Touch3D: Touchscreen Interaction on Multiscopic 3D with Electrovibration Haptics[*]

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Figure 1: Touch3D concept (left); Density and spatial distribution of touch tendencies (middle); Museum application (right).

ABSTRACT

We present Touch3D, an interactive mobile platform that provides realistic viewing and touching experiences through glasses-free 3D visualization with electrovibration. Touch3D is designed to take advantage of both visual and tactile illusions to maximize multimodal experience in touchscreen interaction. We seamlessly integrate two technologies: Automultiscopic 3D Display and Electrovibration Display; and weave both hardware and software into one fluid interface. Our museum application using Touch3D demonstrates important implications for the improvement of 3D perception in both visual and tactile modalities for enhanced touchscreen interaction.

CCS CONCEPTS

•Human-centered computing → Haptic devices;

KEYWORDS

Automultiscopic display, electrovibration display, tactile feedback

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1 INTRODUCTION

With the advent of various 3D applications on mobile platforms, a demand for a more realistic multimodal interaction is higher than ever. As *seeing* and *touching* are closely linked in the human sensory system [Meyer et al. 2011], it becomes very natural that people desire better 3D viewing experiences with tactile interaction.

In touchscreen interaction, combining visual and tactile cues in a seamless way to provide realistic 3D viewing and touching experiences is a significant challenge. Since touchscreen interaction occurs via a flat transparent surface with limited computing resources, a number of important issues should be addressed, including providing 3D binocular illusion with greater depth and motion parallax, tactile rendering of 3D objects with realistic sensations, and capturing visual and tactile cues into a single framework.

In this work, we present *Touch3D*, a multimodal interface that simultaneously provides glasses-free 3D illusion and tactile sensations with realtime touch interaction on mobile platform. This is achieved by coherently integrating two technologies: Automultiscopic 3D Display and Electrovibration Display; and blending hardware and software into a single interface. To the best of our knowledge, our approach is the first attempt to incorporate 3D binocular illusion and tactile sensations into unified framework to improve better 3D perception in the field of touchscreen interaction.

2 RELATED WORKS

A number of researchers have proposed various kinds of autostereoscopic displays without the need of dedicated glasses. In recent years, automultiscopic 3D displays are widely studied in which they provide not only binocular illusion but also motion parallax [Li et al. 2015] by utilizing lenticular lenslets, parallax barriers, projector arrays, or light field displays. Most commercially available mobile devices adopt lenticular lenslets or parallax barriers.

In touchscreen haptics, electrostatic force haptics plays a key role as it provides rich tactile information on the surface; electrostatic force is induced between fingertip and insulated conductive surface by supplying high AC voltage (also called *electrovibration*). In electrovibration, rubbery sensations are created when a fingertip is laterally scanned on a surface by modulating the friction force, yieiding different types of tactile feedback. It was first discovered by Mallinckrodt et al. [Mallinckrodt et al. 1953] but has been recently introduced by TeslaTouch [Bau et al. 2010] with a graphic display.

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3 TECHNICAL APPROACH

3.1 Integration of Two Displays

Facilitating 3D binocular illusion with electrostatic force requires elaborate integration of automultiscopic display and electrovibration display. A key technical challenge is to maintain strong tactile sensations while maximizing 3D depth perception when two displays are combined. We found that very thin PETG[1] lenticular film can maintain electrostatic force when it is placed onto the electrovibration display[2]. This observation was initiated based on our hypothesis that attaching an extra thin PETG film onto the electrovibration display will lead to maintain electrostatic force on the surface since the film is an insulator. We further observed that the thickness of PETG lenticular film should be less than 0.5 *mm* to allow users to touch and perceive strong electrostatic force. This essential prerequisite affects not only the tactile feedback, but also the visual factors such as optimal viewing distance and number of views for motion parallax. Thus, we further tuned up the geometry of the lenticular film under this limited range: it is designed to have 0.4 *mm* of its thickness with optimal viewing distance of 400 *mm*. It consists of microlens arrays which divides an underlying image into 4 distinct views to provide depth illusion and motion parallax. We set the lenslet pitch to 280 μm with its maximum arc width of 60 μm. To minimize rainbow artifact due to pixel interference and maximize the effective resolution of the display, we set the lenslet pattern slanted by 14.6° [van Berkel 2000]. We tightly attached our lenticular film onto the electrovibration display to complete the integration step of two displays.

