Multiuser Collaborative Exploration of Immersive Photorealistic Virtual Environments in Public Spaces

Scott Robertson, Brian Jones, Tiffany O'Quinn, Peter Presti, Jeff Wilson, Maribeth Gandy

Interactive Media Technology Center, Georgia Institute of Technology
85 5th Street NW, Atlanta GA 30308
{scott, brian, tiffany, peter, jeff, maribeth}@imtc.gatech.edu

Abstract. We have developed and deployed a multimedia museum installation that enables one or several users to interact with and collaboratively explore a 3D virtual environment while simultaneously providing an engaging and educational, theater-like experience for a larger crowd of passive viewers. This interactive theater experience consists of a large, immersive projection display, a touch screen display for gross navigation and three wireless, motion-sensing, hand-held controllers which allow multiple users to collaboratively explore a photorealistic virtual environment of Atlanta, Georgia and learn about Atlanta's history and the philanthropic legacy of many of Atlanta's prominent citizens.

1 Introduction

Multiuser Virtual Environments (MUVEs) enable multiple, simultaneous users to explore virtual worlds, interact with virtual objects and actors and participate in collaborative learning activities. Designing multiuser, collaborative virtual environments for public spaces such as museums is a challenging endeavor. Multimedia museum exhibits often only accommodate either single-user interaction (i.e. touch screen kiosk) or large groups of relatively passive viewers (i.e. theater video presentation). Our goal with this project was to create a multimedia museum experience that would enable one or several users to interact with and collaboratively explore a 3D virtual environment while simultaneously providing an engaging, theater-like experience for a larger crowd of passive viewers.

We were tasked with designing and implementing a shared virtual environment exhibit for the Millennium Gate and Museum of Atlanta, Georgia which would allow up to three users at a time to collaboratively visit and explore various important locations around Atlanta and to learn about the history, architecture, cultural and philanthropic heritage of Atlanta and its social, political and economic leaders over the past 150 years. Our primary target demographic was grade school through high school students, typically visiting the museum on field trips. The Millennium Gate Philanthropy Gallery (MGPG) system was developed to achieve these goals.

The MGPG system has been deployed in a theater-like space at the Millennium Gate museum and presents users with a large, high definition panoramic projection display showing interactive, photorealistic scenes around Atlanta, Georgia, a pedestal-mounted touch screen map used for gross navigation among various locations around the metro Atlanta area and three motion-sensing, hand-held controllers derived from Nintendo Wii Remote game controllers (see Figure 1). Up to three active users utilize the touch screen map interface to travel from location to location around a virtual Atlanta with each location displayed on the projection screen as a full spherical panoramic image. Users use the three Wii Remote-based controllers to rotate the main projection screen camera view around and to find and select hidden "hot spots" and icons embedded each location scene, triggering the display of various media: photos, videos, text descriptions, quizzes, animations and audio clips. We found that the combination of gross navigation via touch screen and in-scene navigation and exploration with multiple hand-held controllers allowed several users to collaboratively explore the environments presented by the system.

Fig. 1. MGPG system panoramic display, pedestal touch-screen and motion-controllers

We faced several major research challenges during the design and development of our project. This paper discusses the major technical and usability challenges we encountered and how we addressed each. In the following sections we present a description of the hardware and software architecture of the MGPG system, a

description of how the MGPG system operates, including the educational content it showcases and a discussion of the user interaction challenges we faced and the solutions we developed. The last section discusses the conclusions we have reached thus far and possible future work for this project.

2 Related Work

Many museums have utilized technology to enhance the visitor experience, including the use of various virtual and augmented reality techniques [1][2]. Some museums and other public venues have also experimented with virtual reality environments and large public displays designed to encourage social interaction between on-site visitors or between on-site and on-line visitors [3]. Many studies of such systems have revealed difficulties in encouraging people to interact with them, especially in a public, social context. Brignull and Rogers' Opinionizer system [4], for example, investigated the causes of resistance by the public to participate in large display shared and social experiences and identified feelings of social embarrassment as a significant barrier. In designing our system we also considered ways of mitigating social embarrassment and encouraging collaborative participation. Our design strategies are presented in this paper.

