EE368 Term Project Proposal: Incorporating low-resolution image into phase retrieval process

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1 Motivation

Coherent Diffraction Imaging (CDI), in which the sample's diffraction intensity is measured, is a widely used technique for investigating non-periodic structures in biological systems such as viruses and cells [1]. While the resulting diffraction pattern provides the intensity of Fourier transform (FT) of the original image, the original image is generally inaccessible unless both its spectral amplitude (square root of the intensity) and phase components are available for performing inverse Fourier transform (IFT). Several phase retrieval algorithms have been developed to extract the phase component from the oversampled intensity component [2], the most well-known of which being the Hybrid Input-Output (HIO) algorithm [3]. HIO, an iterative algorithm, starts with a set of random phases as initial guess, then applies IFT and FT to the image to move it back and forth between reciprocal and real spaces, where constraints such as finite support and Fourier amplitude are applied to refine the calculated image, as shown in Figure 1(a).

In general HIO can give reasonable reconstruction result, but it usually takes few thousands of cycles to converge, and sometimes it stagnates at a suboptimal result. In addition, phasing algorithms like HIO are generally vulnerable to data defects such as quantum noise (due to limited photon flux) and missing intensities (due to low frequency components being blocked). For the reasons above, running phase retrieval algorithms like HIO for experimental data is generally costly in terms of computation resources and time, as people would need to run HIO with large iteration numbers multiple times to get optimal reconstruction result. While the calculated image is usually validated by comparing it with a low-resolution (LR) image from other source such as an optical microscope or scanning electron microscope (SEM), here we propose we can incorporate a low-resolution image into the phase retrieval algorithm as a prior to guide the phasing process, thus enhancing the reconstruction fidelity and convergence rate.

2 Project description

This project aims to improve upon the HIO algorithm by incorporating a low resolution image as a stronger prior than the finite support constraint used by most algorithms, developing a phase retrieval algorithm with a higher reconstruction fidelity and convergence rate. Figure 1(b) shows the proposed pipeline we will be developing. We expect the modified algorithm to outperform the original HIO, given a reasonably quality of the LR prior, as the LR image contains not only the support boundary but also local intensities information.

For this project, LR images will be numerically generated by applying a Gaussian filter to the original image with different bandwidth parameters; diffraction pattern will be simulated by using fast Fourier transform (FFT). The reconstruction fidelity will be evaluated by a discrepancy function $E_R(\rho_0, \rho_{calc})$ which compares the calculated image ρ_{calc} with the original one ρ_0.

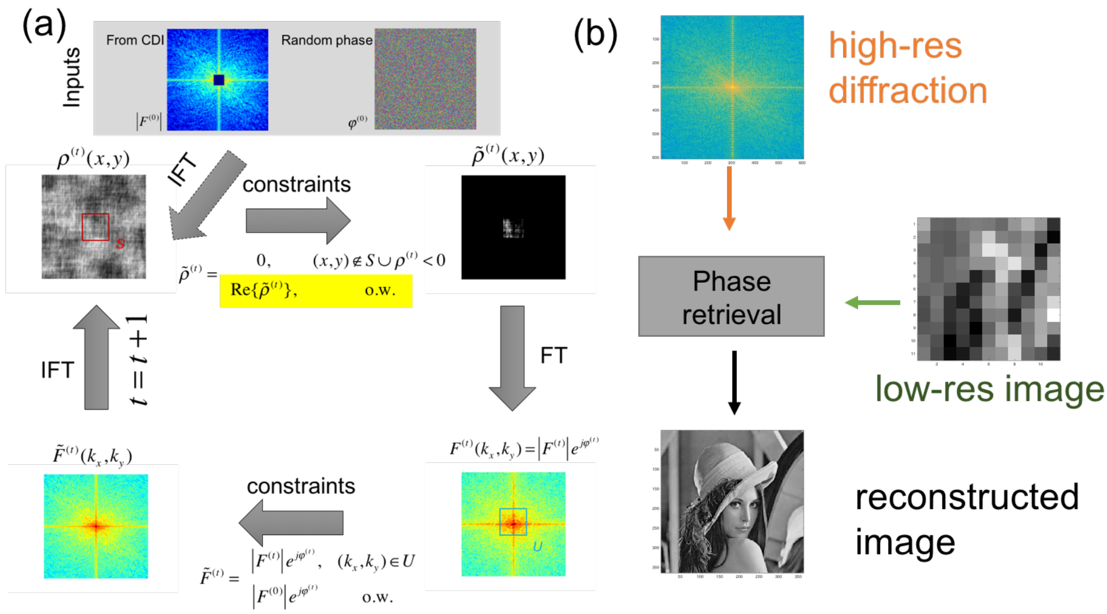

Figure 1: (a) Schematic of the conventional HIO algorithm. The highlighted part indicates the constraint to be studied and improved. (b) Proposed image processing pipeline.

The main challenge of the project is to find a mathematically reasonable and computationally practical way to constrain computed real space images based on the LR image. Previously we have experimented with a naïve technique where the on-the-flight real space image is dynamically guided by the LR image with a simple linear combination [4]. For this project, We will research into different methods for optimizing an image to be closer to the given LR image in a dynamic fashion which can be tuned for convergence. One of the possible candidate method is to use the deblurred LR image computed from Richard-Lucy deconvolution [5] or the ADMM algorithm [6] to constrain the real space domain image.

3 Android devices

This project does not use Andorid devices.

References

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