
A Mobile See-Through 3D Display with Front- and Back-Touch

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Abstract

Touch screens are currently the dominant technology for facilitating input and output for mobile devices. Several directions to extend the possibilities of current touch screen technologies have been explored. In this demonstration we showcase a handheld device that consists of a stack of three see-through displays. Using three display layers enables to realize a volumetric 3D display. As our device is touch sensitive on both display sides it enables touch input on the device's front and back. We demonstrate the device's capabilities through three demo applications. We present 3D images using three display layers, demonstrate a game where the character can move from layer to layer, and show a target selection task to compare selection performance on different display layers.

Author Keywords

3D display, touch input, back-of-device interaction, mobile HCI

ACM Classification Keywords

H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces. - Graphical user interfaces.

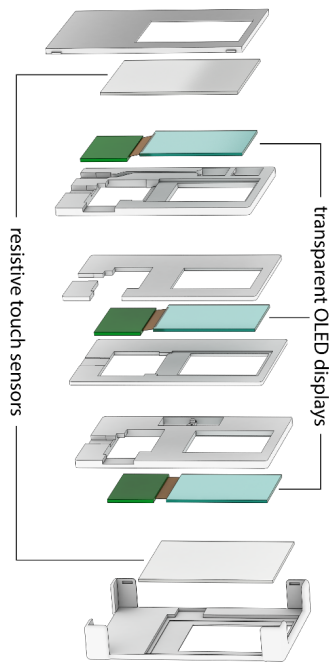


Figure 1: Schematic layout of the multi-layered display prototype.

Introduction

In recent years, touch screen became the most common input and output technique for mobile devices. While the specific abilities of mobile devices' touch screens improved over the years, the general characteristics remained: a 2D display is combined 2D (multi-) touch input. Of particular interest to further improve interaction with mobile devices are the use of 3D display for output and adding back-of-device touch for input. Furthermore, transparent displays for mobile applications have been a growing research topic in recent years.

In this demo, we showcase a mobile transparent multi-layer display device that combines a transparent display, 3D output, and touch input on both device sides. The prototype resulted from our prior work on multi-layer displays [1]. Interaction is realized using touch sensors on the front and on the back of the device. We used it to examine front and back of device interaction in combination with multiple transparent display layers by conduct pointing studies. Stacking multiple transparent displays also enables glasses-free 3D perception from changing viewing angles without the need for eye-tracking.

The developed device combines the use of (pseudo-)transparent displays for back of device interaction [4] with a multi-layered display technology [3] in a mobile device. We envision that such a device can enable different touch input techniques (e.g. [5]) and novel 3D applications (e.g. [2]). In the following we first describe the hardware prototype we developed. Afterwards we highlight three demonstration applications that showcase the input and output capabilities of our prototype.

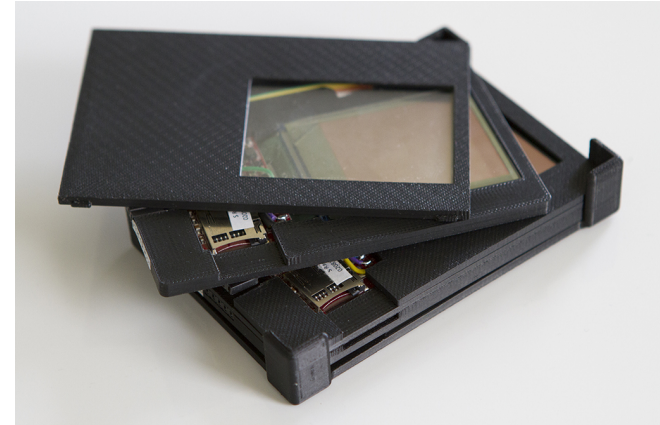


Figure 2: Prototype of the layered display device. Front touch sensor and first display layer are partly removed for illustration purposes.

System Description

The mobile multi-layer display is based on three transparent display layers that are stacked on top of each other. We chose μ TOLED-20-G2 transparent OLED displays from 4D-Systems with each display having a transparency of approximately 40%. Compared to transparent LC panels using OLEDs enables additive colour blending and thus no additional backlight is needed which simplifies the design. The resolution and size of our prototype is currently limited to 160x120 pixels per layer at a screen diagonal of 2,4'' due to limited availability of transparent OLED displays.

