Comparison of Phase Detection Methods

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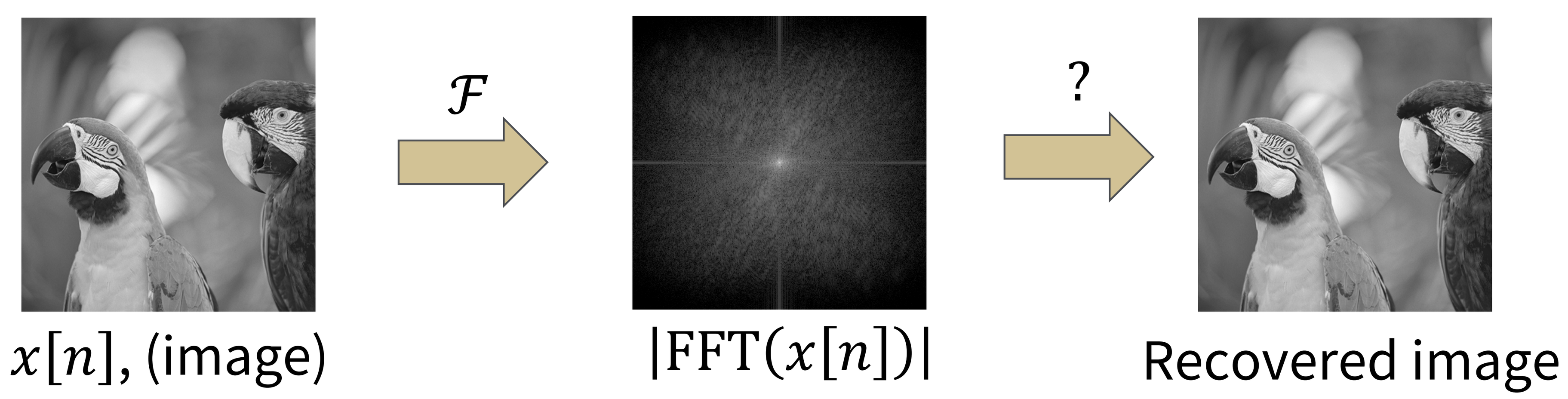
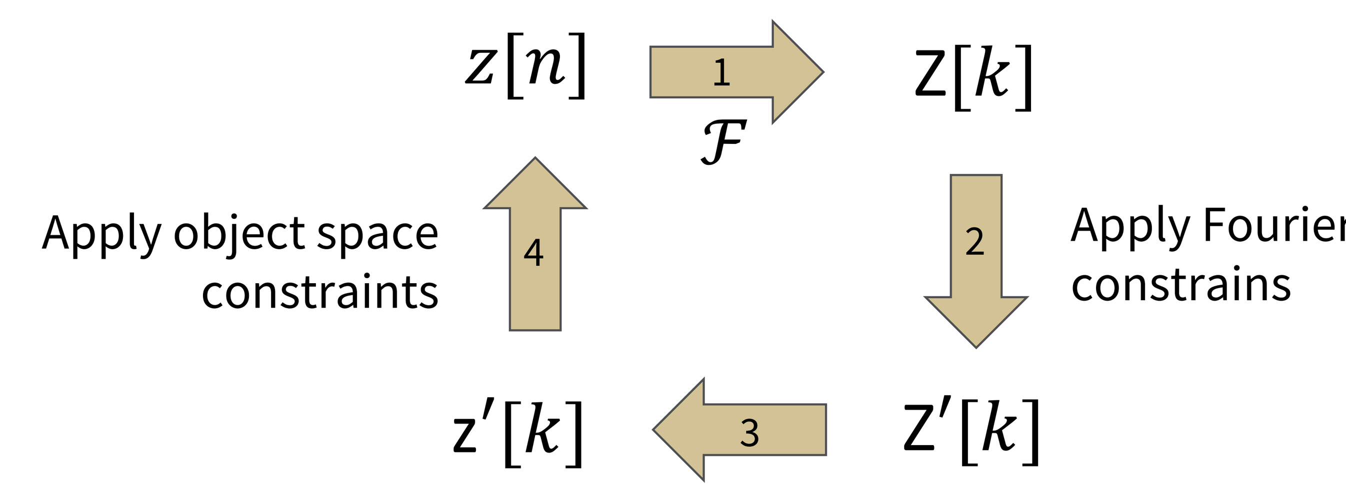
Motivation

- Phase retrieval is an important problem in many fields such as optics, single particle imaging, X-ray crystallography, signal processing and diffraction imaging.
- Mathematically, we wish to recover a signal $x[n]$ from the magnitude of its Fourier transform $|X[k]|$ (no phase information)



Method

- We tested several alternating projections methods such as Gerchberg-Saxton (GS), Hybrid Input-Output (HIO) and Oversampling Smoothness (OSS).
- **Oversampling**: In order to make the problem less ill-posed we oversample by taking the Fourier transform of the original image padded by zeros.
- We also trial the methods without padding.
- Below is an overview of alternating projection methods



Left: This shows the general algorithm for the alternating projection algorithms used. To switch between the different methods usually step 4 is changed. E.g. for OSS, a smoothing gaussian filter (with a decreasing variance for each iteration) is applied as part of the object space constraints the real object space.

