a variety of gestures. I characterize these four different phases of user interaction as passing by and viewing, subtle interaction, direct interaction, and leaving (Hardy et al. 2011).

I. Passing by and Viewing

Anyone who happens to be present in the specified vicinity of a public display can be called a passer-by. The specific area depends on the particular type of public display, and in principle should include anyone who can see the display. This area should generally be restricted to only those people who are sufficiently close to the display that they can observe it. As soon as a passer-by shows any observable reaction to the display, such as looking at it, smiling or turning his/her head, he/she is considered to be a viewer. The mere act of someone glancing quickly at a public display can be very difficult to observe manually.

II. Subtle Interaction

As soon as the viewer shows any signs of movement, it should elicit some reaction from the display. This might happen when a viewer briefly pauses in front of the display or approaches the surface of the screen. Subtle interaction occurs several meters away from the display, where the user does not occupy any part of the display. This allows for the simultaneous interaction of others.

III. Direct Interaction

After a few initial subtle interactions, users typically try to position themselves at the center of the display. This coincides with the user entering a relatively small area within about 1 m of the displays. Once the user is located within the interaction zone, he/she actively engages the display for a period of time and enters the interaction zone in front of the displays.

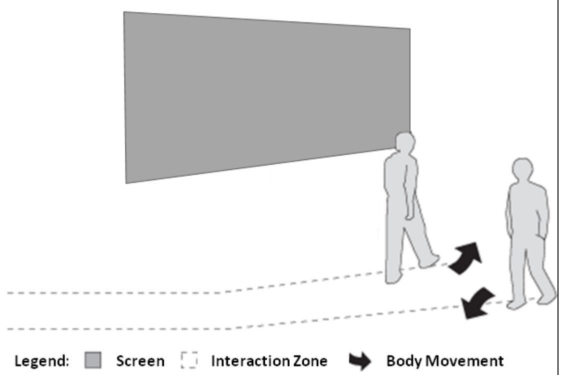
IV. Leaving

In this phase, users are not located within the interaction area. If the user is located outside the interaction range of the display, the display returns to the ambient display phase. This phase produces a central context that anchors all subsequent interaction and gives the user an overview of what types of information or interactive functions the system offers.

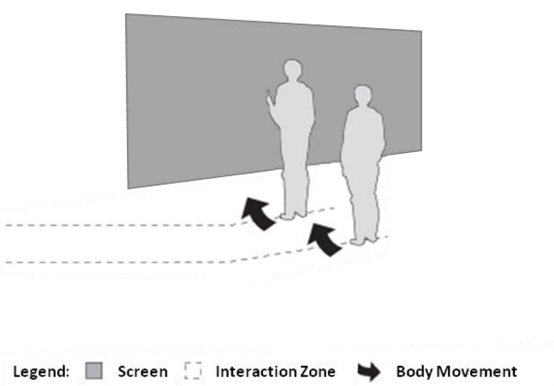
3) Emotional Mapping

In order to properly render emotions from physical movements and expressions, the system must be able to recognize and interpret several gestures from a commonly used set. Sensing technologies such as Microsoft Kinect can be employed to detect a user’s presence and recognize his/her various types of physical body movements as well as the spacing of his/her movements.

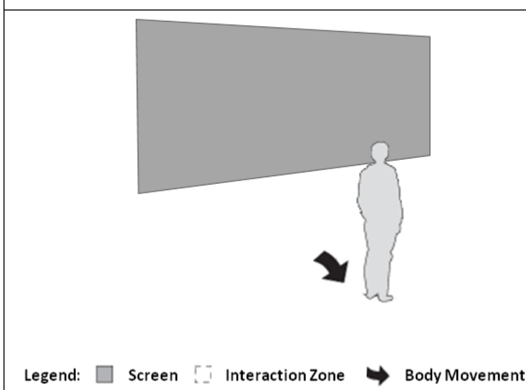
Table 3: Emotional mapping between avatar and user

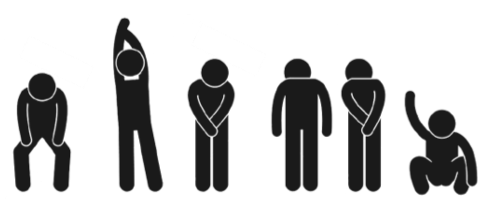
<table>
<tr><th>Interaction Phase</th><th>Avatar’s Emotion</th></tr>
<tr><td>Passing by / Viewing, Reacting</td><td>Greeting Emotions</td></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>Subtle Interaction / Direct Interaction</td><td>Positive / Negative Emotions</td></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>Leaving</td><td>Goodbye Emotions</td></tr>
<tr><td>


</td><td>

</td></tr>
</table>

To map between the user interaction and system reaction phases, I assign a list of actions to each interaction phase. Based on the user's interaction phase, the avatar acts out different emotional states in response to the user. To generate an emotional response to each gesture, the valid responses are determined at random within the same category of the avatar's emotion.

4) Emotional Interaction

The emotional avatar expresses various emotions through the user's gestures and the interaction phase. It can provide emotionally rich interactions while allowing the user to interact with the system. The user's perceived emotion is then used as communication input and the avatar on the screen will respond with an emotional reaction based on the user's movement. This system shows emotional integration between a user outside the screen and another being inside. The presence of the screen expresses various emotional states to stimulate users' interest. For example, it constantly greets people passing by and makes a hand gesture to attract them (See Figure 7). People at first may be confused if the acts are to attract them, but once they approach the screen and recognize that they can be emotionally integrated with it, they would try various things to see its continuous reactions, and at last, the time of using the system will be elongated. In this process, users may be able to precisely and joyfully interact with the system through the novelty differentiated from existing ways. In addition, the hand cursor has a positive effect on users in using the system (See Figure 9). When users use the system well, it gives a 'Correct' message, and when they use the system wrong, it gives an 'Error' message, and through this repetitive learning, users will learn how to use the system.

I. Idle Mode

The ‘idle mode’ avatar creates a sequence of gestures that provoke and respond to the gestures of the people in front of the screen. This avatar must act as provocateur to engage the users. If there is no one in front of the screen, the ‘idle mode’ avatar constantly greets passers-by and makes a hand gesture to attract them. These gestures are intended to grab a user’s attention.

