COMPUTER-GENERATED FOURIER HOLOGRAM IN OPTICAL DEVICES OF VISUAL OBSERVATION

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Motivation

Target pointing application in augmented reality aiming systems

aircraft displays  “smart glasses”  optical sights

Google search on “target sign” request:

Specific problem — target sign MUST pass the parallax test
CGFH: Advances

- Realization of holograms for digitally synthesized objects, non-existent in real nature
- Does not require high precision optical set-up to record the CGH structure onto the holographic carrier
- Zero diffraction order, observed as the central point of the image, can perform the aiming point function for sighting and targeting system.
- The position of target sight central point independent on wavelength fluctuation.
- Information about every element of object is spread along the surface of Fourier hologram providing the defence of recorded information to local damages and scratches
- The possibility to handle the holograms properties: suppression of DC order, phase coding of data object, dynamical range limitation of holograms transparency, correction of dynamical characteristic of holographic media etc.
CGFH recorder optical system

1 - laser; 2 - micro-objective; 3 - objective; 4 - SLM; 5 - PC; 6 - Fourier-objective;
7 - analyser; 8 - diaphragm; 9 - objective; 10 - micro-objective; 11 - holographic carrier

SLM: HOLOEYE_HED-017
Model: Sony LCX017DLT
Modulation: Amp + Ph(?)
Resolution: XGA (1024 × 768)
Pixel pitch: 36μm
Size: 1,8"; 4,6 cm
Equivalent record scheme

\[ t(x, y) \] — object beam amplitude,
\[ r(x, y) = \sqrt{2\pi} \cdot C \cdot \delta(x, y) \] — reference beam source amplitude,
\[ C = \text{const} \]

\[ H(x_f, y_f) \sim I(x_f, y_f) = | T(x_f, y_f) + R(x_f, y_f) |^2 \]

\[ H(x_f, y_f) = | \tilde{F} [t(x, y - \Delta)] + \tilde{F} [r(x, y)] |^2 = \]

\[ \tilde{F} [t(x, y - \Delta)] \tilde{F} [t^*(x, y - \Delta)] + \]

\[ + C \left( \tilde{F} [t(x, y - \Delta)] + \tilde{F} [t^*(x, y - \Delta)] \right) + C^2 = \]

\[ X(x_f, y_f) + C \cdot \text{Real} \{ \tilde{T}(x_f, y_f) e^{-i\Delta y_f} \} + C^2 \]
Equivalent reconstruction scheme

\[ H(x_f, y_f) = X(x_f, y_f) + C \cdot \text{Real} \left( \hat{T}(x_f, y_f)e^{-i\Delta y_f} \right) + C^2 \]

Reconstructed light field calculation

\[ U(x_1, y_1) = \mathcal{F}^{-1} [H(x_f, y_f)] = t(x_1, y_1) = t(x_1, y_1) \otimes t^*(x_1, y_1) + Ct(x_1, y_1 - \Delta) + Ct(x_1, y_1 + \Delta) + \sqrt{2\pi} \cdot C^2 \cdot \delta(x_1, y_1) \]

\[ t(x_f, y_f) = C_0 + \text{Real} \left( \mathcal{F} \left[ t(x, y - \Delta) \right] \right) \]
Random binary phase mask

No phase mask

With phase mask

Threshold = 0.4%

Threshold = 1%
Principal scheme

Holographic target sign indicator:

- Semi-transparent mirror
- Operator eye optical scheme
- Collimating optical system
- Laser or small aperture LED
- CGFH

Simulation

Experiment
CGFH application in optical display devices

Miniature display systems — a combination of CGFH and light guide substrate with DOE:

DG1 injects light into the plate at TIR angle
DG2 is used to emerge light toward to operator's eye

Experimental setup photo
Conclusions

- CGFH showed promising results of application for targeting in augmented reality display systems
- Human eye pupil can be used as backward Fourier transform objective in target sign visualization system
- Application of random phase masks allows to visualize the target with intensity ratio between central point and sign non central elements to be about 100:1
- When CGFH reading beam is properly collimated, the target sight central point being focused on infinity stays on its position on a display independently from operator head movements
- The variation of wavelength does not affect the position of a target sign however it affect the scale of a sign
- Target sign visualization system can be compactly realized using light guiding substrates combined with DOE
Thanks for attention!

Questions?