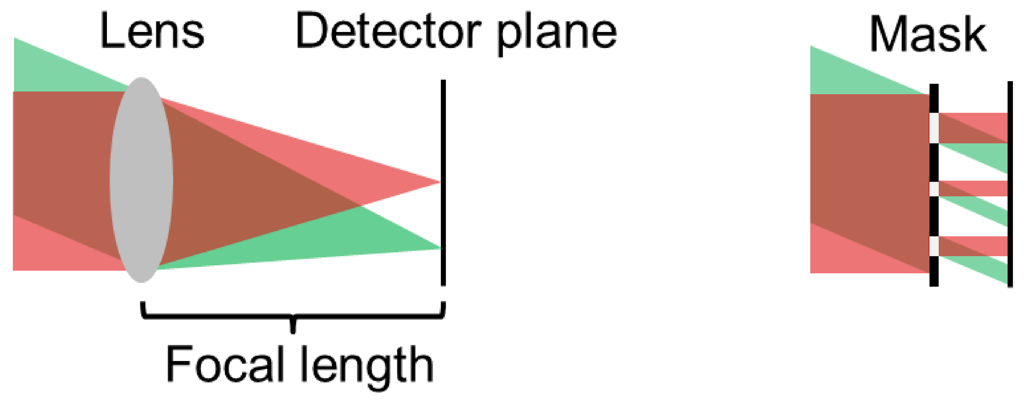
Incoherent Lensless Imaging

Po-Sheng Chiu* and Paul Urbach
Department of Imaging Physics, Delft University of Technology, the Netherlands
*P.Chiu@tudelft.nl

Abstract

An imaging method for detecting application is been studied. A coded amplitude mask is placed in front of the detector and therefore object image is modulated by the apertures. Generated images on the detector are shifted and mirrored of the original object image. Intensity on the detector is the convolution between the object and absolutely square of the Fresnel propagation of the mask. A computational algorithm is then used to reconstruct the object image.

Lens vs. Lensless Imaging [1]

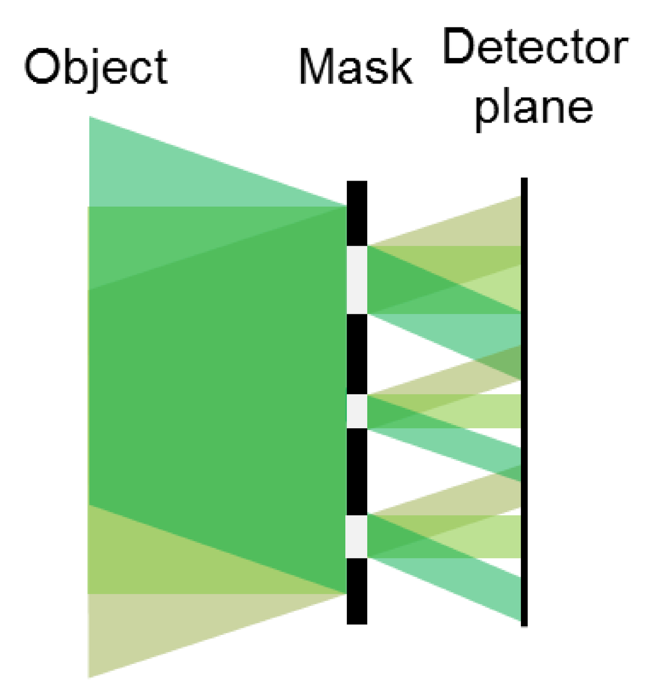


Lens based	Mask based
Bulky	Flat
Costly optics (e.g. x-ray)	No limitation on λ
High cost	Low cost
Low flexibility	High flexibility
High image quality	Low image quality

