Taking advantage of virtual optics in computer holography

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Introduction

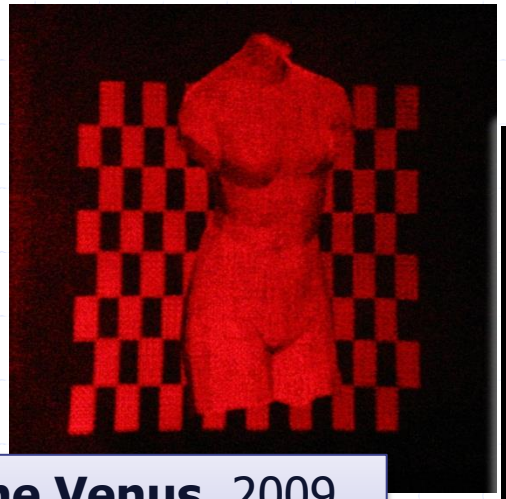
Background

- Resolution of high-definition CGH are being comparable with that in classical holography.
- *Computer holography* is the technique for creating CGHs.
- *Digitized holography* is the technique to digitize the whole process of holography; real-existing object waves are recorded by an image sensor and the object waves are reconstructed by CGHs.
- In computer holography and digitized holography, object waves are handled as digital wave-fields, and thus both can take advantage of virtual optics.

Outline

- Source material of 3D scene in computer holography
- Some techniques used in our computer holography
  - Polygon-based method and Silhouette method
- Creation of holographic stereograms through virtual optics with numerical methods
- Techniques to realize digitized holography
- Digital editing of 3D scene and resizing of 3D object in digitized holography

Some of early works



The Venus, 2009
The first work
4 G Pix (64K × 64K)

Aqua 2, 2009
Hidden-surface removal
8 G Pix (128K × 64K)

The Moon, 2010
Texture-mapping
8 G Pix (128K × 64K)

1K = 1024

Some of early works

The Metal Venus I
2010
Specular flat shading

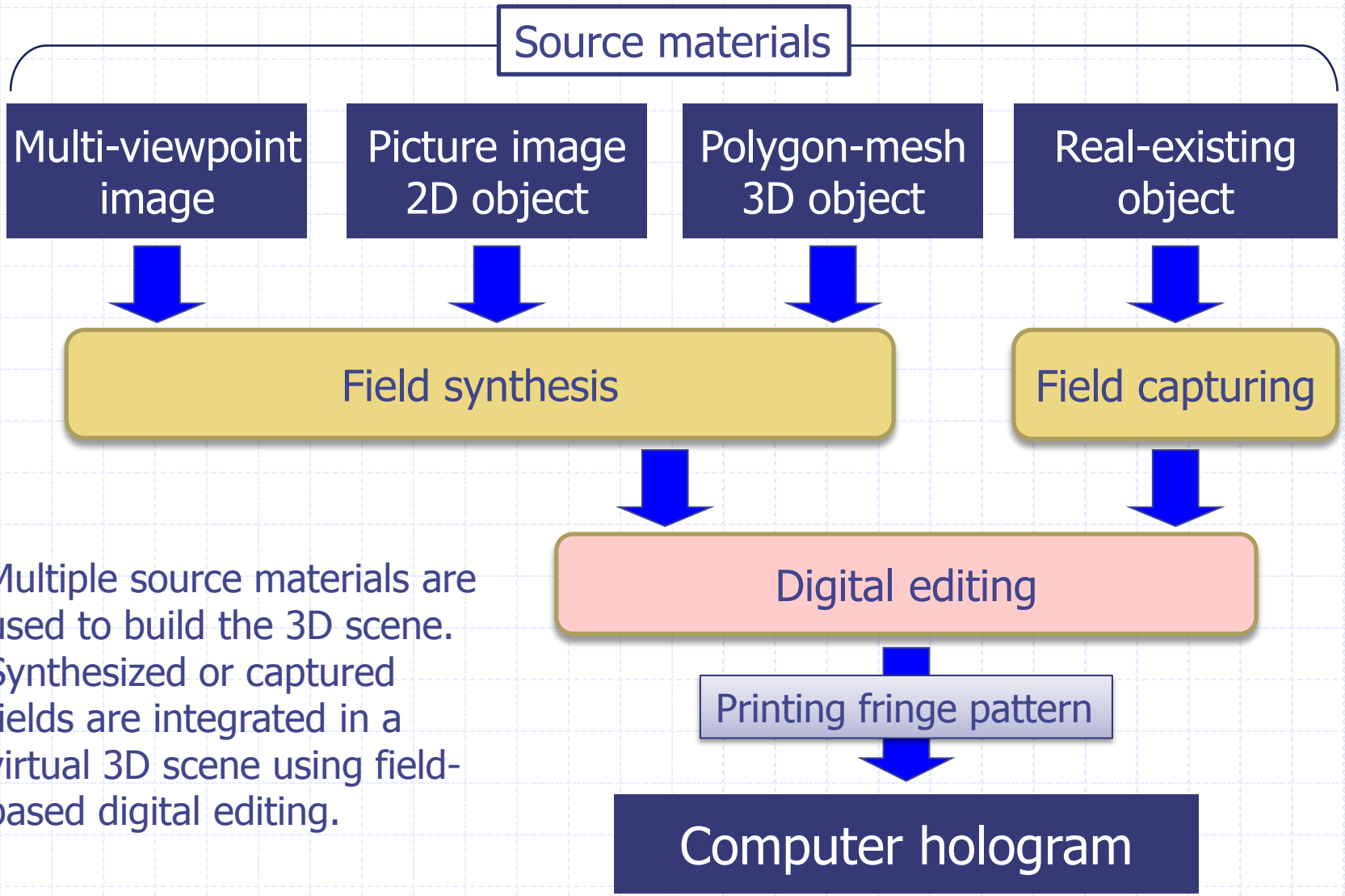
The Metal Venus II
2011
Specular smooth shading

iShion V2, 2011
Image hologram
White light reconst.

Bear II, 2010
Digitized holography

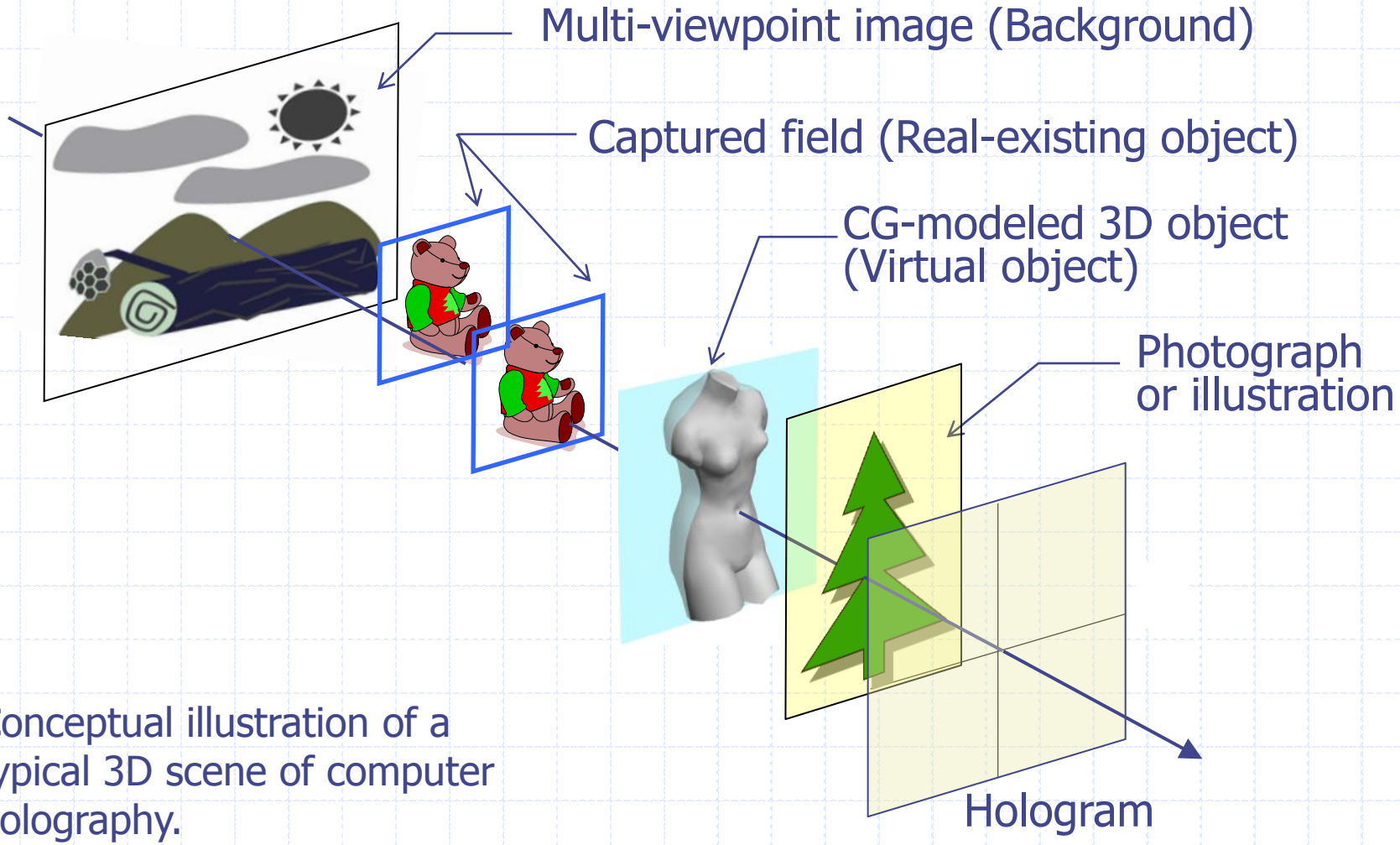
1K = 1024

Computer Holography: A Concept



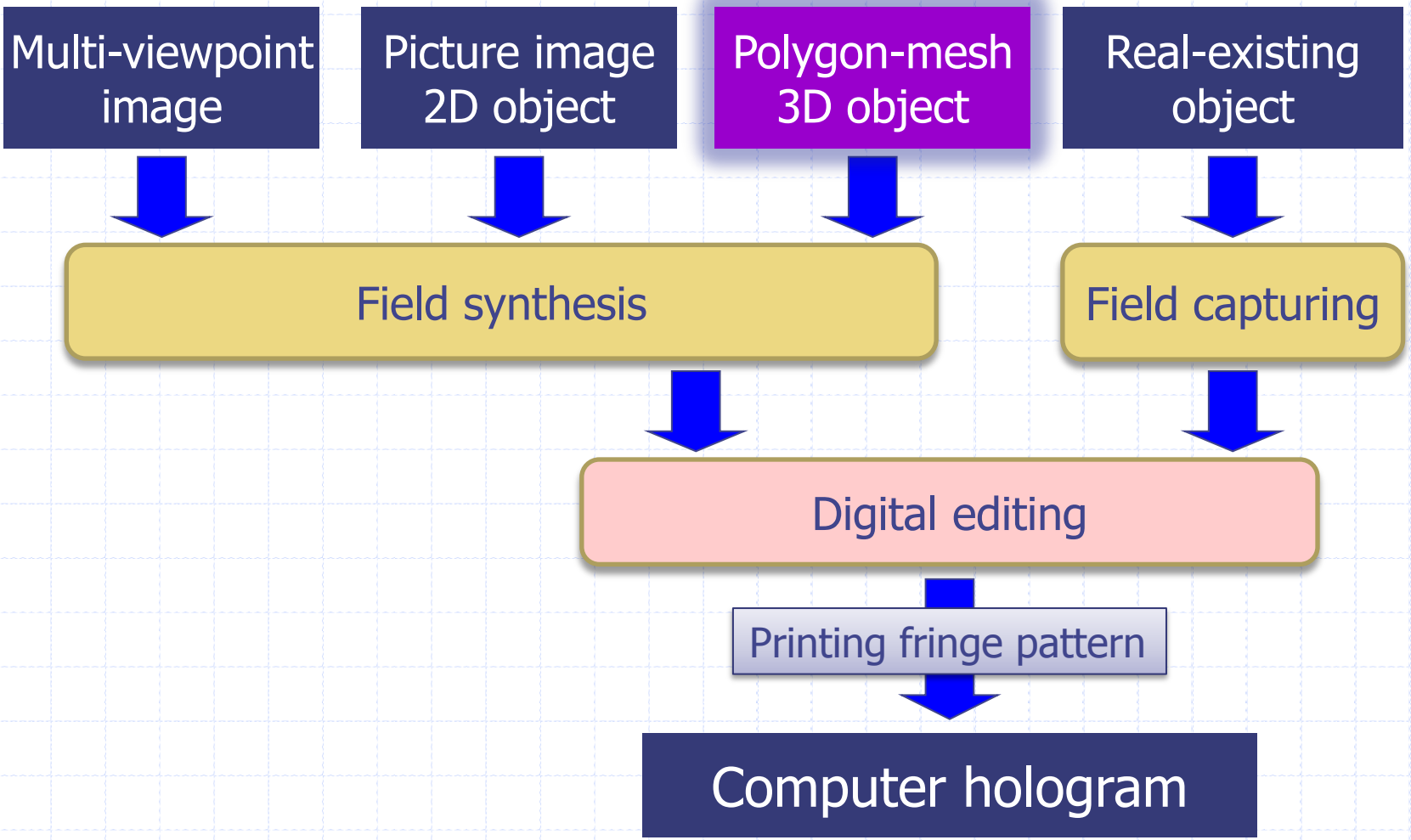
- Multiple source materials are used to build the 3D scene.
- Synthesized or captured fields are integrated in a virtual 3D scene using field-based digital editing.

