Review of real-time reconstruction techniques for aerial-projection holographic displays

Kakue et al.

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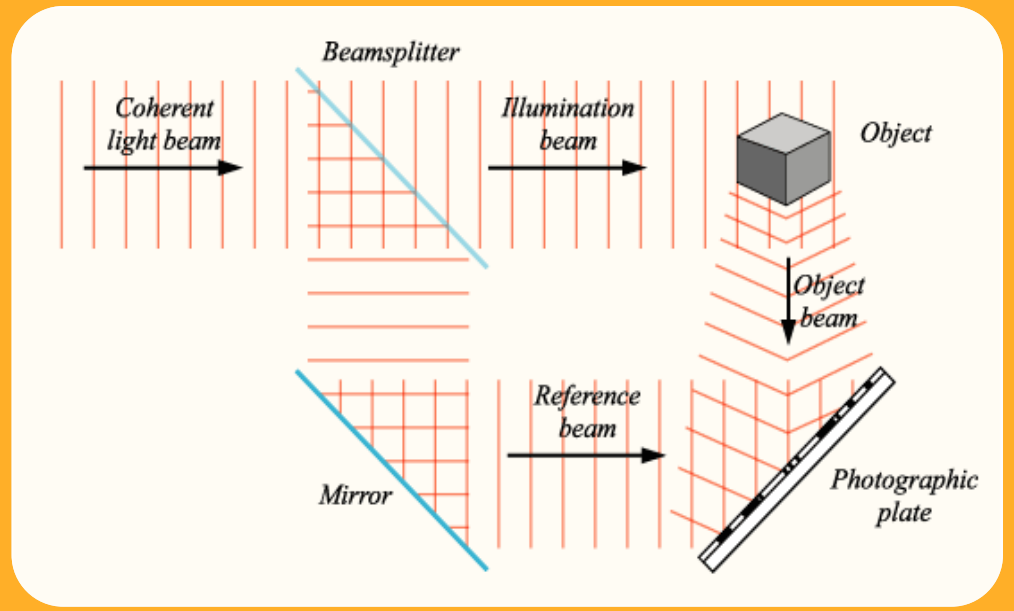
Holography

> Display a 3D image of the object
> without the aid of intermediate optics

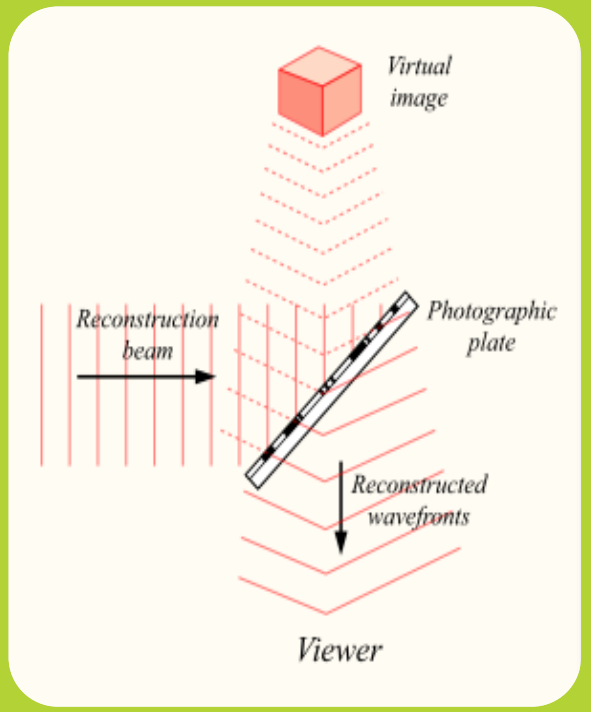


Hologram
Recording

- Record and light fields via light interference and diffraction
- Encode light field as an interference pattern of object opacity, density, or surface profile

Holography

> Display a 3D image of the object
> without the aid of intermediate optics



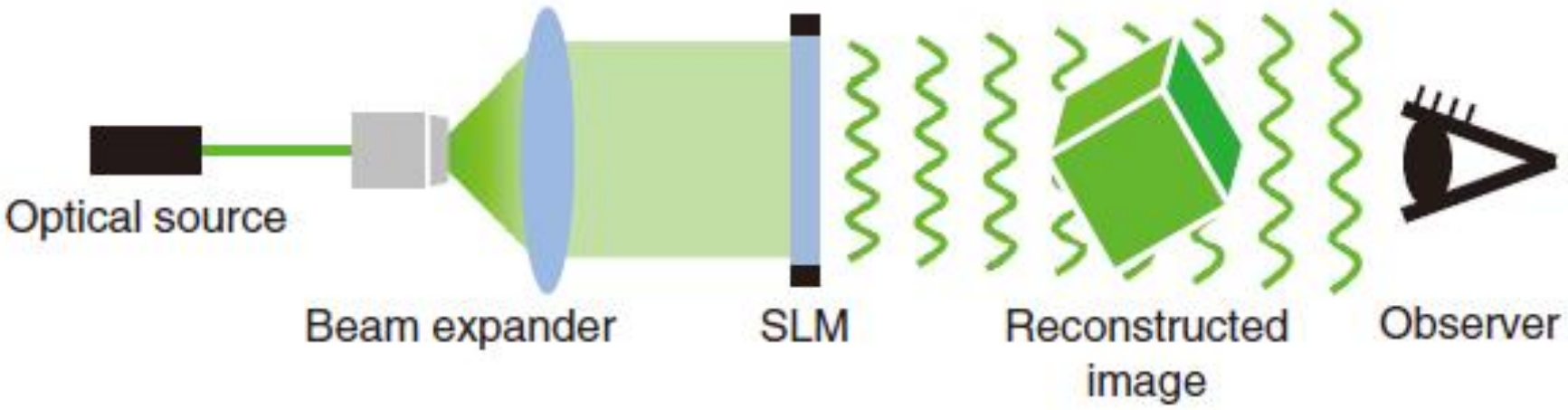
- Reconstruction light is equivalent to the reference light
- The pattern recoded on the photo will be reconstructed and show the object light

Hologram
Reconstruction

Computer-Generated Hologram (CGH)

