Dual-layered Light Field Display: Maximizing Image Perceptibility

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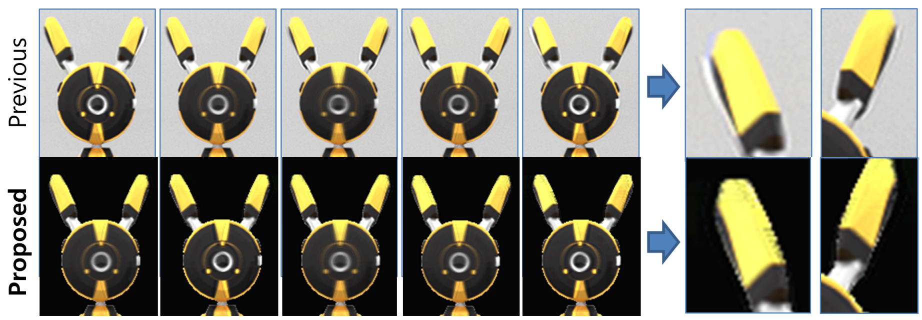

Figure 1: Light field viewpoint image calculation results compared with conventional layered light display image

ABSTRACT

In this work, we propose a novel light field approximation method for multi-layer light field display. Our target light field display consists of two liquid crystal panels with a uniform back-light with no time multiplexing. LCD panels are not necessarily to be parallel. For wide angle of view configuration, we introduce quadratic penalization term to alleviate ghost effects . This creates perceptually improved approximation of light field and increases the possibility of usage in design with a wider field of view configuration.

CCS CONCEPTS

• **Computing methodologies** → **Rasterization**; **Perception**;

KEYWORDS

Dual-layer 3D display, Multi-layer LCD, Human Visual and Perceptual System

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1 INTRODUCTION

Multilayer3D displays are becoming popular due to their full resolution reconstruction and easy fabrication by utilizing existing display technologies such as LCD panels. However, these displays suffer from limited performance gain achieving only narrow angular resolution, field of view and depth of field. Moreover, as these displays approximate 4D light field compressively, achieving reasonable quality images is not a trivial task. In order to get better estimation quality, diverse approaches are introduced; High Dynamic range display [Lanman et al. 2010], Tomographic technology [Wetzstein et al. 2011], Tensor Displays [Wetzstein et al. 2012]. These methods either utilize multiple layers, multiple time-multiplexing frames or combination of both in order to increase degree of freedom. Increasing the number of layers reveals drawbacks such as bigger size device, energy consumption, and decreased brightness and contrast. They do not even provide the expected n-fold increases in approximation quality [Wetzstein et al. 2012]. In this work, we propose a framework to approximate given light field image with dual layer 3D display. We provide *an extended transformation matrix* that maps a group of panels intensities to approximated light field intensities, where display panels are not necessarily be parallel. Such generalized light field estimation method removes restrictions of parallelizing panels in fabrication. Additionally, considering Human Visual and Perceptual Systems, we assign weights to light field rays indicating *degree of perceptibility of information* they holds. We call it *perceptual information gain* or simply *perceptual gain.*

2 PROPOSED METHOD

The main task in this work is finding an approximation $\overline{L}$ to given target light field L with only two LCD panels by maximizing the perceptual information gain. We assume that 3D transformation matrix between two LCD panels are given. We describe approximated light field as function $\overline{L} = F_T(P)$, where P is a vector of all panel intensities. The optimal approximation $\overline{L}$ is obtained by minimizing squared weighted distance. (see 1)

$$\min \|W \circ (L - F_T(P))\|_2^2 \qquad (1)$$

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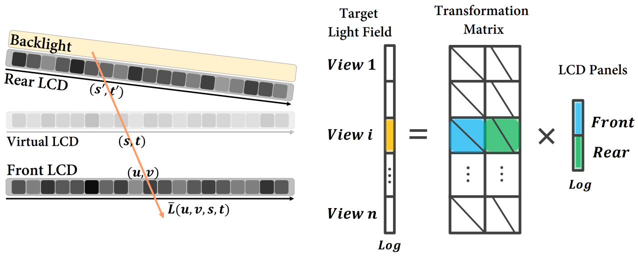


a) *Display design.* ***b)*** *Transformation matrix.*

Figure 2: Dual Layered Light Field Display and Its Transformation Matrix.

where ∘ represents element-wise product.

