2.5D Touch Interaction on Stereoscopic Tabletop Surfaces

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Abstract
Recent developments in touch and display technologies have laid the groundwork to combine touch-sensitive display systems with stereoscopic three-dimensional (3D) display. Traditionally, touch-sensitive surfaces capture only direct contacts such that the user has to penetrate a visually perceived object with negative parallax to touch the 2D surface behind the object. Conversely, recent technologies support capturing finger positions in front of the display, enabling users to interact with intangible objects in mid-air 3D space. In previous works we compared such 2D touch and 3D mid-air interactions in a Fitts' Law experiment for objects with varying stereoscopical parallax. The results showed that within a small range above the surface 2D interaction is beneficial whereas for objects farther away 3D interaction is beneficial. For these reasons, we discuss the concept of 2.5D interaction for such setups and introduce corresponding widgets for interaction with stereoscopic touch displays by means of an example application.

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

General Terms
Human Factors, Performance

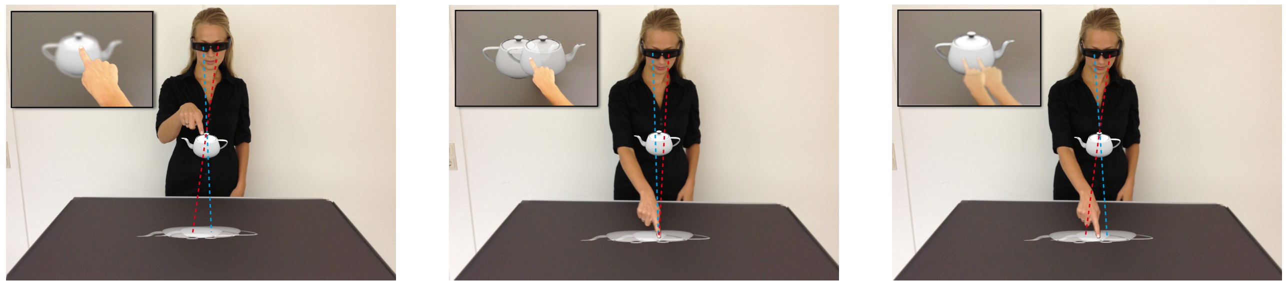

Figure 1: Illustration of touch interaction on tabletop surfaces with stereoscopic display: (left) 3D mid-air interaction, and 2D touch interaction while converging on the (center) finger or (right) virtual object.

Introduction

Recent advances in research and development have laid the groundwork for the combination of two engaging technologies: stereoscopic display and (multi-)touch interaction [2, 4, 9, 10]. While touch interaction has been found to be well-suited and intuitive for interaction with monoscopically displayed content on responsive tabletops and handhelds, introducing stereoscopic display to such surfaces raises challenges for natural interaction [5, 7]. Stereoscopic display provides the affordances to display virtual objects either with negative parallax in front of the display surface, with zero parallax centered around the display, or with positive parallax behind the display [3].

While direct on-surface touch interaction with objects displayed at a large distance in front of or behind the surface is not possible without significant limitations [10], objects displayed stereoscopically near zero parallax can elicit the illusion of a registered perceptual space and motor feedback. Thus, graphical elements (e. g., buttons, sliders, etc.) displayed close to zero parallax may afford a more natural interaction than their monoscopically displayed counterparts.

In previous work we compared interaction techniques for tabletop setups with stereoscopic display. We analyzed the differences between 3D mid-air selection and a technique based on reducing the 3D selection problem to two dimensions by touching "through" the stereoscopic impression of 3D objects, i. e., a 2D touch on the display (see Figure 1). The experimental results show a strong interaction effect between input technique and the stereoscopic parallax of virtual objects for different performance metrics, including movement time, errors, and effective throughput. Our main findings are:

- The 2D touch technique outperforms 3D mid-air selection for objects up to ca. 10cm height above the display surface.
- 3D mid-air selection is a better alternative for higher targets.
- Performance decreases faster for the 2D touch technique than for 3D selection with increasing height of virtual objects.

