Content-Adaptive Parallax Barriers for Automultiscopic 3D Display

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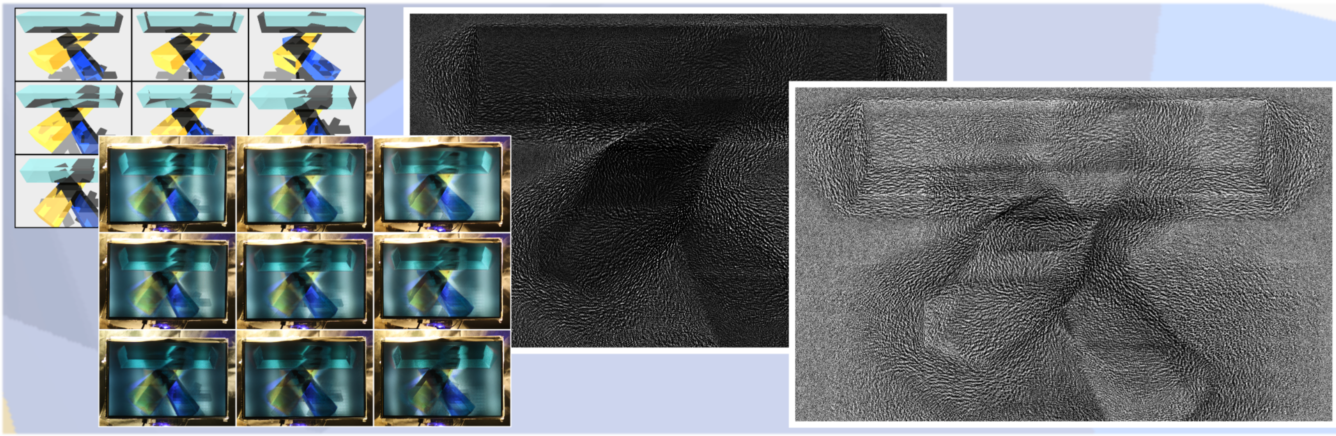

Figure 1: *Automultiscopic 3D display with content-adaptive parallax barriers. (Left) A 4D light field, represented as a set of oblique projections of a synthetic scene, is displayed using our dual-stacked LCD prototype, with corresponding photographs shown in the overlaid region. (Right) A pair of content-adaptive parallax barriers, drawn from a rank-15 decomposition of the reshaped 4D light field matrix. Such masks allow increased display brightness and frame rate, when compared to conventional parallax barriers [Konrad and Halle 2007].*

Abstract

We optimize the performance of automultiscopic barrier-based displays, constructed by stacking a pair of LCD panels. To date, such displays have conventionally employed heuristically-determined parallax barriers, containing a fixed array of slits or pinholes, to provide view-dependent imagery. While recent methods adapt barriers to one or more viewers, we show that both layers can be adapted to the multi-view content as well. The resulting *content-adaptive parallax barriers* increase display brightness and frame rate. We prove that any 4D light field created by dual-stacked LCDs is the tensor product of two 2D mask functions. Thus, a pair of 1D masks only achieves a rank-1 approximation of a 2D light field. We demonstrate higher-rank approximations using temporal multiplexing.

1 Content-Adaptive Parallax Barriers

We define a pair of 2D masks $\mathbf{f}[i,j]$ and $\mathbf{g}[k,l]$, corresponding to the images displayed on the front and rear LCD panels, respectively. A 2D slice of the 4D light field is given by the outer product

$$\mathbf{L}[i,k] = \mathbf{f}[i] \otimes \mathbf{g}[k] = \mathbf{f}[i]\mathbf{g}^{\mathsf{T}}[k]. \tag{1}$$

Similarly, the complete 4D light field is given by the tensor product

$$\mathbf{L}[i,j,k,l] = \mathbf{f}[i,j] \otimes \mathbf{g}[k,l]. \tag{2}$$

These expressions imply a fixed mask pair only produces a rank-1 approximation of a 2D light field matrix. To our knowledge, this limitation has not been previously described for dual-layer displays.

Conventional parallax barriers result in reduced spatial resolution and image brightness. Recently, translated barriers have been proposed to eliminate spatial resolution loss [Kim et al. 2007]; here, a high-speed LCD sequentially displays a series of translated barriers. If the complete mask set is displayed faster than the flicker fusion threshold, no spatial resolution loss will be perceived.

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We generalize the concept of temporal multiplexing by considering all possible mask pairs. Any sequence of T mask pairs represents (at most) a rank-T decomposition of a 2D light field matrix as

$$\mathbf{L}[i,k] = \sum_{t=1}^{T} \mathbf{f}_t[i] \otimes \mathbf{g}_t[k] = \sum_{t=1}^{T} \mathbf{f}_t[i]\mathbf{g}_t^{\mathsf{T}}[k]. \tag{3}$$

Thus, time-multiplexed light field display can be cast as a matrix (or more generally a tensor) approximation problem. Specifically, the light field matrix must be decomposed as

$$\mathbf{L} \approx \mathbf{F}\mathbf{G}, \tag{4}$$

where $\mathbf{F}$ and $\mathbf{G}$ are $N_i \times T$ and $T \times N_k$, respectively. Since each mask must be non-negative, we seek a decomposition such that

$$\arg\min_{\mathbf{F},\mathbf{G}} \frac{1}{2}\|\mathbf{L} - \mathbf{F}\mathbf{G}\|^2_{\mathbf{W}}, \text{ for } \mathbf{F},\mathbf{G} \geq 0. \tag{5}$$

Unlike conventional barriers, we allow a flexible field of view tuned to one or more viewers by specifying elements of the weight matrix $\mathbf{W}$. General 4D light fields are handled by reordering them as 2D matrices, whereas 2D masks are reordered as vectors.

Equation 5 can be solved using non-negative matrix factorization [Lee and Seung 1999], with typical results shown above. In conclusion, we propose the resulting *content-adaptive parallax barriers* as a generalization of conventional barriers, in which both layers are jointly optimized depending on the multi-view content.

References

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