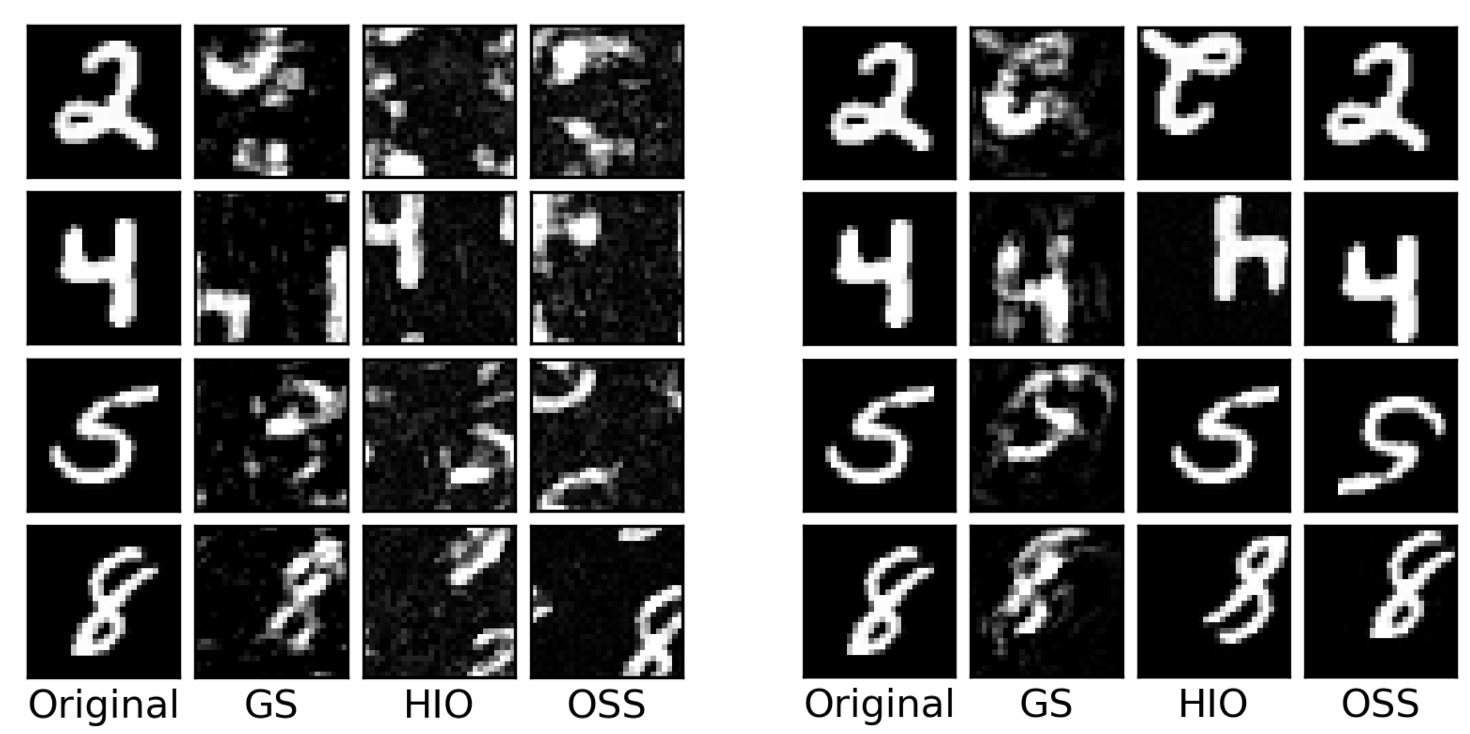
Related Work

- Alternating projections methods such as Gerchberg-Saxton [1], and Fienup's methods such as Hybrid Input-Output [2], as well as extensions such as Oversampling Smoothness [3]
- Signal sparsity has been used to give additional prior information [4].
- PhaseLift [5], which uses a method based on complex programming and matrix completion to estimate the phase.
- More recent approaches have trained a neural network to calculate the inverse mapping [6].