Hence, we suggest to use 2.5D user interfaces, in which users can interact with objects close to the screen by 2D touch interaction and with 3D mid-air interaction for objects farther away from the screen. In the following section we describe an example application, which underlines how we use such a 2.5D user interface.

Example Application: Vehicle Configurator

We implemented 2.5D user interfaces for a visualization environment for vehicle configurations that we developed in cooperation with T-Systems Multimedia Solutions GmbH. The prototype runs on a responsive touch-enabled stereoscopic display (cf. [6]).

Stereoscopic Touch-Enabled Tabletop Surface

The 62cm $\times$ 112cm multi-touch enabled active stereoscopic tabletop system uses rear diffuse illumination [8] for the detection of touch points. Therefore, six high-power infrared (IR) LEDs illuminate the screen from behind. When an object, such as a finger or palm, comes in contact with the diffuse surface it reflects the IR light, which is then sensed by a camera. The setup uses a PointGrey Dragonfly2 camera with a resolution of 1024×768 pixels and a wide-angle lens with a matching IR band-pass filter at 30 frames per second. We use a modified version of the NUI Group's CCV software for detection of touch gestures with a Mac Mini server. Our setup uses a matte diffusing screen with a gain of 1.6 for stereoscopic back projection. For stereoscopic display on the back projection screen we use an Optoma GT720 projector with a wide-angle lens and a resolution of 1280×720 pixels. The beamer supports an active DLP-based shutter at 60Hz per eye. For view-dependent rendering we attached wireless markers to the shutter glasses and track them with a WorldViz PPT X4 optical tracking system.

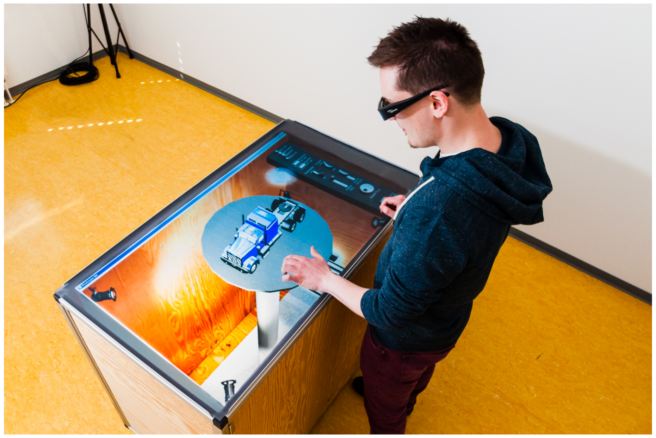

Figure 2: Screenshot of the implemented prototype. The widgets are displayed on the right.

Application and 2.5D User Interfaces

The vehicle visualization and configurator application is shown in Figure 2 and was implemented using the game engine Unity3D. In order to synchronize virtual camera objects with the head movements of a user, we integrated the *MiddleVR for Unity* software framework [1], ensuring a correct perspective from the user's point of view.

The application for vehicle configurations consists of the registered view of the virtual “inside” of the wooden tabletop box, in which virtual cars can be visualized. The 2.5D GUI widgets are displayed on the right of the virtual view with a base at zero parallax and less than 10cm height for 2D touch interaction. The widgets are labeled for users to change the visual appearance of the currently displayed vehicle. For instance, widgets allow users to turn on blinkers or headlamps, or change the height and orientation of the vehicle. The vehicles are positioned on a large interactive plate with variable height in the center.

Conclusion and Future Work

Our previous work shows that 2D touch interaction has benefits for objects located close to the interactive surface in stereoscopic tabletop environments, and is well-suited for interaction with wigets at near-zero parallax. Moreover, by exploiting limitations in human motion perception it may be possible to extend the range of effective and efficient use of 2D touch interaction by reducing differences between perceptual and motor space during touch gestures. The perceived affordances of stereoscopically displayed widgets may cause differences in touch behavior, which may be evaluated in future work.

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