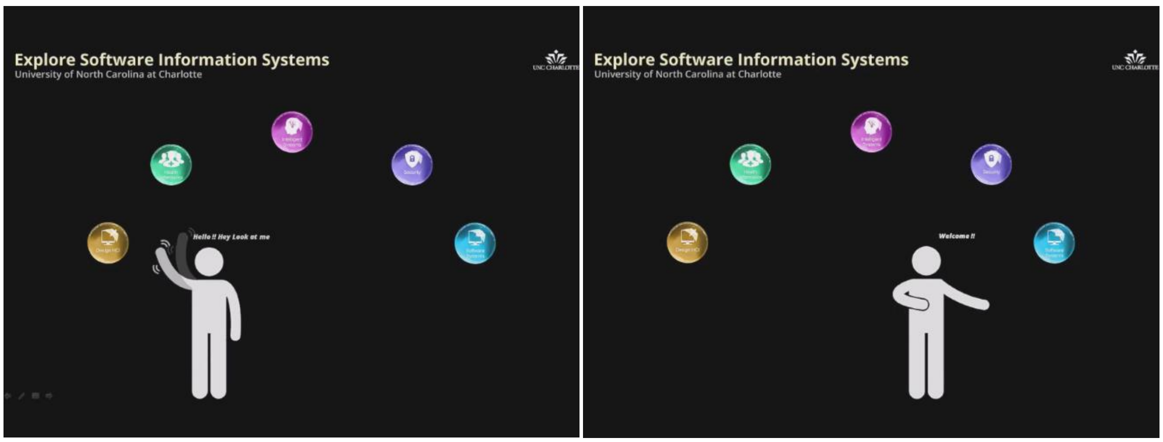


Figure 7: Emotional interaction, idle mode

II. Subtle Interaction Mode

When a user is detected, the interface tries to captivate him/her with a greeting message. The interface can also maintain the user’s attention by displaying animated rotating bubbles. A virtual character is created to express various emotions through the user’s gestures and the interaction phase. It can also provide emotionally rich interactions while the user is interacting with the system.

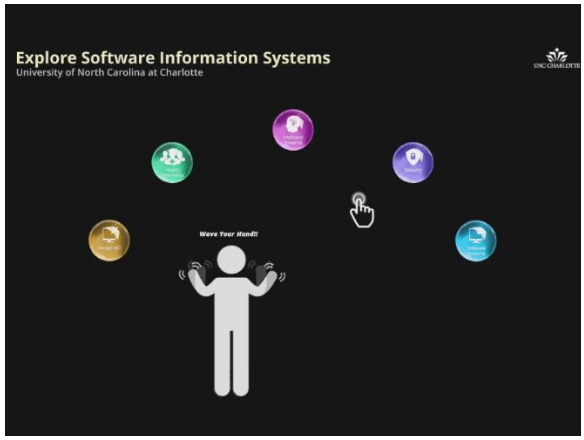
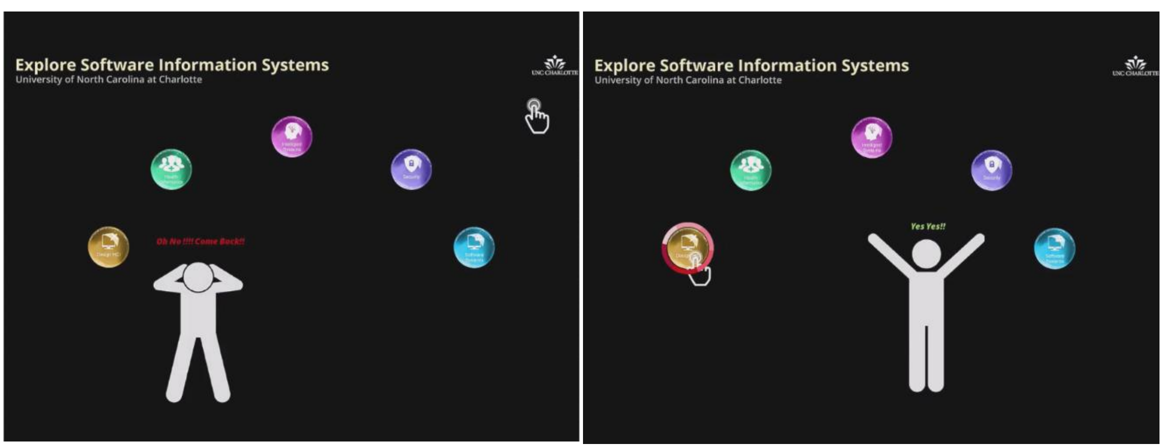


Figure 8: Emotional interaction, subtle interaction mode

III. Direct Interaction Mode

When the user is actively interacting with the system, this mode presents positive and negative gestures from the avatar to the user, which helps him/her discover appropriate ways to interact with the system. The system responds with visual feedback based on the presence of the user's hand pointer. Upon the completion of the correct selection, a congratulatory message is displayed along with complementary information such as fun facts that are related to the action that was just performed. If the user's hand pointer is too far away from the information, the avatar presents negative gestures to him/her.



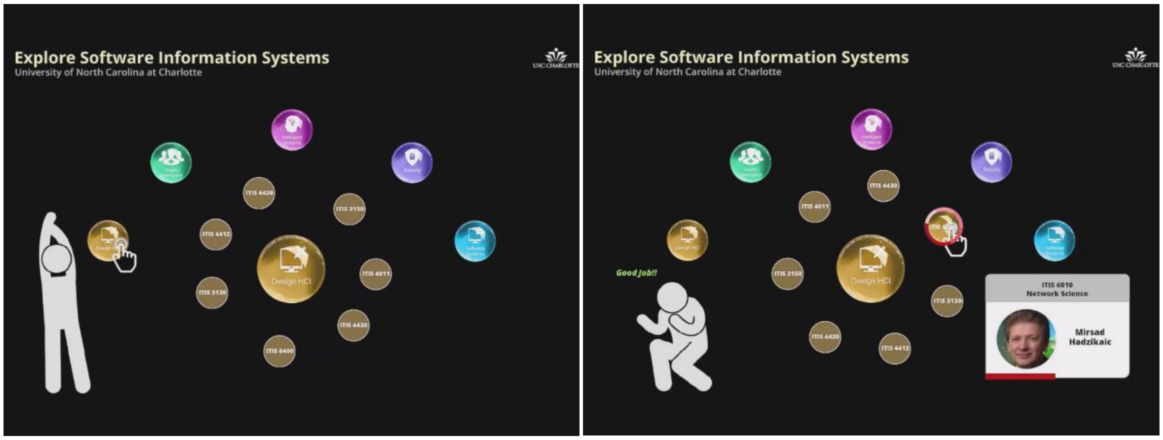


Figure 9: Emotional interaction, direct interaction mode

IV. Leaving

When users are not in the interaction area, the avatar presents 'goodbye' gestures that intend to convey sadness. In addition, the system reverts to 'idle mode' with the expectation that other users will interact with it.

3.4.2 Shadow

The goal of the shadow design concept is to create a display that attracts a passer-by to look at the screen and choose to interact with it. The idea is to create the illusion of a shadow that is controlled by a given user by mimicking the motions and actions of the user. This shadow image serves to attract the user's attention. When users look at the display and notice their own projected shadows, they can initiate subtle interactions, and if they are convinced that the display is reacting to them, their curiosity may be raised. They can start to directly interact and play with the system by walking back and forth and playing with their shadow images. I offer the users a mirrored display that helps them learn how the system works.

