FAST CALCULATION OF CGH FOR RECTANGULAR PATCH MODEL

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Electro-holographic displays

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Our HMD
Outline

1. Electro-holography & Computer-generated hologram (CGH)
2. Proposed method
3. Experimental results
4. Conclusions
Electro-holographic display

- Capability of holographic television
  - How to display the interference pattern instead of a photo-plate.
  - How to get the pattern
Electro-holographic display

Capability of holographic television

- How to display the interference pattern instead of a photo-plate.
  - Spatial light modulator (SLM)
    - Laser, LCD, DMD

- How to get the pattern
  - Calculations of interference patterns by a computer
    - Computer-generated hologram (CGH)
Computer-generated holography (CGH)

Point light source (PLS) method

\[ u(x, y) = C \sum_{i}^{N_i} g_i e^{-jkr_i} \]

- \( g_i \): Luminance of a PLS
- \( r_i \): Distance between a PLS and hologram
- \( k \): Wave number

Discrete Fresnel–Kirchhoff diffraction formula

Fresnel zone plate (FZP)
Calculation time

Time [ms/point/px]

1000 100 10 1 0.1 0.01 0.001 0.0001

Year


Calculation-time trend of PLS methods
Proposed method

A novel fast calculation algorithm of CGH for a rectangular patch model using GPUs.
Derivation of equation

\[ u(x_h) = \sum_i L_i \sum_j g_{ij} \exp(-jk \delta_i) \]

\[ O(Np Lx Ly Nh) \]

\( Np \): The number of patches  
\( Nh \): The number of hologram pixels

**Assumption for approximation**

PLSs are arranged at equal interval.  
\( r_{ij} \gg \) Patch size.  
\( g_{ij} \) are constant.
Derivation of an equation

Assumption for approximation

- PLSs are arranged at equal interval.
- $r_{ij} \gg$ Patch size.
- $g_{ij}$ are constant.

The sum of complex geometric series
Derivation of an equation

\[ u(x_n) = C \frac{1 - \exp(-jkL_x \Phi_x)}{1 - \exp(-jkL_y \Phi_y)} \frac{1 - \exp(-jkL_y \Phi_y)}{1 - \exp(-jk \Phi_y)} \]

**C, \Phi_x, \Phi_y**: Constants dependent on parameter of \( x_n, \Delta x, \Delta y, x_p \)

1. No loop calculation in terms of PLSs.
2. The calculation time is unrelated to the number of PLSs.
3. It is only depend on the number of patches.

\[ O(N_p N_h) \quad N_p: \text{The number of patches} \quad N_h: \text{The number of hologram pixels} \]

Very fast calculation!
Experimental results

Does the equation work well?
Experimental results 1

- Depth representation
- 25 points / patch
  Pitch 0.25[mm]
  Depth 500[mm], 700[mm]

Forces at left patch

Forces at right patch
Experimental results 2

Parallax representation

100 points / patch
Pitch 0.25[mm]
Depth 500[mm], 600[mm], 500[mm]

View from the left  View from the center  View from the right
Experimental results 3

Multi-patch object

100 points / patch
Depth 700[mm]
Pitch 0.25[mm]

A cube (3 patches)

Three cubes (9 patches)
Calculation time

256 points / patch
1M hologram pixels

Calculation time [ns]

Number of points
(Number of patches)

0.5ms / patch

Real time calculation > 60-patch scene
Calculation time

Calculation-time trend of PLS methods
Conclusions

- We proposed a fast calculation method for rectangular patch model.
- It is about 100 times faster than the ordinal PLS method.
- It is a step closer to the realization of real time calculation for holographic video.
Thank you for your kind attention.

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