Recent interactive installations have made effective use of hand-held tracking or pointing controllers, such as Wii Remote controllers to allow multiple users to collaborate and interact with large display walls. Infrared-filtered flashlights and camera tracking was used in the Beware Home demonstration [5] and Blitz Agency's "Adobe Creativity Conducted" interactive art wall [6] utilized multiple Wii Remote controllers to allow users to collaborative paint on a large display wall. The MGPG system is one the first permanent museum installations to use such technology. We purposely chose to use multiple Wii Remote controllers, a common paradigm from video game console systems, to appeal to young, game-savvy museum visitors and encourage them to interact with one another while exploring the system.

In designing the Millennium Gate Philanthropy Gallery System, we have attempted to address our client's desire to produce an entertaining and educational interactive experience for small groups of museum visitors, particularly grade school aged children. Given the design goal of multiuser collaborative exploration, we devoted considerable effort to developing and testing modes of system operation which would foster constructive social interaction among active and passive users.

3 System Hardware Architecture

Our system consists of several hardware components, including a high-definition, panoramic front projection display, a pedestal mounted touch screen, three Wii

Remote-based motion-sensing input controllers and several CPUs to drive the displays and Wii Remote controllers.

3.1 Input Devices

We investigated a number of user input devices from touch screens to camera-based motion trackers before choosing the wireless, motion-sensing Wii Remote controllers used by Nintendo's Wii game system. Our main requirements for the input devices were to allow one to three simultaneous users to control the view of a virtual camera and to select and interact with graphical objects on a large projection screen. Wii Remote controllers naturally allow a "point and shoot" style interaction with large display screens which has proven to be good for object selection tasks [7]. We also found that the motion tracking Wii Remote controllers could allow several users to cooperate in controlling a virtual camera showing scenes around Atlanta and to explore and select graphical objects in each city scene. We briefly considered building custom motion tracking devices similar to Wii Remotes, but decided instead to modify the relatively inexpensive Wii Remote controllers, removing most buttons, replacing the battery power source with a hard-wired power cable that doubles as a security tether and fabricating new cases and buttons for the modified electronics. We also surmised that Wii Remote controllers would present a familiar and fun interaction mode to many, if not most of our target audience and that users not intimately familiar with using Wii Remotes would likely still find them intuitive to use as their size, shape and function is similar to television remote controls, a device that most of our users would be familiar with.

The Nintendo Wii Remote game controller contains traditional control buttons, a three-axis accelerometer, and an infrared fiducial tracking camera. These sensors allow the Wii Remote to be used as a "magic wand" pointing device. Wii Remotes report position, orientation and button data to the game console via a wireless Bluetooth connection. In our system, users simply aim the controller at a location on the large projection screen to control a cursor or reticle, which is used for discovering "hot-spot" objects, and use an eight-way direction pad button to rotate the virtual camera view to see different areas of the scene. Users activate the multimedia content attached to hot-spots either by dwelling their cursor over the hot-spot for a short time or by pressing a second button on the controller.

3.2 System Displays

The main projection screen in our system is quite large and high-resolution, utilizing two 1080P HD projectors. The two projectors' images are tiled side-by-side with image overlap and edge blending to create a seamless and extreme panoramic view (see Figure 1). The approximately twenty-feet wide and seven-feet tall screen is cylindrically curved and provides an immersive and theater-like experience to both active and passive viewers. Due to the rather shallow depth of the room in which our system is installed, most viewers stand close to the projection screen, between six to

ten feet from the screen. This close proximity to such a large, high-definition cylindrical display produces an immersive experience similar to a CAVE [8].

We considered utilizing the large projection screen as the sole display, but ultimately decided to use a secondary pedestal-mounted touch screen for gross system navigation. The touch screen pedestal also houses cradles for the wired Wii Remote controllers. We fabricated retracting security and power cables for the Wiimote controllers to facilitate return of the control to its cradle, while constraining the use of the Wiimotes to be within optimal viewing range of the screen-mounted infrared tracking beacons and preventing their theft.