1) System Characteristics

I. Shadow Background

My system shows a mirror image and reacts to the gestures of the user with optical effects. User silhouettes are more effective than other types of user representation such as avatars and abstract representations at conveying display interactivity and users are able to more quickly notice this interactivity when passing by such displays. Users often interact immediately with the system when they are shown their own silhouette on the screen (See Figure 11). The implementation of the shadow involves a mounted Microsoft Kinect box to monitor the actions of the users and mimic them.

II. Shadow Color Indicator

When objects or the user's hands enter the interaction area, they are displayed in red in contrast with the grey background on the screen. In this manner, users can actively participate in reducing their own errors as they learn to recognize what works and what causes problems for the system. The system provides red and green dot feedback supporting the proper distance between the user and the system (See Figure 11). Color is a critical factor for the visibility and readability of the system. The color red seems to be a very natural way to communicate an error state; similarly, the color green intuitively indicates a successful state.

III. Distance Dialogue

The distance dialogue helps the user find the appropriate distance for using the system. Sensing technologies such as Microsoft Kinect can be employed to detect the user's presence and recognize the user's distance from the system. The system responds with visual feedback based on the user's distance from the system. If the user is too close, the system will present an error message and vice versa (See Figure 11). The distance dialogue between the user and the system provides positive effects such as satisfaction, pleasure, and fun, and enhances the user's understanding of the system. The shadow and distance dialogue help users become aware of the concept of gestural commands and how to use them. Because passers-by are not generally aware that public displays are interactive, the system must show them how to interact with them and indicate whether gestural interaction is supported by the system.

IV. Conversational Dashboard

Public interactive information displays have the potential for fostering complicated communications and can contain hierarchical content that is not immediately visible to the users (See Figure 10). Is it possible for a system to give a simple conversational hook to the users, providing them with a simple message to convey its interactivity? I created a conversational dashboard, which is a full-screen image that must be dismissed with one of the system's recognizable gestures before the system can be used. The conversational dashboard attracts additional users to interact with the system.

2) Shadow Interaction

The shadow can be used as an artistic interactive form through which people can express themselves. Because the shadow mirror can interact with more than one person, it can bring individual audience members together by interacting with all of them at the same time. All in all, the shadow mirror provides an uplifting, creative, and fun atmosphere for people in public areas. By creating the shadow mirror, I want to achieve the goals of embracing the shared experiences between people and introducing an innovative platform for creativity and learning. The shadow concept provides an enjoyable display for users to play around with and can draw in additional people and perhaps even inspire them to explore the possibilities of the technology and make their own displays.

I. Idle Mode

This interface presents a conversational hook to the users, providing them with a simple message to convey the system's interactivity. The interface presents a mirror image to the user that shows the user's own silhouette on the screen.

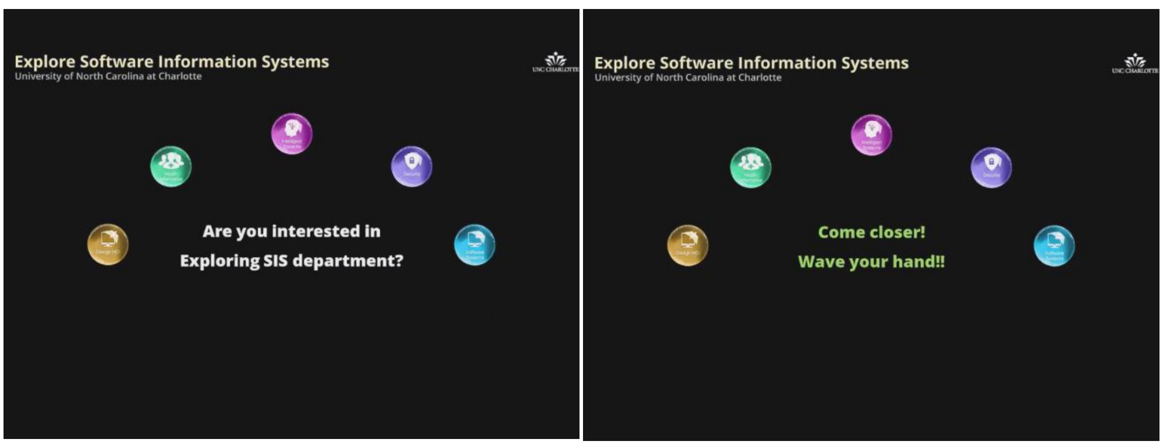


Figure 10: Shadow interaction, idle mode

II. Subtle Interaction

When a user is detected, the interface tries to captivate him/her with a greeting message and can also maintain the user's attention by displaying animated rotating bubbles and shadow images. When objects or the user's hands enter the interaction area, they are displayed as red in contrast with the screen's grey background. In this manner, users can actively participate in reducing their own errors as they begin to recognize what works and what causes problems for the system.

Figure 11: Shadow interaction, subtle interaction mode

III. Direct Interaction

When the user is actively interacting with the system, it presents a distance dialogue that helps users to find the appropriate distance for using the system. The system responds with visual feedback based on the user's distance from the system. If the user is too close, the system will present an error message such as 'You are too close,' and if the user is too far away, the system will present a message such as 'Come closer.' This distance dialogue between the user and the system provides positive effects such as satisfaction, pleasure, and fun, and enhances the user's understanding of the system.

Figure 12: Shadow interaction, direct interaction mode

IV. Leaving

When users are not in the interaction area, the system reverts to ‘idle mode’ and displays conversational dialogue to entice other users to interact with it.

3.4.3 Skeleton

A major challenge in gesture systems is how to inform users of the gestures they can use to interact with the display. The design concept of the skeleton is to provide accurate gesture information on joint positions, angles, and displacement. Unlike the other two systems, the skeleton mode supports a clear tutorial on what exactly the user should do when interacting with the system (See Figure 14). Some tutorial systems, when used in appropriate ways to support learning, have the potential to engage users in a profound way. An effective tutorial system is essential for increasing the user’s proficiency in using the system. Well-timed, appropriate visual feedback provides an indicator of the user’s performance, giving him/her time to make adjustments while keeping him/her motivated to interact with the system. I assume that skeleton systems prompt users to generate significantly more enjoyable and learnable experiences over short timer periods to inspire them to maintain relatively long performance times.

1) System Characteristics

I. Gesture Registration

The skeleton mode introduces a novel initial gesture for mid-air gestural interaction on a public display that requires users to raise their hands to activate the system. The initial gesture was designed to be particularly easily recognized by the system so that users can proceed to use the system without any difficulties (See Figure 13). By activating the initial gesture, users can recognize the system's interactivity and discover the appropriate distance for interacting with the system.

