Phase Retrieval Using Conditional Generative Adversarial Networks

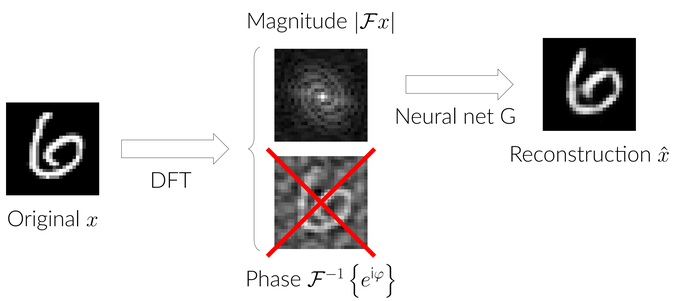
Tobias Uelwer , Alexander Oberstraß, Stefan Harmeling

Heinrich Heine University Düsseldorf, Germany

Problem Definition

Phase retrieval aims at recovering a signal x from its Fourier magnitudes

$$y = |\mathcal{F}x|, \text{ where } \mathcal{F} \text{ is the DFT.} \tag{1}$$



Proposed Method

We train a cGAN [2, 5] to recover images given their magnitudes.

- **At training time** we solve

$$\min_G \max_D \mathcal{L}_{\text{adv}}(D,G) + \lambda \mathcal{L}_{\text{rec}}(G), \tag{2}$$

consisting of an *adversarial component*

$$\mathcal{L}_{\text{adv}}(D,G) = \mathbb{E}_x\big[\log D(x,y)\big] + \mathbb{E}_{x,z}\big[\log\big(1 - D(G(z,y),y)\big)\big], \tag{3}$$

and a *reconstruction component*

$$\mathcal{L}_{\text{rec}}(G) = \mathbb{E}_{x,z}\big[\,\|x - G(z,y)\|_1\big]. \tag{4}$$

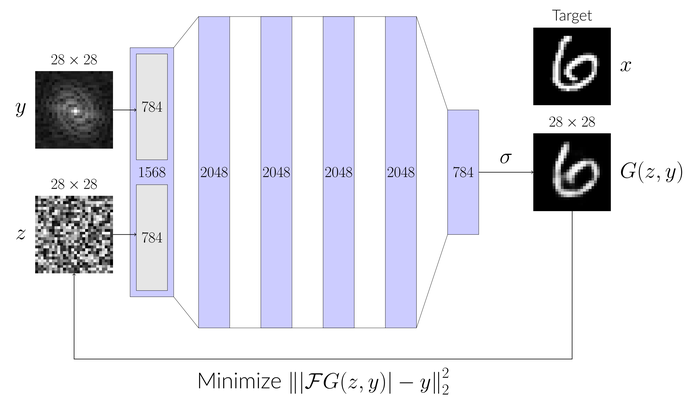
- **At test time** the latent variable z is optimized for each measurement y to minimize the error

$$z^* = \arg\min_z \|y - |\mathcal{F}G(z,y)|\|_2^2. \tag{5}$$

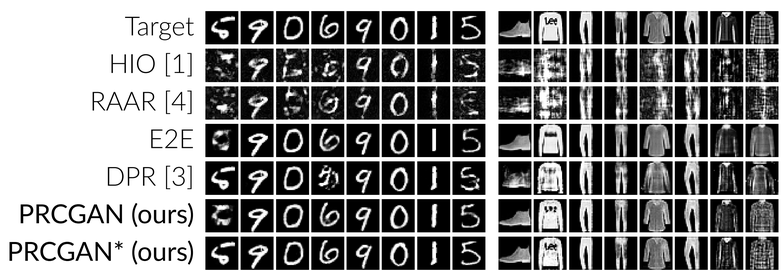
to find an $\hat{x} = G(z^*, y) \approx x$.

Our Model

- Our model can be seen as a hybrid of end-to-end learning and a generative prior.
- Including knowledge about the *measurement process* and the *data distribution* can greatly improve the reconstruction quality.
- PRCGAN: model trained with *adversarial* and *reconstruction loss*
- PRCGAN*: same as PRCGAN but with additional *latent optimization* during test time



Results on MNIST and Fashion-MNIST



Results on CelebA

Quantitative Results

Dataset	Metric	HIO	RAAR	E2E	DPR	PRCGAN	PRCGAN*
MNIST	MSE	0.0441	0.0489	0.0183	0.0093	0.0168	**0.0010**
	MAE	0.1016	0.1150	0.0411	0.0221	0.0399	**0.0043**
	SSIM	0.5708	0.5232	0.8345	0.9188	0.8449	**0.9898**
Fashion-MNIST	MSE	0.0646	0.0669	0.0128	0.0280	0.0151	**0.0087**
	MAE	0.1604	0.1673	0.0526	0.0856	0.0572	**0.0412**
	SSIM	0.4404	0.4314	0.7940	0.6602	0.7749	**0.8580**
CelebA	MSE	0.0737	0.0729	0.0106	0.0388	0.0138	**0.0093**
	MAE	0.2088	0.2073	0.0699	0.1323	0.0804	**0.0642**
	SSIM	0.1671	0.2274	0.7444	0.5299	0.6799	**0.7631**

References

[1] James R Fienup. Phase retrieval algorithms: a comparison. *Applied optics*, 21(15):2758--2769, 1982.

[2] Ian Goodfellow, Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio. Generative adversarial nets. In *Advances in neural information processing systems*, pages 2672--2680, 2014.

[3] Paul Hand, Oscar Leong, and Vlad Voroninski. Phase retrieval under a generative prior. pages 9136--9146, 2018.

[4] D Russell Luke. Relaxed averaged alternating reflections for diffraction imaging. *Inverse problems*, 21(1):37--50, 2005.

[5] Mehdi Mirza and Simon Osindero. Conditional generative adversarial nets. *arXiv preprint arXiv:1411.1784*, 2014.

tobias.uelwer@hhu.de, alexander.oberstrass@hhu.de, stefan.harmeling@hhu.de