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 \( f[i,j] \) and \( g[k,l] \), 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

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

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

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

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.

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

\[
L[i,k] = \sum_{t=1}^{T} f_t[i] \otimes g_t[k] = \sum_{t=1}^{T} f_t[i]g_t^T[k]. \tag{3}
\]

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

\[
L \approx FG, \tag{4}
\]

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

\[
\arg\min_{F,G} \frac{1}{2} ||L - FG||_F^2, \text{ for } F, G \succeq 0. \tag{5}
\]

Unlike conventional barriers, we allow a flexible field of view tuned to one or more viewers by specifying elements of the weight matrix \( W \). 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