II. Tutorial

The skeleton mode gives a tutorial on how to execute commands via hand gestures as the user follows the skeleton's movement (See Figure 14). At the initial phase of interaction, the system provides the tutorial to users to guide them in the correct way of interacting with it via a skeleton avatar on one side of the screen. Thus, users can see that gesture based interaction is possible and learn how the gestures are invoked in a short period of time. Generally speaking, the tutorial gives users the opportunity to practice and understand patterns. These patterns require interaction and feedback, and this mode allows users to develop their own mental models of the system and its objects and allows them to iteratively improve upon their mental models.

2) Skeleton Interaction

I. Idle Mode

In this first stage, the system is in an idle state because no users have been detected in the surrounding area by the sensor. The ‘idle’ interface presents the default skeleton position. When a user is detected in the sensor’s area, the skeleton tries to captivate the user’s attention via a change of pose. Movement feedback with text labels such as “raise your hand” will be provided to activate the system.

II. Subtle Interaction Mode

The subtle interaction phase initiates when a user is detected. The user is asked to perform certain gestures, such as the activation gesture with his/her hand, in order to calibrate the gesture recognition system. The user enters the direct interaction mode by following the skeleton’s suggested pose, which is intended to match the user’s gesture.

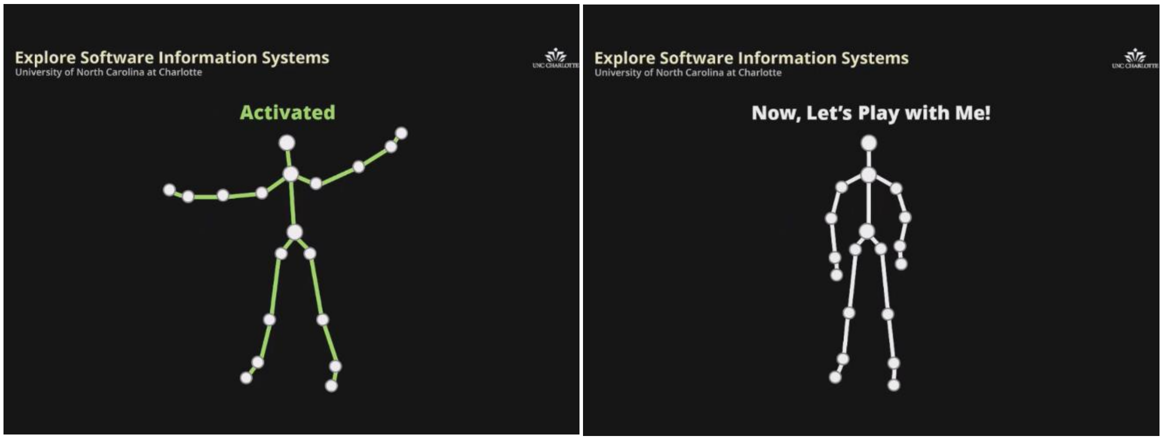


Figure 13: Skeleton interaction, subtle interaction mode

III. Direct Interaction Mode

In the direct interaction phase, the system provides a more detained tutorial on how to select one of the displayed clusters and their related bubbles. After the user is finished with the tutorial, the system allows him/her to perform a variety of gestures and actions by selecting information. The implementation that allows users to interact with the main content is identical to that of the emotional avatar and shadow mode. When a cluster is activated, the skeleton representation decreases in size and moves to the left bottom corner of the screen to make a more room for the user to explore information. The system continues to respond to the user with the skeleton representation. The hand cursor is directly controlled by the hand of the user to give him/her clear visual feedback.

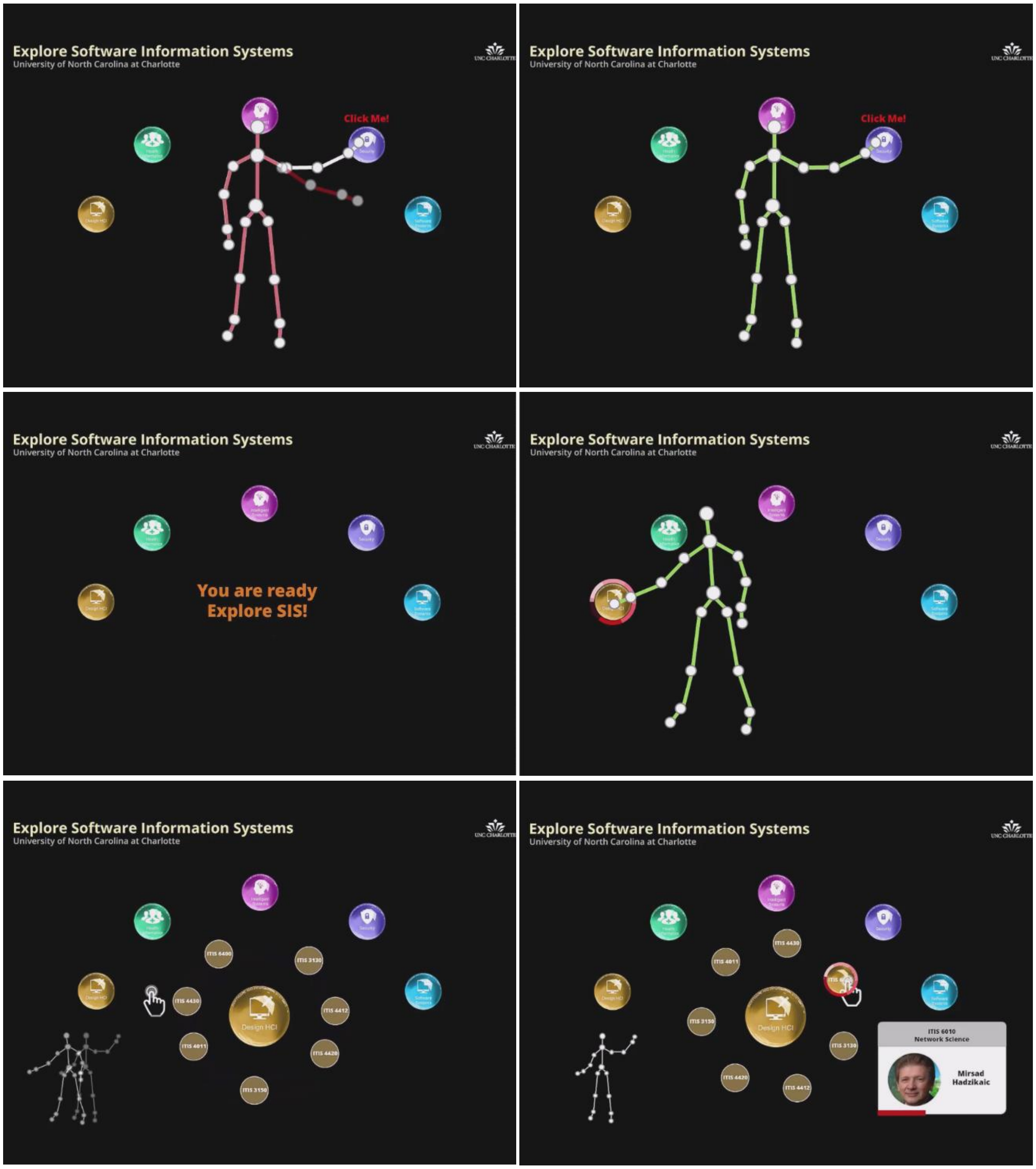


Figure 14: Skeleton interaction, direct interaction mode

IV. Leaving

To exit the interaction, the user has to move far away from the screen. As soon as the interaction system identifies that the user is no longer in front of the system, the ‘idle’ phase is displayed.

