NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

EEE24070 – AI-Based Lens-less Imaging for Early Disease Detection

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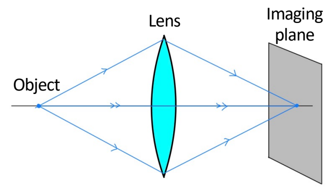
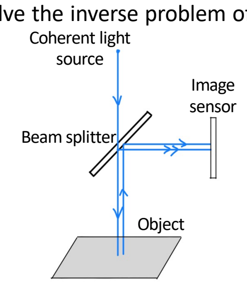
Introduction

- Lens-based imaging requires carefully designed lenses to clearly capture image of an object at a certain distance, which is costly and inflexible [1].
- Lens-less system, though is more compact and easily integrated into diagnostic platforms, gives images not interpretable by humans. Additionally, image reconstruction is challenging due to system noise and ill-posed nature [1].

→ Need deep learning algorithm to solve the inverse problem of imaging process.



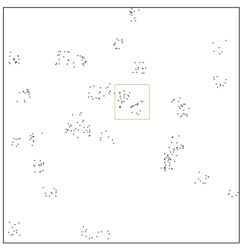
Lens-based optical system



Lens-less optical system

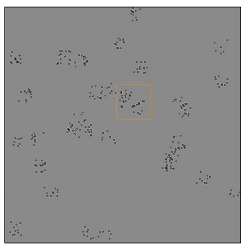
Dataset

The network is trained on a synthesized dataset due to scarcity of labelled experimental dataset. Ground truth images are images of randomly generated nanoparticles of uniform size. Measurements are simulated by using forward function that describe the propagation and interaction of coherent light reflecting from object to image sensor.
Random noise is added to reduce noise-sensitivity of model.



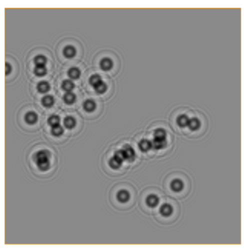
Simulated ground truth

Light propagates a distance z from object



Simulated measurement at z=2mm

Zoom in ground truth



Zoom in measurement at z=2mm

References:

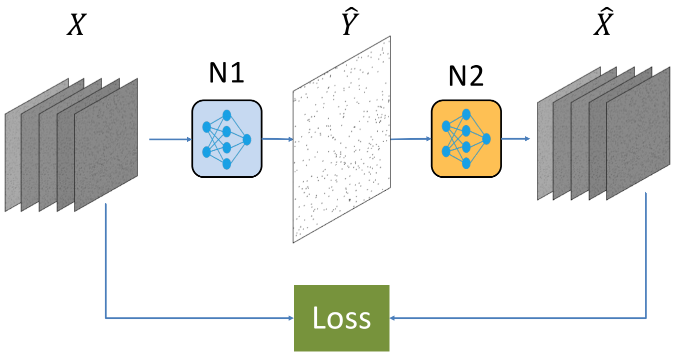
[1] Li, S. *et al*. Lensless camera: Unraveling the breakthroughs and prospects. *Fundam. Res*. (2024).

[2] Wang, K. et al, J. Y-Net: a one-to-two deep learning framework for digital holographic reconstruction. *Opt. Lett*. **44**, 4765–4768 (2019).

[3] Chen, H., *et al*. Fourier Imager Network (FIN): A deep neural network for hologram reconstruction with superior external generalization. *Light Sci. Appl*. **11**, 254 (2022).

Neural Networks

Unsupervised training with 2 distinct networks N1 and N2 pre-trained with supervised synthesized dataset.
The networks N1 and N2 are inspired by state-of-the-art networks Y-Net [2] and Fourier Imager Network (FIN) [3] in biomedical image segmentation and reconstruction.

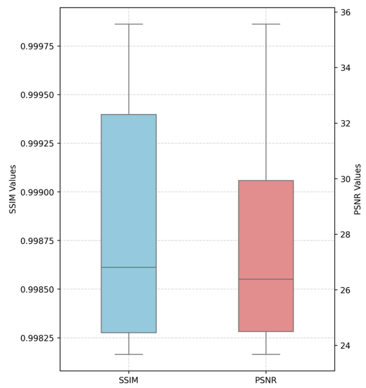


Our Y-Net decomposes images into low-frequency and high-frequency information. Each information goes to an encoding path and then is fused at a decoding path [2]. Skip connections [2] are applied to allow low-level features to remain deeper in the model.
Along with CNN layers, FIN uses spatial Fourier transform modules [3], which extract frequency features from images by utilizing learnable weight matrices in the spatial frequency domain.

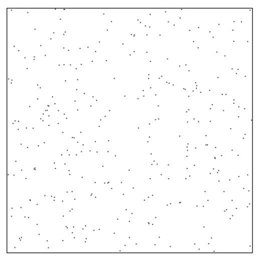
Result

The unsupervised model converges after 20 epochs and can give a high-fidelity reconstruction of the synthesized dataset. Some methods to improve the result:
- Training with larger batch size.
- Trying different loss metrics and tuning hyperparameters.

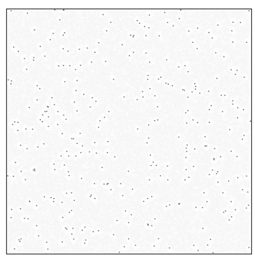
Future work includes testing the model with the experimental dataset.



Distribution of PSNR (above) and SSIM (below) values measuring similarity between output and ground truth over 100 images



Simulated ground truth



Output from N1,
SSIM = 0.9993