Phase Retrieval using the Gerchberg-Saxton Algorithm

Yuyin Zhou1, Chien-Hung Lu2, Jen-Tang Lu2, and Jason W. Fleischer2

1 Huazhong University of Science and Technology, Wuhan, China
2 Department of Electrical Engineering, Princeton University, Princeton, NJ
email: 369576245@qq.com

The phase of a complex function carries much more information than the amplitude. However, cameras only record intensity (amplitude squared), so that phase cannot be captured directly. A popular method of retrieving the phase uses a numerical iterative process, called the Gerchberg-Saxton (GS) algorithm, which requires at least two intensity measurements at different propagation distances [1]. The GS algorithm has the advantages of simple experimental setup, good anti-noise performance, and relatively fast convergence. Unfortunately the accuracy of the outcome and convergence speed often depend on the initial phase selection. As the phase is unknown, this initial guess is typically chosen to be \( \phi_0 = 0 \) uniformly across the object.

Inspired by Ref. [2], a Kerr nonlinearity \((-\gamma I)\) was used to improve the performance of GS phase retrieval. We set the initial phase to be \( \phi_0 = \gamma I_d \), where \( I_d \) is the intensity at propagation distance \( z = d \). We then observed how the error of phase reconstruction changed under different values of \( \gamma \). To perform the simulation, we used a 0.68 x 0.68 mm\(^2\) neuron network model, which has different spatial distributions for the phase and amplitude, shown in Fig.1(a). We assumed the light propagated in air (refractive index \( n_0 = 1 \)), the wavelength of light was 532nm, and the propagation distance from object to detector was 1mm. In the GS algorithm, we performed 50 iterations for each value of \( \gamma \). A plot of the corresponding phase errors is shown in Figure 1(d). The curve is parabolic, with a reconstructed error that reaches a minimum at \( \gamma = -0.8 \). At this value, the phase and amplitude improvements are 6% and 7%, respectively, compared with reconstructions using the standard assumption of \( \phi_0 = 0 \).

![Gerchberg-Saxton phase retrieval](image)

**Figure 1.** Gerchberg-Saxton phase retrieval. (a-c) The amplitude and phase of (a) the original object, (b) the numerical reconstruction when initial phase =0, and (c) the numerical reconstruction under optimal \( \gamma \). (d) Plot of the phase error as a function of \( \gamma \).

References:
