An Experimentation Environment for Mobile 3D and Virtual Reality

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Abstract
Unlike desktop screens, mobile devices can be moved around freely. This allows us to create different experiences when exploring 3D data and virtual environments on such handhelds. Yet, this additional degree of freedom not only introduces exciting new possibilities, but also potential issues when used in actual applications. We present a demo environment that enables users to explore different kinds of 3D visualizations on smartphones and tablets, experiment with various characteristics and implementation options, and experience the advantages and disadvantages of these different realizations.

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Mobile 3D, mobile virtual reality, interactive 3D.

ACM Classification Keywords
I.3.6 [Computer Graphics]: Methodology and techniques – interaction techniques.

General Terms
Experimentation, Design, Human Factors.

Introduction
Today’s smartphones and tablets are powerful enough to visualize interactive 3D graphics at high quality, resulting in an increasing usage of 3D environments in
application domains such as mobile gaming, virtual reality (VR) simulation, information visualization, cultural heritage, and many more. Traditional 3D graphics assume a fixed position of the human observer in front of the center of the computer screen. As illustrated in Figure 1, a 3D scene is projected onto the 2D screen in the direction of a virtual camera placed at the expected position of the user. This creates a realistic perspective if and only if the user’s position matches the one of the virtual camera. Yet, people can move in front of the screen and, especially in a mobile context, the device itself can be rotated, resulting in “flat” visualizations with an incorrect 3D perspective.

Approaches have been proposed dealing with this issue, most importantly the so-called Fish Tank VR approach, introduced by [4, 1] and implemented on mobiles by [2], and the so-called Shoebox VR concept, that was formally described in [3]. In Fish Tank VR, the mobile’s camera tracks the observer’s position and adapts the projection accordingly – as illustrated in Figure 2c. Shoebox VR still assumes a fixed observer position but adapts the position of the virtual camera accordingly if the device is tilted – as illustrated in Figure 2b.

Adapting the perspective projection accordingly creates a more realistic 3D image and is thus generally assumed to be more visually appealing. It also enables us to create new, exciting 3D experiences (for example, a 3D game where you can look around the corners of a building by moving your head or tilting the device). Yet, the full potential of these approaches has not been explored yet. How much can we improve the 3D experience with such new visualization concepts? What new opportunities do they provide for a concrete application domain? Likewise, these advanced mobile 3D visualizations can also introduce certain issues and potential problems. For example, can people still orient themselves in such a 3D environment in the same way as in a traditional 3D visualization? How does it influence interaction when the device is tilted while aiming at a touch screen?

**Mobile 3D & Virtual Reality Visualization Concepts**

**Standard VR:** Projects in the direction of the center of the screen; creates wrong perspective if the user is not in front of the center of the mobile’s screen or when the device is tilted.

**Shoebox VR:** Projects considering the tilting angle of the mobile; creates wrong perspective if the user is not in front of the center of the mobile’s screen. Covers a larger range of device rotations than Fish Tank VR but does not consider user movements. Relies on accelerometer sensors.

**Fish Tank VR:** Projects towards the tracked head position of the user; creates wrong perspective if the user leaves the field of view (FOV) of the camera used for tracking. Considers user movement as well as device rotation, but covers a much smaller range of device motions due to the rather limited FOV. Relies on computer vision techniques.

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In this demonstration, we present an interactive 3D experimentation environment for different incarnations of the Shoebox VR concept for 3D virtual worlds on mobile devices. Our framework enables users to explore the influence of different implementation options, test their suitability for various views (first person, third person, bird’s eye view), experience different ways to navigate such 3D worlds, and verify if and how it influences interaction. Our demo highlights advantages and disadvantages of certain setups in different contexts and provides insight into open research questions worth further investigation.

**The Shoebox VR Experimentation Environment**

Tilting a device when looking at the 3D graphic on a mobile’s screen creates a wrong perspective projection due to the mismatch of the virtual camera and the observer’s position in front of the display – as discussed in the previous section and illustrated in Figure 2a. Assuming a user position in front of the center of a mobile device’s screen – a realistic assumption in common mobile usages – we can adapt the projection...
in a way that matches the virtual camera position to the expected location of the observer when the device is rotated. Information about the orientation of the device can be estimated using the integrated accelerometer or gyroscope data – two sensors commonly found in today’s mobiles. If the perspective view into the virtual environment is adapted in a way as if the 3D graphic is “glued” to the device, the resulting effect resembles looking into an actual tridimensional box, which is why [3] coined the phrase Shoebox VR for this 3D visualization concept. It is illustrated in Figure 3.

Figure 3: The Shoebox VR concept (illustrated in top view): left the standard view; center and right the view when tilting the device to the left and right, respectively. Adapting the projection in a way that considers the tilting angle of the device with respect to the original observer position enables the user to explore the left and right side of the “VR box”.

Standard techniques from computer graphics, such as off axis projection, can be used to perform the perspective correction by replacing the virtual camera depending on the rotation angle of the device. Yet, different options exist for the actual implementation. For example, the field of view (FOV) of the virtual camera can be modified, resulting in different effects for the 3D experience: whereas a wider FOV enables you to see more (cf. Fig. 4), it can also introduce distortions at the outsides of the image which in turn can have a negative impact on the 3D perception, especially in relation to the Shoebox VR visualization.

Figure 4: The implementation of the virtual camera’s FOV has a significant influence on what is seen on the screen and the subjective 3D perception of the scene.

Likewise, the subjective 3D experience and immersion can differ depending on the actual view in relation to the character that is exploring a virtual world (cf. the three views illustrated in Fig. 5). For example, generally the actual 3D experience and perceived realism increases for first person views, yet the area that can be explored by tilting the device is rather limited. In contrast to that, bird’s eye views enable you to look at a much larger part of a scene in Shoebox VR, yet the resulting distance from the actual objects can result in a less immersive 3D experience. Another parameter is the actual mapping of device rotation angle to the rotation of the virtual camera. For example, mapping tilting angles to larger movements of the camera results in an “exaggerated” 3D effect that makes the 3D perspective more apparent at the price of decreasing realism. While less naturalism is often considered negatively in graphics, certain applications such as games or specific information visualizations could actually benefit from it.
Features and Research Questions

Our Shoebox VR experimentation environment enables users to modify various parameters in order to experience and evaluate their effect on, for example, 3D perception and immersion, identify inherent characteristics of different setups, and explore potential advantages and disadvantages. It also serves as a framework for our ongoing research efforts investigating the characteristics of different implementations and identifying most useful usage scenarios. For example, it enables us to study the influence of the parameters discussed in the preceding section with respect to objective depth perception, subjective visual appeal, etc. Another area of research investigates navigation within these virtual worlds. For example, our initial informal testing suggests that there might not be much of a performance benefit when trying to reach a target using Shoebox VR compared to standard 3D graphics. Yet, there might be a benefit in terms of memorizing and experiencing the 3D world. The demo environment also enables users to explore potential issues when interacting with such advanced 3D visualizations. For example, in one of our studies we identified a decreased clicking accuracy on larger devices (e.g. 10 inch tablets) compared to smaller ones. Because of the larger screen size, people often tilted the device slightly when reaching with their thumbs to, for example, the center of the screen, causing a re-adaptation of the projection which in turn leads to frequent miss-clicks. Finally, another area worth investigating is how motion of objects can influence 3D perception and overall experience. Our initial results indicate that although motion usually increase depth perception, very high speeds might actually lead to a worse 3D experience due to the additional and complementary motion introduced by Shoebox VR when tilting the device.

References


