Portable CAVE Using a Mobile Projector

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Abstract
Virtual environments have traditionally been accessed either with conventional 2D displays, or with complex equipment such as wearable displays or CAVEs. In this demo, we show how a projector phone can be utilized to create an ad-hoc, low-fidelity immersive environment. The user holding a projector phone stands in the middle of a virtual sphere, or cube, that is revealed by the projection which can be pointed in any direction.

Author Keywords
Mobile projection, projector phones, immersive environments.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Immersive environments, where the user experiences the illusion of being in the middle of surroundings other than the current physical environment, have traditionally used one of the following two technical approaches to display the digital landscape to the user. The first approach utilizes a CAVE type system, which was first introduced in the early 1990's [2] and where the user is surrounded with large projected displays,

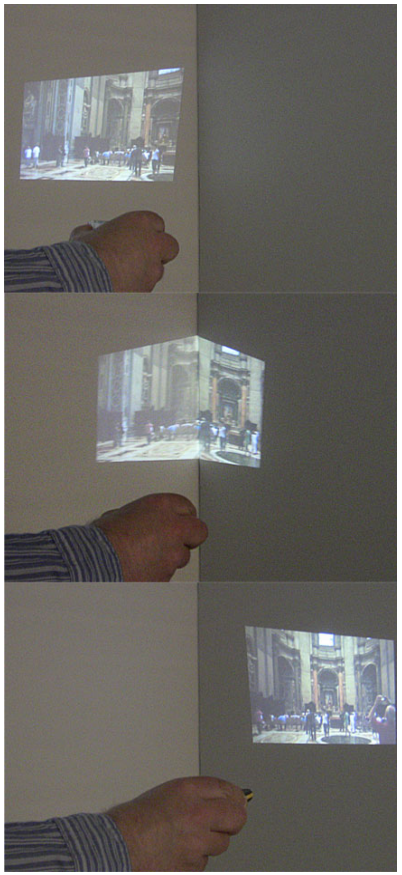

Figure 1. Portable CAVE

which form walls (and maybe a floor and/or ceiling) around the user. The second approach utilizes head-mounted displays (HMD) [5], where the virtual environment is visualized to the user via a wearable display. In this paper, we propose another technique, utilizing a handheld portable projector. Whereas our approach does not provide immersion in the same sense as CAVE and HMD systems, it offers an interesting approach which combines the benefits of portability, *in situ* sharing of the visualization to a group of people, and low cost.

Mobile projector technology has potential for use in various different types of application areas [3], in addition to the obvious use case of showing videos and photos. For instance, it has been used to augment physical objects, such as maps [4], by projecting digital information on top of them. Winkler et al. [11] proposed a mobile phone attached projector for projecting content on to a table and sharing it with the person in the call, the Sixth Sense [9] project illustrated several possible concepts e.g. for creating ad-hoc user interfaces with a mobile projector unit, and Molyneaux et al. [6] have extensively studied environment-aware projection for infrastructure-based and infrastructure-less cases. Our demonstration expands the set of proposed use cases for projector phones introduced in prior art by linking it more closely to the domain of immersive environments.

Prototype

In the Portable CAVE project, we examine the possibilities of using projector phones to create ad-hoc immersive environments. Our prototype uses the spotlight metaphor [7] to reveal parts of a virtual environment, which is visualized as a sphere (or rather, a cube) around the user. The system aims to create the illusion of the user standing in the middle of a hidden, virtual environment, which the user can access by pointing the projector phone to an arbitrary direction (360 degrees in 3D) around him/her. The use of the prototype is illustrated in Figure 1, where the user is moving the projector horizontally. The same action can be done also vertically, using the floor and the ceiling as surfaces for projected images of the virtual environment.

The CAVE projector application consists of two parts: a 3D-scene with a skybox (a 3D cube with textures on the inside surfaces) with a camera in the center, and a sensor fusion algorithm which uses the phone's gyroscope, accelerometer and magnetometer to calculate the phone's orientation. The orientation is used to rotate the camera in the scene to point in the direction where the phone is pointing. In order to maintain a stable visual presentation, the rotation of the phone around the axis of the hand is corrected, thus keeping the virtual world image horizontally aligned with the physical world. The demo implementation uses the Samsung Galaxy Beam Android phone.

Discussion

To best of our knowledge, our demonstrator illustrates a novel way to browse and access a virtual environment. Immersive environments have been used e.g. for applications related to gaming [10] and architectural and historical constructions [1], and we see that our approach has potential for application development in these areas. The research on immersive environments has so far been dominated by approaches utilizing large and/or special equipment

such as HMDs. We believe our approach is interesting particularly for its low cost and accessibility, since small projectors can already be integrated into ordinary smart phones. When interacting with the system, we found the browsing experience surprisingly smooth and engaging, and in the future we aim to validate this by conducting user studies with the prototype. Our plans for the future include studying the use of perspective correction [8], as well as further application development around the technology.

References

[1] Cabral, M., Zuffo, M., Ghirotti, S., Belloc, O., Nomura, L., Nagamura, M., Andrade, F., Faria, R., Ferraz, L. An experience using X3D for virtual cultural heritage. *Proc. Web3D'07*, 161-164, ACM (2007).

[2] Cruz-Neira C., Sandin D., DeFanti T., Kenyon R. and Hart J. 1992. The CAVE: audio visual experience automatic virtual environment. *Communications of the ACM* (1992), 33, 64-72.

[3] Dachselt, R., Häkkilä, J., Jones, M., Löchtefeld, M., Rohs, M., Rukzio, E. Pico projectors: firefly or bright future? *Interactions, Vol. 19. Iss. 2*, March 2012. ACM Press (2012).

[4] Löchtefeld, M., Schöning, J., Rohs, M., Krüger, A. Marauders Light: Replacing the Wand with a Mobile Camera Projector Unit. *Proc. MUM 2009*. ACM (2009).

[5] Messing, R., Durgin, F. H. Distance Perception and the Visual Horizon in Head-Mounted Displays, July 2005, *Transactions on Applied Perception (TAP), Volume 2 Issue 3*, ACM (2005).

[6] Molyneaux, D., Izadi, S., Kim, D., Hilliges, O., Hodges, S., Cao, X., Butler, A., Gellersen, H. Interactive Environment-Aware Handheld Projectors for Pervasive Computing Spaces. *Proc. Pervasive 2012*. LNCS 7319, 197–215, Springer-Verlag Berlin Heidelberg (2012).

[7] Rapp, S., Michelitsch, G., Osen, M., Williams, J., Barbisch, M., Bohan, R., Valsan, Z., Emele, M. Spotlight navigation: interaction with a handheld projection device. *Proc. Pervasive'04*. Video paper, 397-400. 2004.

[8] Raskar, R., van Baar, J., Beardsley, P., Willwacher, T., Rao, S., Forlines, C. 2003. iLamps: Geometrically Aware and Self-Configuring Projectors. *Proc. SIGGRAPH 2003,* 809-818, ACM (2003).

[9] SixthSense. http://www.pranavmistry.com/projects/sixthsense/ (Last accessed Jun 28th, 2013).

[10] Ultimate Battlefield 3 simulator. http://planetbattlefield.gamespy.com/fullstory.php?id=165550 (Last accessed Jun 28th, 2013).

[11] Winkler, C., Reinartz, C., Nowacka, D., Rukzio, E. Interactive phone call: synchronous remote collaboration and projected interactive surfaces. *Proc. ITS '11,* ACM (2011).