We added resistive touch sensors (Nintendo DSL digitizer) to the front and the back of the device for user input. Thus interaction is limited to single-touch per surface. However due to the small screen diagonal this restriction is minor.

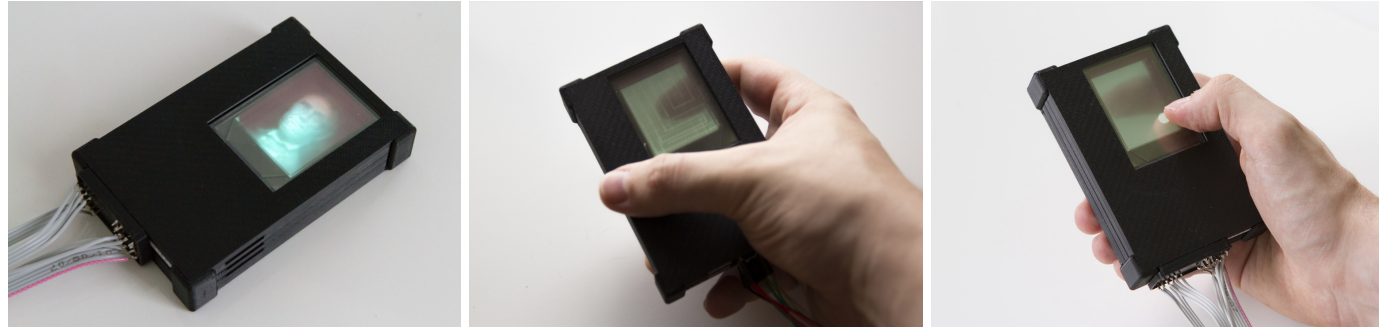


Figure 3: The three demo applications we realized for the developed device. We present 3D images using three display layers (left), a game where the character can move from layer to layer (center), and show a target selection task (right).

The display layers are 4.5 mm apart resulting in a total depth of 18.6 mm including touch sensors on both sides and the enclosure. The enclosure is 3D printed and modular so each layer can be replaced and the device can be easily extended if necessary. A schematic drawing is shown in Figure 1 and the partly assembled prototype in Figure 2. CAD-files for 3d-printing are freely available¹.

Both the displays and the touch sensors are connected to an mbed NXP LPC1768 development board which is connected to a PC via USB. It is responsible for dispatching drawing commands sent from the PC to the respective display and also for generating input events from touch sensor readings.

Demonstrations

To show the characteristics of the developed hardware prototype we present three demo applications (see Figure 3). Each focuses on different aspects of the device.

¹<https://github.com/patrigg/Layered-3D-Display-Case>

First the device serves as a volumetric 3D display by slicing a 3D scene at various depth levels and rendering each slice into an image. Each display layer shows one of these images according to its depth level. The depth ranges represented by each layer can be varied depending on the properties of the scene. Since opacity of transparent OLEDs depends on their brightness, objects without depth information can also be used for 3D imaging. In this case, faces or bright objects can easily be isolated due to their brightness and while the front layer displays a sharp image, layers behind the front are rendered with an increasing Gaussian blur according to their distance. This technique generates an depth-of-field effect also for images without depth information.

Furthermore, we show a game in which the player has to navigate through a layered 3D-maze by changing the character's movement direction. Each display layer represents one layer of the maze. The layers are connected through portals. The player moves along one of these planes and can change the planes by reaching a portal. All parts of the maze are shown simultaneously

and independent of the plane the player is currently on. This way the maze shown at a back layer may be partially occluded by walls displayed at a front layer. Thus completing the game requires users to tell apart slices based on their depth layer.

Finally, we demonstrate the target selection task used in [1]. The goal is to precisely select targets by tapping on them, either from the front or the back of the device. The targets are white circles with a diameter of approximately 5 mm and shown at random positions on one of the three layers. Depending on the task the touch surface and display layer used may be varied. A target is successfully selected if the most recent touch location lies in the target circle when the finger is released. Touch locations are visualized by a red dot on the same layer as the target.

To demonstrate the developed device and the demo applications we only require the device itself and a connected notebook. Thus, we do not have any special requirements beyond a power supply and a table. Dimmed light conditions would, however, be preferred.

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