Unlocking Inverse Problems Using Deep Learning: Breaking Symmetries in Phase Retrieval (PR)

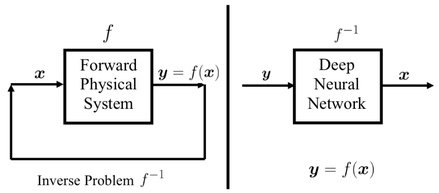
Kshitij Tayal, Chieh-Hsin Lai, Raunak Manekar, Zhong Zhuang, Vipin Kumar, Ju Sun

UNIVERSITY OF MINNESOTA
Driven to Discover℠

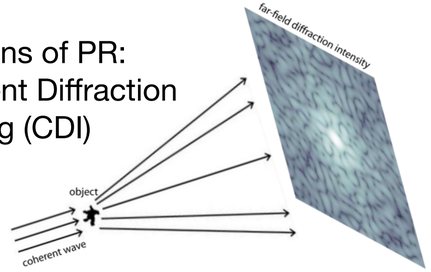
NEURAL INFORMATION PROCESSING SYSTEMS

INVERSE PROBLEMS

- Inverse Problem deal with the reconstruction of an unknown signal (e.g. image) from observation.
- Observations are obtained from a forward process (ill -posed), which is typically non-invertible.



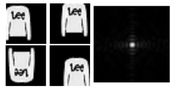
- We focus on the end-to-end approach applied to **NONLINEAR** inverse problems, and take phase retrieval (PR)—which is central to scientific imaging
- Applications of PR:
  — Coherent Diffraction Imaging (CDI)



Full Paper - https://sunju.org/pub/NIPS20-WS-DL4INV.pdf

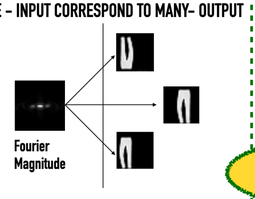
SYMMETRY BREAKING

Fourier-PR has **3 symmetries**.
– shift
– 2D flipping
– global phase (only for complex images)



What it **means** ?
—shifted and flipped copies of the same image have same Fourier magnitude
— forward system can relate multiple inputs to the same output

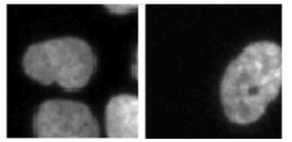
Why does it create **difficulty** ?
— inverse function determined by the training set, which the network is trying to approximate becomes highly oscillatory



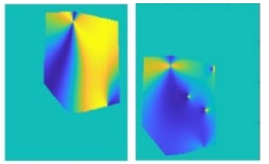
What is our **contribution** ?
— we show that careful symmetry breaking on the training data can help get rid of the difficulty and improve learning performance

NUMERICAL EXPERIMENTS

Real **Scientific** Images
– No Natural Orientation
– No Centering

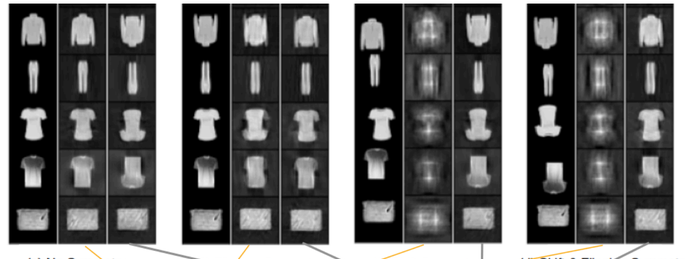


(a) Biological Cells



(b) Crystal structure in CDI

Natural Image Datasets
— Centered and Naturally oriented
— To emulate real scientific images, we introduce shift and flipped copies of images



TAKE-HOME

ReConstruction **BEFORE** breaking symmetry

ReConstruction **AFTER** breaking symmetry

SYMMETRY BREAKING is SIGNIFICANT in unlocking the true potential of the end-to-end approach for solving PR in particular, and nonlinear inverse problems with symmetries in general.