CHAPTER 4: EVALUATION PLAN

This section describes the evaluation plan, methodology and expected results. In order to evaluate proposed prototype, heuristic evaluation, engagement evaluation, and discoverability evaluation are described here.

4.1 Heuristic Evaluation

Heuristic evaluation is a UI evaluation method proposed by Nielsen and Molich (1990) in the early 1990's. The goal of heuristic evaluation is to find usability problems in an existing UI design, so they can be fixed. Heuristic evaluation is performed by usability professionals, who evaluate a UI design against a set of accepted usability principles called evaluation heuristics. The severity and location of each problem is noted and evaluators provide their opinions on how to improve the UI. Nielsen and Molich argued that heuristic evaluation is an inexpensive and effective alternative to formal empirical user testing.

Nielsen (1994) classified heuristics that explained the majority of usability problems.

1. Visibility of system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose and recover from errors
10. Help and documentation

The goal in this section is to develop a new set of heuristics that can be used by mid-air interactive display designers to evaluate both early mockups and functional prototypes. Nielsen developed his heuristics primarily for evaluation of desktop applications. Since Nielsen's heuristics is regarded suitable for generic usability evaluation, Nielsen's heuristics can be adapted for mid-air interactive displays, however, no evaluation heuristics have been proposed specialized for mid-air interactive displays. Existing heuristics have been used as a starting point to develop interactive display heuristics. A new set of heuristics is introduced that can be used to carry out usability inspections of mid-air interactive displays. The heuristics are developed to help identify usability problems in both early and functional interface prototypes. I developed new set of usability heuristics based on the problem categories, and they describe how common usability problems can be avoided.

4.1.1 Procedures

To obtain a heuristic guideline centered in public mid-air interactive display environments, I follow below process. I rearrange existing and well-known heuristics into a new compilation and develop a set of categories that group similar usability problems. And I create heuristics that are the inverse of the problem categories and that describe how common usability problems can be avoided (Pinelle and Stach 2008).

The heuristics are primarily based on literature reviews or author interpretation about design problems that commonly occur in interactive displays. The heuristics describe design principles that are intended to help designers avoid common usability problems seen in interactive displays. In order to define heuristics, I consider how engaging and entertaining interface is, as well as usability issues, such as control system and the understandability of visual representations. I analyze to identify common usability problems and to understand the common ways that the problems occur in interactive interfaces.

Table 4: Defining usability problems

Does not provide playful and enjoyable experiences	Hard to remain user’s attention and interest, evoke user’s curiosity, emotionally appealing
Unpredictable and inconsistent response to user’s gestures	Poor detection, inconsistent response to input, unnatural controls, unresponsive controls
Does not provide enough information	Does not provide adequate visual indicators, icons, maps
Command sequences are too complex	Learning curve is too steep, making interface difficult to interact
Visual representations are difficult to interpret	Bad visualization of information, too much screen clutter, too many contents or elements on the screen at the same time, difficult to distinguish interactive content from non-interactive content
Response to user’s action not timely enough	Slow response time interferes with user’s ability to interact with the display successfully
Mismatch between camera view and action	Bad camera angle, view is obstructed; view does not adjust to user’s action quickly enough
Does not provide adequate training and help	Does not provide default and recommended choice, does not provide suggestions and help, does not provide adequate instructions, tutorials, and training mission

4.1.2 New Set of Heuristics

A new set of heuristics is considered which applicable to the mid-air interactive system. I created a set of heuristics to fill two main roles in the interaction design process. First, the heuristics can serve as a set of design principles that can be used during the formative stages of interaction design and development. Second, they can be used to carry out usability inspections where evaluators use them to critique the design. The heuristics concerning the special properties of mid-air interactive displays have been developed through literature review. Nielsen's title was used but redefined as much as possible keep his definition because it will be easy to explain to people who know this already. Two additional heuristics such as 'Provocative interaction' and 'Muscle fatigue' were added which have significant differences from origin definition.

I. Visibility of System Status

Interactive display should provide feedback on user's key actions, in a clear manner and within a reasonable time. User should be able to clearly identify their interaction location into the application, and the available options. In order to provide clear understanding of system usage and information navigation, showing system status with visual feedback is necessary for effective interaction design. Interactive display should provide navigational feedback such as showing a user's current and initial states, where they have been, and what options they have for where to go.

II. Match between System and the Real World

Interactive display should be designed with familiar user interface metaphors and analogies to help users understand the system. Interactive applications should use specific conventions of the real world and should show the information in a natural order. The sequence of activities and gestures for using mid-air interactive system should follow user's mental processes. Metaphors should be easy to understand with natural, intuitive gestures; there should be an intuitive mapping between controls and their functions.

III. User Control and Freedom

Nielsen’s origin definition of user control and freedom is that “Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo”. Offering this function is not relevant to interactive displays, but the concepts of user control and freedom are still important to interactive display design. If the user feels that system is difficult to use, and the result can be disinterest during usage of the system. Therefore, the user needs to feel that they are in control not only of the user’s gestures and movements, but the manner in which they explore the system. This heuristic is also related to navigation. User should easily move through the system and location information of interest.

IV. Consistency and Standards

Interactive display should be designed to present similar elements in similar ways. It might be more powerful to keep what real world conventions and affordances are. Gestures should be consistent throughout the system. Gestural interfaces are more powerful but less discoverable than traditional such as clickable interfaces. Gestures adds an additional interaction layer, so clear affordances and consistent interaction are critical for this heuristics to work.

V. Error Prevention

Interactive interface design should provide appropriate interaction in order to prevent users' errors and provide clear feedback indicating causes and solutions for errors. The major case of error in interactive display is imprecise gestures recognition. In mid-air, precision is even worse. If the design is coded the gesture to respond to system but no feedback on the screen, users would be frustrated. Expecting too much precision leads to mistakes, so interactive system should allow a wide margin to reduce errors. Interactive system should provide error notification as response to the users.

VI. Recognition rather than Recall

Relationship between controls and user's gestures should be obvious. Input formats and units of values should be indicated to minimize the user's memory load. Gestures should be designed understandable and intuitive way so that user can understand how to use the system without difficulties or memorizing all the gestures to interact with it.

VII. Flexibility and Efficiency of Use

Interactive display should offer appropriate guide to novice users. Experienced users should get appropriate mechanism to utilize applications according to their needs, skills, and personal preferences.