3D scene in computer holography

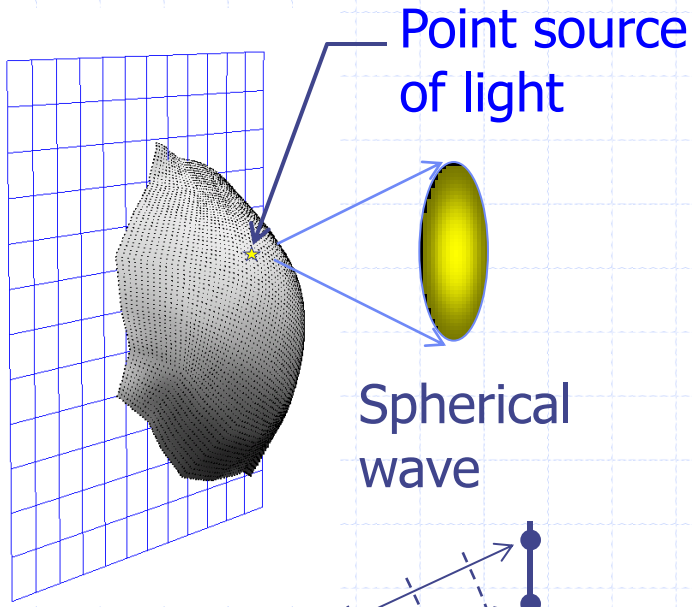


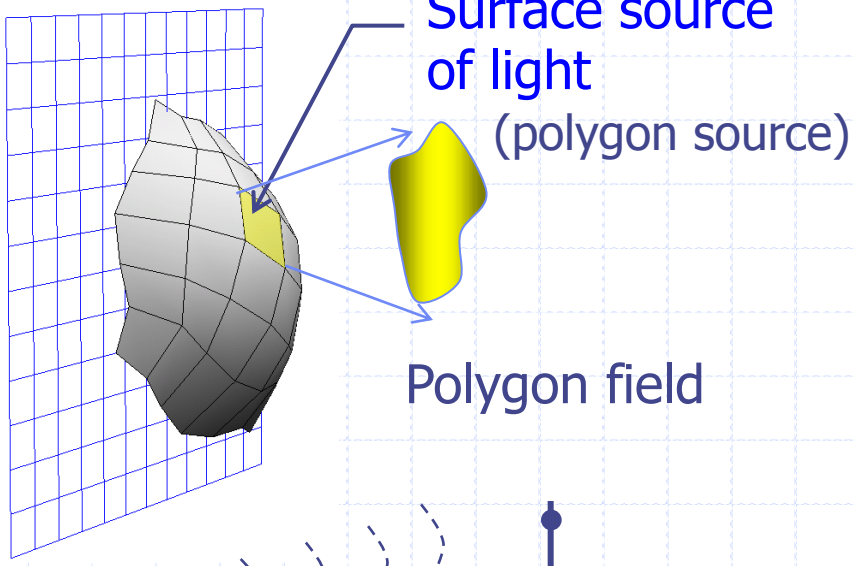
- Conceptual illustration of a typical 3D scene of computer holography.

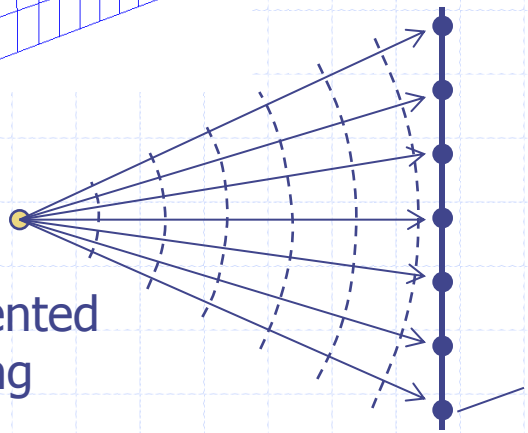
Computer holography for polygon-mesh objects

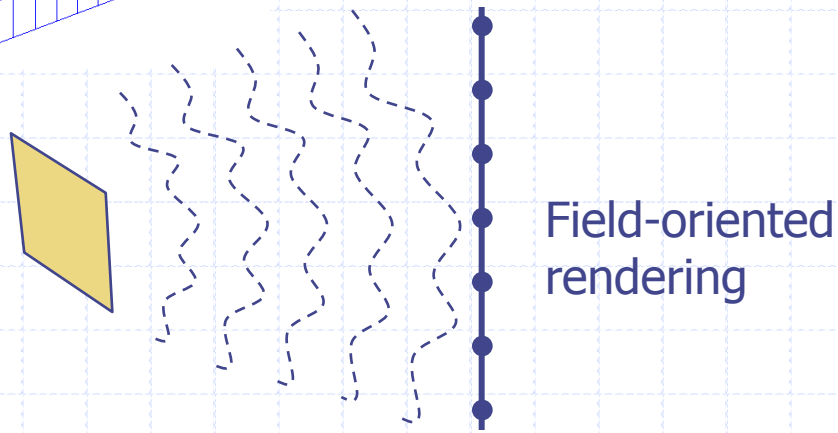


Polygon-based method



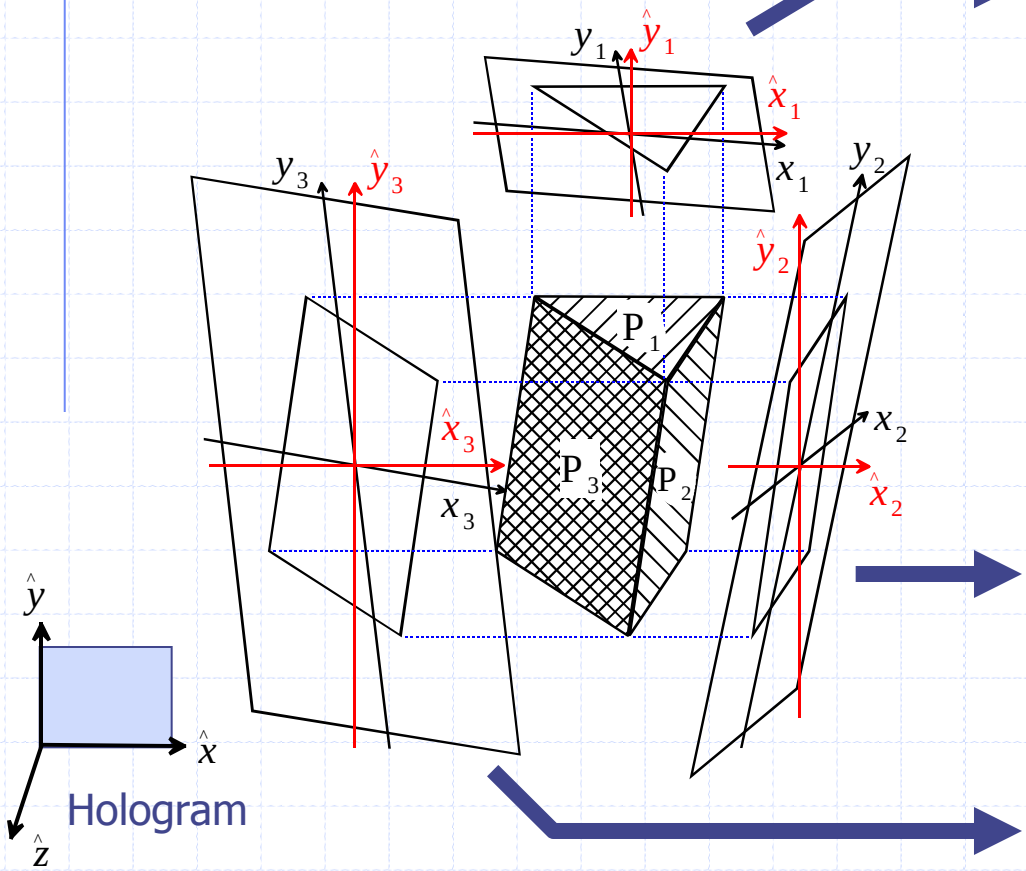


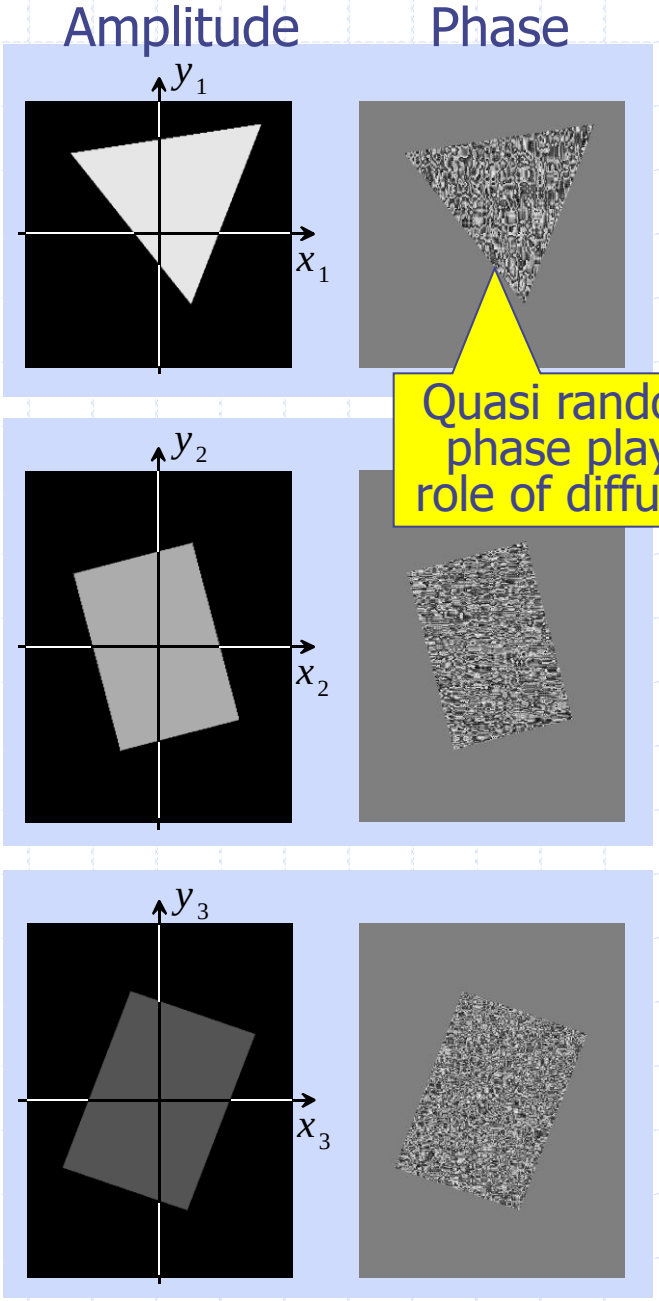




Polygon-based method is usually faster than the point-based method in rendering surface objects, because the number of the polygons composing a surface object is much smaller than that of point sources.

Surface function

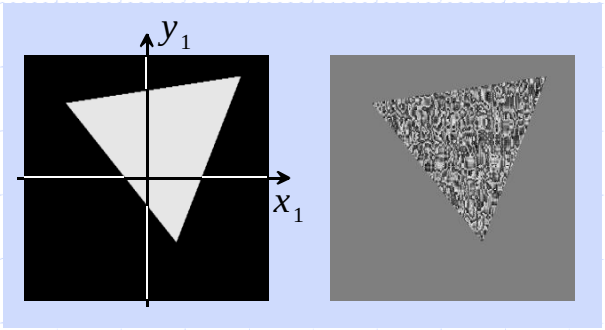


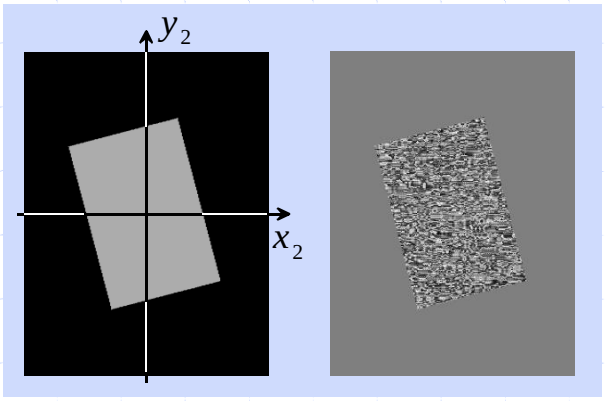


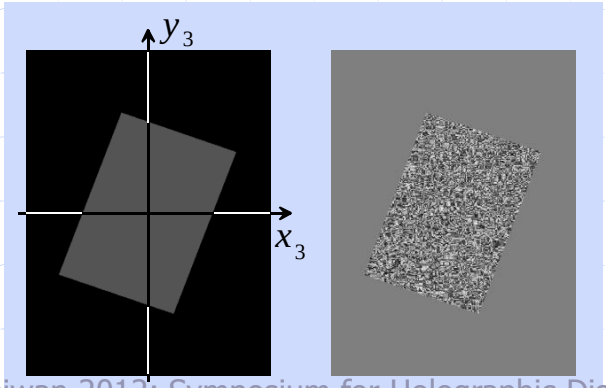
$$h_n(x_n, y_n) = a_n(x_n, y_n)\exp[i\varphi_n(x_n, y_n)]$$