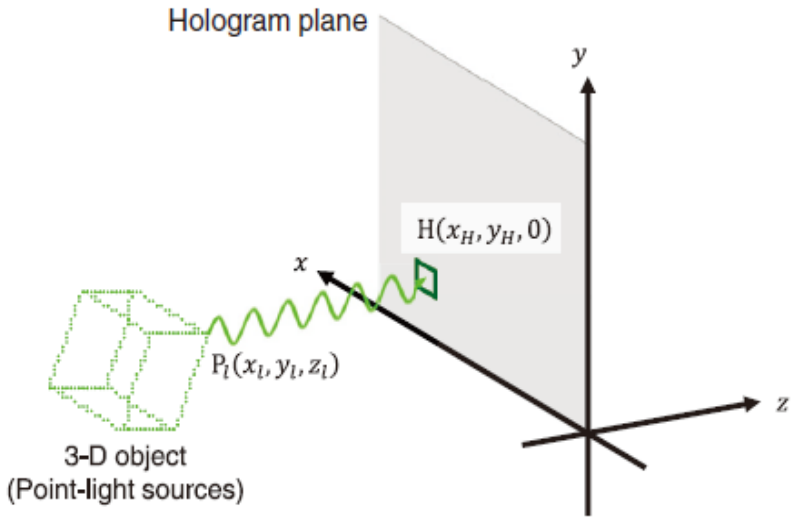
> The method of digitally generating holographic interference patterns

Point-cloud • Polygon • Multiview-image • Others

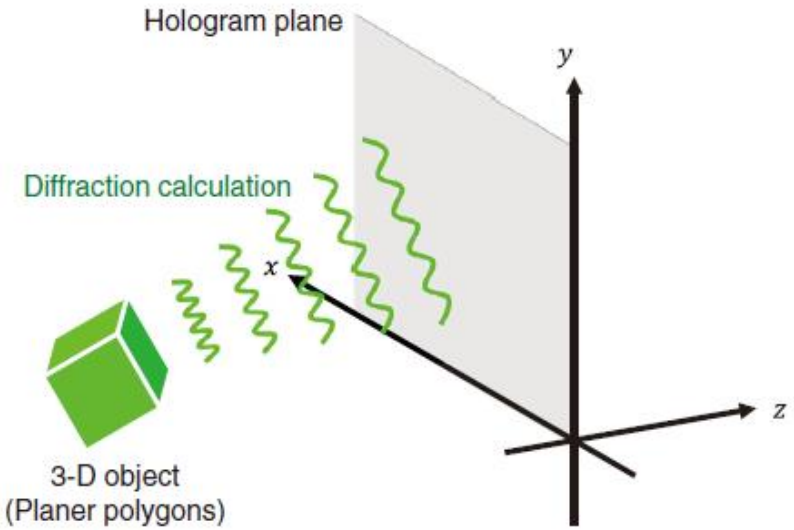


Computer-Generated Hologram (CGH)

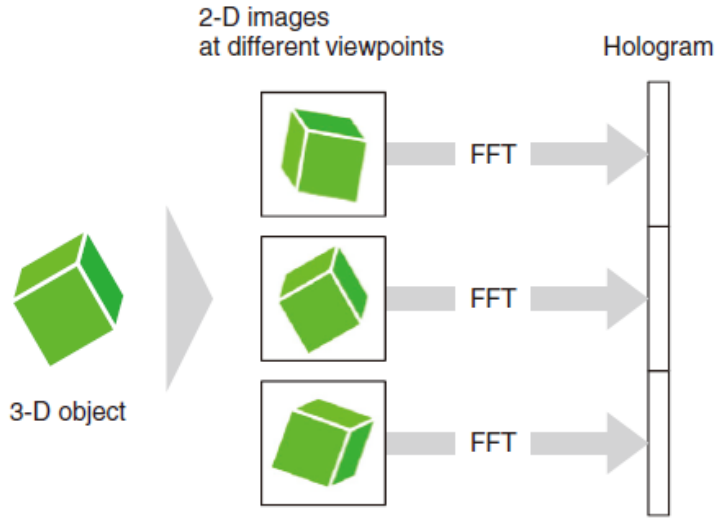
Point-cloud
method



Polygon
method



Multiview-image
method



Computer-Generated Hologram (CGH)

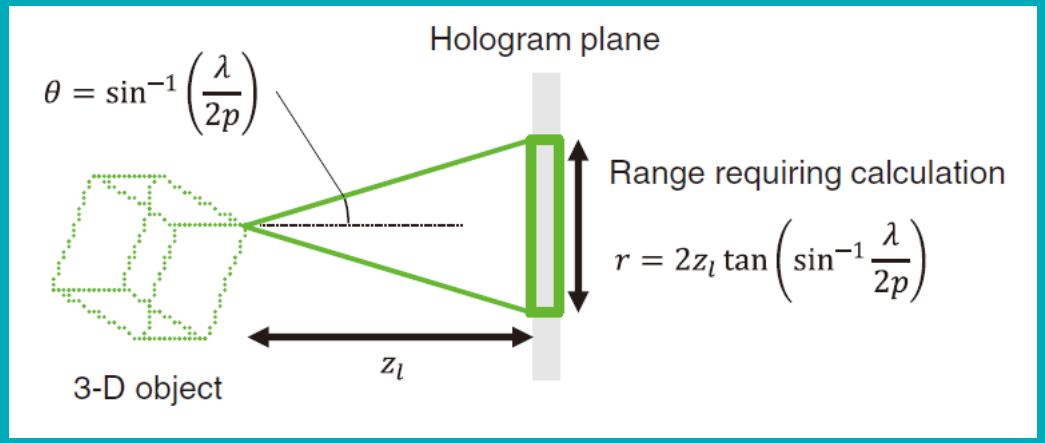
Method	Image Quality	Computational Cost	Ease of Post-processing
Point-cloud	Very high	Very High	Very complicated
Polygon	High	High	Complicated
Multiview-image	Low	Low	Easy

Post-processing: occlusion culling, shading, texture expression

Contributions

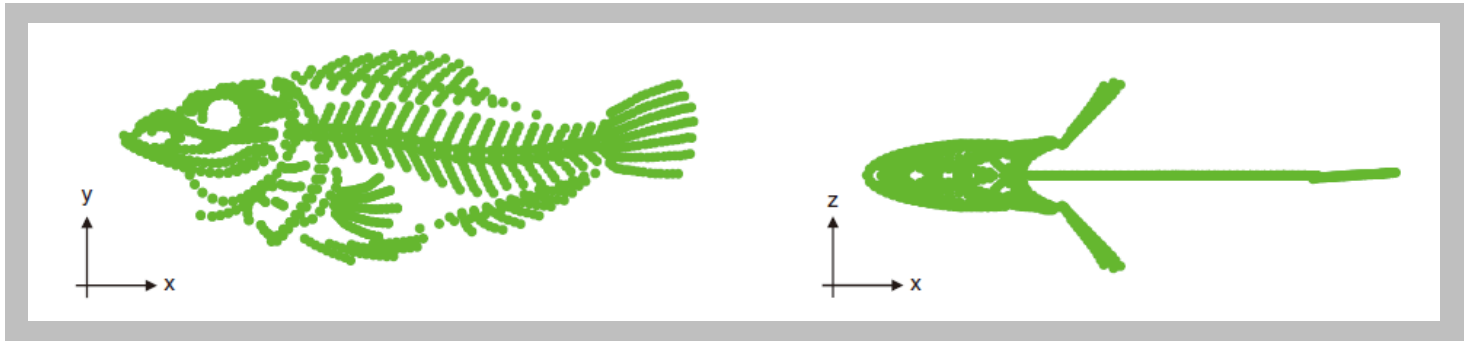
1. Propose and implement a holographic aerial-projection system
2. Propose and implement a holographic AR display
3. Hold evaluations to prove the CGH calculation can be done in real-time