VIII. Aesthetic and Minimalist Design

The system should not overload users with irrelevant and unnecessary information. Interactive display should show concise information. Interactive display's data structure should be design in simple and easy to pick up way. Related pieces of information should be clustered together; the amount of information should be minimized to easily explore information with gestures interaction.

IX. Help

Nielsen's origin definition of help and documentation is that desktop application is necessary to provide help and documentation. Documentation was eliminated because interactive display does not need to provide detailed help screen or documentation. The meaning of help is very different in gestural system because the system will help users with the way of interacting with the system. Help will be part of the user experience that comes up naturally, not a separately user should go looking for documentation.

X. Provocative Interaction

Interactive display should engage users to remain user's attention and interest, evoke user's curiosity, emotionally appealing. Interaction should display visual effects, animations that can be manipulated by a user with the gesture of a hand or body for a fun and novel experience. Provocative interaction is new term for mid-air interaction heuristics. When Nielsen developed a set of heuristics for desktop application, there is no deed to be provocative or be engaging. The word engaging, fun and interesting don’t appear in his heuristics at all. Because desktop application is intended to design for system that people use for work. Whereas interactive display should be considered to be engaging on public space.

XI. Muscle Fatigue

Nielsen’s heuristics did not include any ergonomics because they were thought of this is separate from the system design. The design of the interaction system changes the ergonomics. Interactive display should avoid repetitive or prolonged gestures tire people out, and as muscle strain increases precision decreases, affecting performance.

4.2 Engagement Evaluation

The goal of engagement study is to determine the attractiveness of the system to gauge user interest to interact with the system and to test which visual feedback prototypes are more attractive to users to evoke their curiosity and hold their attention, while comparing different aspect of visual feedbacks (Shadow vs Emotional avatar vs skeleton).

4.2.1 Methodology

1) Participation

The target participants for this study is current students at the University of North Carolina at Charlotte enrolled in The College of Computing and Informatics. These students are going to be interacting with the system the most and interested in exploring

SIS department, events, and course information, therefore, can benefit the most from its use. The ten participants will be recruited randomly using email and word of mouth. The participant must be unfamiliar with the interactive system but they are fluent with various computational experiences.

2) Installation

The system will be installed on a 47-inch display, standing 4-feet off of the ground that has the video installed on it.

3) Procedure

At the beginning of the study, the participants are given a brief overview of the study. The within-subject experimental design will be used to test the effect of different types of visual feedback to determine which design is more engaging to users. The within-subject experimental design is when the participants go through all the conditions of the experiment. The three different conditions are: shadow, emotional avatar, and skeleton. Each participant is shown three types of video prototype and asked a series of questions. With permission of participants, a video is recorded. As an evaluation tool, I utilize video prototype which use prototype video to illustrate how users will interact with a new system. Video prototypes are organized as scenarios that illustrate how people might interact with new visual feedbacks in a realistic setting. The method should be on helping designers to consider the details of how users will react to and control new system.

4.2.2 Comparative Interview Plan

I improve three visual techniques that use three different user representations to test which visual representation is better to invite more users to interact with it and to improve immediate usability. This visual feedback is intended to grab user's attention before users can interact with the system. Engagement evaluation study is considered to determine 1) Does user notice the display? 2) Does user understand that the system is interactive? 3) Does user understand how to interact? 4) and finally, does is user motivated to interact? Following are the engagement questions in the interview:

Table 5: Comparative interview questions

Overall system	a. If these three of displays are installed in public setting, would you be interested enough to interact with the display? Which display do you like the most, why? b. Do you think interacting with these three displays would be enjoyable and engaging experiences?
Noticing displays	a. Which display is more noticeable and recognizable from a distance?
Communicating interactivity	a. Which display is better for communicating that a passerby can interact with it and see more information? Are any of the displays better at communicating that you can control the visual display with gestures? b. Which display would provoke your curiosity and encourage you to play with the system longer? Why?

Understanding initiation of interaction	a. How did you know the display supports gesture-based interaction and hand tracking? b. Were you able to identify with the shadow image, emotional avatar, and skeleton? Which one do you think is more attractive?
Understanding interaction techniques	a. Does hand icon help you to understand how to use the system? b. Which interaction techniques (positive and negative reaction from avatar, color coded distance feedback, and skeleton tutorial) help you to reduce errors while using system? Why? c. Which interaction techniques are more understandable and easy to use? Why?

4.2.3 Expected Results

Overall system interview questions are also intended to determine which display is more attractive to the users. Each of the systems currently employs a different design and each of these designs have their own respective advantages. For example, users might enjoy seeing animations of the emotional avatar that correlate with the real emotional feedback that the system generates in response to the user’s movements (See Figure 8). Furthermore, the animated visualization provided by some of avatars may be useful for grabbing the user’s attention from a distance, greeting them and inviting them to interact. Some users may like to see the shadow effects because it gives them clear feedback when their hands enter the interaction area; they are displayed as red dots in contrast to the grey background. In addition, the shadow promotes conversational dialogue, which is a familiar concept to textual interactions (See Figure 11). The skeleton may provide a visual guide that helps the users to understand what they should do. It is also big enough to attract attention from a distance (See Figure 13).

Noticing display interview questions are designed to help me to determine which display is noticeable from a distance, how users perceive them and to determine which display is better for communication with the system. The initial assumption is that the shadow concept works the best in this situation. This is especially true if the red threshold trigger is active in the systems standby state. This, coupled with the cursor, informs the user that they can interact with the system. The distance notification also provides a good indicator that the system has an interactive nature (See Figure 11).

Understanding of interaction interview questions are intended to determine how users figure out that the display supports gesture-based interaction. People are already familiar with the concept of Kinect and will be able to learn from observing other people how to interact with the system. Since the system incorporates a variety of visual feedback, I can verify how much the proposed visual feedback will influence the user's understanding of how to interact with the system.

The role of the hand plays an important role in helping the user to understand the interaction techniques. The cursor appears at the exact same position on the screen in a mirror representation of the user's hand position. The inclusion of the hand symbol tells the user that they can interact with the system, even if there is an initial glitch to begin with.

4.3 Discoverability Evaluation

Discoverability can affect the adoption and potential success applications. The goal of discoverability study is to determine the usability of the system, how well users navigate the information and understand the overall usage of the system and how they discover and access the system, while taking into consideration any errors and difficulties that might be involved in the use of the system.

4.3.1 Methodology

1) Participation

The ten participants will be recruited randomly using email and word of mouth. Conditions are the same as the engagement evaluation study.

2) Installation

The system will be installed on a 47-inch display, standing 4-feet off of the ground. A single Kinect camera is mounted in the center of the projection area.

