Immersive Training Games for Smartphone-Based Head Mounted Displays

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Abstract

Thin computing clients, such as smartphones and tablets, have exhibited recent growth in display resolutions, processing power, and graphical rendering speeds. In this poster, we show how we leveraged these trends to create virtual reality (VR) training games which run entirely on a commodity mobile computing platform. This platform consists of a commercial off-the-shelf game engine, commodity smartphones, and mass produced optics. The games utilize the strengths of this platform to provide immersive features like 360 degree photo panoramas and interactive 3D virtual scenes. By sharing information about building such applications, we hope to enable others to develop new types of mobile VR applications. In particular, we feel this system is ideally suited for casual "pick up and use" VR applications for collaborative classroom learning, design reviews, and other multi-user immersive experiences.

Index Terms: H.5.1 [Information Interfaces and Presentation (I.7)]: Multimedia Information Systems—Artificial, augmented, and virtual realities B.4.2 [Input/Output and Data Communications]: Input/Output Devices—Image display

1 Introduction

Early virtual reality systems involved substantial technical and financial investments since real-time graphics and tracking were serious challenges for then state of the art computing. The magnitude of these investments were often perceived as barriers to the widespread adoption of virtual reality. Accordingly, researchers and entrepeneurs have long been on a quest for cost effective virtual reality, aided by Moore's Law, new research, and new technologies.

Recent trends in mobile computing have truly commoditized a large number of components required for immersive virtual reality. Current thin client devices, such as smartphones and tablets, represent a renaissance in mobile computing. With gaming as a driver for the adoption of mobile graphics chipsets, these devices package unprecedented graphics processing with position/orientation sensing, wireless networking, and high resolution displays. As we have previously demonstrated [6], such systems provide unique opportunities for constructing low-cost, mobile virtual reality systems.

In this poster, we demonstrate how we have leveraged these trends to create immersive training games for a mobile virtual reality system (see Figure 1). We share technical details used to create the various features of these games, such as interactive 3D virtual scenes and 360 degree photo panoramas. We feel that these applications are of particular interest due to their "pick up and use" nature. We also hope to inspire others to develop additional mobile VR applications for learning and training.

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Figure 1: A smartphone based virtual reality system.

2 Related Work

Many researchers have designed and built virtual reality demonstration systems with the specific goals of limiting cost and adapting off-the-shelf components. One notable system was "Virtual Reality on Five Dollars a Day" [7]. This system had a cost of just under USD $5000, amortizing cost over three years to reach $5 a day.

Similarly, new commodity game peripherals have often been appropriated as inexpensive 3D interaction devices. Examples include finger and head tracking demonstrations based on the Nintendo Wii Remote [5], use of the Nintendo Power Glove [1] and, more recently, toolkits and demos incorporating the Microsoft Kinect depth sensing camera, such as [8].

Smartphone based augmented reality applications, such as Layar [4] and Argon (based on the Kharma architecture) [3], utilize some of the same components as our mobile virtual reality system. While there are differences, such as the use of camera based augmented reality instead of stereoscopic optics, advances in smartphone based AR will likely benefit VR applications, particularly in areas such as graphics rendering and tracking/registration.

3 Apparatus

For under USD $300, users can experience a functional mobile virtual reality system. The system components include: iPod Touch (from $199), Hasbro my3D [2] for stereoscopic optics ($25), and a Bluetooth keyboard ($20). The more expensive Apple iPhone can also be used. An iOS developer registration ($99) and a Unity iOS developer's license ($400) may also be necessary for developers.

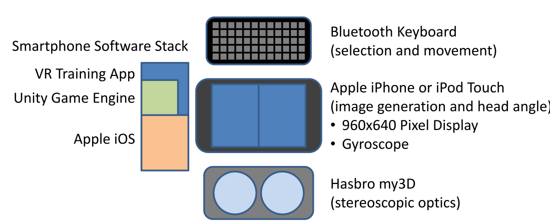

Figure 2: Smartphone based virtual reality system diagram.

Users can move around and interact with virtual scenes with a combination of head orientation and keyboard button presses. The stereoscopic imagery is rendered for each eye using two viewports defined with the Unity game engine. Current iPhone and iPod Touch devices have a 960x640 resolution. The my3D uses an asymmetrical side-by-side format with a 450x592 resolution for each eye. Unity uses normalized coordinates to specify the render position of each viewport, so the left view is set to (0.0, 0.0, 0.4685, 1.0), and the right view to (0.529, 0.0, 0.4685, 1.0).

The my3D has a magnification factor of about 1:1. Thus, the resulting stereo image is fairly narrow. This has the disadvantage of showing a clearly framed image with no extension into the periphery. We therefore placed the point of stereoscopic convergence fairly close, so the scene is almost entirely behind the display plane.