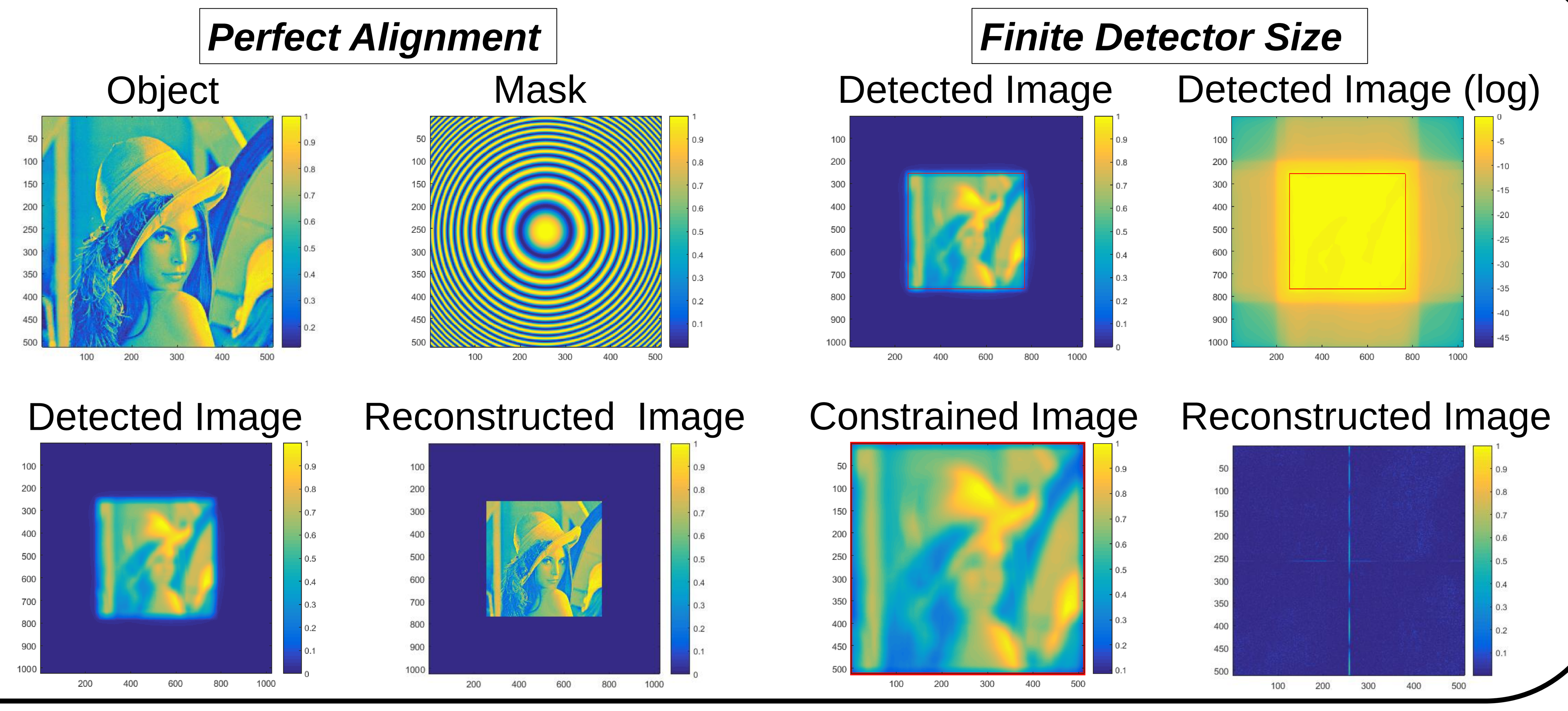
Physical meaning

- Light from the each object point (X) is modulated by the mask (M). Each object location generates a shifted mask shadow (Y) on the detector. The shadows are added together.
- Object points (X) pass through each pinhole on the mask (M). Each pinhole creates a shifted image (Y) on the detector. These images are added together.

Simulation



$$X * M = Y \rightarrow X = \mathcal{F}^{-1}\left\{\frac{\mathcal{F}\{Y\}}{\mathcal{F}\{M\}}\right\}$$



Summary

- Theoretically, the object image can be successfully reconstructed from a lensless system without noise.
- The reconstructed image quality is constrained by the finite detector size (lose part of the information).
- If the denominator becomes small, the inverse calculation will become numerically unstable.

$$X = \mathcal{F}^{-1}\left\{\frac{\mathcal{F}\{Y\}}{\mathcal{F}\{M\}}\right\}$$

Outlook

➢ Reconstruct a image with good quality
- If F{M} is a (near) flat Fourier spectrum, the image can be reconstructed.
- e.g. Uniform redundant array (URA), Modified URA

➢ Reconstruct a recognizable image (Application-driven)
- Unlike the camera, the recognition system does not need to be a perfect imaging system. Instead, satisfied quality threshold is enough for recognition system.
- Pattern recognition system needs to produce satisfactory image quality at the least computational expense.

Reference

[1] M. S. Asif et al., “Flatcam: Thin, lensless cameras using coded aperture and computation,” IEEE Trans. Comput. Imag., vol. 3, no. 3, pp. 384–397, 2017.

Acknowledgement

This research has received funding from the European Union’s Horizon 2020 research and innovation program under the Marie Skłodowska-Curie Grant Agreement No. 675745.