Aerial-Projection System

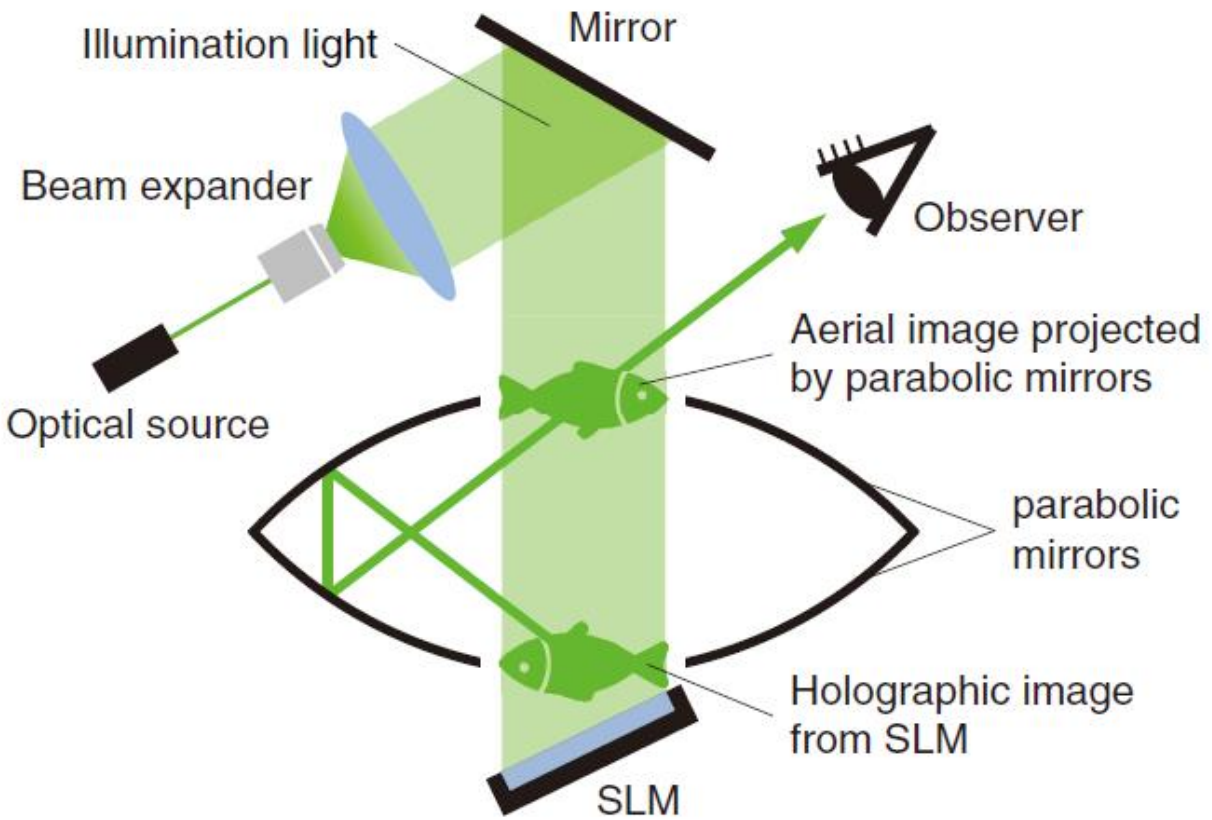


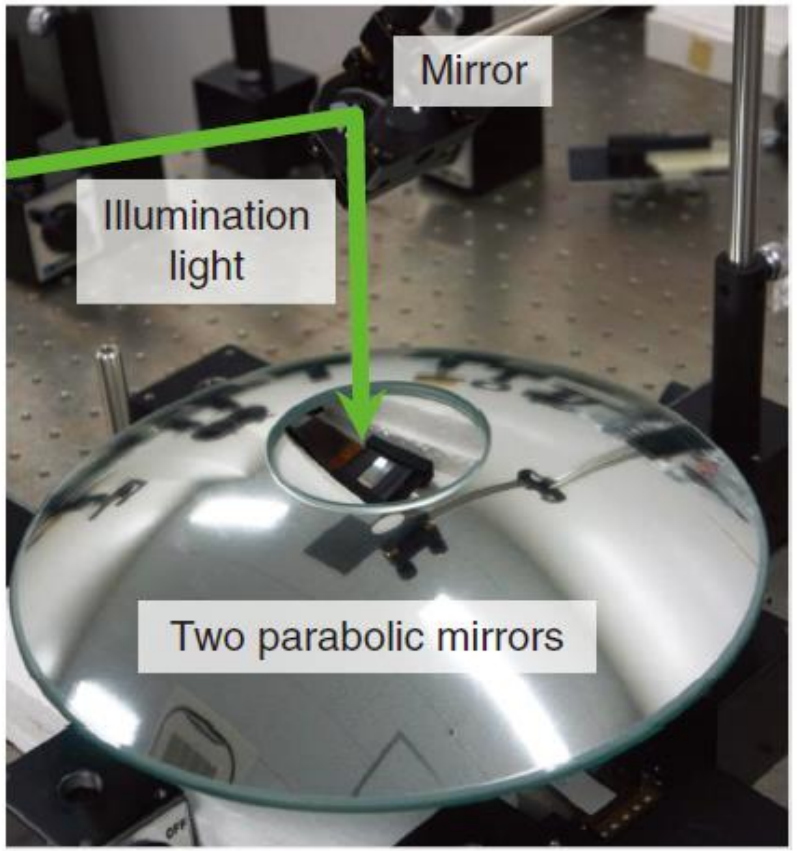
Range-dependent calculation:
Limited by the pixel pitch of p the SLM

- Real-time holographic system that yields short CGH computation time
- Image-type hologram can only reconstruct images close to the hologram plane
- Include 2 parabolic mirrors to achieve aerial projection



