Time-Resolved Imaging by Multiplexed Ptychography (TIMP) with Physics-Based Unsupervised Deep Learning

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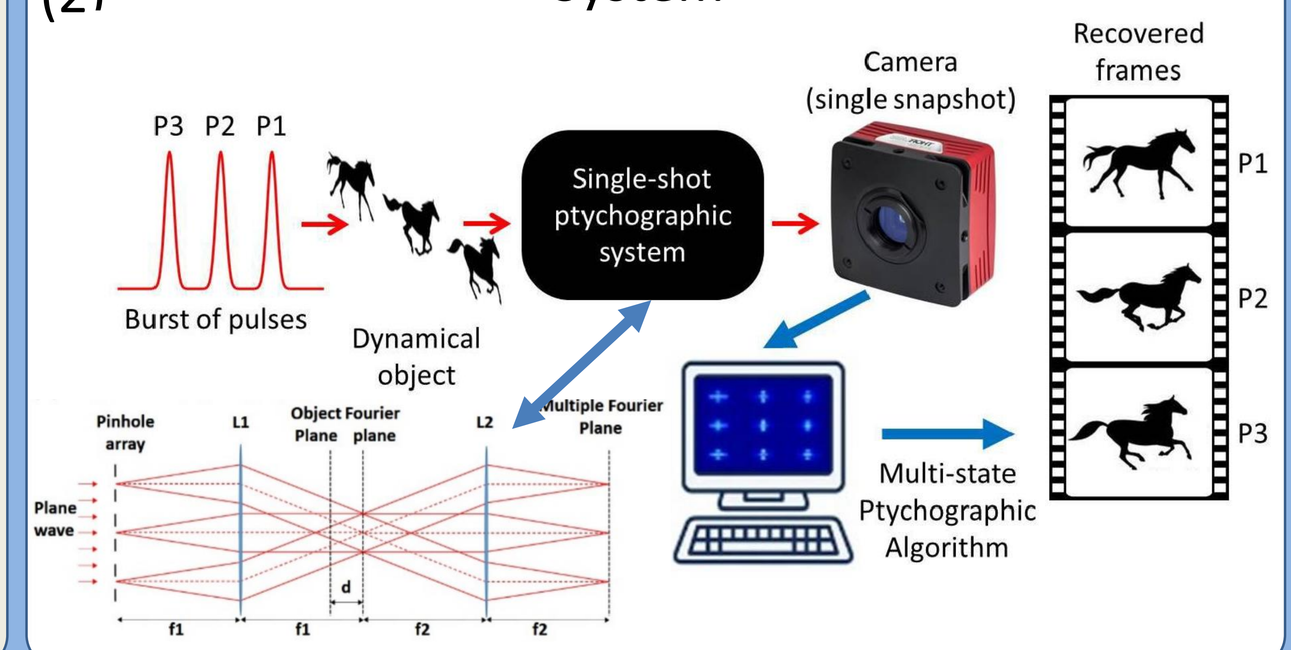
(1) Introduction

- We explore TimpNet – a DL approach to time-resolved imaging by multiplexed ptychography (TIMP) [1].
- Ptychography – coherent diffractive imaging scanning technique [2].
- Single-shot ptychography (SSP) – all diffraction patterns in one shot [3].
- SSP→TIMP – spatiotemporally engineered pulse burst illumination [1].
- TimpNet – parallel projection → untrained neural network.
- Overfitting a single sample assuming a forward model.
- Advantage: resolution cutoff, frame capacity, no dataset, simple NN [4].

