UNIVERSITY OF MAINE

Using Mobile Devices for Indoor Spatial Awareness

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Background:

Conducting building maintenance is a difficult and time consuming task. In order to do any new construction or to repair a system that is not easily accessible, the maintenance workers either need to go in blindly and risk upsetting a hidden system, or to increase the time requirement of the project and pull out all of the building drawings to make sure there are no other networks running through the construction zone. This is an accepted dilemma in the world of facilities management, but what if the workers could access an accurate display of the buildings infrastructure without dramatically increasing the project length? Not only would the stay informed about the project, but they could do so at a lower time-cost and become more valuable to their employer.

In this day and age, the forefront of facilities management is led by Computerized Maintenance Management Systems (CMMS) (Dahoo & Liyanage, 2008). These systems are incredibly comprehensive and, assuming they are kept current with building plans and maintenance warehouse inventory, make administrating any facility they govern exponentially easier and more efficient. The shortfall of these systems, however, is that they only assist the administrators and supervisors. The actual technicians going out to perform the maintenance still need to survey they area, check the system they're repairing against any neighboring networks and then preform their maintenance. The goal of this project is to put the power of a CMMS system in the hands of the maintenance workers. I want to give them access to the most recent building plans in a format that is portable and easy for them to view.

I plan to accomplish this with the help of the Virtual Environments and Multimodal Interaction (VEMI) Laboratory at the University of Maine. The staff at the VEMI lab is experienced in creating interactive virtual reality environments that will prove vital in the completion of this project. With the help of the VEMI lab, and through the use of an Apple iPad 3 (iPad), we will virtualize a physical building and display it, with full control of motion, on the iPad.

Other software has been created for the iPad that allows for simply reading a blueprint (Honeyman-Buck, 2010). Likewise, there is a multitude of software (mostly video-game related) that allows for a user to explore a Three-Dimensional (3D) model or environment (Yoo, Woo, Sohn, & Nam, 2010). What I will do is incorporate the two into one package, allowing the user to explore a virtual 3D model of a physical building. For a maintenance worker, who is used to reading blueprints and building plans, navigating this virtual facility will be a logical extension of reading those plans. Having access to this virtual facility on an easy to use, mobile device will decrease the time required to check building plans by putting them in the users hands and increase that users understanding of the plans by displaying them as part of a 3D model (Wang, Chang, & Li, 2007).

Process:

To accomplish this task we decided to create a virtual replica of a real facility. The building that we selected to virtualize is part of the University of Maine campus: the most recently renovated wing of Boardman Hall. We chose Boardman because we believed the semi-recent renovations would give us access to both old and new construction in order to compare the two and decide which would be best to model. After comparing the two, we chose the newer wing because the documentation had a shorter history and was easier to follow.

The preliminary preparations for this project were challenging due to the nature of the aged building records. After numerous communications with the facilities management, they sent us copies of the building plans for Boardman. There were many files, most of which were un-usable do to their hand drawn nature, but we did find a few that had useable information about the electrical wiring of the building. For the physical dimensions of the rooms (e.g., wall height and length) we decided it would be more accurate and time effective for use to take certain measurements ourselves. Using a laser rangefinder for accurate measurements, we created a three-dimensional virtual model of Boardman hall. The exterior and three select rooms were built with precise measurements, while the rest of the interior were built to a less precise specification using the supplied drawings. These three rooms would become our testing rooms, while the rest would just be used for background visuals.

Included in the virtual model of Boardman are three-dimensional reproductions of the walls, ceilings, floors, doors and windows in the real facility, as well as selected lighting fixtures, furnishings and electrical fittings. Behind the scenes it also includes a partial recreation of the plumbing, electrical and heating networks which can be overlaid on the virtual structure.

