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# The World is Your Canvas: XL-Virtual Workspaces for Projector Phones

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**Abstract**

Peephole interaction is a promising interaction technique for mobile projector phones. It allows the creation of extra-large virtual workspaces which contain more information than can be appropriately displayed on a small smartphone screen. In this paper we describe a projector phone prototype that implements peephole interaction without instrumenting the environment or using any additional hardware besides a smartphone and a handheld projector. This device allows for the first time to perform peephole interaction in the wild. Moreover, we demonstrate some applications we have built to exploit and investigate the full potential of peephole interaction with projector phones.

## 1 Introduction

In 2005, Beardsley et al. (Beardsley et al. 2005) were among the first who investigated interaction techniques for handheld projectors. They probably envisioned that one day projectors are small enough to be carried in a pocket. Samsung recently revealed its redesigned Galaxy Beam projector phone at the World Mobile Congress in 2012 showing that it is even possible to embed a projector into a smartphone while maintaining a compact and light weight form factor. However, even though handheld projectors, and soon projector phones, are becoming mass market products, their full potential has not been exploited so far.

We present a projector phone prototype that demonstrates the potential of interactive handheld projectors by enabling their operators to display and to interact intuitively with a large virtual workspace through peephole interaction. Normally, a mobile device operator uses panning, scrolling and zooming to access portions of a workspace that lie outside display boundaries, whereas in peephole interaction a spatially aware display serves as a viewport (the peephole) that is moved across a stationary workspace. When the peephole window is moved in space, by pointing with the projector along the projection wall, different areas of the virtual workspace can be accessed (see Figure 1). Calculating the orientation of the projector allows for creating the illusion that the workspace is fixed to the projection wall. A good way to understand peephole interaction is to think of a dark room and a large picture hanging on the wall. By moving a flashlight across the wall, parts of the picture can be examined.

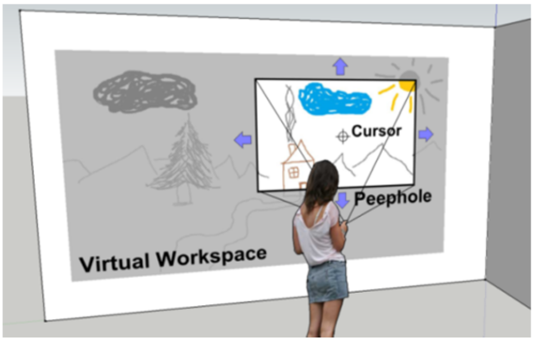


*Figure 1: Peephole interaction allows for interacting with a large virtual workspace. The peephole is moved by pointing with the device. The cursor stays fixed at the peephole center.*

Although peephole interaction has been explored in various research projects (Cao & Balakrishnan 2006; Fitzmaurice 1993; Rapp 2010; Yee 2003) as a promising basis for emerging mobile interaction scenarios and applications, it has never been applied to mobile projector phones. Previously shown peephole pointing devices required highly accurate location tracking (Cao & Balakrishnan 2006) and/or relied on additional hardware, e.g. a laptop computer, for rendering and application hosting (Rapp 2010), or external 9DOF, distance and infrared sensors (Willis et al. 2011). The presented projector phone prototype enables peephole interaction without instrumenting the environment or cable-connecting any additional hardware to the otherwise mobile device. Our prototype consists solely of a smartphone and a pico-projector, both off-the-shelf components, and uses inertial sensors for orientation determination allowing for the first time to perform peephole interaction in the wild.

# 2 Projector Phone Prototype

Our interactive projector phone prototype consists of an LG Optimus 3D smartphone running stock Android 2.2 and a MicroVision SHOWWX+ HDMI laser pico projector. The smartphone is mounted on top of the projector with the touchscreen facing up. An HDMI cable connects the projector directly to the phone. The native resolution of the projector is 848×480 pixels and the mass of the prototype (phone and projector) is 290 gram.

Since most phones do not support rendering two different frames at the same time, the content delivered to the projector is the same as shown on the touch display (i.e. HDMI output simply mirrors the content). With our prototype we focus on peephole interaction through the projected screen. Thus, although the rendered content is simultaneously displayed on the touchscreen, it is not meant to be looked at. In fact, the screen is displayed in landscape mode to fully exploit the native resolution of the projector, even though the phone is held in portrait mode. Since in peephole interaction UI elements are selected with a cursor fixed at the center of the screen (see Figure 1), all touch events are remapped to center screen coordinates. This way the entire touchscreen works as a big easy to hit touch button.

The smartphone uses the built-in gyroscope sensor to calculate its orientation. Getting accurate device orientation information is crucial and allows creating the illusion of a workspace that is attached to the projection surface. The algorithm used to calculate the orientation of the device is based on gyroscopic data only and works as follows:

1. Gyroscopic samples are collected at a rate of 50 Hz and integrated over time to convert the data from angular speed to orientation angles. Integrating gyroscopic data turns into drift when the data is noisy. For our prototype we use an LG Optimus 3D smartphone that fortunately has a built-in calibration routine for eliminating drift. The phone starts its calibration routine when the device is laid onto a flat surface. After about 2 to 3 seconds drift is eliminated. As a result, drift is not an issue in our implementation.
2. The resulting orientation angels are then smoothed by applying a moving average filter over three samples.
3. Next the smoothed orientation angles are linearly mapped to screen coordinates.

Although a filter is applied to reduce jitter, latency is kept below the level where it would be noticeable. Informal tests showed that with our inertial-sensor-only prototype it is possible to select small targets (<2 cm) from about one and a half meters distance with ease and high performance.

# 3 Peephole Applications

We developed a few applications to explore the potential of peephole interaction with projector phones. Two selected applications are briefly described.

## 3.1 Peephole Drawing

A comprehensive example to demonstrate peephole interaction is our peephole drawing app (Figure 1). It allows users to draw onto a virtual canvas that seems to be attached to the wall. The experience is similar to painting with a laser pointer except that this time strokes remain at the wall. Touching the touchscreen with two fingers brings up a pie menu next to the peephole cursor allowing the painter to choose color, brush, and size among other options.

## 3.2 Brainstorming through Peepholes

The peephole brainstorming multi-user application supports brainstorming sessions. Participants of the brainstorming meeting can send their ideas as text messages to the projector phone. Once the projector phone receives the text, it is added to a huge brainstorming canvas (virtual workspace) where the projector phone operator can grab received messages to align or cluster them. The color of a message bubble as well as its content can be changed by the operator through the peephole interface. Being able to use an entire wall or even a room for positioning ideas is one of the big advantages of the peephole brainstorming application.

# 4 Conclusion and Future Work

We presented an interactive projector phone prototype that allows further exploration of collaborative scenarios on mobile devices and in particular peephole interaction. The prototype works outside constrained environments and therefore is perfectly suited for user studies in the wild (provided a flat projection surface is available and the light is not too bright).

Next, we are planning on equipping the projector phone prototype with additional features like a full 360 degree workspace, semantic zooming, and image distortion correction. Additionally, we want to investigate dual screen scenarios where the touch display serves as a second but private screen next to the peephole interface that is more likely to be used as a collaborative public display.

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