Results and Discussion

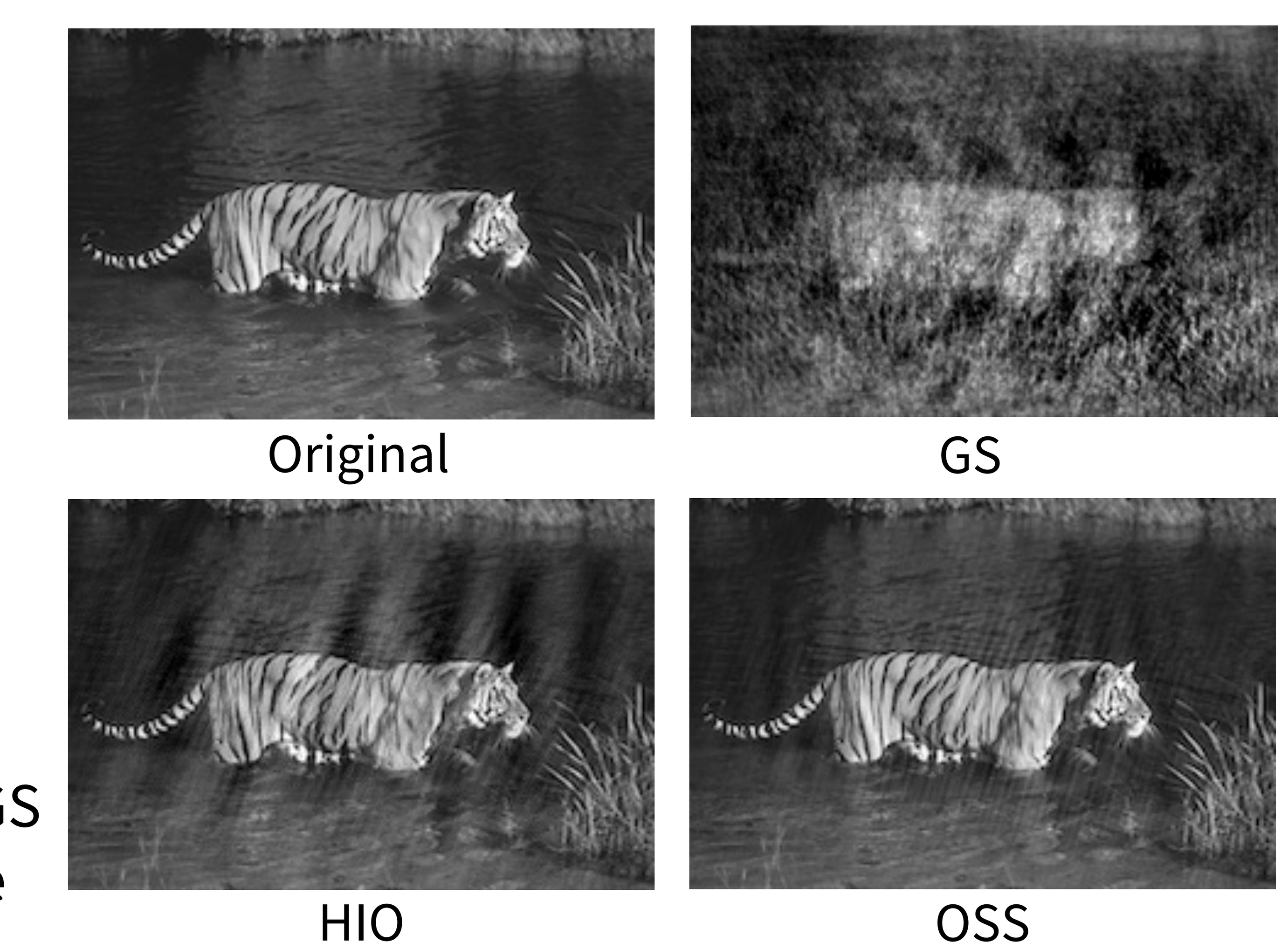
Samples from MNIST Dataset

Not over-sampled   Over-sampled



Sample from BSDS300 Dataset

Over-sampled



Method	GS	HIO	OSS
PSNR	17.4	25.3	33.8

- HIO and OSS methods perform better than simple GS
- Without the mask constraint from oversampling the reconstructed images can wrap around the edges

References

[1] R. W. Gerchberg and W. O. Saxton, "Practical algorithm for determination of phase from image and diffraction plane pictures," OPTIK, 1972.
[2] J. R. Fienup, "Phase retrieval algorithms: a comparison," Appl. Opt.,1982.
[3] Rodriguez JA et al., "Oversampling smoothness: an effective algorithm for phase retrieval of noisy diffraction intensities." J Appl Crystallogr., 2013.
[4] K. Jaganathan, et al., "Sparse phase retrieval: Convex algorithms and limitations," 2013.
[5] E. J. CandÂšs et al. "Phase retrieval via matrix completion," SIAM Review, 2015.
[6] R. Manekar et al. "End to end learning for phase retrieval," ICML workshop on ML Interpretability for Scientific Discovery, 2020.