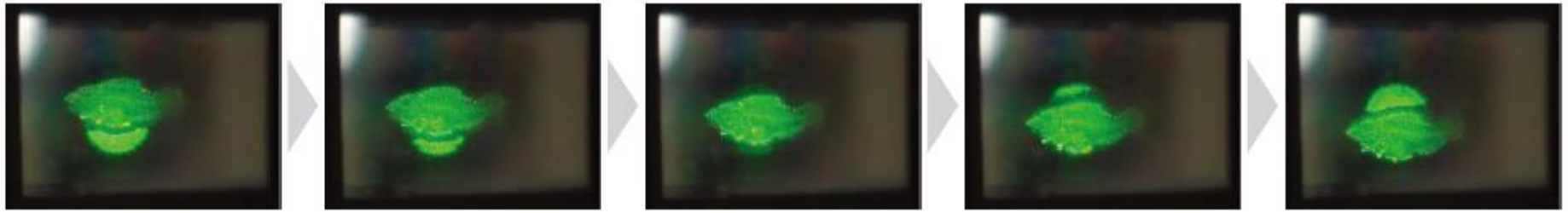
Setup


Illumination light
Mirror
Beam expander
Observer
Aerial image projected by parabolic mirrors
Optical source
parabolic mirrors
Holographic image from SLM
SLM