2.1 Transformation Matrix Construction

Lets assume that l_r is a light ray. Given configuration of layered LCD panels, one can construct a function that orthographically projects panel positions onto given light field. The set p_r of panel positions that are projected exactly onto l_r approximates light field ray l_r in concert. The intensities of this light rays can be approximated by multiplying attenuation values of LCD panels at positions in set p_r. We assume that back light's intensity is 1 (normalized intensity). Let $\bar{l}_r$ be an approximation of l_r light ray. Squared approximation error for a given light ray can be calculated as follows.

$$err_r = |l_r^i - \prod_{p \in p_r} p^i|^2 \quad (2)$$

l_r^i is intensity of light ray l_r and p^i is an attenuation term at position $p = \{p | p \in p_r\}$. The error term for all approximated rays in log scale takes following form:

$$err = \| \log L - T \log P \|_2 \quad (3)$$

where T is transformation matrix whose rows indicate weather each pixel is used for ray approximation. The size of columns equals to the size of vector L which stores all light ray intensities. Figure 2b illustrates the transformation process. Generally one can minimize the objective function (equation 4) to find optimal approximation.

$$\arg \min_{0<p<1,\ p \in P} \| \log L - T \log P \|_2 \quad (4)$$

2.2 Maximizing Perceptual Gain

Human Vision and Perception System Analysis. Human vision system reacts more quickly and strongly to some visual conditions. Following are visually saliency terms that are considered in our perceptual gain maximization.

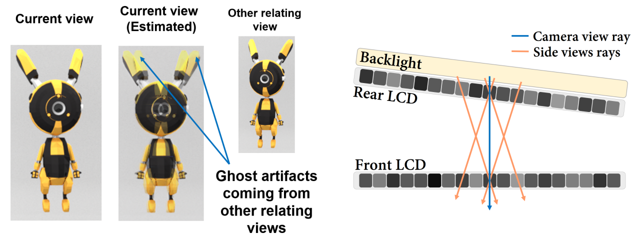
2D saliency: *We perceive color and texture patterns better than others, so any mismatches on this rays decreases perceptual information gain.*

HVS limitations: *Any mismatches in both color and 3d geometry are better perceived in near objects than those of further ones.*

3D geometry saliency: *We perceive any abnormal deformation and change on salient object parts better than other parts.*

We define a score with weighted saliency terms as follows.

$$\arg \min_{0<p<1,\ p \in P} \| W \circ (\log L - T * \log P) \|_2 \quad (5)$$



a) *Ghost artifact example.* ***b)*** *Neighbour views.*

Figure 3: Ghost artifact from its neighbour views.

Enhancing Perceptual Gain by Ghost Reduction. In dual layered display, bigger view angle configuration suffers from ghost artifact caused by neighbor view images in the composition of light rays (Fig. 3a)). Each LCD pixel contributes to multiple perspective views rendering. Bigger angle difference between views increases the color difference in expected light rays that share a LCD pixel for rendering. Figure 3b illustrates relationship between rays of current view and its neighbour.

We perform ghost penalization. Let's fix one view to camera view L_c and all other side views L_S respect to this camera view L_c. So for the camera view's approximation $\overline{L_c}$, one ghost penalization function $err_g(L_s, L_c)$ from each side view $s \in S$ is evaluated. Denote ghost penalization function $err_g(L_s, l_c)$ for one ray l_c of camera view L_c. If we pick only one ray l_s from L_s which has a common LCD pixel relation with camera view ray l_c, the ghost penalization function $err_g(l_s, l_c)$ can be thought of symmetric continuous function that gains its maxima at l_s. The penalty function coming from other rays of L_s for camera view's ray l_c can be defined. All these functions have one peak and have two minimum locations inside the intensity range. The minimum points are located at the boundaries of intensity range. We manage multiple views with multiple rays. Each of them has its own penalization distribution for approximation $\overline{l_c}$. Therefore the minimization problem in this penalization is NP-hard and the task is NP-complete(the number of minimum points grows exponentially to the resolution of views). For simplicity, we choose one half of these symmetric functions - the half that includes the intensity value which camera rays should converge. For example for $\overline{l_c}$ approximation we choose one half of symmetric ghost penalization functions that includes l_c intensity. We fit a quadratic penalization function. Then we combine both main and regularization terms into one least square optimization function.

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