Nanjing University
Computational
Perception Lab
南京大学计算感知实验室
https://computationalperceptionlab.github.io/

Fisher Information Guidance for Learned Time-of-Flight Imaging

Jiaqu Li, Tao Yue, Sijie Zhao, Xuemei Hu
School of Electronic Science and Engineering, Nanjing University, Nanjing, China

Challenge

- **Coding Functions**

[Lange et al.QE 2001]

[Grootjans *et al.* LEOS 2006]

[Ferriere et al. OE 2008]

[Gupta *et al.*ToG 2018]
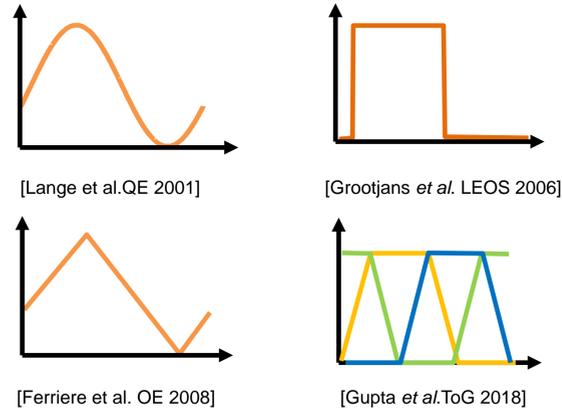
- **Depth Reconstruction Algorithm**

  ➢Conventional:

  N-quad [Hansard *et al.* Spring 2012]

  ZNCC [Mirdehghan *et al.* CVPR 2018]

  ➢Learning based:

  Raw data → Depth

  [Su *et al.* CVPR 2018;
  Agresti *et al.* CVPR 2019]
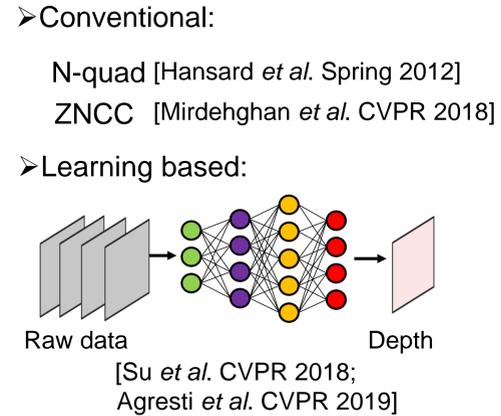
Depth accuracy of existing iToF imaging schemes under low SNR is still **limited**

Jointly Optimize

Coding Functions

Reconstruction Network

1.Suffer from nosie
2.Gradient vanishing

Local minimum   global minimum
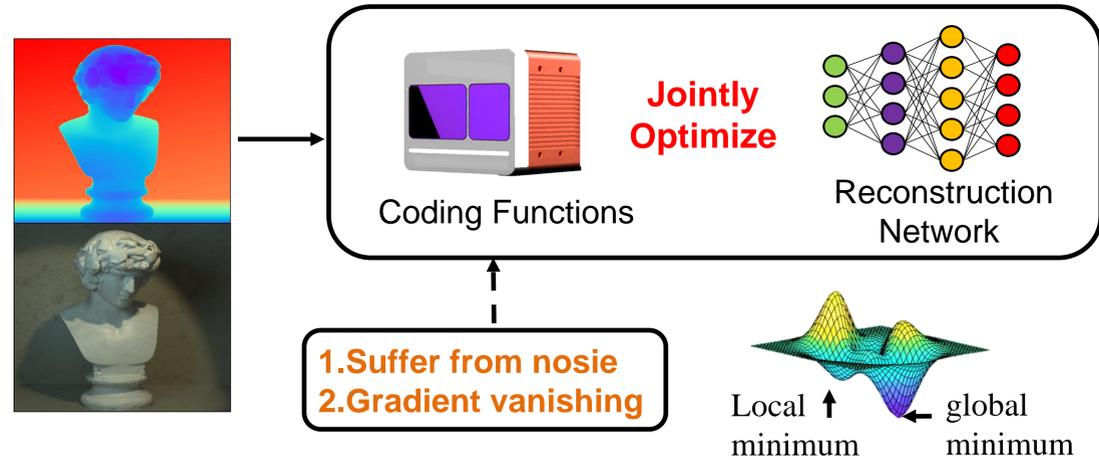
Contribution

- We *propose* a Fisher-information guided learning framework.
- We *model* the physical constraints of iToF system to learn the physical implementable coding functions.
- We *introduce* discriminative fisher loss to maximize the depth information that could be encoded.
- We *build* a prototype system that can implement iToF imaging with arbitrary coding functions.

