Phase Retrieval by Using Point Spread Function with Deep Learning Compared to Machine Learning

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Motivation

Phase retrieval is a fundamental problem in many areas of optics and imaging systems. It allows the recovery of phase information from intensity measurements, which is crucial in fields such as microscopy, holography, and astronomy. Traditional phase retrieval methods, such as iterative algorithms, rely heavily on prior knowledge of the system's characteristics and may be computationally expensive or prone to errors. With deep learning (DL) and machine learning (ML) techniques, there has been a surge in novel approaches to solve phase retrieval problems more efficiently and accurately.

This project aims to investigate the effectiveness of deep learning-based phase retrieval method using PSF and compare the performance to machine learning-based approach.

Related Work

1. **Traditional Phase Retrieval Methods**: Many algorithms, such as the Gerchberg-Saxton and Fienup algorithms, have been developed over the years to perform phase retrieval from intensity measurements.[1] These methods require multiple intensity measurements at different object-plane positions or various angles, and they are often iterative, requiring high computational power.
2. **Deep Learning in Phase Retrieval**: Recent advancements in deep learning have led to the development of neural networks for phase retrieval. Methods like convolutional neural networks (CNNs) and U-Net architectures have shown promising results in recovering phase from noisy and sparse data.[2, 3]
3. **Machine Learning in Phase Retrieval**: Machine learning techniques have also been explored for phase retrieval tasks. These methods, however, require careful feature extraction and may not perform as well as deep learning models when it comes to handling complex and large-scale data. [4]

Project Overview

This project aims to explore the feasibility and performance of phase retrieval by using through-focus PSF with deep learning, and to compare this approach with machine learning techniques. The project will focus on the following key areas:

1. **Data Collection**: Generate through-focus PSF images.
2. **Model Development**: Building and training deep learning models and machine learning models for phase retrieval.

3. **Evaluation**: Comparing the performance of the models in terms of accuracy and computational efficiency.

Milestones, Timeline & Goals

Milestone	Duration
Data Collection	1 week
Model Development	1 week
Evaluation	1 week
Final Report	1 week

Goals:

- Develop and train deep learning and machine learning models.
- Achieve high phase retrieval accuracy while maintaining computational efficiency.

References

1. R. W. Gerchberg and W. O. Saxton, "A Practical Algorithm for the Determination of Phase from Image and Diffraction Plane Pictures" *Optik (Stuttg.)* 35, 237–246 (1972).
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3. Dzyuba, A. P. "Optical phase retrieval with the image of intensity in the focal plane based on the convolutional neural networks." In *Journal of Physics: Conference Series*, vol. 1368, no. 2, p. 022055. IOP Publishing, 2019.
4. Chimitt, Nicholas, Ali Almuallem, and Stanley H. Chan. "Phase retrieval of a point spread function." In *Unconventional Imaging, Sensing, and Adaptive Optics 2024*, vol. 13149, pp. 220-224. SPIE, 2024.