3) Procedure

The participants will be asked to perform a series of tasks relevant to the system's functionality, while no further hint is provided. They are free to try multiple actions consecutively. The evaluator highlights that there are no wrong or right actions, and asks the participants to think aloud and freely express their thoughts and considerations during the task. After participants state to have finished the task, the evaluator proceeds with a semi-structured interview asking to describe the tasks they performed in detail. The video is recorded for further information while collecting time and error rate.

4) Usability Metrics

I. Activation Time

Activation time means the time taken for a user to approach the system and learn how to use it. How well a user understands the system, whether a user has any difficulties in using the system, and whether the visual feedback plays a great role for a user to find an appropriate distance in using the system can be examined.

II. Error Rate

Error rate is the percentage of unintended selection when the participant performs the tasks. The number of errors will be recoded every single task. The result of each task will represent what task is more difficult to control and the total error number will show how well the system work according to the user's intention. In addition, the error rate is an indicator of gesture accuracy. After a user successfully activated the system and selected one cluster, the number of error will be counted, because errors that occur after a user exactly understands the system direction prove that the system does not operate in accordance with the user's intention.

III. Completion Time

The time to complete a task is referred to as "time on task". It is measured from the time the participant begins the task to the time participant complete the task. Moreover, it is measured in each task to determine what task requires more time. The result of completion time will show the average time to get particular information and help to establish the object time.

4.3.2 Tasks Design

Tasks are composed four categories, one is to test entire system's functionality and others are to test specific functions of the system such as animated rotating bubble, progress bar, and hand pointer.

1) Entire System's Functionality

This system consists of five clusters (HCI, Health Informatics, Intelligent Systems, Security, and Software Systems) and related nodes (detailed course information within each cluster). User can use their hand as a cursor to interact with the system. Users can explore one of the clusters, one of the nodes in the selected cluster and other clusters.

Following are the participant's tasks in this study:

I. Explore One of the Clusters:

Participants will be presented with five clusters on the screen and asked to select one cluster (the cluster will be randomly selected by the evaluator and communicated to the participant) by moving their hand as accurately as possible. This task is to determine how well participants understand how to select information about a cluster and how well the system responds to the user's hand movement.

For example, Select "Design HCI cluster"

II. Explore One of the Nodes in the Selected Cluster:

Participants will be presented with five clusters with related nodes on the screen and asked to select one node to display more information (the node will be randomly selected by the evaluator and communicated to the participant) to moving their hand as accurately as possible. The participant will be asked to repeat this process five times. The goal of this task is to observe difficulties in selecting one of the moving bubbles, and to count: the number of errors that occur during the tasks. the number of times participants select the information unintentionally which is not asked by evaluator. And to test how well participants understand the course information.

For example, Select the "ITIS 4412" in the current cluster of courses (Design HCI). Tell me the course name and instructor?

III. Explore Other Cluster and Related Nodes:

Participants will be asked to select other clusters in order to display different course information. This task will be repeated five times as well to determine the error rate per cluster. We assume that participants may get confused when changing their selection of a specific cluster due to the overlay information over the bubbles. This goal of this task is to count the number of errors that occur while completing the tasks, and to test how well participants understand the cluster and related node information.

For example, Select "Security" and then select the "ITIS 6392". What is the course name and instructor?

2) Other Functionality

I. Animated Rotating Bubble:

Participants will be asked to select the HCI cluster which includes a lower related bubble (there are six related bubbles) and then to select one of the related bubbles. The participant will be asked to repeat this five times to determine the error rate of selecting a bubble. Then Participant will be asked to select the Software systems cluster which includes more related bubble (thirteen related bubble) and then to select one of related bubbles. The participant will be asked to repeat this five times to determine the error rate of selecting bubble. I assume that participants will make more errors in the second task because of the large number of related bubbles. The goal of this task is to determine animated rotating bubble speed and the number of related bubble.

Select "Design HCI cluster" and select randomly five related bubbles

Select "Software Systems cluster" and select randomly five related bubbles

II. Progress Bar

Participants will be asked to select one cluster, then select one related bubble and describe the progress bar's functionality. The goal of this task is to determine how well the participant understands the progress bar's function while interacting with the system. An additional goal of this task is to determine the progress bar's dwell time and size.

Select "Security cluster" and then select the "ITIS 6392". Tell me what you think is the purpose of the bar moving around the circle.

III. Gesture Recognition

Participants will be asked to select one cluster, then select one related bubble, and describe the purpose of the image of the hand. The goal of this task is to determine how well user understands the function of the hand pointer's and to test is the participant is able to recognize the intent of the user's hand tracking.

Select "Security cluster" and then select the "ITIS 6392". Describe the purpose of the hand pointer.

4.3.3 Interview

After the participants perform the tasks, they will go through a short interview. The interview questions consist of subsections based on the study goal to improve the system; appropriate speed of the animation, gesture recognition, information legibility, system difficulty, and appropriate feedback. Following are the usability questions in the interview:

Table 6: Interview questions

Entire system functionality	a. Is the system easy to use? b. Does the system provide adequate interaction feedback? c. Does participant immediately understand that department, course number, course instructor, and course information?
Rotating Bubble	a. Do you think the moving speed of bubble is appropriate? b. What do you think is the maximum number of related bubbles for ease of selection?
Progress Bar	a. Do you think the size and dweel time of progress bar dwell time is appropriate? b. DId you notice that you don’t need to hold your hand up during progress bar process to reduce your muscle fatigue?
Gesture Discoverability	a. Do you think the interface is able to recognize your intention from your gesture? b. Did you understand how to change your body position to control the interaction and change the visualization of the information? c. Were you confused about the distance you need to be from the display for the interaction to work properly?

4.3.4 Expected Results

1) Task

These tasks were designed to identify any difficulties that users encountered when interacting with the system. Several different outcomes are possible that might occur when users interact with the system. This system was designed to operate as an average point tracking system. This means that the Kinect establishes a stable threshold that is an appropriate distance from the screen. Any points found within that threshold are averaged to create a cursor. One problem with this approach is that the user's head and hand can be detected at the same time. As a result of this, the system may place the hand cursor at the mid-point between the user's head and hand. If this occurs, the user may experience difficulties activating the system. Furthermore, the system is programmed to place the hand cursor on the default position on the lower right part of the screen when the user's movement is not detected; as such, the hand cursor cannot be controlled in accordance with the user's intention.

Because the selectable area decreases as the number of bubble increases due to accuracy problems with gesture recognition, a lot more errors may occur when 13 related nodes are available as opposed to five. The most distinct problem is that as the bubbles constantly rotate, information can easily be lost.

2) Interview

Most people will be able to use the system and select the items without experiencing difficulties and the system gives appropriate interaction feedback. Gesture recognition may not always be accurate because, if the user attempts to move the spot of the screen to another area, hand recognition reduces and jumps around. The biggest problem that was encountered with the system was that users did not stretch their hand forward enough. As a result, the system was unable to distinguish between the user's hand and head, and the average point was therefore placed at the mid-way point between the two areas, resulting in errors. There is also a need to observe the extent to which participants experience difficulties as they read information about how to use and interact with the system.