3.1 3D Virtual Scenes

The first training application we have developed is a memory game in which the user is driven through a desert environment with instructions to pay attention to each and every detail (see Figure 3). The user then revisits the scene, looking at various objects and indicating whether the object has changed from the first drive-through. A cursor is shown when an object of interest is centered in the frame. The user can indicate a change or no change in the object by using the keyboard.

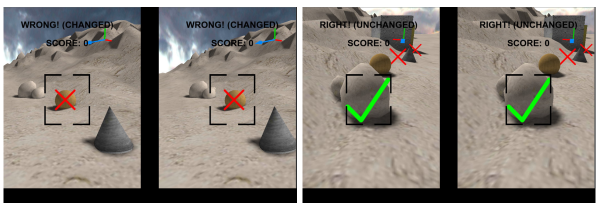

Figure 3: Screen images from smartphone based virtual reality system displaying stereo pairs from the memory game.

3.2 Photo Panoramas

Our second application features 360 degree stereoscopic photo panoramas which can be perused by changing head orientation and using keyboard buttons to zoom in and out (see Figure 5). The panoramas are prepared from multiple photos taken with a wide angle (fish eye) lens. Typical monoscopic panoramas are created from multiple photographs which are stitched together. However, stitching panoramic stereoscopic imagery is a non-trivial problem, so we have judiciously chosen a fast and robust method which results in a limited number of slightly discontinuous seams.

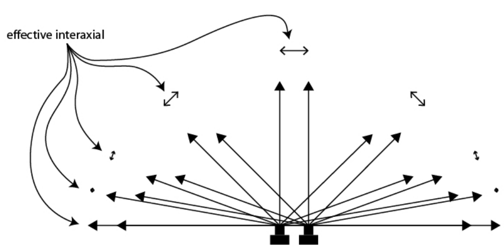

Figure 4: Stereo image pairs taken with fisheye lenses result in interaxial distances that fall off with relative viewing angle.

Using a pair of DSLRs with 8mm fisheye lenses, four full 180 degree stereo pairs are captured at orthogonal directions. Fisheye optics result in a distorted stereoscopic field that drops off to an entirely monoscopic view at the left and right edges (see Figure 4). However, the center part of the image (from about -45 degrees to 45 degrees) retains an adequate interaxial distance. Instead of stitching the images, we simply transition between views as the user turns past 45 degrees. Since the interaxial is reduced as we move from the center, the stereoscopic space bulges unnaturally. By texture mapping the left and right views onto a hemisphere, we can cancel out this bulge and correct the distortion. These two techniques result in a natural and convincing stereoscopic view (see Figure 5).

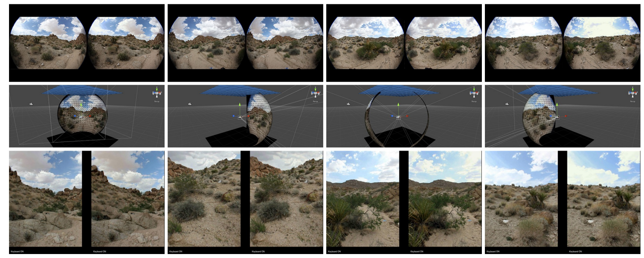

Figure 5: Four pairs of stereo images are mapped to hemispheres to compensate for distortion. Transitions between image pairs are made when the relative viewing angle reaches plus or minus 45 degrees, limiting falloff of the interaxial distance.

4 Discussion

Strengths of the system include a well supported game engine with graphical editing, making it easy for new developers to design and implement immersive applications. As the system uses inexpensive off-the-shelf components, it can be easily replicated, leading to scenarios such as classroom use in which each and every student could be given their own viewer. Handheld (head-coupled) virtual reality displays have the advantage of allowing an effortless transition into a virtual world; donning a head-mounted display is a much more involved process and can be unwieldy or uncomfortable.

Because the my3D viewer encloses the phone, the touchscreen becomes inaccessible, requiring alternate methods of user input. The Bluetooth keyboard is one of the few input devices available for the iPhone/iPod Touch, and while convenient, it is unnecessarily complex for our use, which requires only a few keys that should be operated by touch alone. We plan to modify the full keyboard, removing unneeded keys and replacing the top cover of keyboard.

5 Conclusion and Future Work

We are considering a number of features to add to this prototype. We have experimented with camera based tracking to provide additional degrees of user movement. Headphones could be added for 3D stereo sound. Wireless networking could also be used for multi-user environments or to drive virtual environment content using data from the real world.

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