3.2 Automultiscopic Visualization

Automultisopic visualization consists of rendering images at multiple viewpoints and merging them into one single image to be finally displayed on the LCD panel. To minimize image distortion among the views, we set up the virtual camera rig in the *off-axis* manner. By skewing the frustum of each camera instead of rotating its direction, we can obtain better convergence along the screen plane for both eyes while minimizing keystone artifact.

The lenticular lenslet array refracts light rays from underlying LCD pixels to directions based on their spatial locations. Thus after the images are rendered at all camera positions, they should be spatially-multiplexed into one image such that it can be correctly split into the four original per-view images by the lenslets. Based on the geometry of the lenslets, each of the RGB sub-pixels has different fractions of contributions along viewing directions. By merging the view-dependent images based on the pixel contributions, the final image is generated in consistent with our lenticular setup. To keep the interactive framerate for touch interaction, we implemented this merging process within a single call of a multi-texture shader.

3.3 Tactile Rendering based on Visual Saliency

When it comes to creating more realistic 3D displays and greater visual depth perception, there is a need to investigate what kind of tactile information users would want to obtain from a 3D object. Our tactile rendering based on visual saliency information reflects the spatial data observed from a pool of users who have interacted with the 3D object. Figure 1 (middle) shows the results of density and spatial distribution, according to this data, which provides a compounded illustration of multiple users (N=14) and their tendency to become fixated on specific areas of a 3D object. We found that multiple users are interested in high frequency features of both the geometry and color texture. We further noticed that a number of users were very interested in the broken parts of the relic, which can be an another valuable observation. As shown in Figure 2, we extracted the curvatures and geometry features from the 3D object using Sobel filter and further divided the textures into several salient segments to be mapped with different haptic feedback signals (e.g. bumpy signal on broken parts, smooth signal on face, and rugged signal on neckless, etc.). In this way, not only the users can perceive the feeling of geometric shapes and textures, but also the feedback from specific regions of the 3D object.

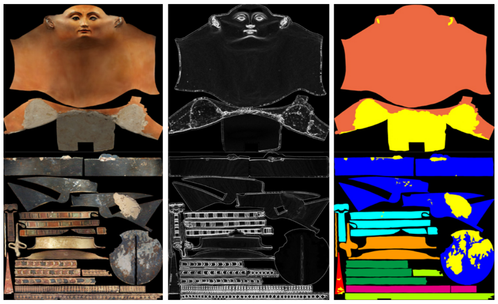

Figure 2: Albedo (left); Feature (middle); Region map (right).

4 APPLICATION AND CONCLUSION

Figure 1 (right) shows a museum application using Touch3D. This application displays the Nefertiti bust and it is designed as if it would be installed next to the real Nefertiti bust in the Neues Museum, Germany. While the real bust is protected with transparent cover, the visitors can intuitively touch and feel every single parts of the virtual Nefertiti bust, allowing tactual exploration of the masterpiece at their fingertip with realistic 3D viewing experience.

In this work, we present Touch3D, an interactive mobile platform that provides realistic 3D viewing and touching experiences. We believe Touch3D lays the foundation for the next generation mobile platform supporting multimodal touchscreen interaction.

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[1] Polyethylene terephthalate glycol-modified

[2] Senseg's Feelscreen development kit (www.senseg.com) in which an electrostatic display is overlaid on Google Nexus 7 tablet