4 System Software Architecture

The MGPG system's hardware components are driven by a set of applications and servers running on three separate CPUs, including a high-power graphics workstation dedicated to driving the large projection display. The software architecture consists of a 3D graphics application, developed using the Unity 3D game engine, which drives the projection display, a separate Adobe Flash application displaying a map user interface on the pedestal touch screen, and a Wii Remote server application which is responsible for establishing and maintaining Bluetooth connections to the Wii Remote controllers and streaming tracking, orientation and button press data to the Unity application. The touch screen Flash map application, the projection display Unity application and the Wii Remote server communicate via socket messages.

Fig. 2. Touch screen map showing panorama nodes.

The touch screen map application sends messages to the projection display application in response to touch screen input selections, sending commands to change city location, play and skip introduction videos, display help instructions, timeout the display systems when idle, etc. Figure 2 shows a sample map screen from the center console touch screen.

4.1 System Operation

The pedestal touch screen is used to navigate between the major city areas, or nodes, of Midtown Atlanta, Downtown Atlanta and the Atlanta University Center. Users zoom into individual city scenes by touch-selecting a major node icon (i.e. Downtown Atlanta), then a sub-node icon (i.e. Centennial Olympic Park) and finally touch icons for individual panoramic environments which display on the projection screen.

The projection display is used to show help instructions (see figure 3), node introduction videos, panoramic city scenes and all of their associated media and educational content. Users use the Wii Remote controllers' eight-way direction button to rotate the camera view. By aiming a controller at the projection screen each user controls a color and number coded cursor to select floating icons and hidden "hot spots" in the scene to activate various educational media content such as pop-up text and image "billboards", animations, videos, interactive quizzes and audio effects related to the location node the users are currently exploring. Some content naturally relates to visible objects in each scene, a building or monument for example, and in these instances we create hidden "hot-spot" area triggers which, when "rolled" over with a user's Wii Remote cursor first highlight and after a dwell time threshold or controller button press activate or pop up the associated content object. We purposefully designed as many of these hidden hot-spots as possible in each scene to encourage exploration. Whenever there was not a large enough visible scene object or element to associate a media asset to, we instead designed a representative icon to insert into the scene and act as a hot-spot trigger.

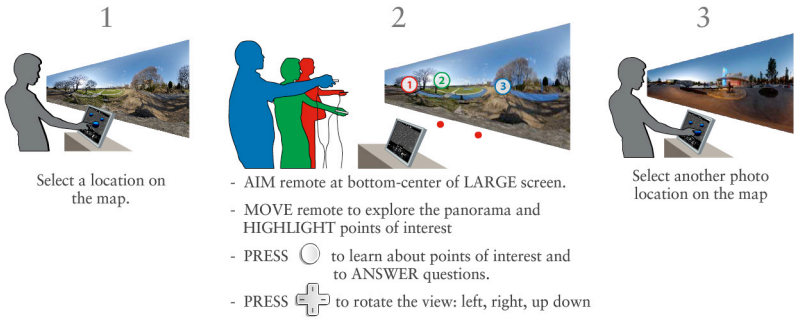

Fig. 3. Touch screen help screen showing system interaction instructions.

4.2 System Media Content

The MGPG system allows users to explore a number of locations around the metro Atlanta, Georgia area. Each location was photographed using a high resolution digital still camera and a spherical panorama tripod head to produce a 360° by 180° equirectangular image. These images are mapped to textured, environment maps to produce a photorealistic background for 2D and 3D overlay graphics. These photographic scenes are similar to Apple's Quicktime VR movies. Figure 4 shows example panoramic camera scenes with Wii Remote cursors and various activated media overlays.

Fig. 4. Panoramic scenes with pop-up media activated.

A large database of photos, videos, audio clips and text scripts are embedded in the many city panoramic scenes. We worked with a team of museum exhibit designers, curators and subject matter experts who were responsible for the assembling the educational content of the project, including writing all scripts, researching and acquiring media assets and insuring that the presented content meets Georgia public school educational requirements.