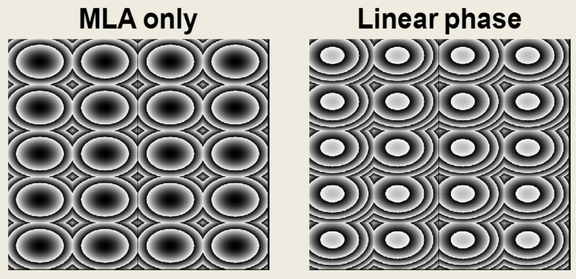
(2) System



(3) Mutually Orthogonal Probe Encoding

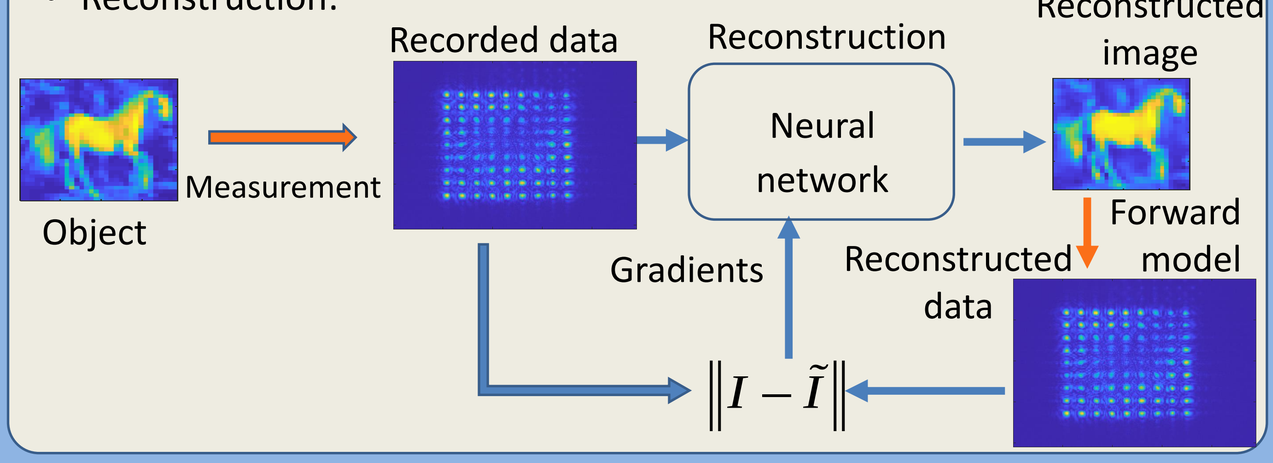
- Mutually orthogonal probes for multiple frames reconstruction [5].
- The basic probe (ground state) has only quadric phase (lens).
- The other probes are encoded using linear phase.

$$\phi_n\left(\vec{r}\right) = e^{i\pi\left|\vec{r}\right|^2/\lambda f_{MLA}} \cdot e^{i\vec{k}_n\cdot\vec{r}}$$



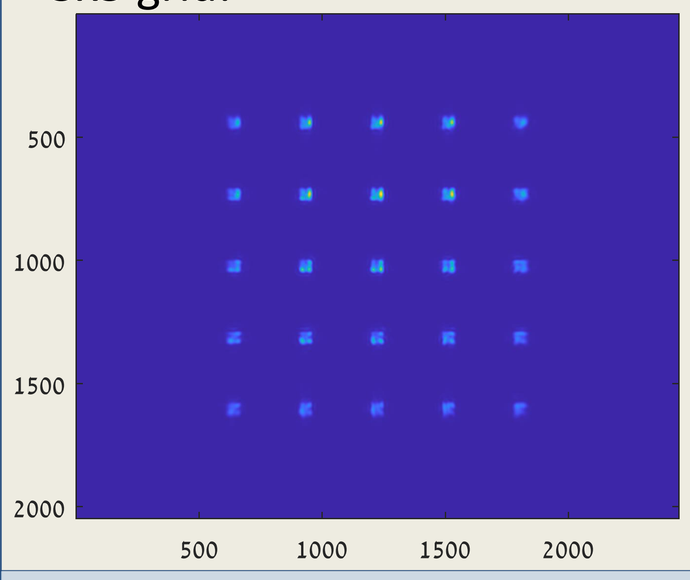
(4) Measurement and Reconstruction Algorithm

- Measured intensity distribution: $I_m(v) = \sum_{k=1}^{K}\left\|F\left[P_k\left(r-R_m\right)O_k\left(r\right)\right]\right\|^2$
- Reconstruction:



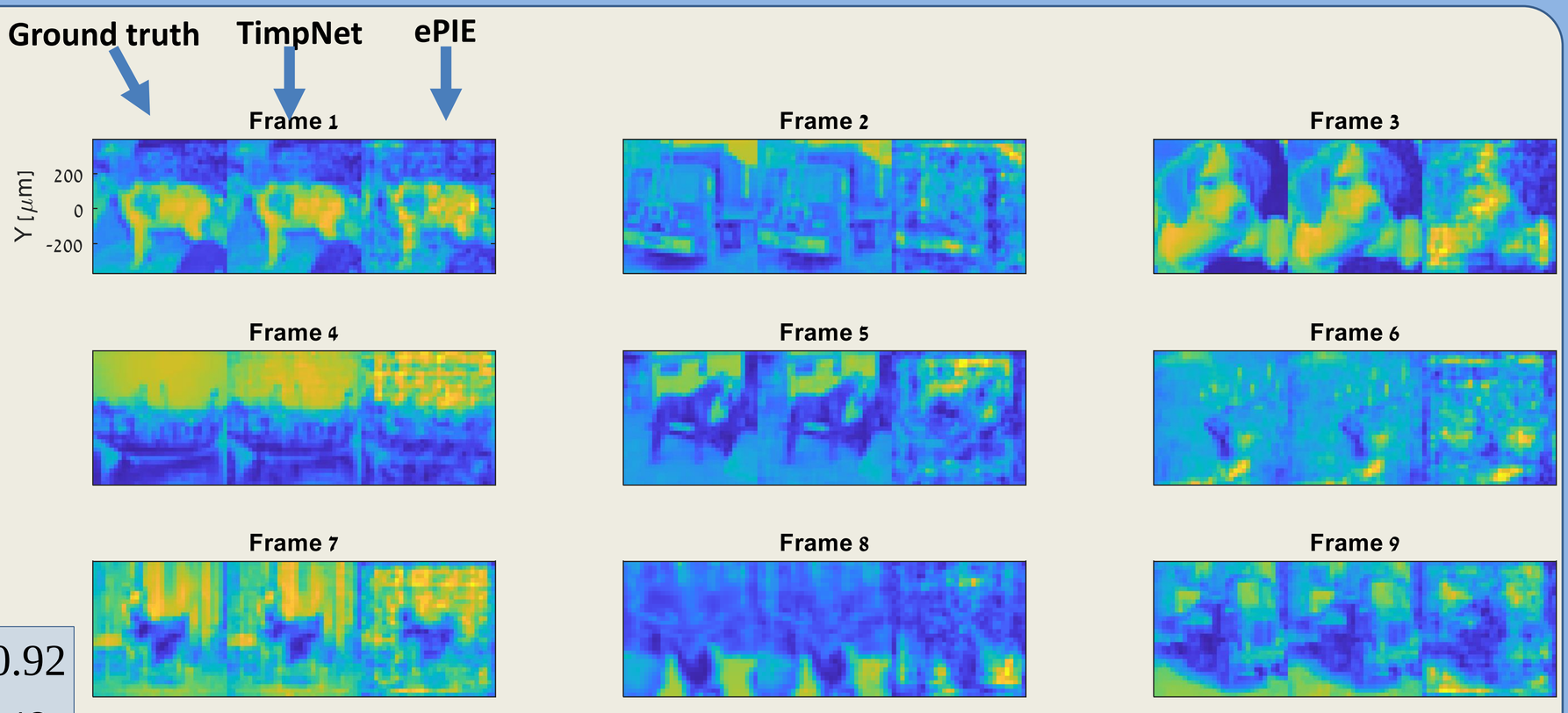
(5) Numerical Results

5x5 grid:

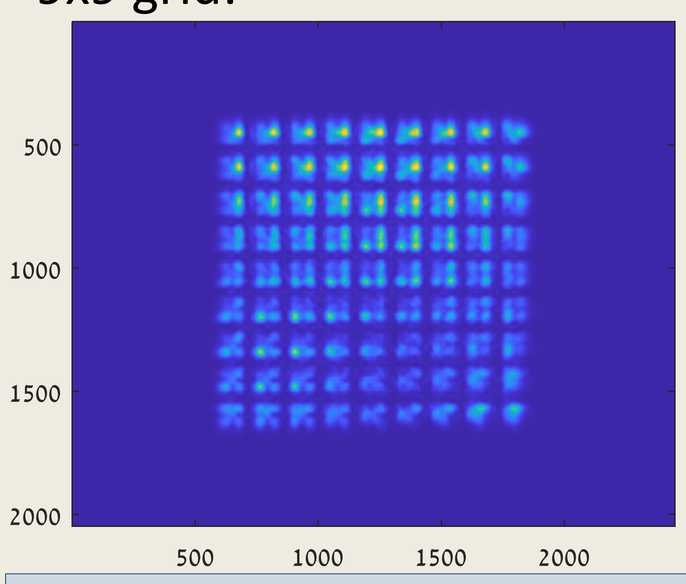


$PSNR_{TimpNet} = 28[dB]$ $SSIM_{TimpNet} = 0.92$

$PSNR_{ePIE} = 17[dB]$ $SSIM_{ePIE} = 0.48$

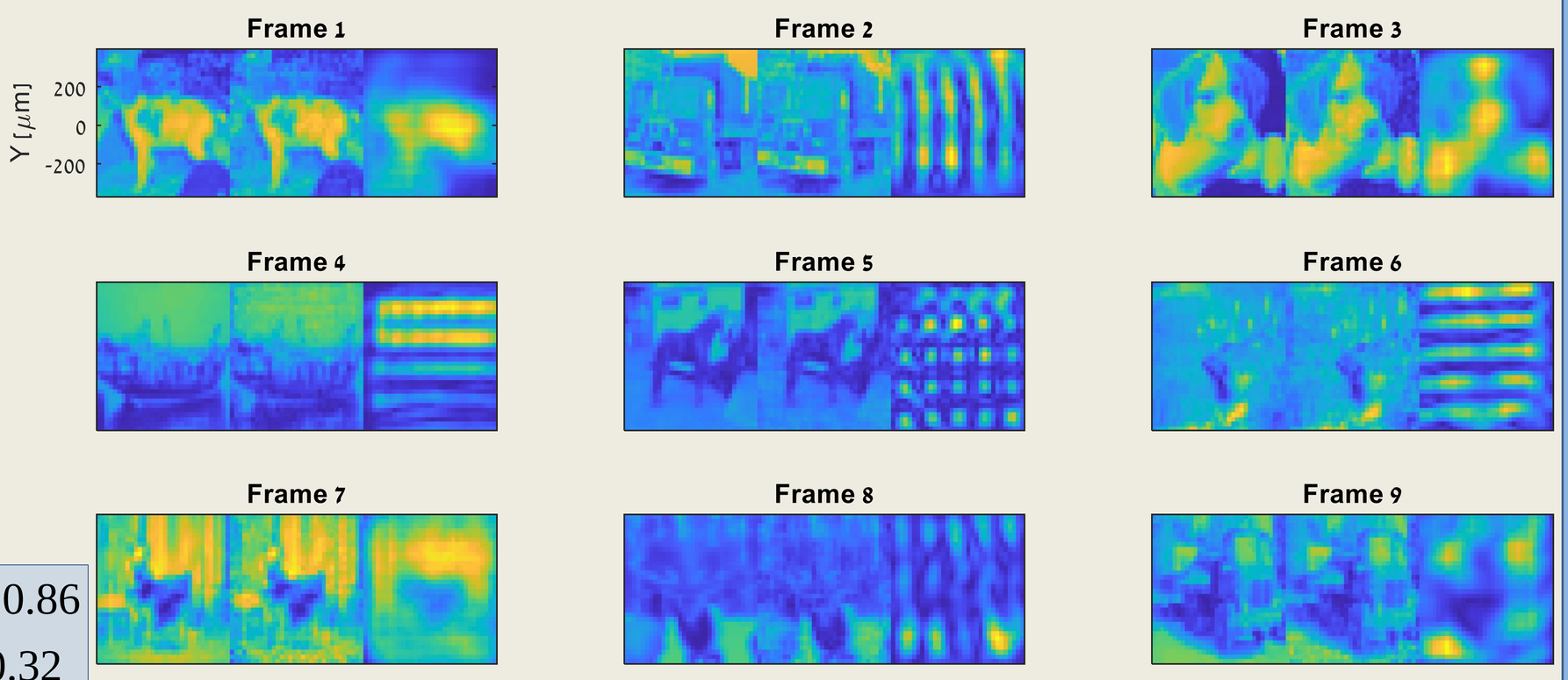


9x9 grid:



$PSNR_{TimpNet} = 25[dB]$ $SSIM_{TimpNet} = 0.86$

$PSNR_{ePIE} = 13[dB]$ $SSIM_{ePIE} = 0.32$



Conclusions

- First NN-based method for reconstruction of TIMP
- Forward model required instead of large dataset.
- Simpler network than required for a supervised learning approach.
- Better results than the commonly used iterative algorithms:
  - Higher reconstruction quality
  - Lower sensitivity to the number of frames.

References

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4. O. Wengrowicz et al., Opt. Express28, 17511-17520 (2020).
5. P. Li et al, Opt. Express 24(8), 9038–9052 (2016).

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