After creating the computer model of Boardman we had to put the model into a program to make it easy to view. To create this preliminary demo we used a program called Unity3D (Unity). Using Unity we imported the base model and added textures and lighting to simulate the physical building. We added a physics-based first-person controller for ease of movement and an Augmented Reality (AR) setting to view the hidden architecture at the touch of a button. This AR setting is accomplished by changing the transparency the walls, ceilings and floors and by adding a glow effect to the electrical, plumbing and heating systems to accent them from the rest of the building.

Once the basic demo was created in Unity, we had to convert it for use on the iPad. In order to export to the iPad, we had to upgrade our Unity license to support the iPad Operating System (iOS). We also needed to obtain an Apple developers license to even be allowed to create software for the iPad. Once we had all of the necessary licenses, we still had to do the manual conversion from a computer demo to an iOS demo.

The iPad is a powerful piece of equipment considering how small and lightweight it is, but compared to hardware strength of our development computers it left much to be desired. In order to get our program to run on the iPad we had to institute a rendering method known as Occlusion Culling. Occlusion Culling is a method a computer program can use to only draw (or render) objects that the camera can see. In a normal rendering environment all objects are drawn regardless of the cameras line of sight. By only rendering the objects that are visible to the main camera, the Graphics Processing Unit (GPU) can perform faster and output a greater number of Frames per Seconds (FPS). This makes the best use of the iPad's GPU and lets the demo run at a comfortable frame rate (60FPS ± 5).

The other time intensive change that needed to be made was integrating the iPad's touchscreen interface to control the position and rotation of the camera within the demo. Using the iPad support for multi-touch input, we decided to mimic the motion of two joysticks using two control zones. The control zone used to change the cameras position is located in the lower left corner of the screen, while the control zone used to control the cameras rotation is located in the lower right corner of the screen. With the simultaneous use of both control zones, the user can navigate around the virtual replica of Boardman Hall.

Results:

The results for this project were positive. We created a virtual model of Boadman hall and integrated it onto the iPad using Unity. The user has the ability to move around Boardman hall, and to toggle an Augmented Reality mode that allows them to change the transparency of the walls and reveal electrical and plumbing systems hidden within the walls. This program would be very useful for maintenance workers attempting to make repairs by visually showing the worker what systems are hidden within a wall. Also, having the program exist on a display as portable and user friendly as the iPad means the program would be likely to be used as designed and not require the extra effort and time it would take to check the older building drawings.

Future Plans:

There are many features we wanted to use for this project but could not incorporate within the given timeframe. We had originally planned to extend the functionality of the software by adding a top-down view of the building that you could reference as if they were normal plans. We also wanted to integrate some of the iPad's internal sensors into the program, and use a process known as "Structure from Motion" to determine the iPad's position and orientation within a given space.

The top down 'blueprint' style layout is supported in the background of the software, but it is not an accessible function for the user. When using the current version of the blueprint view we lose all of the optimization that the Occlusion Culling granted us because we are rendering an entire floor of the building. If we can strip-down the model of the building that's used for the blueprint view to a true two-dimensional figure then it should be able to render at a comfortable frame rate and become a useful addition to the software.

The use of "Structure from Motion" is a feature we had not yet begun to implement. The basic idea of structure from motion is to take the data input from the camera and compare each individual frame with its predecessor and successor and compare the distance certain tracker pixels have moved. (Makadia, Geyer, & Daniilidis, 2007) Once the structure from motion algorithm determines the general size and shape of the room, we begin tracking the iPads orientation with its internal compass and gyroscope. We will then overlay the infrastructure hidden behind the walls, ceiling and floors onto the cameras video feed and output an augmented view of the room. This view will show the physical structure that the camera records as well as the virtualized infrastructure behind the structure for easier identification of hidden systems.

The addition of these features would make the software perfect for a maintenance workers daily use. It would give him access to all of his blueprints at the touch of a screen, and it would allow him to look at the room around him and quickly determine whether a given area is safe for new construction, or where to find and object or device that requires maintenance.

Works Cited

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