# Interactive Light Field Display from a Cluster of Projectors

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## Abstract

We are developing a novel display system that physically realizes a sampling of the light field emitted by a three-dimensional scene. An array of projectors, each with a two-dimensional framebuffer, populates the 4D space of the light field. The view of the scene is simultaneously correct for all head positions within a volume. This eliminates the need for head tracking, produces binocular disparities without the need for glasses, and supports any number of viewers. Input to our display could be streamed from a light field sensor [1], or can be efficiently rendered in parallel using a cluster of standard computer graphics pipelines. For static scenes, no run-time rendering is necessary. We demonstrate the feasibility of the approach using a prototype cluster of projectors.

## 1 Introduction

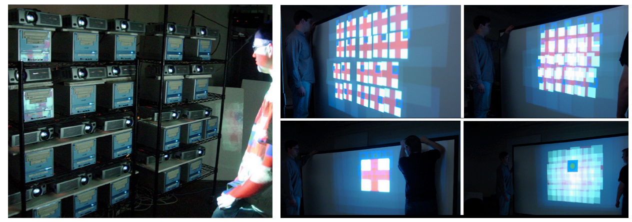
This work introduces a novel approach to interactive display that is inspired by recent advances in capturing and rendering the light field [1]. The *Light Field Display* uses an array of digital light projectors to simulate the 4D light field emitted by a three-dimensional scene. Advantages of the approach over other interactive and immersive three-dimensional displays are significant. Tracking the user's head position is not required, binocular disparities are realized without additional hardware, and any number of viewers are supported. For static scenes, the light-field can be pre-computed and loaded onto the display without the need for run-time rendering. Existing techniques, such as ones based on holography [2] or lenticular images, are similar, although we are unaware of anyone previously using our methodology that emphasizes direct production of the light filed using loosely configured projector clusters.

Our current work focuses on 1) a demonstration of the feasibility of the method including automatic and scalable calibration of large clusters of projectors and 2) low-cost approaches to that will eventually achieve high-resolution display. The reader is encouraged to visit webpage-removed for videos and more detail.

## 2 Technical Sketch

The prototype system uses a 5x4 array of projectors that generate a static Light Field (see Figure 1a). Projectors are loosely positioned and oriented so that their frustums overlap in the volume where the light field is to be constructed (Figure 1b, bottom). Light incident on any given point in the viewing volume includes rays originating from a single pixel in each projector's frame buffer. A user in the volume, looking back at the array, sees each projector's lens as the color of the framebuffer (pixel) ray that intersects the nodal point of her or his eye. As the user moves to a different position, different rays from each projector, and therefore different framebuffer pixels, illuminate the eye. These images are 2D samples of the Light Field corresponding to the three-dimensional scene being visualized.

The contents of each projector's framebuffer needed to realize a model's light field is determined via a projective map. We use an automated, camera-based calibration technique to estimate the projection matrix for each projector. These matrices map each projector ray into the given Light Field and are used to compute, in parallel, each projectors framebuffer contents (or direction map) with a standard z-buffering render.

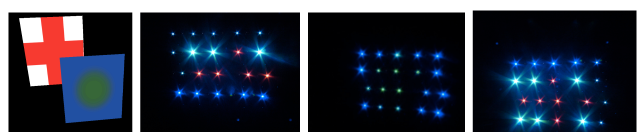


(a) (b)

Figure 1: (a) The 5x4 Light-Field Display. (b) Slices of the light field scattered by a planar surface. Top left clockwise, the plane is moved away from projectors, at near distance, projector direction maps are visible, other offsets show rays converging and forming images of a three-dimensional scene.

## Initial Results

A three-dimensional scene consisting of two textured planes was used to demonstrate feasibility (Figure 2a). A camera was moved to several locations in the light field to observe the three-dimensional model from that view (Figure 2b-d). Users also interact with the display by wearing sunglasses and interactively looking into, and moving through, the light field.



(a) (b) (c) (d)

Figure 2: Initial results. (a) A rendering of the test scene. (b-d) Three different views of the light field. (b) Looking over the front blue plane (c), A perspective view of the font plane and its green dot, and (d) looking below front plane to see a red cross on a white field.

Our prototype display has a resolution of only 5x4, limiting the quality of the sampled field. Adding more projectors will help but is not cost effective. Improvements can be made by trading off directional resolution in each framebuffer to gain the effect of a greater spatial resolution. We expect to accomplish this using large lens array that replicate each projector nodal point into potentially hundreds of samples.

## References

[1] LEVOY, M. AND HANRAHAN, P.. Light Field Rendering. In *Proceedings of SIGGRAPH 1996*, ACM Press, Computer Graphics Proceedings, Annual Conference Series, ACM, pp. 31-42, 1996.

[2] LUCENTE, M. AND GALYEAN, T. Rendering Interactive Holographic Images. . In *Proceedings of SIGGRAPH 1996*, ACM Press, Computer Graphics Proceedings, Annual Conference Series, ACM, pp. 387-394.