Fully computed holographic stereogram

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Holographic 3D display

- Reconstruction of whole optical wavefront
- Can provide all the depth cues

- Binocular cues
- Motion parallax & occlusion
- Accommodation

By Nathaniel Dornik
Computer-generated holograms

- Without using interference of coherent light
- Can display both real and virtual scenes
Can CGHs be more photorealistic?

By Henrik Wann Jensen
Physically based algorithms

- Modeling optical wave transmission
- Discretizations of 3D scene (points and facets)
- Difficult to express occlusion and other view dependent effects
Motion parallax and occlusion effect

- Blocked area
- Contributed area
- Point source
Holographic stereogram

- Computer graphics implemented
- Lack of depth information
Phase profiles of CGHs

physically based CGH

holographic stereogram

object plane

spatial frequency

Point source

Hologram plane

Hologram plane

spatial frequency

Point source
Fully-computed holographic stereogram

Physically based algorithm + Holographic stereogram based algorithm

Geometrical transmission

\[ A \text{ amplitude} \]

\[ \sin \theta_{\text{max}} = \frac{f_{\text{max}} \lambda}{2d} \lambda \]

\[ h_{\text{hogel}}(x, y) = \sum_{j=1}^{N} \frac{A_j}{r_j} \exp[i(kr_j + \phi_j)] \]

\[ r_j = \sqrt{(x-x_j)^2 + (y-y_j)^2 + z_j^2} \]

\[ (\theta_x, \theta_y, z_p) \]

\[ \begin{align*}
  z_o &= z_p \\
  x_o &= z_o \tan \theta_x \\
  y_o &= z_o \tan \theta_y \\
\end{align*} \]

\[ (x_o, y_o, z_o) \text{ coordinates} \]
Reconstructions using LCOS
High-resolution CGH

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pixels</td>
<td>$4 \times 10^8$ ($20,000 \times 20,000$)</td>
</tr>
<tr>
<td>Pixel pitch</td>
<td>1 micron</td>
</tr>
<tr>
<td>Hologram size</td>
<td>20 mm $\times$ 20 mm</td>
</tr>
<tr>
<td>Modulation type</td>
<td>Binary amplitude</td>
</tr>
<tr>
<td>Wavelength</td>
<td>532 nm</td>
</tr>
<tr>
<td>Viewing angle</td>
<td>30.9°</td>
</tr>
</tbody>
</table>
Optical reconstructions

- Focusing on the bunny
- Focusing on the wall
- Left
- Center
- Right

Left

Center

Right

Right
Acceleration

2688 CUDA Cores

<table>
<thead>
<tr>
<th>CGH(1024x1024)</th>
<th>CPU</th>
<th>GPU</th>
<th>5GPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 points</td>
<td>83.9s</td>
<td>60ms</td>
<td>13ms</td>
</tr>
<tr>
<td>5000 points</td>
<td>427.9s</td>
<td>298ms</td>
<td>65ms</td>
</tr>
<tr>
<td>10000 points</td>
<td>847.4s</td>
<td>605ms</td>
<td>129ms</td>
</tr>
<tr>
<td>50000 points</td>
<td>4203.4s</td>
<td>3002ms</td>
<td>664ms</td>
</tr>
</tbody>
</table>
Layered holographic stereogram

\[ H = \sum_{i=1}^{n} \text{Fresnel}^{-1}(L_i) \]
Sampling in Fresnel propagation

\[ \Delta x = \frac{\lambda d}{N \Delta \xi} \]

\[ x \in \left[ \frac{\lambda d}{2 \Delta \xi^2}, \frac{\lambda d}{2 \Delta \xi^2} \right] \]

\[ \tan \frac{\theta}{2} = \frac{\lambda}{2 \Delta \xi} \]
Reconstructions

Point based

Layer based

Calculation time: 3390s VS 21s (CPU)
2.42s VS ? (GPU)
Conclusion

- Computer graphics rendering can be used in CGH calculation to improve the image fidelity
- More depth information can be reconstructed by integrating physically based algorithm and holographic stereogram
- Use GPU for acceleration
Thank you