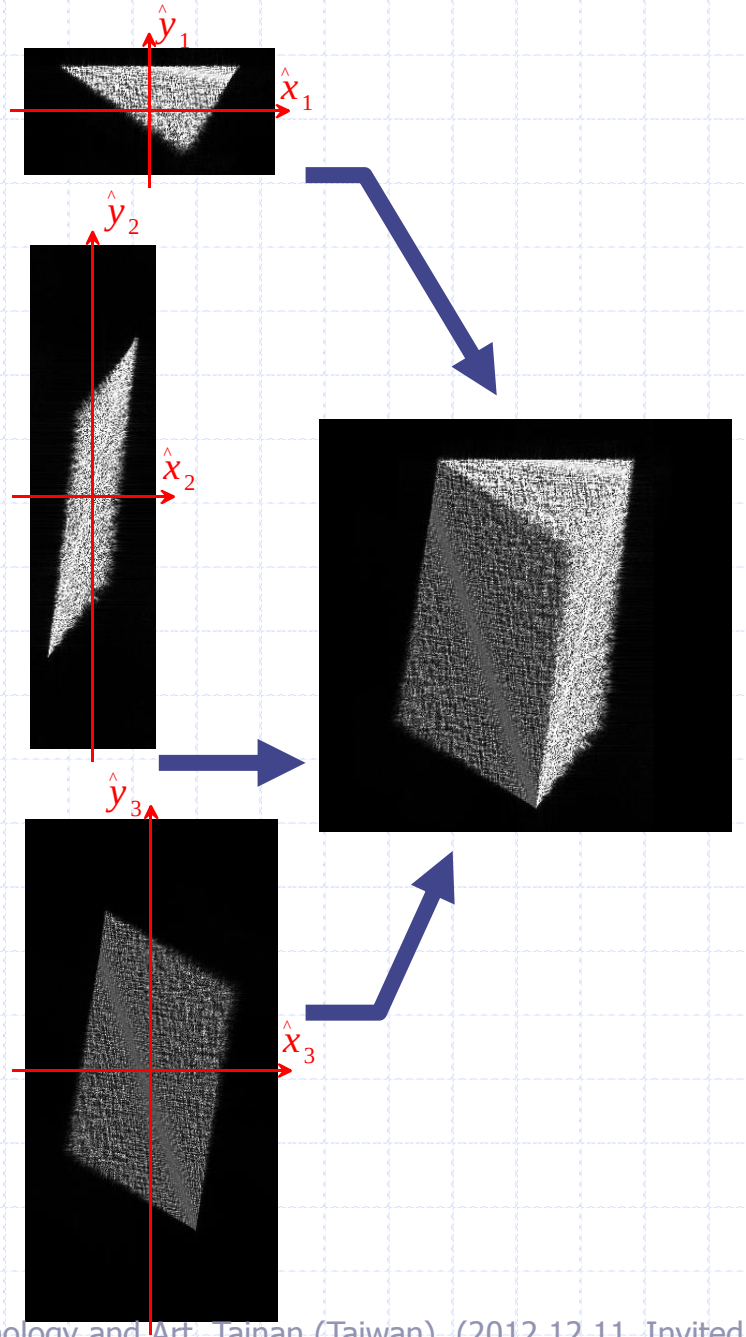
Amplitude Phase

Surface function



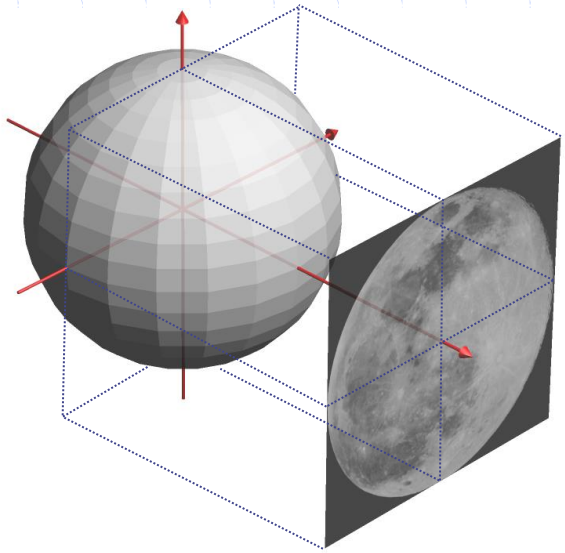




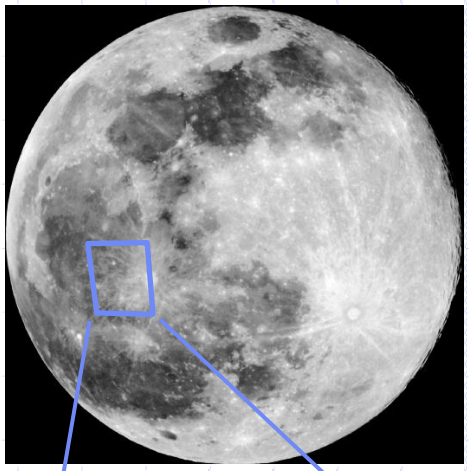


Texture mapping in polygon-based method

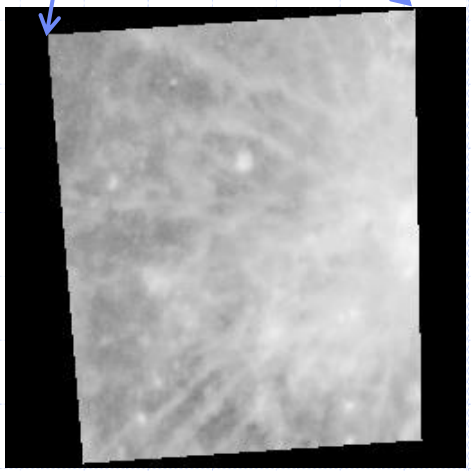
Sphere



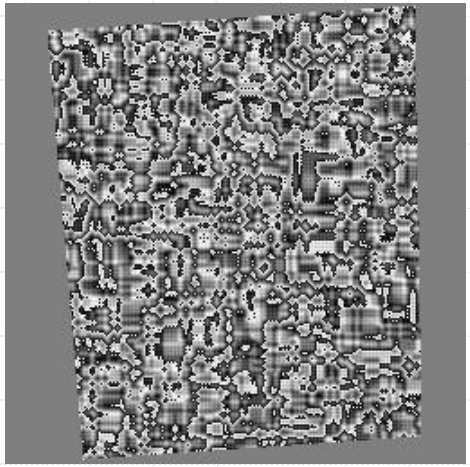
Texture



Surface function



Amplitude

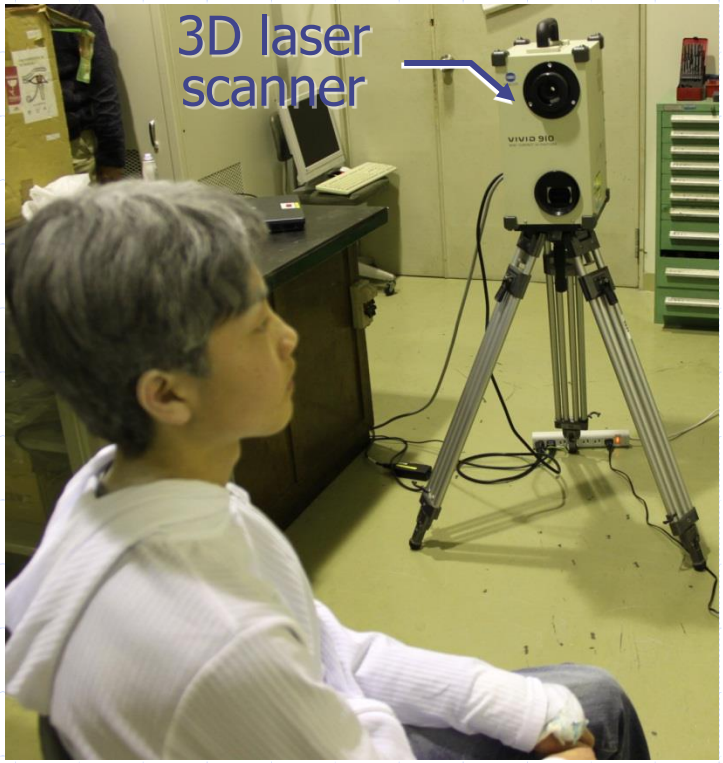


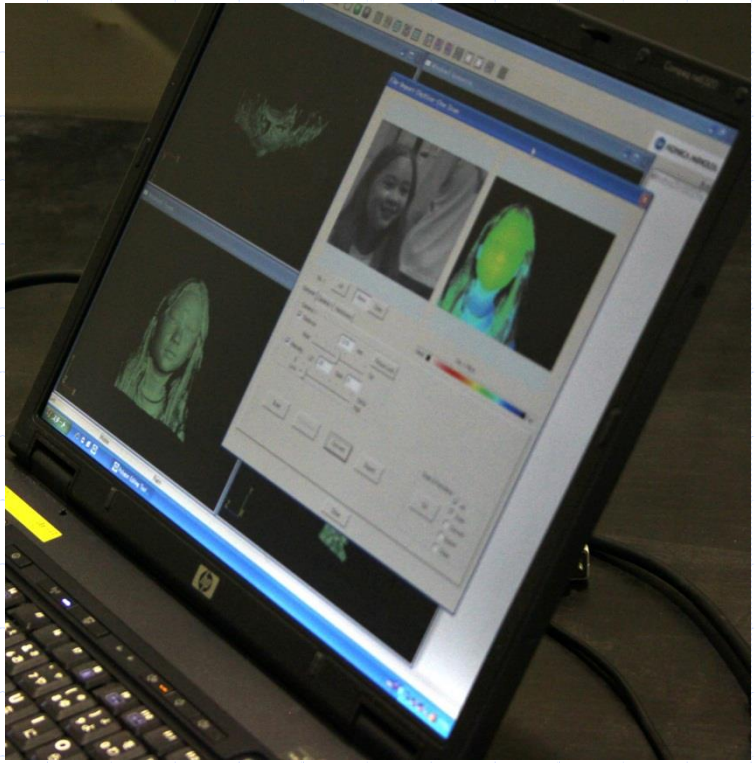
Phase

$$a_n(x_n, y_n) \equiv \sqrt{I_n(x_n, y_n)}$$

$I_n(x_n, y_n)$: Texture image

Brothers exhibited in MIT museum



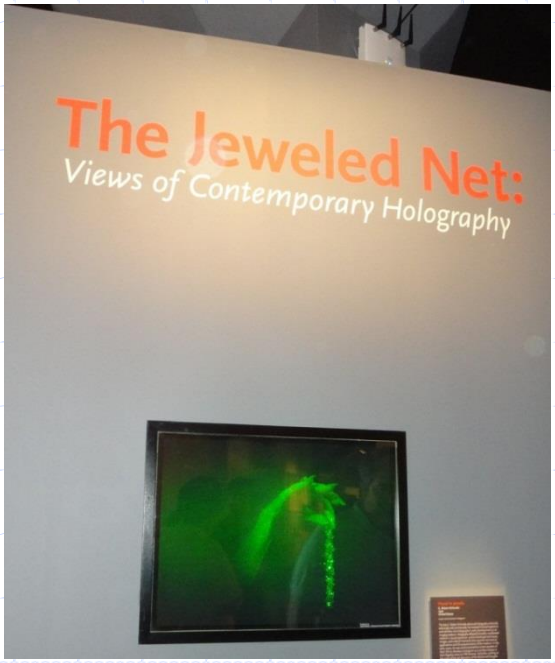


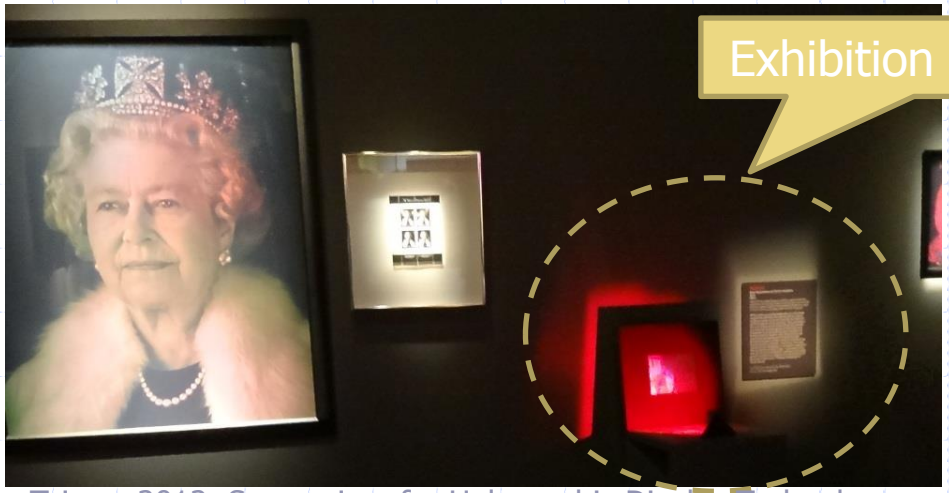
The shape of live faces are measured by 3D laser scanner, Konica Minolta Vivid 910.

Optical reconstruction

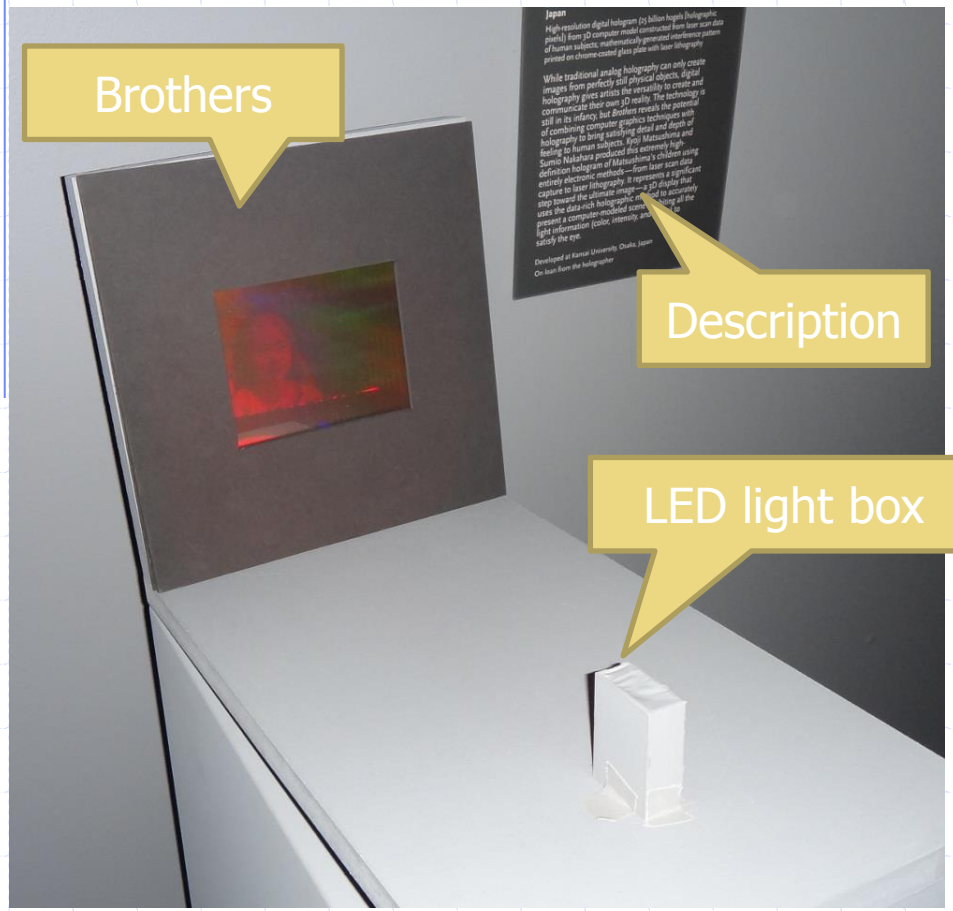
Brothers, 2012
Diffuse smooth shading, Live faces
Big hologram, 25 G pix (196,608 × 131,072)

Exhibition in MIT museum

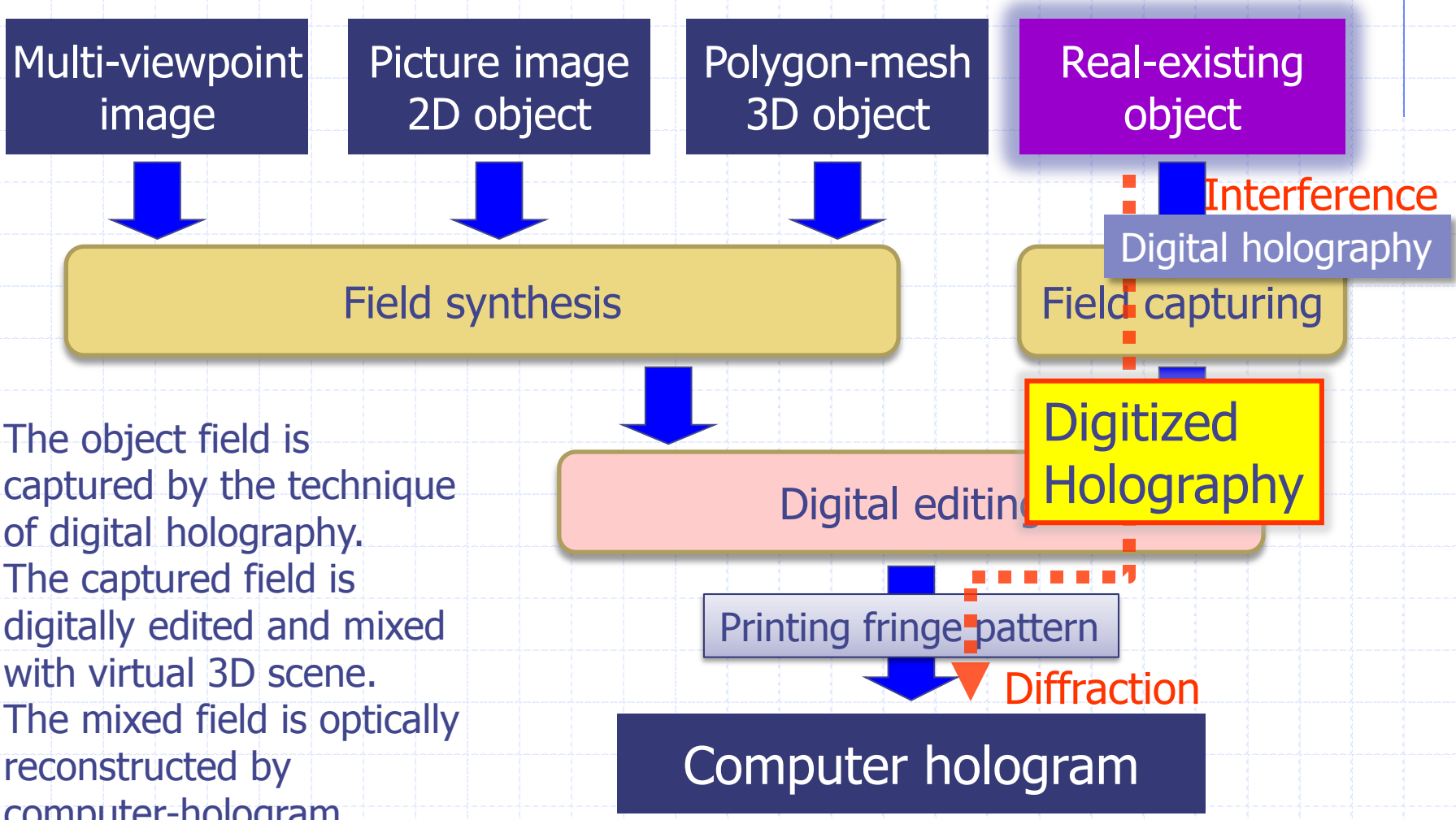




Exhibition in MIT museum



Digitized holography: Computer holography for real-existing objects

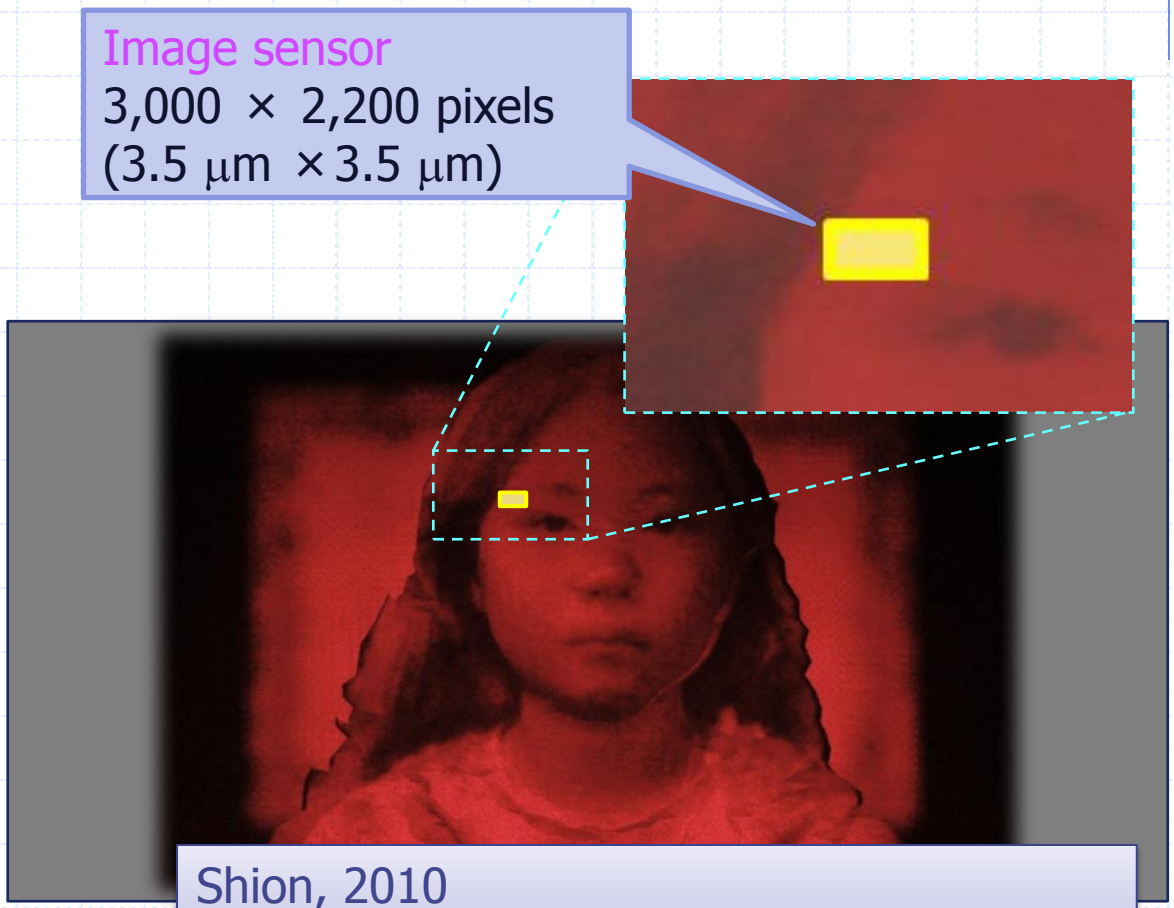


- The object field is captured by the technique of digital holography.
- The captured field is digitally edited and mixed with virtual 3D scene.
- The mixed field is optically reconstructed by computer-hologram.

Problems to realize digitized holography

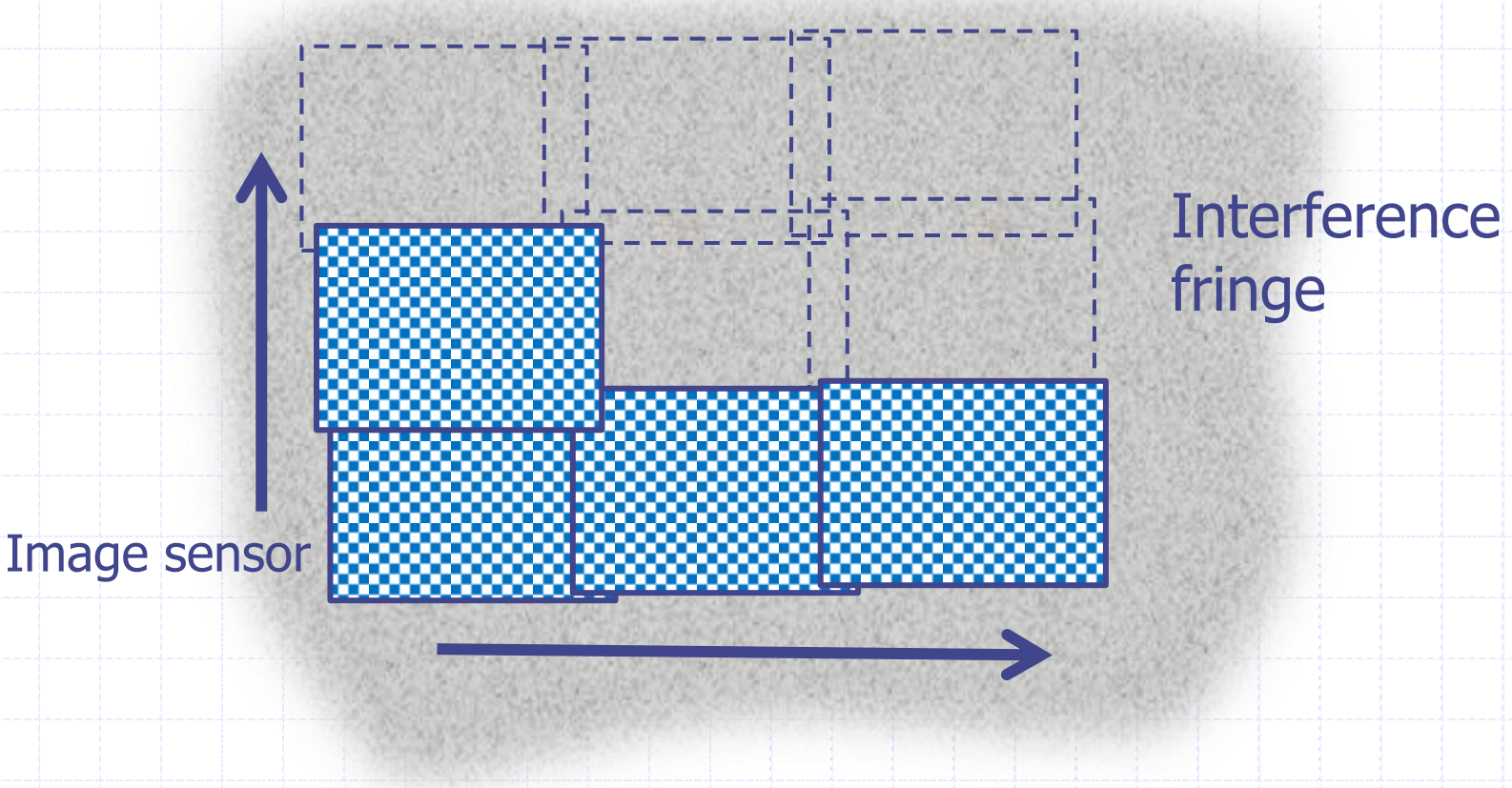
1. Expansion of captured area (Increase of number of samplings)
2. Reduction of sampling intervals

- The captured area of current image sensors is not sufficient for high-definition computer holograms.
- The sampling interval of the captured field is also not sufficient for high-definition computer holograms.



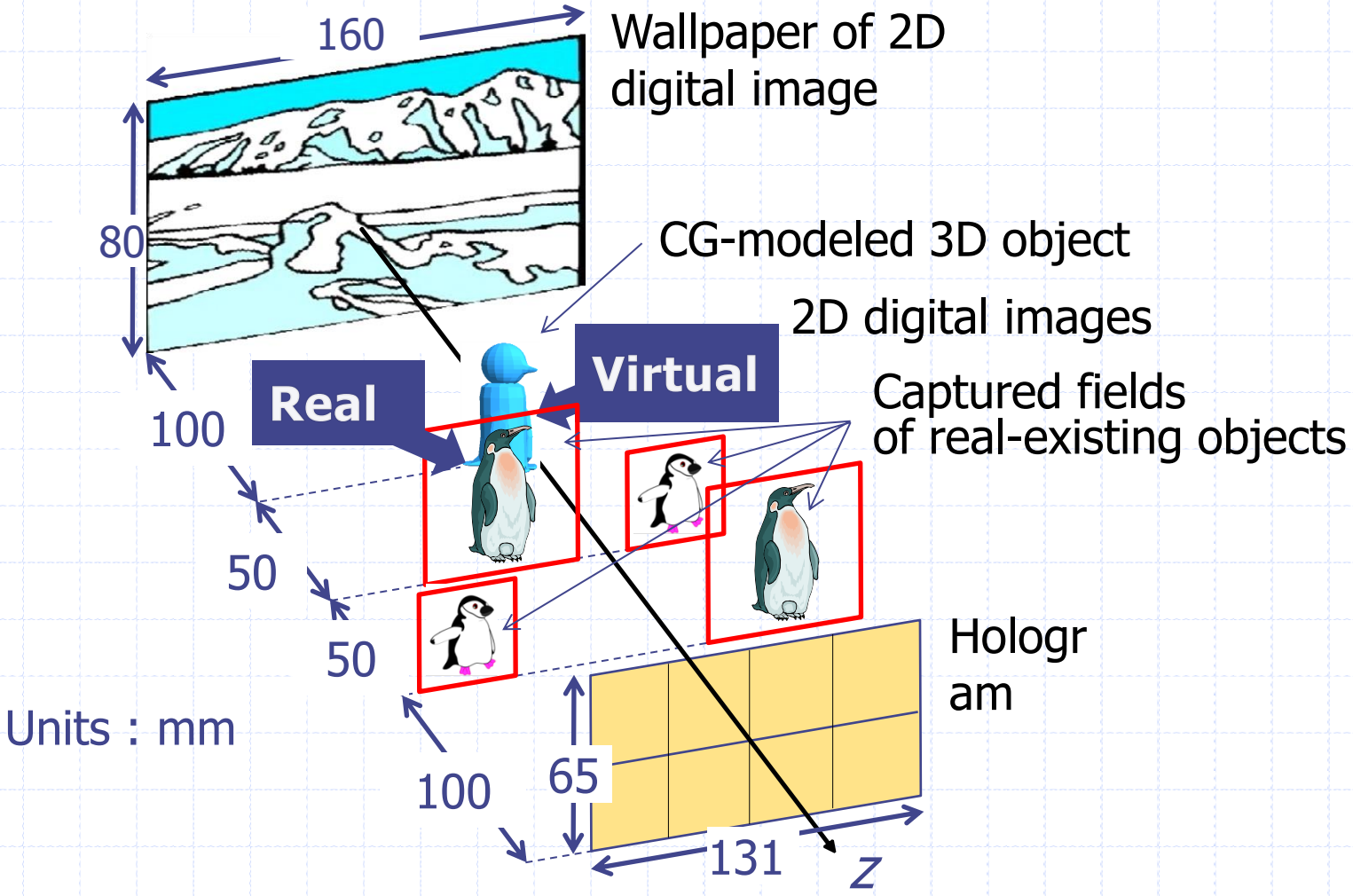
Techniques for capturing large fields at high-sampling density

1. *Lensless-Fourier setup for reducing sampling interval*
2. *Synthetic aperture digital holography for extending captured area*



- As the sensor moves, a part of field is captured.

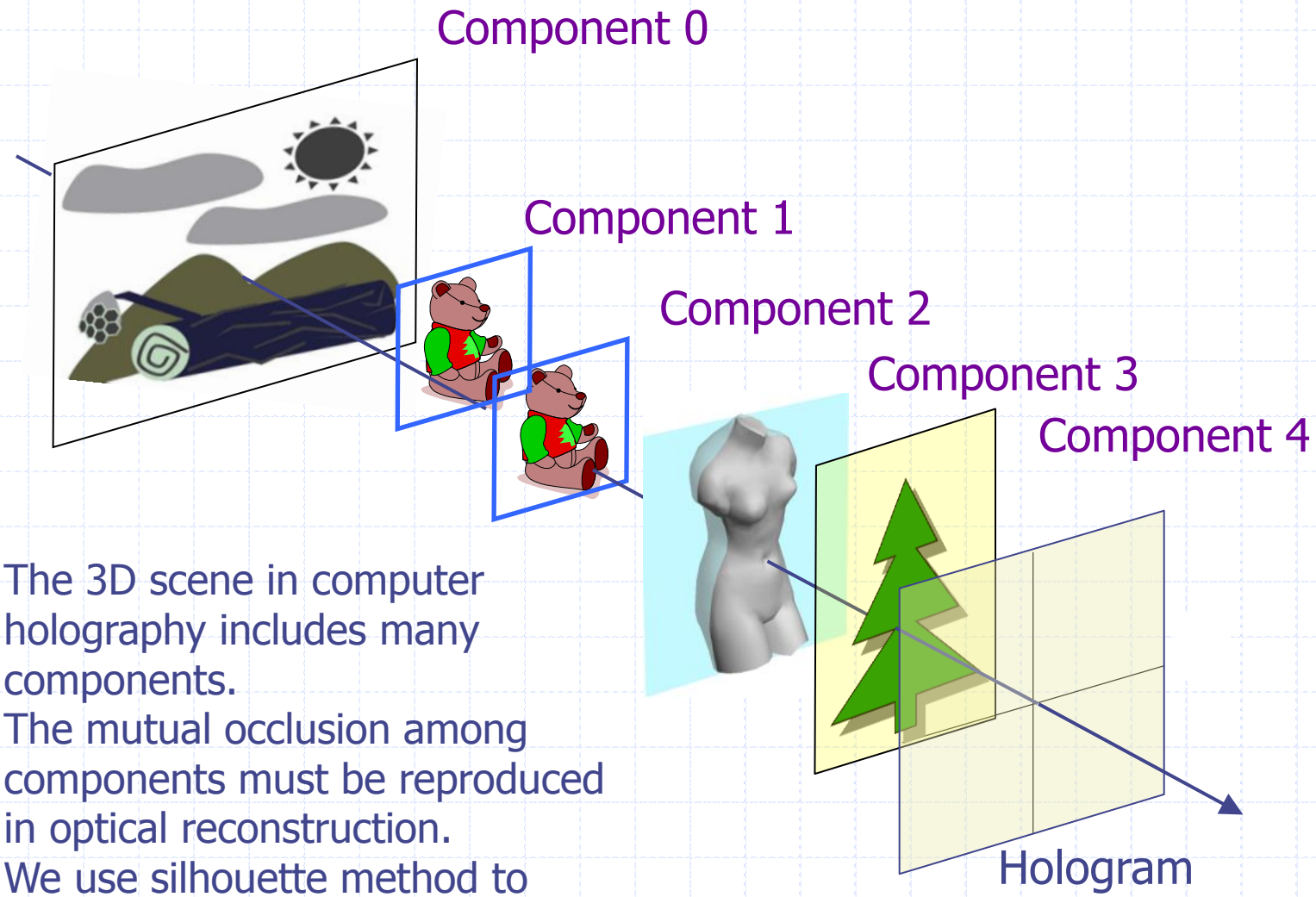
3D scene including real-existing fields : Penguin



Optical reconstruction

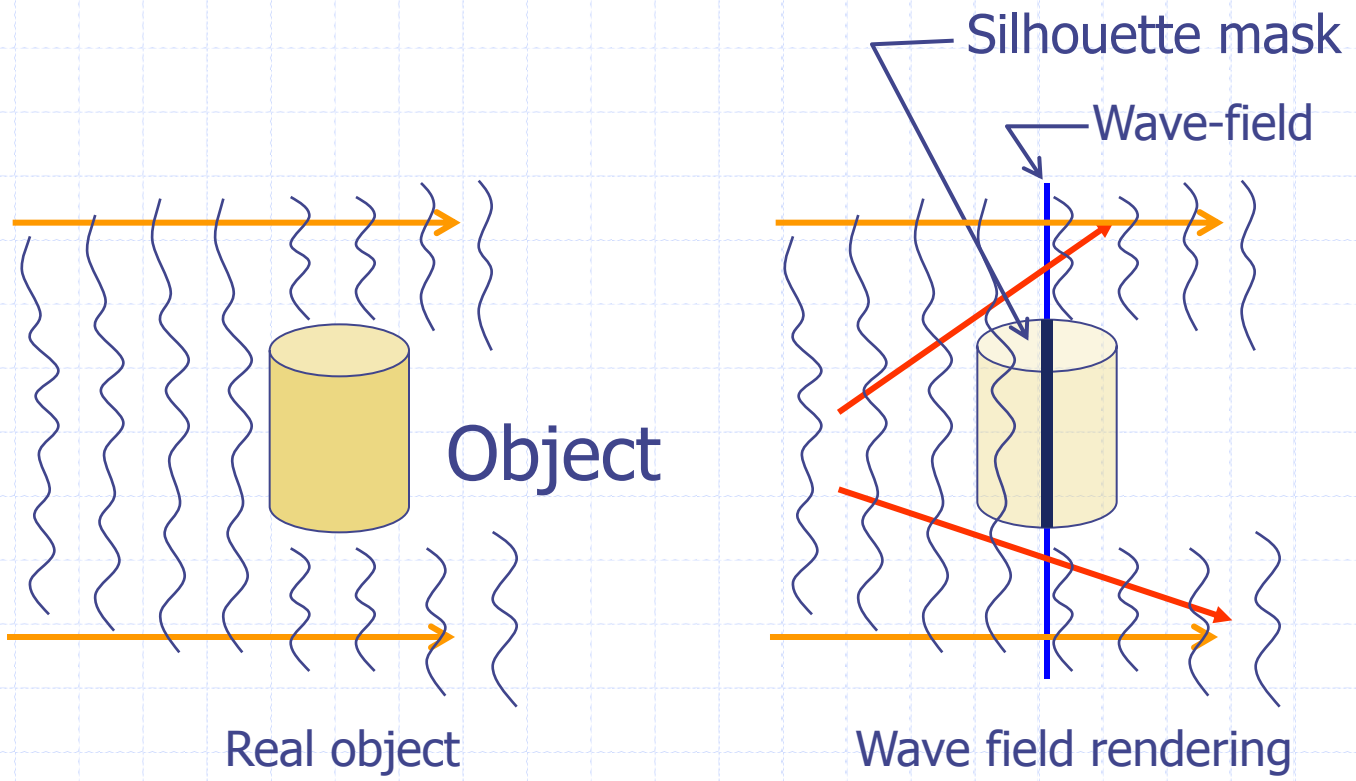
Penguin, 2012
Digitized holography
8 G pix

Field-based digital editing of 3D scene



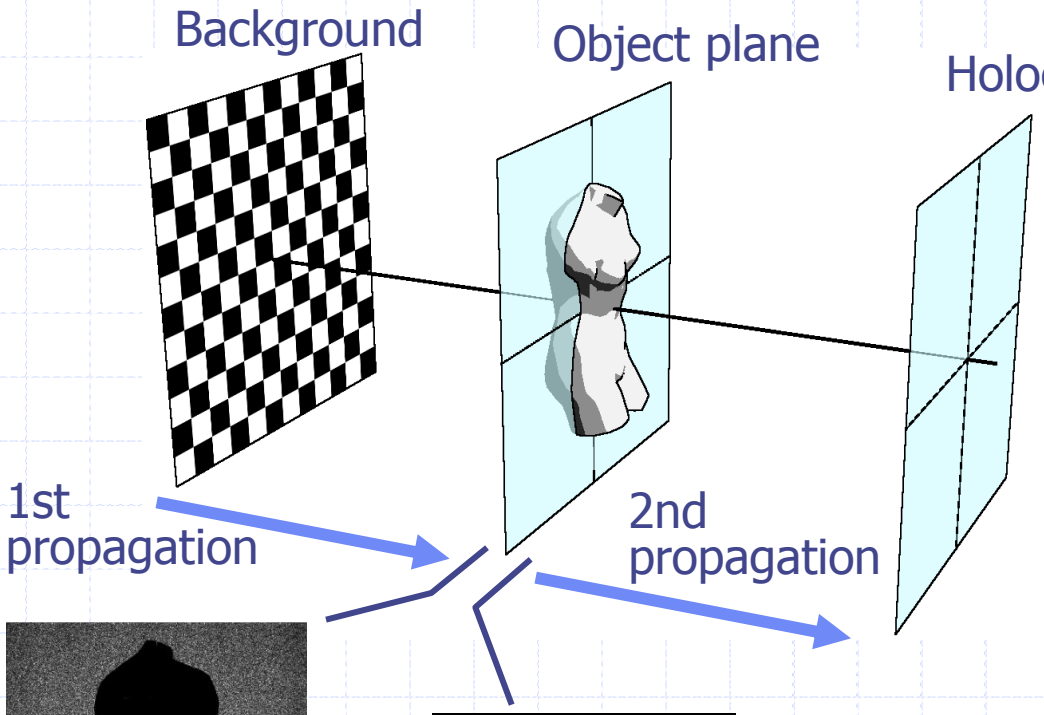
- The 3D scene in computer holography includes many components.
- The mutual occlusion among components must be reproduced in optical reconstruction.
- We use silhouette method to achieve this.

The silhouette method: light-shielding by opaque object

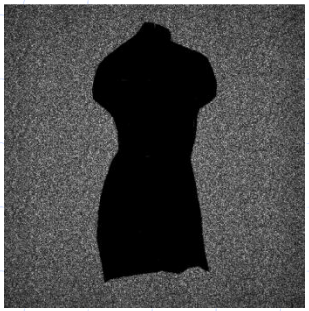


- A real opaque object shields light behind the object.
- In computer holography, to prevent the object being a phantom image, the field of incident light is masked by the object' silhouette.
- We calculate the background field at the center of object and then mask it by the object' silhouette.

Example of Silhouette Masking

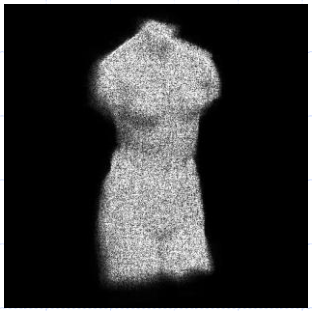


- The background field, propagated to the object plane, is masked with the silhouette of the Venus stature.
- After superimposing Venus field, the wave field is propagated to the hologram.



