Glasses-free 3D Display using Content-Adaptive Parallax Barriers
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How can we create a 3D display that does not require viewers to wear special glasses?

Thin displays that present an illusion of depth have become a driving force in the electronics and entertainment industries. Binocular depth cues are achieved by presenting different images to each eye. Current-generation 3D displays require special eyewear, such as LCD shutters or polarizing filters. Glasses can be eliminated by modifying the optical design of existing displays. Historically, glasses-free 3D displays require adding optically-attenuating masks, known as parallax barriers, or refracting lens arrays to a 2D display. We optimize the performance of 3D displays built by stacking a pair of modified LCD panels. We introduce adaptive masks, optimized for each multi-view video frame, that increase the brightness and frame rate compared to conventional parallax barriers. These patterns can extend the battery life of next-generation mobile 3D displays and enable full motion parallax—allowing a viewer to tilt his head and still perceive the illusion of depth.

We construct a dual-stacked LCD for 3D display using off-the-shelf parts. (Left) A side view of the prototype, showing from right to left: (a) the rear LCD and backlight, (b) an adjustable spacer, (c) the front LCD, and (d) a polarizing sheet. (Right) A photograph of the prototype taken from a viewpoint directly in front of the screen. Content-adaptive parallax barriers are used to recreate the 4D light field for a rendered scene, allowing depth perception without special eyewear.

We consider dual-stacked LCDs as general spatial light modulators that act in concert to recreate a target light field by attenuating rays emitted by the backlight. A conventional parallax barrier 3D display, shown above, uses a front panel containing a uniform grid of slits or pinholes. The viewer sees each pixel on the rear panel through this grid, selecting a subset of visible pixels depending on viewer location. In contrast, we allow both masks to exhibit non-binary opacities and thereby enable the display brightness to be increased.

A thin, dual-layer display (e.g., a dual-stacked LCD) allows depth perception without special eyewear. Multi-view content is rendered or photographed and represented as a 4D light field. Content-adaptive parallax barriers are obtained by applying non-negative matrix factorization to the input light field, increasing display brightness and frame rate compared to conventional parallax barriers. The resulting set of content-adaptive parallax barriers are displayed using the dual-layer display, emitting a low-rank approximation of the input light field and enabling depth perception.

We show that light field display using dual-stacked LCDs can be cast as a matrix approximation problem, leading to a new set of content-adaptive parallax barriers. (Left) A 4D light field, represented as a 2D array of oblique projections. (Middle and Right) A pair of content-adaptive parallax barriers, drawn from a rank-9 decomposition of the reshaped 4D light field matrix using non-negative matrix factorization. Compared to conventional parallax barriers, content adaptation increases display brightness and increases the effective frame rate of projected images.

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