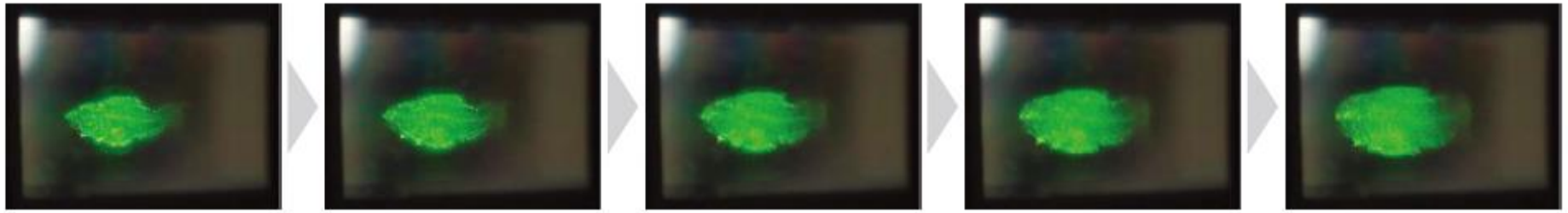

Mirror
Illumination light
Two parabolic mirrors

Experimental Results

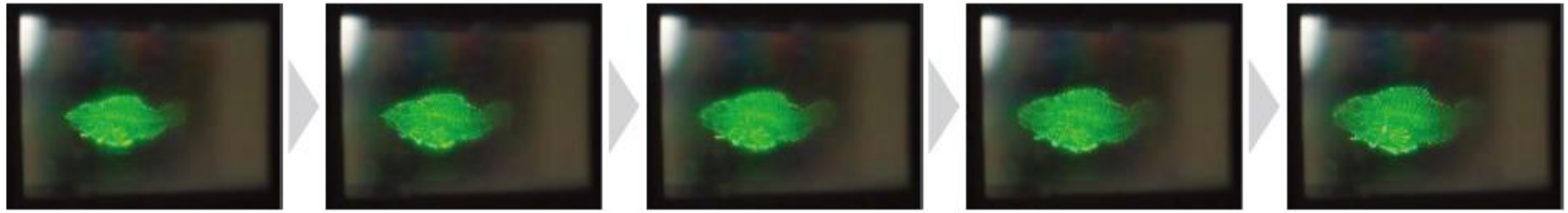
Y-axis transition



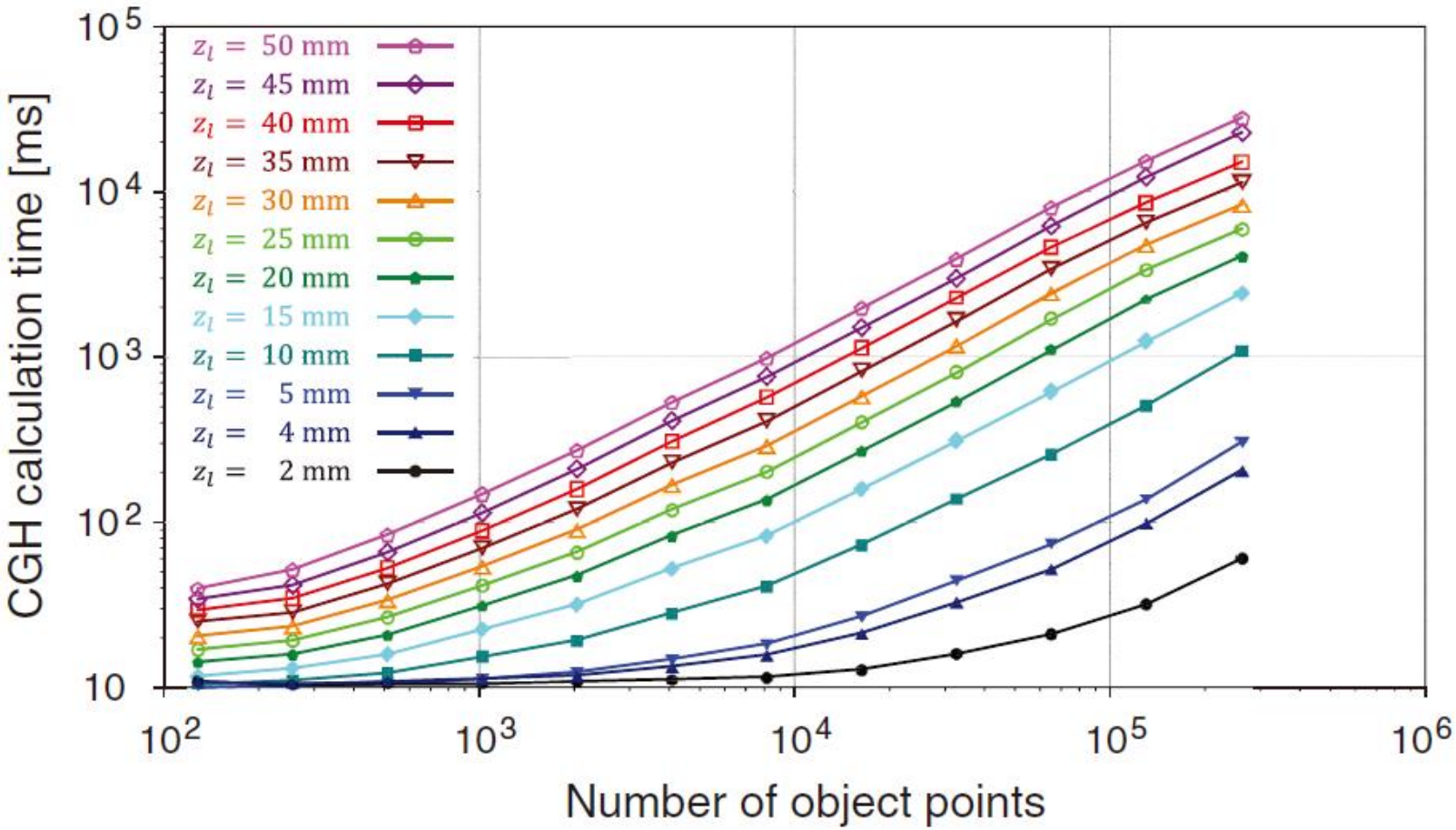
Z-axis transition



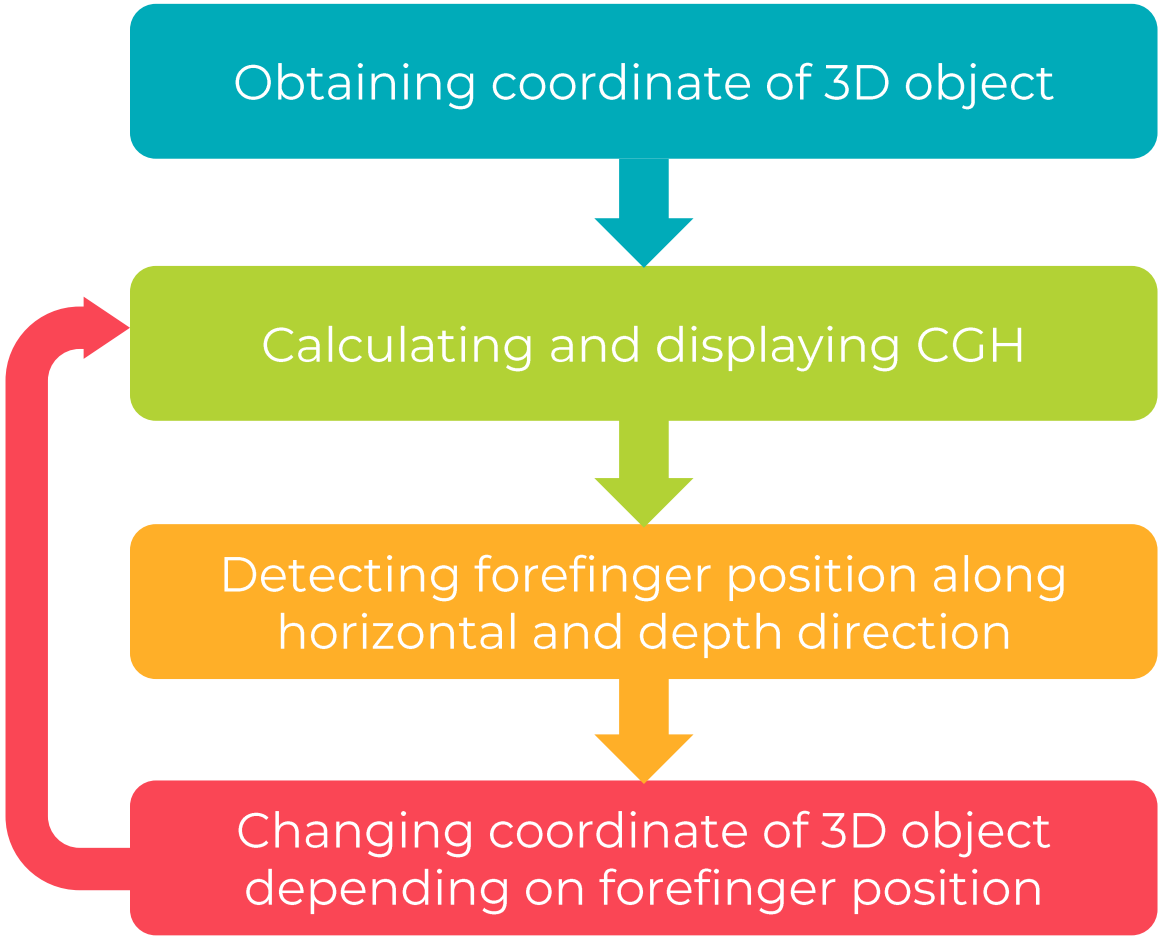
Scaling



Evaluation


z_l = 50 mm
z_l = 45 mm
z_l = 40 mm
z_l = 35 mm
z_l = 30 mm
z_l = 25 mm
z_l = 20 mm
z_l = 15 mm
z_l = 10 mm
z_l = 5 mm
z_l = 4 mm
z_l = 2 mm
CGH calculation time [ms]
10^5
10^4
10^3
10^2
10
10^2
10^3
10^4
10^5
10^6
Number of object points

