Light Field Display

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Content-Adaptive Parallax Barriers: Optimizing Dual-Layer 3D Displays using Low-Rank Light Field Factorization

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Problem – 2D

Scene

Camera

Display

Viewers
Problem – 2.5D

Scene  Camera Array  Multiplexed Display  Glasses-bound Viewers
Problem – 3D

Conventional display are view-independent
- Pixel intensity/color does not vary as a function of viewing angle
Problem – 3D

Light Field display are view-dependent (automultiscopic)
- Achieved with pinhole/lenslet array placed close to the display
- Trades decreased spatial resolution for increased angular resolution
Problem – 3D

Light Field display are view-dependent (automultiscopic)
- Achieved with pinhole/lenslet array placed close to the display
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Solution

Tiled-Broadband Patterns

Light field camera

Content-Adaptive Parallax Barriers

Light field display
Parallax Barrier Front Mask
Parallax Barrier Rear Mask
Light Field Analysis of Barriers

\[ L[i,k] = f[i] \cdot g[k] \]

\[ L[i,k] = f[i] \otimes g[k] \]
Time-Multiplexing using Shifted Pinholes

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

Content-Adaptive Parallax Barriers

\[
\tilde{L} = FG
\]
Optimization: Iteration 1

rear mask: $f_{1}[i,j]$

front mask: $g_{1}[k,l]$

$$F \leftarrow F \circ \frac{[(W \circ L)G^{t}]}{[(W \circ (FG))G^{t}]}$$

$$G \leftarrow G \circ \frac{[F^{t}(W \circ L)]}{[F^{t}(W \circ (FG))]}$$

reconstruction (central view)
Optimization: Iteration 10

**rear mask**: $f_1[i,j]$

$$F \leftarrow F \circ \frac{[(W \circ L)G^t]}{[(W \circ (FG))G^t]}$$

$$G \leftarrow G \circ \frac{[F^t(W \circ L)]}{[F^t(W \circ (FG))]}$$

**front mask**: $g_1[k,l]$

**reconstruction** (central view)
Optimization: Iteration 20

rear mask: \( f_1[i,j] \)

front mask: \( g_1[k,l] \)

\[
F \leftarrow F \circ \frac{[(W \circ L)G^t]}{[(W \circ (FG))G^t]}
\]

\[
G \leftarrow G \circ \frac{[F^t(W \circ L)]}{[F^t(W \circ (FG))]}]
\]

reconstruction (central view)

Optimization: Iteration 30

rearr mask: $f_1[i,j]$

$$F \leftarrow F \circ \frac{[ (W \circ L) G^t ]}{[ (W \circ (FG)) G^t ]}$$

$$G \leftarrow G \circ \frac{[ F^t (W \circ L) ]}{[ F^t (W \circ (FG)) ]}$$

front mask: $g_1[k,l]$

reconstruction (central view)

Optimization: Iteration 40

rear mask: $f_1[i,j]$  
front mask: $g_1[k,l]$

$$F \leftarrow F \circ \frac{[(W \circ L)G^t]}{[(W \circ (FG))G^t]}$$

$$G \leftarrow G \circ \frac{[F^t(W \circ L)]}{[F^t(W \circ (FG))]}$$

reconstruction (central view)

*Daniel Lee and Sebastian Seung. Non-negative Matrix Factorization. 1999.*
*Vincent Blondel et al. Weighted Non-negative Matrix Factorization. 2008.*
Optimization: Iteration 50

rear mask: $f_1[i,j]$

front mask: $g_1[k,l]$

$$F \leftarrow F \odot \frac{[(W \odot L)G^t]}{[W \odot (FG))G^t]}$$

$$G \leftarrow G \odot \frac{[F^t (W \odot L)]}{[F^t (W \odot (FG))]}

reconstruction (central view)

Optimization: Iteration 60

rear mask: $f_1[i,j]$

$$F \leftarrow F \odot \frac{[(W \circ L)G^t]}{[(W \circ (FG))G^t]}$$

$$G \leftarrow G \odot \frac{[F^t(W \circ L)]}{[F^t(W \circ (FG))]$$

front mask: $g_1[k,l]$

reconstruction (central view)


Optimization: Iteration 70

rear mask: $f_1[i,j]$

$$F \leftarrow F \cdot \frac{[(W \circ L)G^t]}{[(W \circ (FG))G^t]}$$

$$G \leftarrow G \cdot \frac{[F^t(W \circ L)]}{[F^t(W \circ (FG))]}$$

front mask: $g_1[k,l]$

reconstruction (central view)

Optimization: Iteration 80

rear mask: $f_1[i,j]$

$$F \leftarrow F \circ \frac{[(W \circ L)G^t]}{[(W \circ (FG))G^t]}$$

$$G \leftarrow G \circ \frac{[F^t(W \circ L)]}{[F^t(W \circ (FG))]$$

front mask: $g_1[k,l]$

reconstruction (central view)

Benefits of Content-Adaptation

1) Increasing brightness:

\[
\arg \min_{F,G} \frac{1}{2} \left\| \alpha L - FG \right\|_W^2, \text{ for } F, G \geq 0
\]

2) Increasing refresh rate:

\[
L[i, j, k, l] = \sum_{t=1}^{T} f_t[i, j] \otimes g_t[k, l], \text{ for } T < N_h N_v
\]
Increasing Brightness and Refresh Rate

1) Increasing brightness: \( \arg \min_{r,s} \frac{1}{2} \| dL_r - FG_r \|^2 \), for \( F, G \geq 0 \)

2) Increasing refresh rate: \( L[i,j,k,l] = \sum_{t=1}^{r} f_t[i,j] \otimes g_t[k,l] \), for \( T < N_hN_v \)
Prototype
Result - Video