5 System Design and Usability

We faced several major research challenges during the design and development of our project: How can we allow up to three people to simultaneously interact with and explore this shared virtual environment? What types of interactions will be pleasing to users, both those experienced in using the system and new visitors who walk up to the exhibit while it is currently in use by others? Can we provide an engaging experience for the one to three users actively interacting with the system as well as with a potentially large group of passive observers? How can we ensure usable navigation of the virtual environment for a single user as well as two or three users? Can normal social rules help mediate the interactions or will specific technology limitations need to be put in place? We developed a number of hardware and software solutions to address these challenges.

We chose to use Nintendo Wii Remotes for the major projection screen interaction and navigation because they have been proven to work well other multiple user applications, namely Wii video games. We were confident that most of our primary audience, grade school and high school children, would understand the Wii Remote interaction paradigm since many would certainly already be familiar with the operation of such controllers. We were pleased to discover after deployment of the system that most users, regardless of age or familiarity with video game systems, seemed to quickly learn how to use our controllers.

5.1 Usability Testing

Due to the limited budget and timeline and the manner in which components came together during the development and installation of the MGPG, we had little time or resources to conduct formal user studies. However, informal evaluation of the interactions was conducted during development to ensure the system would be usable and function as planned. We also were able to observe visitors to the museum interacting with the system during the opening weekend.

5.1.1 User Testing During Project Development

During project development we constructed a slightly scaled-down version of the museum's Philanthropy Gallery in our lab space using two 1080P home theater projectors. We used this development system to conduct informal usability testing with other IMTC personnel, Georgia Tech grad students and a group of visiting high-school students. Feedback from these users helped us define and refine the user interface components of the MGPG system.

Initial observation and feedback during testing of our simplified Wii Remote controllers by IMTC personnel and grad students revealed that while the controllers were quite good for navigating around a single city node, they did not afford intuitive

navigation between different areas of the city or between multiple camera views, or sub-nodes, of an area. We ultimately decided to add a separate touch screen, map-based display for gross navigation. In further observation, interview and group review sessions with grad students and a group of high-school students we discovered that this configuration allowed two or three users to easily share control of the touch-screen while simultaneously exploring the main projection screen with their hand-held Wii Remote controllers.

5.1.2 User Testing After Deployment

In casual observations of user interactions during the opening weekend of the museum, we found that larger groups of passive viewers enjoyed the theater-like experience of watching the active users explore the extensive content. We also observed the Wii Remote controller users verbally negotiating and sharing control of the virtual camera view and touch-screen map navigation. Rather than devolving into conflict, the social interaction required of users allowed them to collaborate in exploring the virtual environments and, we suspect, created a better learning experience for them.

Brignull and Rogers [4] describe the "honey pot effect", a type of social affordance in which a number of people congregating near or using their Opinionizer system enticed a progressively increasing number of users to participate. We observed the same effect with the MGPG system. During the museum's opening weekend event, we repeatedly observed how one or two users actively controlling the system seemed to attract the interest of other visitors, friends and family and strangers alike. In some cases, children would operate the system while parents and grand-parents would give verbal directions for navigating the system. The active users would often take on a kind of tour guide role in their social interactions with passive users.

When visitors encountered the system without anyone actively using it, we often observed some hesitancy to begin interacting with the touch screen or Wii Remote controllers. This behavior may have been the result of visitors' fear of social embarrassment [4] to be the first or only person in a group to attempt to operate the system. This reluctance was mainly observed in older adults and not younger adults and children, perhaps owing to younger users' comfort level with technology and video game controllers.

6 Conclusion and Future Work

We have developed and deployed a multimedia museum installation that enables one or several users to interact with and collaboratively explore a 3D virtual environment while simultaneously providing an engaging and educational, theater-like experience for a larger crowd of passive viewers. We have taken pains to insure that the

employed user interface technologies afford quick understanding of interaction paradigm by our target audience. Further, we made design choices to encourage people to feel comfortable using the system.

We hope to secure future funding to expand the scope of the MGPG system to include many more areas around Atlanta and to add more content features such as educational games, videos and quizzes. In future studies we also wish to investigate our hypothesis that the social interaction and cooperation required of users in controlling and navigating around in the MGPG system facilitates a better collaborative learning experience.

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