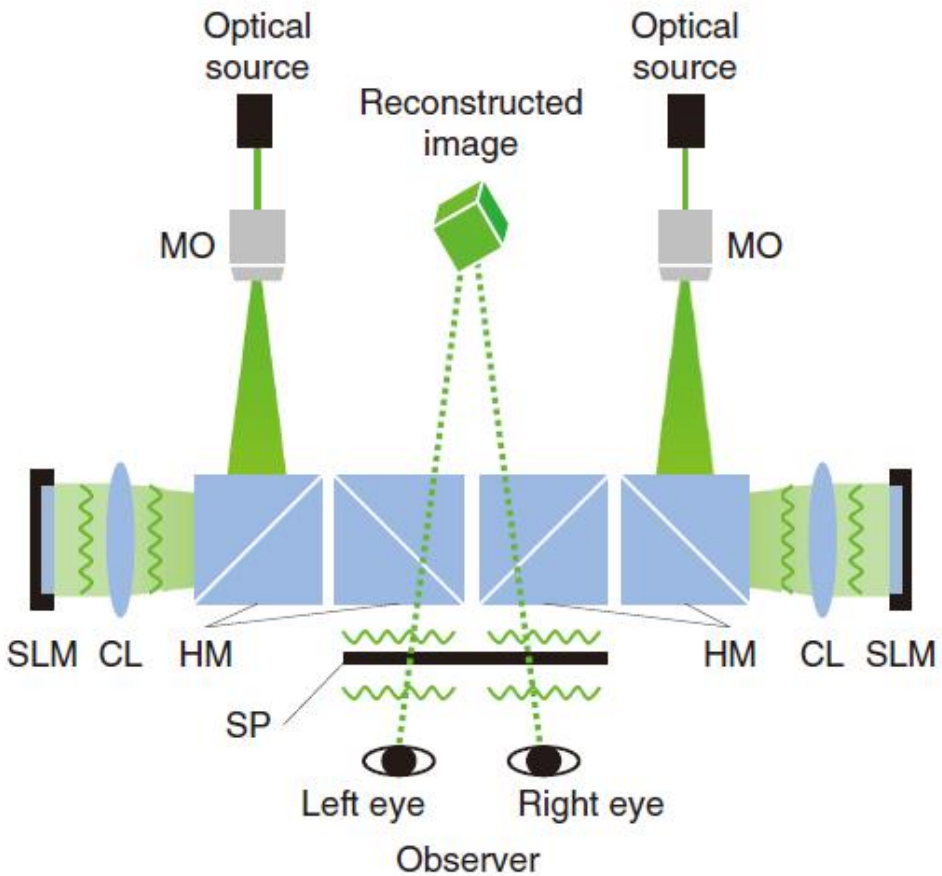
Holographic AR Display

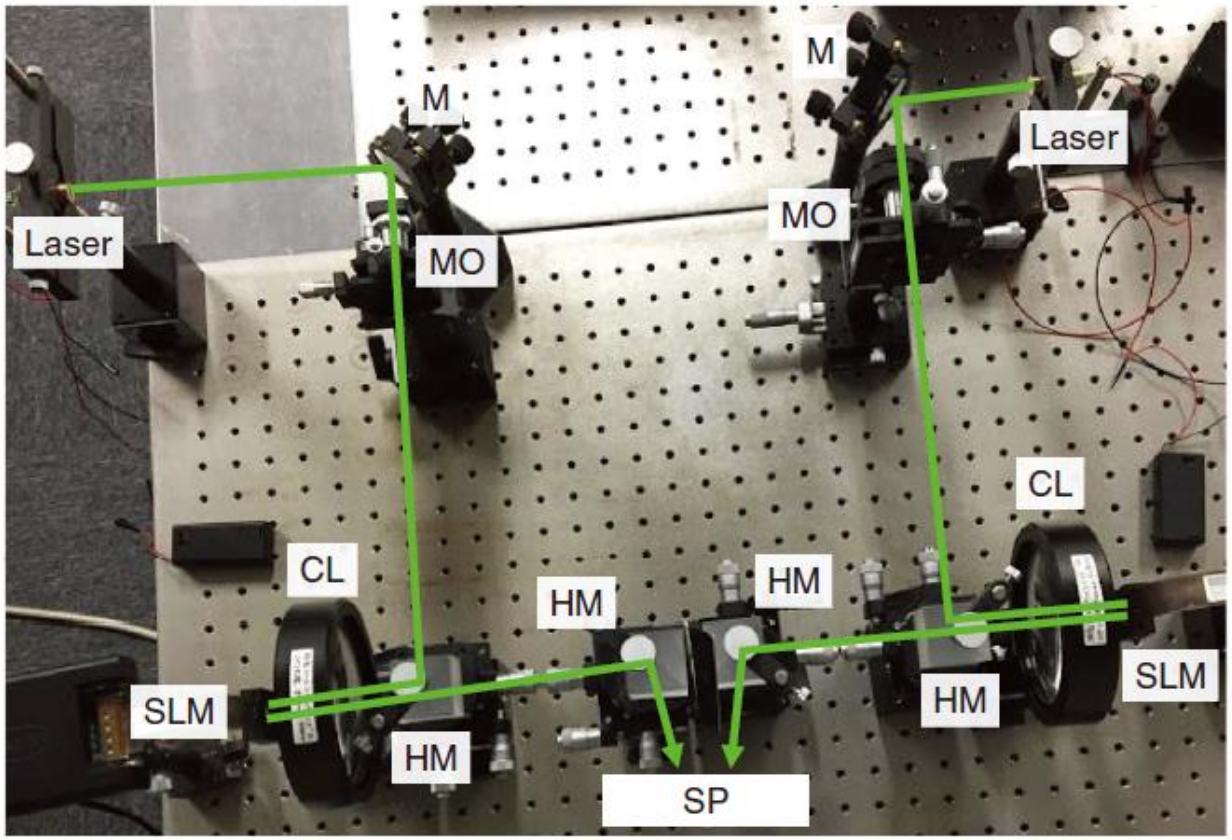


- Compute CGH with a GPU performing in parallel
- Based on Ichiwaka's Fourier-based optical setup
- Use Leap Motion sensor to allow interactive hologram manipulation

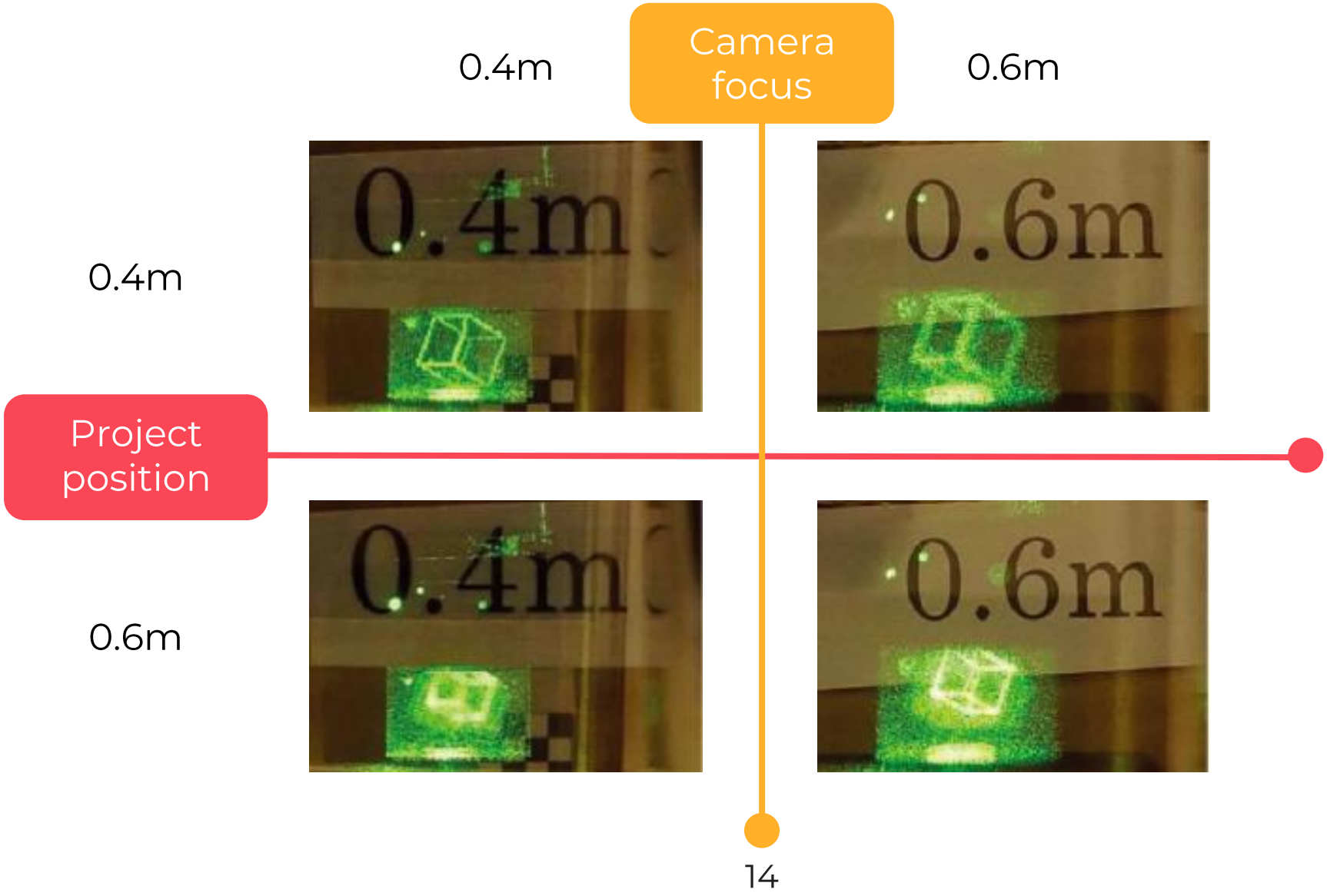
System Design

Setup


Optical source
Reconstructed image
Optical source
MO
MO
SLM
CL
HM
HM
CL
SLM
SP
Left eye
Right eye
Observer