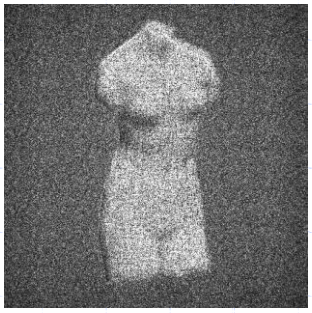
Wave-field of background

+



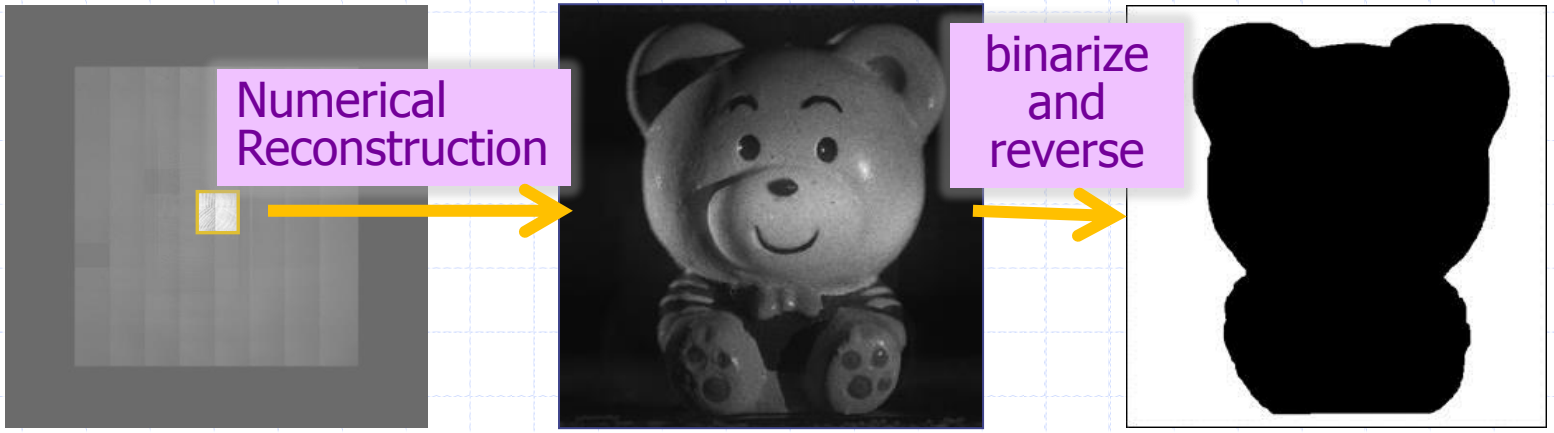
Wave-field of object

=



Superimposed wave-field in object plane

Silhouette mask in digitized holography



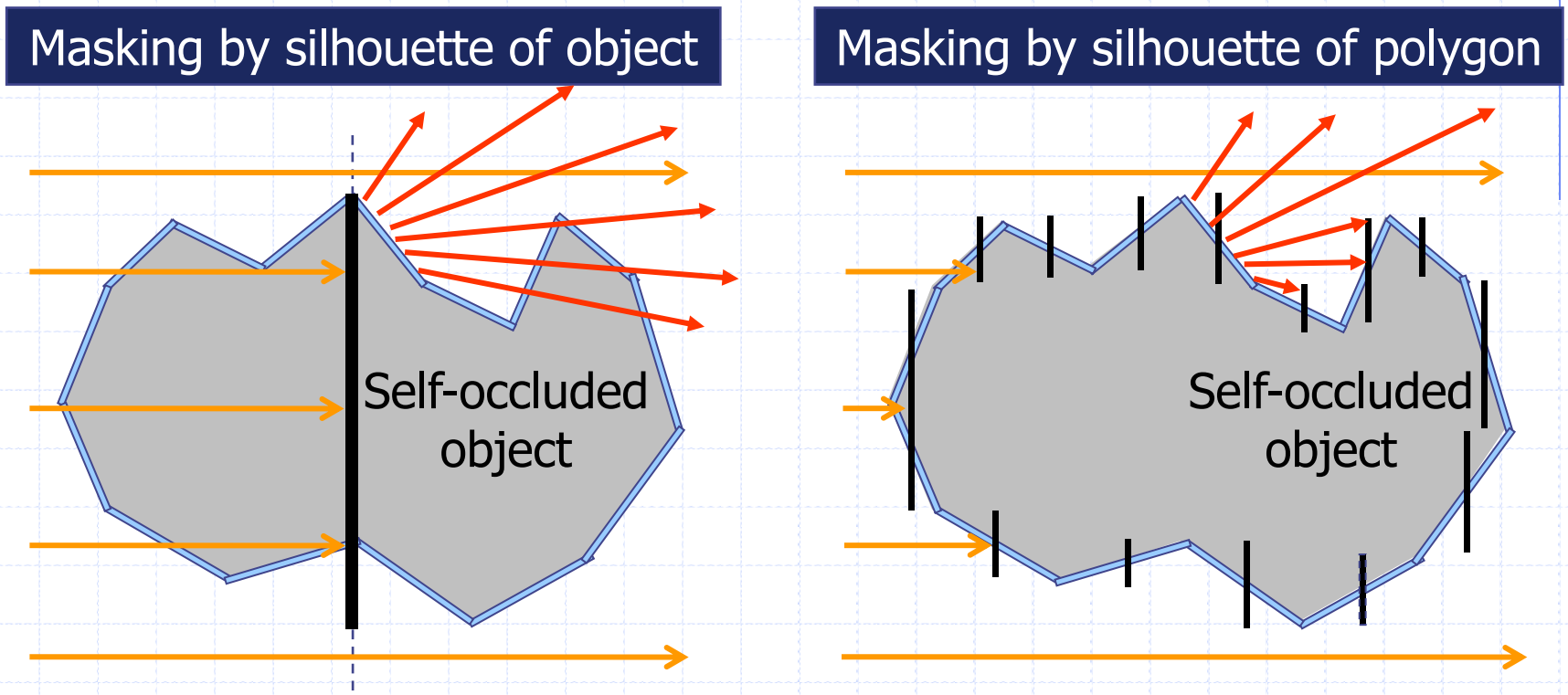
Small part of captured field

Amplitude image

Silhouette mask

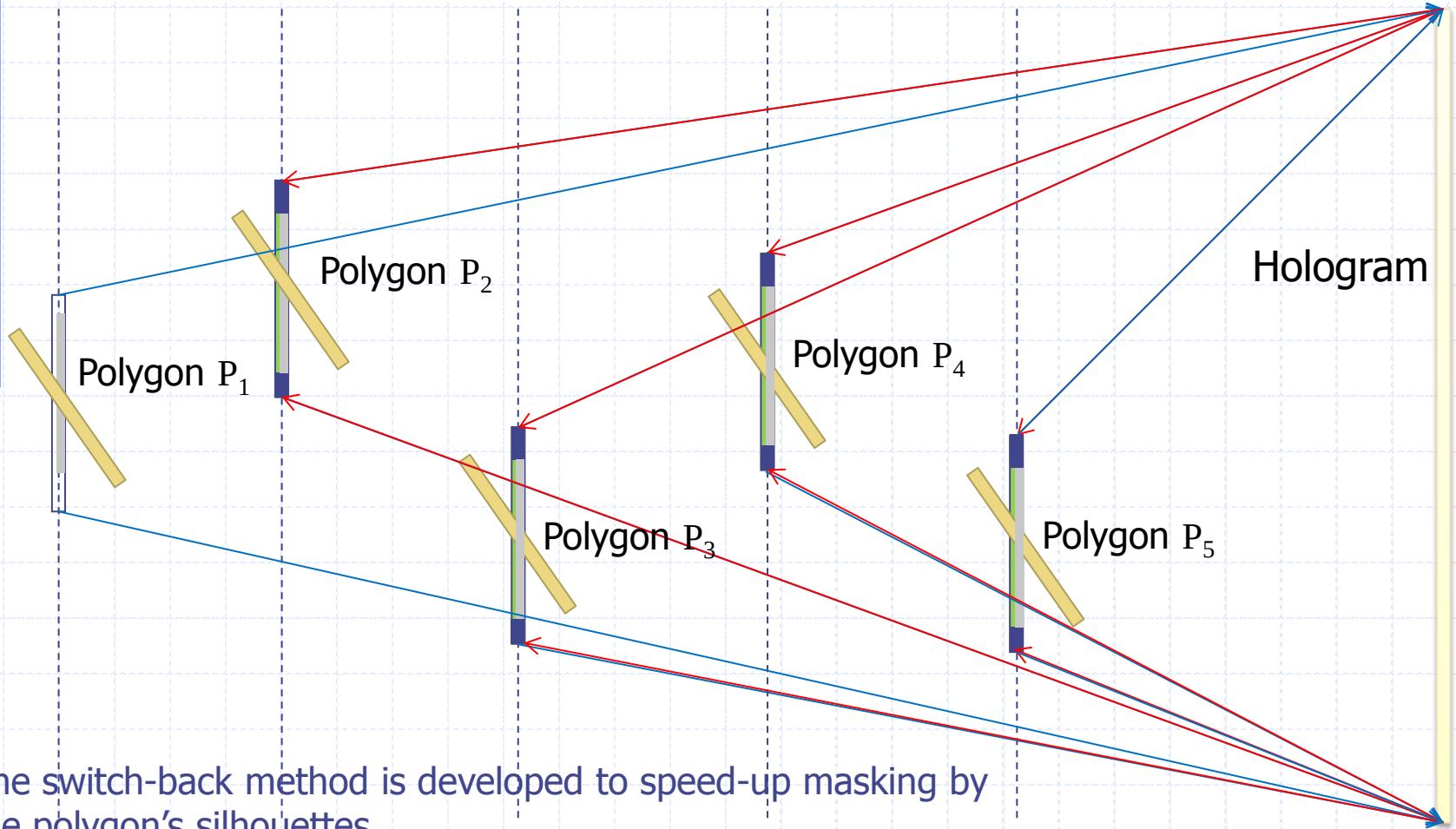
- In digitized holography, we have no information about the object shape.
- Numerical reconstruction of real fields is used for produce the silhouette mask.

Problems of self-occluded objects



- Masking technique by object silhouettes does not work well in self-occluded objects.
- To properly shield light of self-occluded object, fields must be masked by the silhouette of every polygon.
- However, masking by the polygon's silhouettes is very time-consuming.

Procedure of switch-back method



- The switch-back method is developed to speed-up masking by the polygon's silhouettes.
- In this technique the field of object is numerically propagated back and forth and masked by the polygon's silhouette.
- Many formulas are necessary for the explanation of the mechanism.

Hologram for self-occluded object

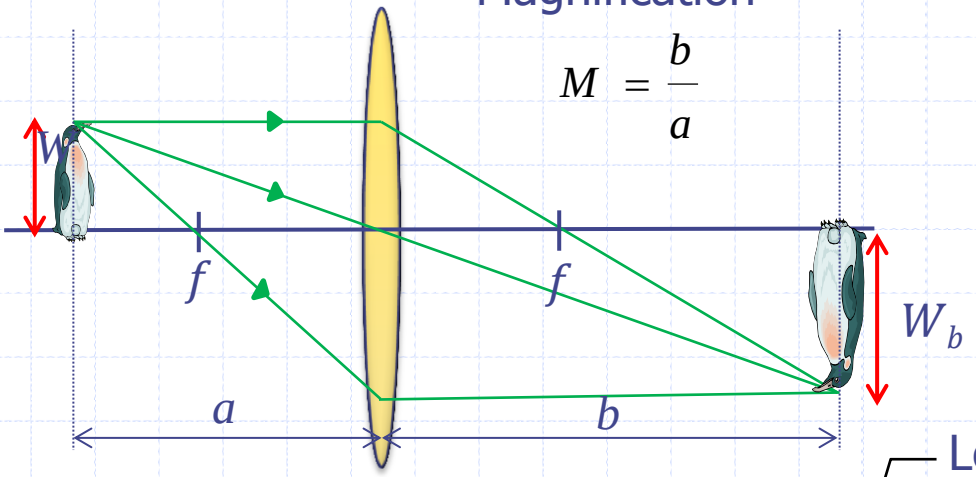
Rose in Ring, 2012
Self-occluded object (Switch-back method)
Specular smooth shading

USE OF VIRTUAL OPTICS

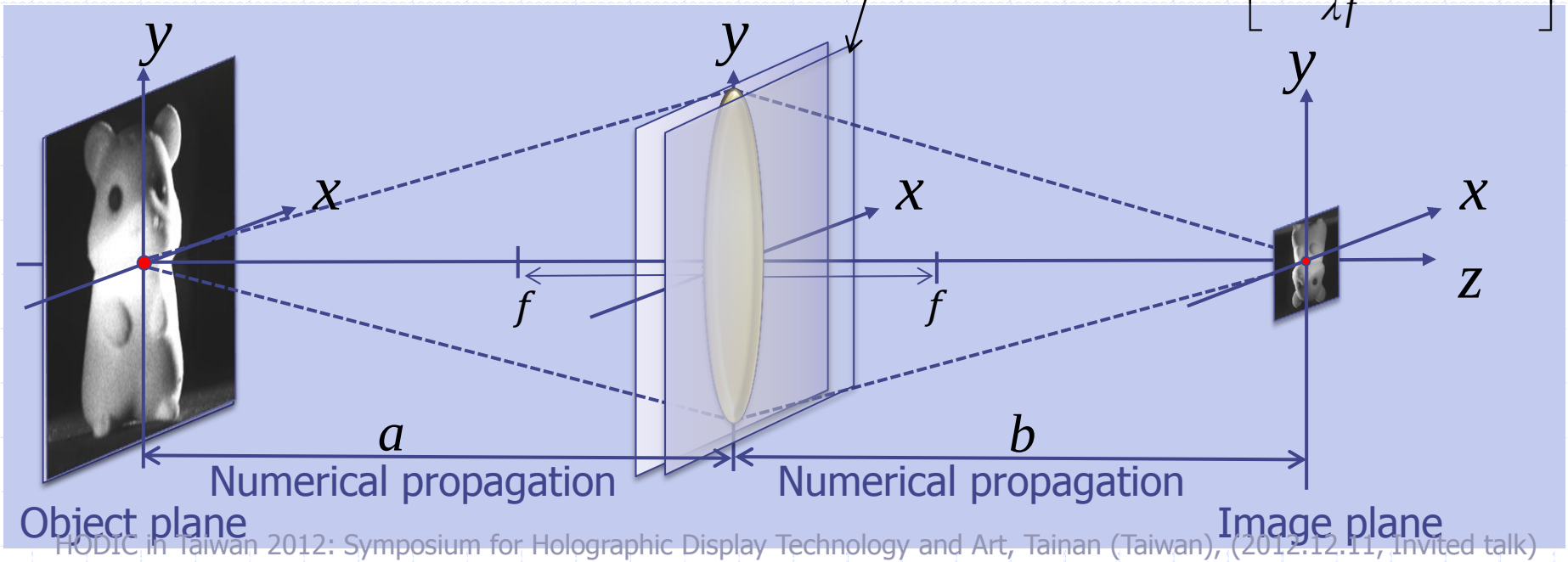
Resizing objects in digitized holography

