Comparison of Phase Retrieval Methods

EE367 Project Proposal

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1 Motivation

Phase detection is an important problem in many fields such as optics, single particle imaging, X-ray crystallography, signal processing and diffraction imaging. In diffraction imaging, an object is placed in front of laser, and based on how the light interacts with object, a diffraction pattern emerges, and usually only the magnitude of this light can be measured with a detector [1]. In order to fully reconstruct the image we need magnitude and phase information and trying to estimate the phase in this kind of situation is the problem that phase detection seeks to solve. Mathematically the problem involves recovering the entire signal x when only the Fourier transform magnitude information $|\mathcal{F}(x)|$ is known. This is a common situation for many other measuring devices where particular systems may only record magnitude information, but not phase information. The difficulty is that the problem is fundamental ill-posed. If a is a complex number indicating a point in Fourier space, then any of $ae^{i\theta}$ will have the same magntiude $|a|$. Especially if the measurements are noisy, it can become very difficult to reconstruct the original image [1]. However many methods have been able to achieve good phase estimation with various methods, some of which are described below.

2 Related Work

One of the most fundamental methods in phase retrieval is the Gerchberg–Saxton algorithm [2], which employs an iterative method to retrieve the phase. In many cases multiple image measurements will be combined to give more data to determine phase. Recent methods also include PhaseLift [3], which uses a method based on complex programming and matrix completion to estimate the phase. Some more recent work has used end-to-end deep learning methods for phase retrieval, where a nerual network is trained to calculate the inverse mapping. Manekar et al. [4] employed this approach and used the U-Net architecture and trained on the MNIST handwritten dataset. They obtained good qualitative performance, but did not undertake a thorough quantitative comparison with other methods. They also experimented with the effect of symmetries of the image on learning.

3 Overview of Project

In this project we seek to test and compare several methods to perform phase retrieval, as listed in the timeline. Firstly, we just implement methods directly from papers, but as a stretch goal, we will consider making adjustments to the methods to determine if we can improve performance.

4 Timeline

- Week 8: Conduct review of literature and implement baseline methods of Gerchberg–Saxton algorithm [2].
- Week 9: Implement PhaseLift [3], which is a resonably recent and widely recognised algorithm.
- Week 10: Implement an end to end approach using pretrained neural network and quantitatively compare to other methods and write up report.

References

[1] Guo zhen Yang, Bi zhen Dong, Ben yuan Gu, Jie yao Zhuang, and Okan K. Ersoy. Gerchberg–saxton and yang–gu algorithms for phase retrieval in a nonunitary transform system: a comparison. *Appl. Opt.*, 33(2):209–218, Jan 1994.

[2] R. W. Gerchberg and W. O. Saxton. Practical algorithm for determination of phase from image and diffraction plane pictures. *OPTIK*, 35(2):237–&, 1972.

[3] Emmanuel J. CandÃšs, Yonina C. Eldar, Thomas Strohmer, and Vladislav Voroninski. Phase retrieval via matrix completion. *SIAM Review*, 57(2):225–251, 2015.

[4] Raunak Manekar, Kshitij Tayal, Vipin Kumar, and Ju Sun. End to end learning for phase retrieval. *ICML workshop on ML Interpretability for Scientific Discovery*.