Rotating bubble interview questions are intended to determine the appropriate speed for the animated rotating bubbles and to identify the number of related bubbles required. This might be a problem because it is hard to select the bubbles as they are rotating. Some of participants may prefer the system if the bubbles are not animated or if they rotate at a slower speed because of ease of selection. If the cursor moves well in accordance with the user's intention, the number of bubbles is irrelevant. However, because the cursor currently moves very easily and is not accurate, the maximum number of bubbles should be less than 10.

The information progress bar was intended to not only give users enough time to read the information, but also to reduce muscle fatigue so that they don't need to hold their hand up continually during the progress bar process. The progress bar function is useful because it helps the user to identify the status of the system as they progress through it. However, there is the risk that if the user passes his or hand over the sub category, another bubble may be inadvertently activated. Users will be observed as they interact with the system to assess whether the purpose of the bar moving around the circle is suitable or not.

Because of the accuracy problem, there is the risk that the user will inadvertently select related nodes when attempting to select an area of the screen. Some users may potentially use both of their hands. Even if they could use their left hand to better reach an item at the left side of their body, they would still use their right hand. People might stick to one hand.

There could also be problems as users attempt to calculate the appropriate interaction distance. It was assumed that it would not be difficult to grasp the appropriate distance and that users would quickly figure out the fact that the dots on the shadow background and in the system turn red when the distance is too far. The distance dialogue hint can be ignored and users may not notice that the distance notification shows a mirror-image representation because the location is not appropriate; i.e., it is not in the center of the screen. As such, there is a need to observe the function of the distance dialogue to elicit interaction feedback.

CHAPTER 5: CONCLUSION

This study proposed three visual feedback prototypes, emotional avatar, shadow, and skeleton, which are mid-air interactive systems that offer the functionality for members of the public to use free-hand gestures to explore information. These systems were designed to provide a discoverable interaction system that is operated by mid-air gestures. It was envisaged that this system would deliver an engaging and enjoyable experience within a publicly relevant context that is ideal for public displays and exhibitions. The proposed system has both strengths and disadvantages.

Visual feedback prototypes provide a general approach through which people can interact with information systems and engaging visual interfaces using gestures. They have been proven to appeal to audiences and are largely regarded as attractive systems that offer engaging interactive experiences that either attract audiences in their own right or spread in popularity as a result of word-of-mouth marketing. However, the system are not without their disadvantages. One of the biggest weak points of visual feedback prototypes is that they suffer from usability issues. That said, these problems can be resolved through iterative modifications of the design concept.

The aim of this research was to identify the main characteristics of visual feedback prototypes that allow the delivery of engaging visual feedback on public displays and to identify the main design heuristics associated with discoverable mid-air gestures. This paper describes a methodology for evaluating engagement with interactive systems; however, a number of limitations were identified in the research approach and the prototype itself and a number of open issues remain that require further investigation. That said, it is anticipated that this work will make a positive contribution to research in the field of mid-air interaction and this, together with recommendations pertaining to the future direction of the research, will be described in the next section.

5.1 Contribution

This thesis aims to integrate engaging interaction feedback systems into public information displays in order to deliver an enjoyable interface that attracts the attention of passers-by and motivates them to communicate and interact with the system.

First, three prototypes were presented, each of which uses different visual interaction techniques to attract more users to the public display. The mirror concept as a design principle was suggested to provide a real-time on-screen user representation. The thesis described the design and presentation of a set of new interaction techniques, which consisted of emotional avatars, shadows, and skeleton concepts. These three design prototypes represent an attempt to develop simple and easy-to-understand user interfaces. Although mirror implementation undoubtedly has significant room for further improvement, this work does deliver a number of inspiring results that suggest engaging interaction techniques have substantial potential for the development of natural user interfaces. The ideas and concepts presented in this work could inspire further research in this area as a means of effectively delivering a unique user experience. By using appropriate visual manipulation techniques, users can quickly and easily control a public display through the use of interaction alone.

A number of design issues pertaining to the development of public mid-air interactive displays were identified and I believe these will be of significant benefit to the research community. However, further research is required to explore the issues of real-time visual feedback systems. This research should consider methods of indicating the status of the system, improving gesture recognition and reducing mid-air interaction system errors. Furthermore, human gestures and behaviors should be studied in more detail to gain insights that can aid the design of effective mid-air interaction techniques. A more detailed description of these is presented in Section 5.3.

Third, a new set of heuristics frameworks were developed for mid-air interaction and evaluation methodologies were designed for the user study. This heuristic framework can be applied to various mid-air interaction systems to address common usability problems. Two additional heuristics, provocative interaction and muscle fatigue, were developed in this thesis and these may be applicable to a wide range of mid-air interaction systems.

This study could be an ideal starting point for further research into interactive technologies. As the architecture associated with these technologies is a physical and static element, it has a limited ability to actively interact with people. Architectural designers have invested a great deal of time and attention in identifying methods of efficiently delivering information to people via the use of interactive display and signs, or through the effective organization of space. This is of particular important in the design of spaces in which people need to access significant amounts of information, such as airports or shopping malls. However, while architects have focused heavily on providing information in a passive way, the area of interactive displays remains relatively neglected.

I believe that the current study proposes a novel method of delivering important information to people in an interesting, engaging and entertaining manner that will stimulate their interests and invigorate buildings by both providing useful information and presenting a surprising user experience that contributes to the field of architectural design.

5.2 Future Direction

There are many outstanding issues in this work that would benefit from further research. First, there is a need to design a more effective visual feedback system. During the study, a large number of passers-by were interested in the real-time reflection of their silhouette at first; however, they quickly lost interest. Moreover, users who had previously experienced the system did not appear to have any interest in it the second time. To attract people on a continual basis, the system needs to provide more interesting aspects, such as hook or feedback mechanism that changes in response to the user interaction. The system should incorporate more methods of keeping users informed about what is going on, through appropriate feedback within reasonable time.

Second, gesture recognition in this project was influenced by the capabilities of the Kinect device used for sensing the user’s intent. While this was promising, the interface was often inaccurate, jumping from one users’ hand to another, and it generally displayed cursor movement that did not correspond to the user’s actions. The issue with these errors was mainly that the general public user had no way of understanding how to compensate for the errors, or how to use the interface in a manner that reduced inconsistencies. The next step of this project should involve developing a more accurate and sensitive tracking system.

Third, the unique characteristics and requirements of public interactive displays should be taken into consideration in future studies. There are numerous forms, constructions, sizes, variations and extensions of the screen that could produce very different kinds of devices, displays, content and applications. Midair displays may soon become widely available for location-based advertisement, digital signage and entertainment purposes. More work is required in the area of interaction technology, user interface and application possibilities, and further studies should focus on possible location, target group, appropriateness of the displayed content, usability studies and methods of creating suitable mid-air interactive displays in public spaces.

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