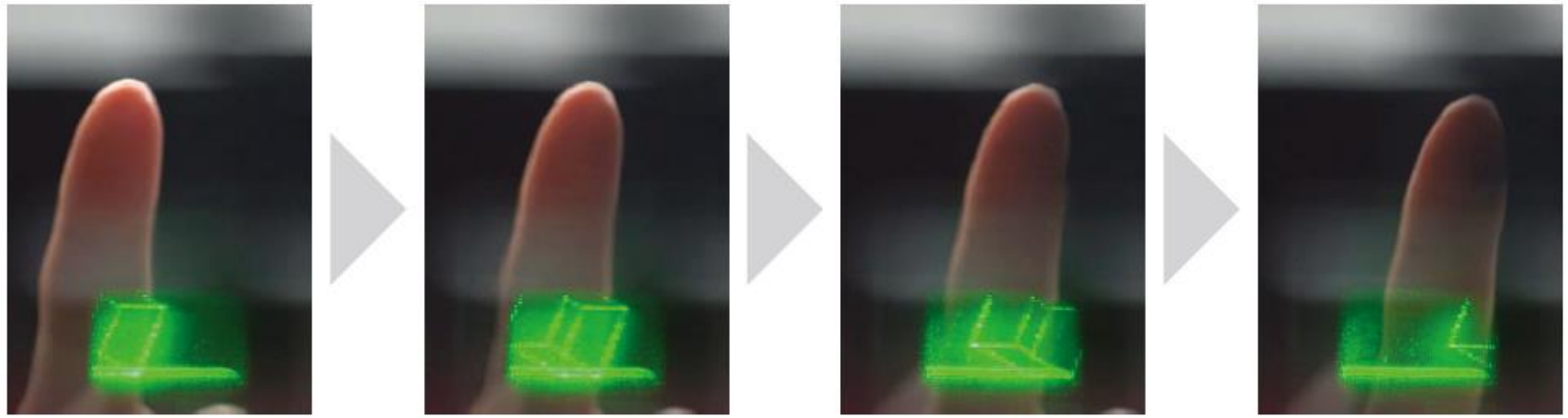

M
M
Laser
MO
MO
Laser
CL
CL
HM
HM
HM
SLM
SLM
HM
SP

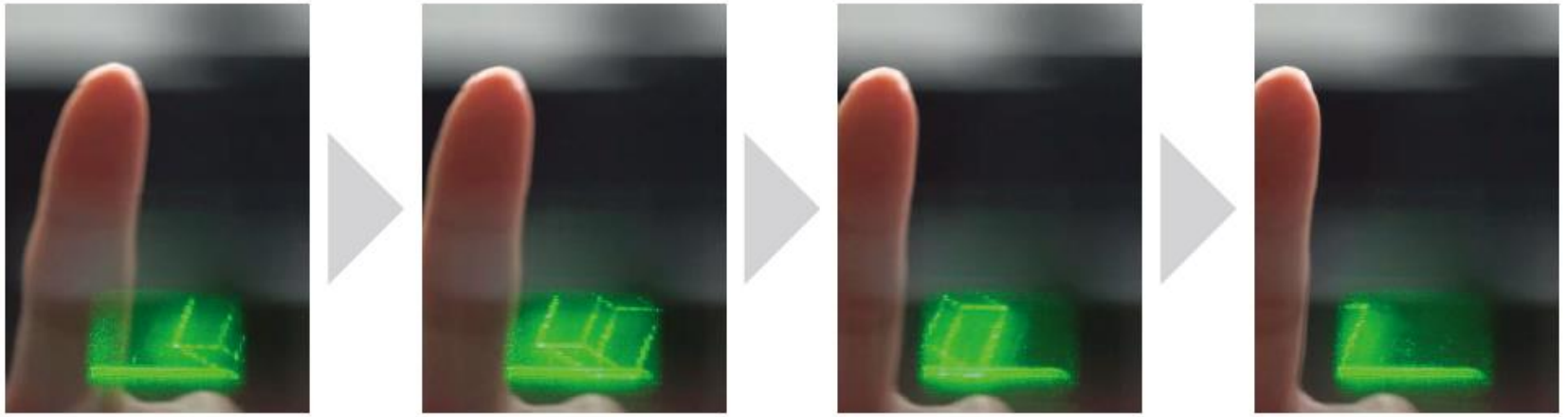
Experimental Results



Experimental Results

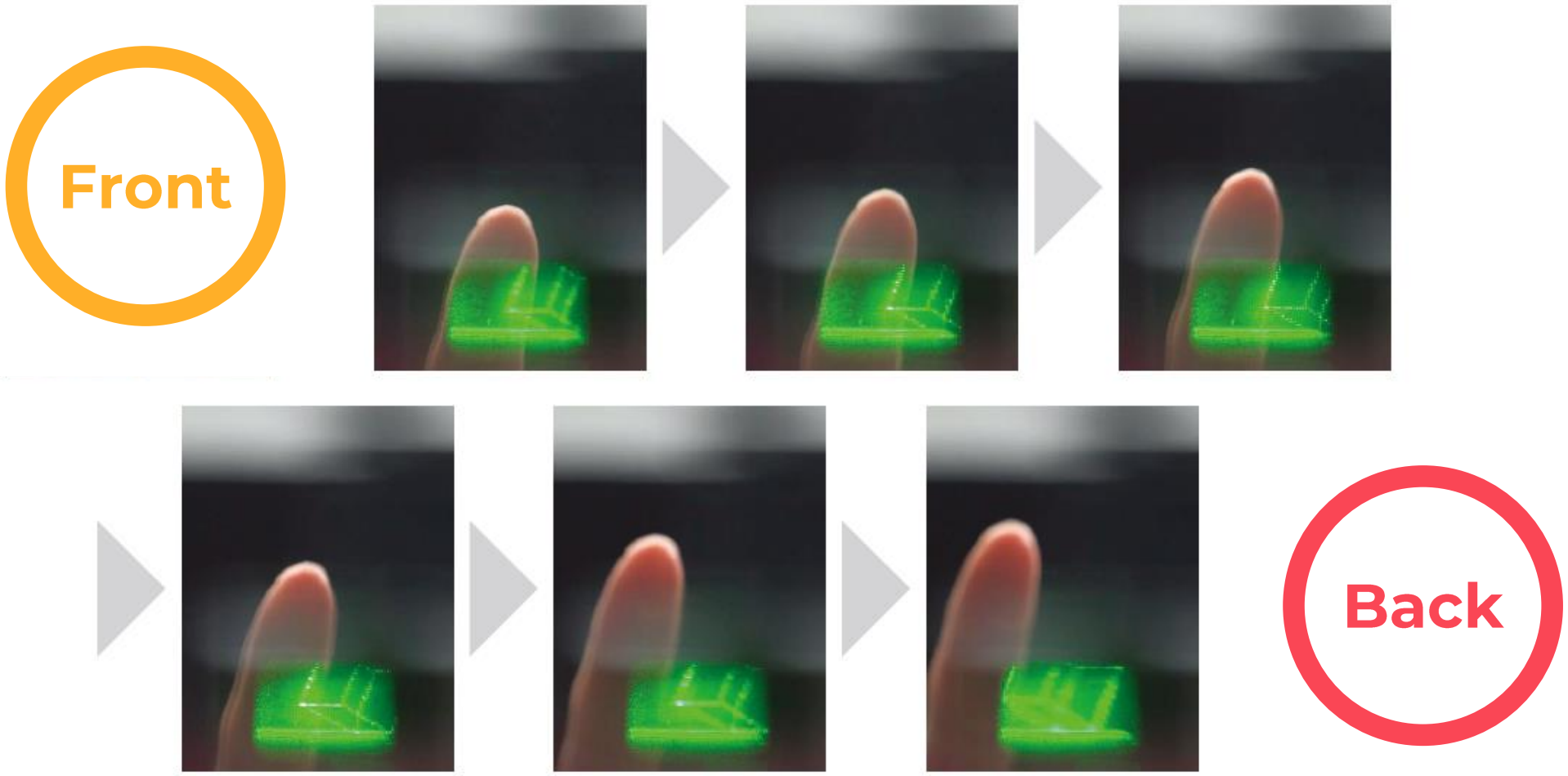
Swipe right



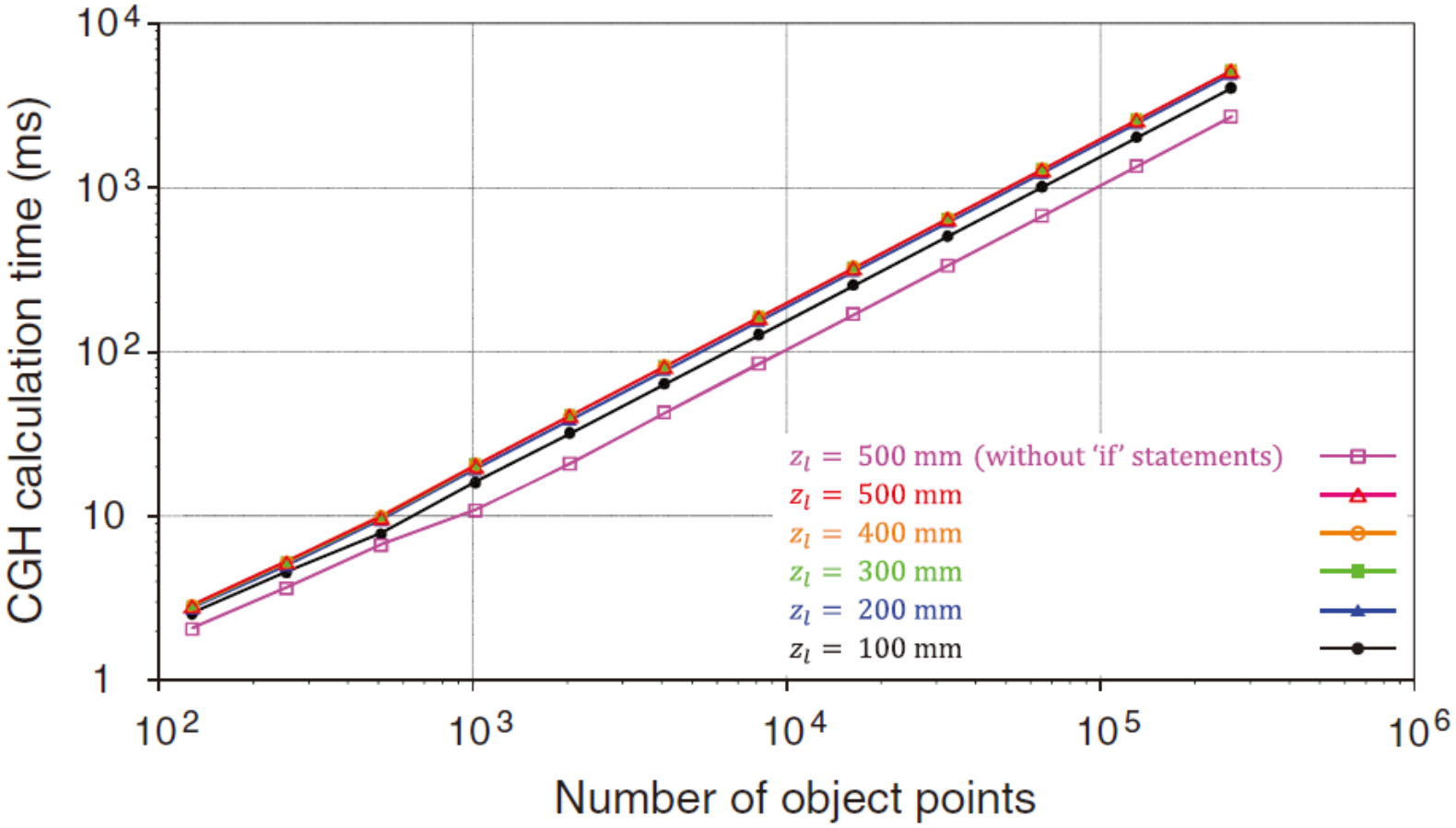


Swipe left

Experimental Results



Evaluation



"if": whether to do the range-dependent calculation

Conclusions

1. Two strategies are proposed to improve the performance of holographic system
2. Aerial hologram with ~100000 point light can be done at 30 fps
3. Use Leap Motion sensor to provide interactivity in AR system
4. AR device can run ~2000-point-light-sources object with 30 fps

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Any questions?

Thanks for Listening