Magnification

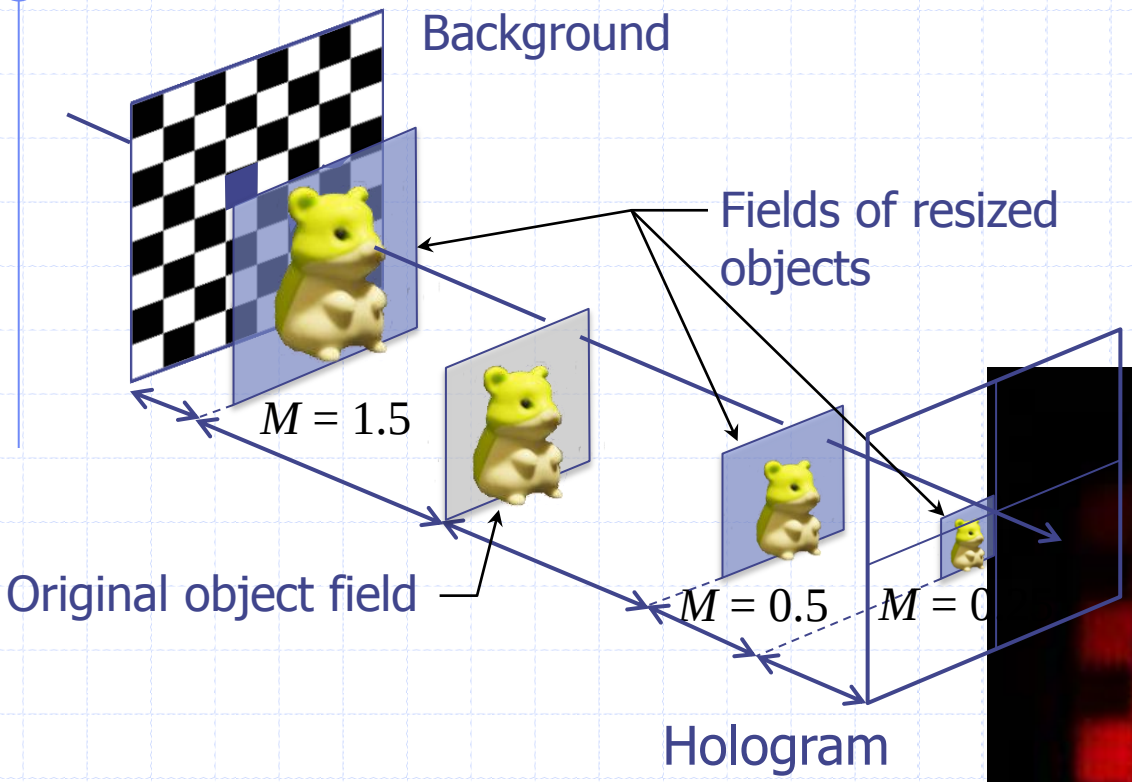
$$M = \frac{b}{a}$$

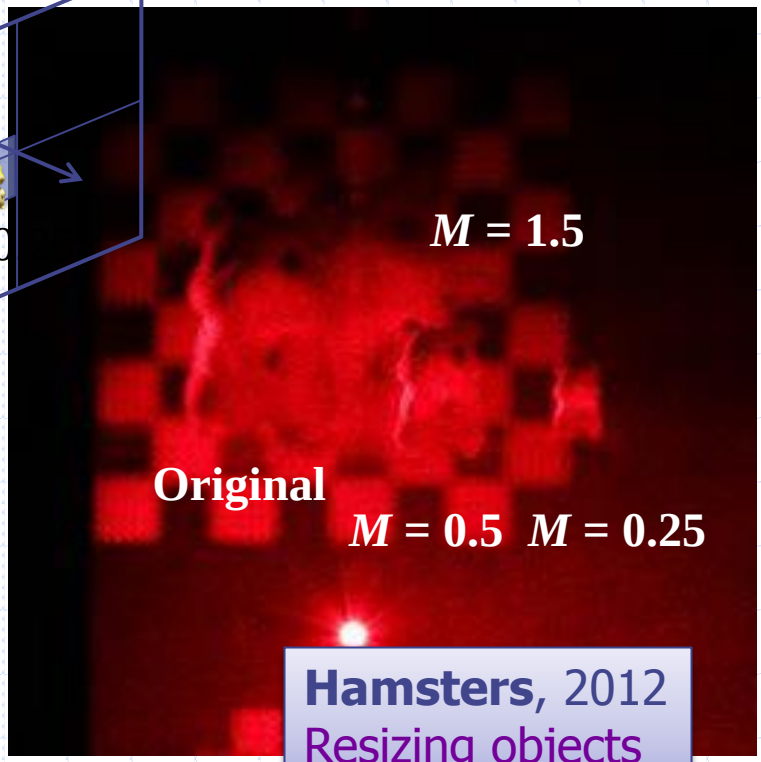


Lens function $\exp\left[-i\frac{\pi}{\lambda f}(x^2+y^2)\right]$



Computer hologram for resizing objects: Hamsters

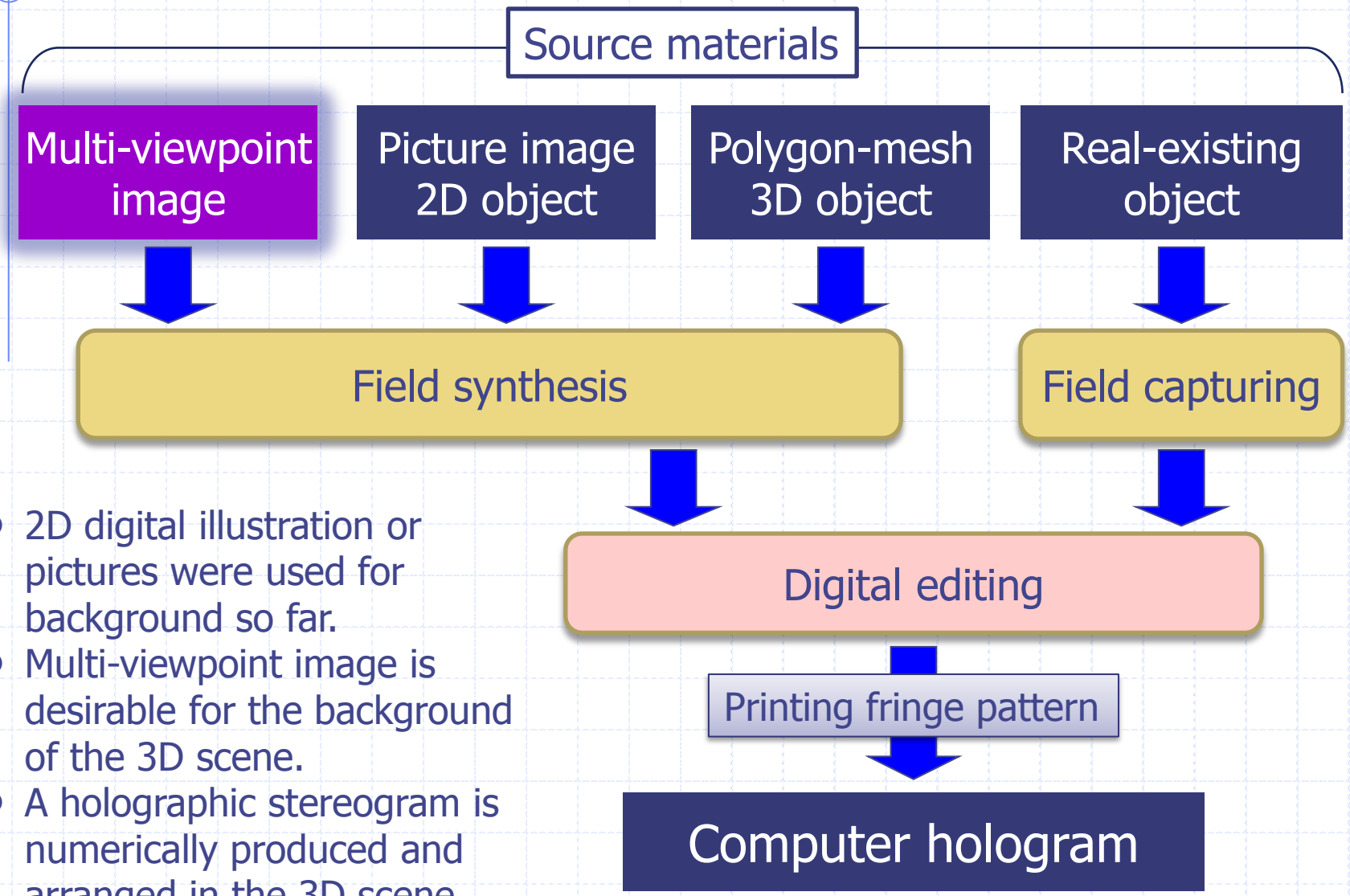




Hamsters, 2012
Resizing objects

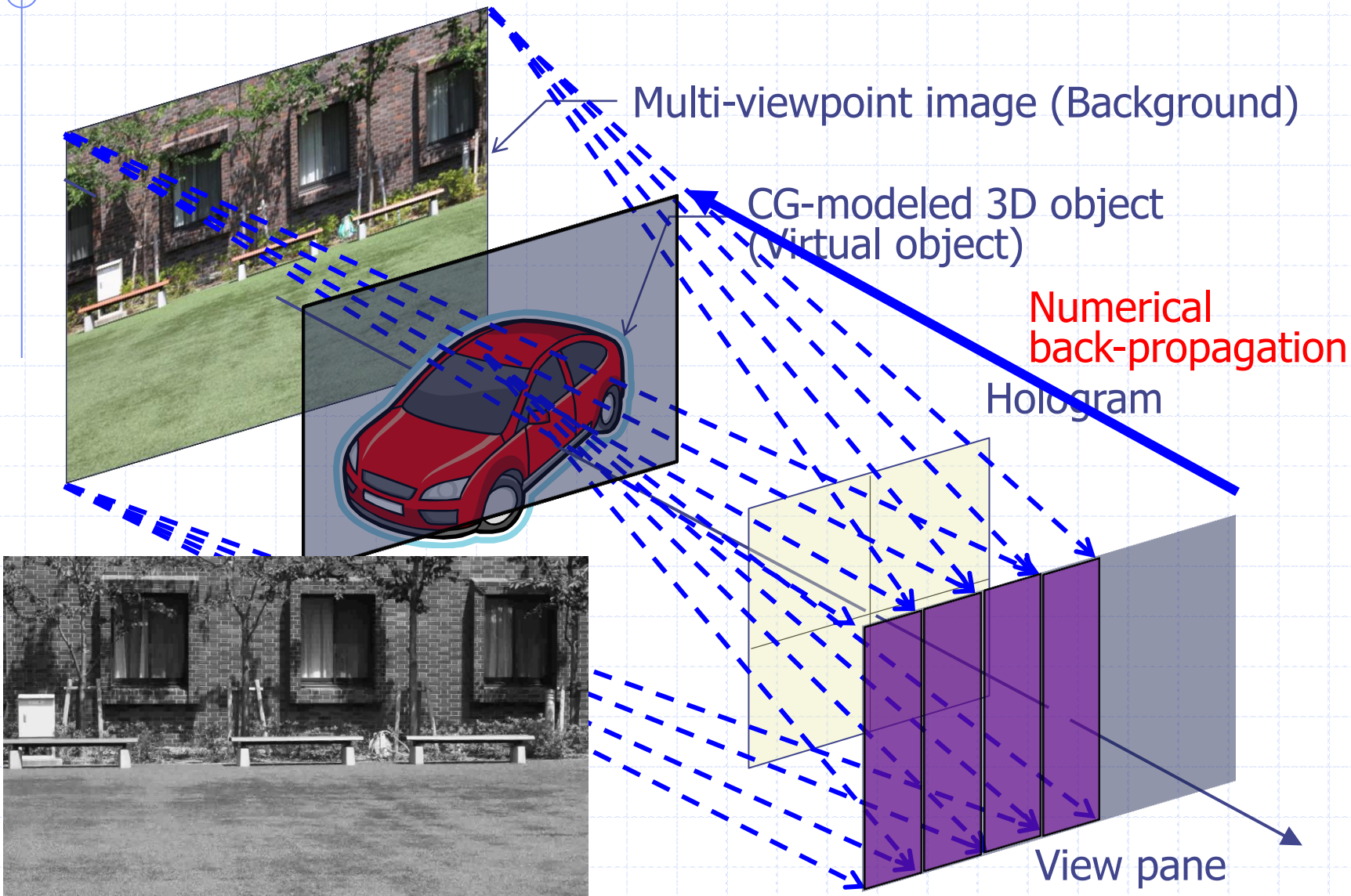
- Hamsters was created for testing the technique.
- The 3D scene include 3 resized object obtained from the original field.

Using multi-viewpoint image as background



- 2D digital illustration or pictures were used for background so far.
- Multi-viewpoint image is desirable for the background of the 3D scene.
- A holographic stereogram is numerically produced and arranged in the 3D scene.

3D scene in computer holography



Hologram using multi-viewpoint image

Parked Car 1, 2012
Multi-viewpoint image as background

Software

- Software can be downloaded from our website:
  - http://www.laser.ee.kansai-u.ac.jp/WaveFieldTools
  - Or search keyword WaveFieldTools
  - All contents are written in Japanese.
- The current software is provided as Library of C++. Windows software will be available in a few months.

Conclusion

- Computer holography can use many source materials and create brilliant CGHs whose reconstructions are comparable with that by traditional holography.
- Computer holography has the advantage that the 3D images are digitally archivable and transmittable.
- Real-existing objects and 3D scenes can be incorporated into CGHs by using digitized holography or as holographic stereograms through virtual optics with numerical methods.

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