Method

- **Overview of the proposed fisher information guided framework**

Differential Physical Imaging Model

Discriminative Fisher Loss
$$L_{fisher} = -\sum_p I_{fisher}, \qquad L_{dis} = -\sum_p Dis$$

Light Falloff

Power Constraint   Positive Constraint

Bandwidth Limit

Measurements

$L_{fidelity}$

Reconstruction Network   Error

Modulation1   Demodulation1   Demodulation2   Demodulation3   Demodulation4
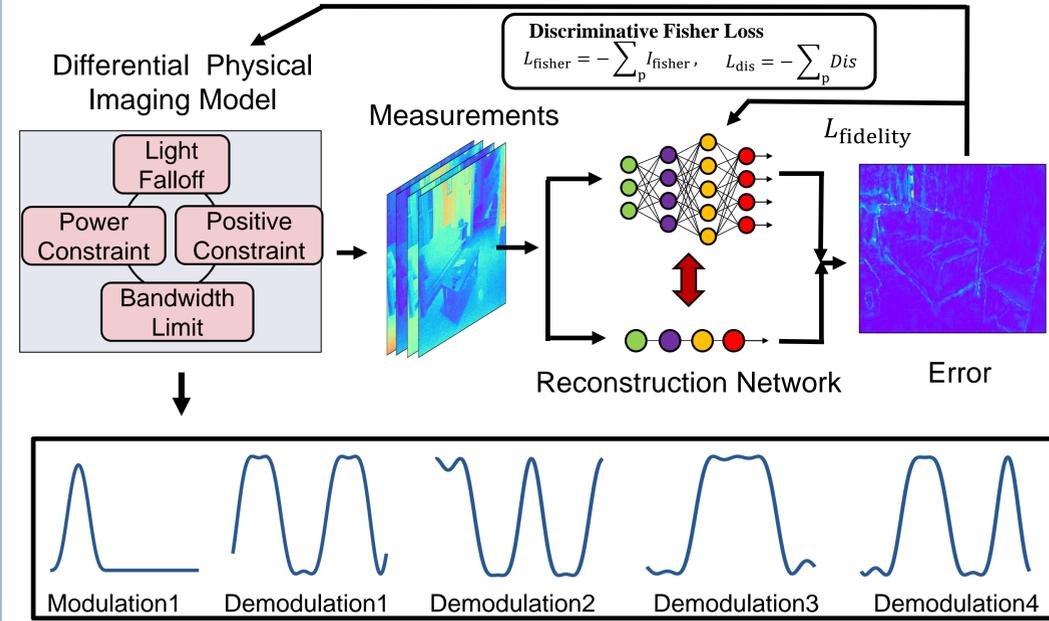
- **Dual-branch depth reconstruction network**

W/8×H/8×256
W/4×H/4×128
W/2×H/2×64
W×H×32

W×H×4

Resize & concate

Measurements

Inter-branch feature fusion

W×H×4   W×H×64   W×H×128

W/8×H/8×256
W/4×H/4×128
W/2×H/2×64
W×H×32

W/8×H/8
W/4×H/4
W/2×H/2
W×H

Attention map

Attention map   Depth map

Depth map

Reconstructed Depth

W×H×64   W×H×4

Upsample X2

Cross-scale Feature Fusion Block   Point-wise Residual Block   Dense Block

3×3 Convolution   Batch Normalization   Prelu   Channel Maxpooling   Channel Avgpooling   Ⓢ Softmax   Ⓒ Concate   ⊕ Add

Experiments

- **Overall comparisons in synthetic experiments**

High SNR → Low SNR

Scene   GT   Sinusoid + PS   Square + PS   Hamilton   Sine + DeepToF   Ours
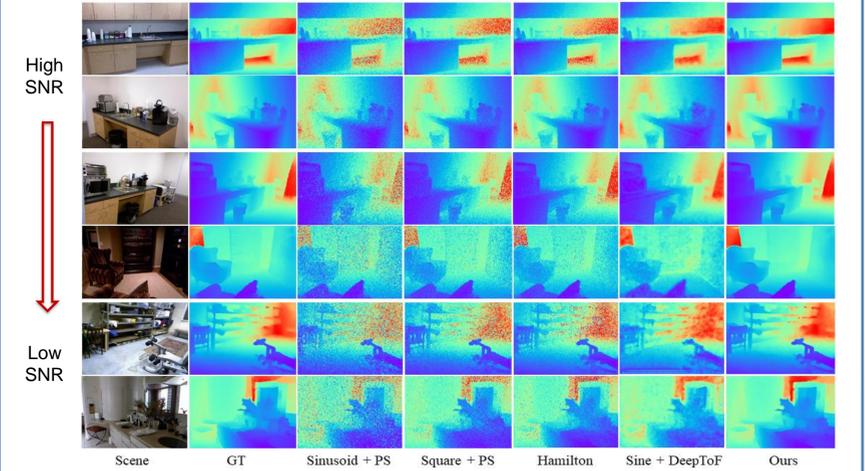
- **Prototype iToF imaging system**

Galvo-scanner
Laser Diode
Arbitrary Signal Generator
Power Source
Beamsplitter
Lens
APD
Laser Driver & Temprature Controller
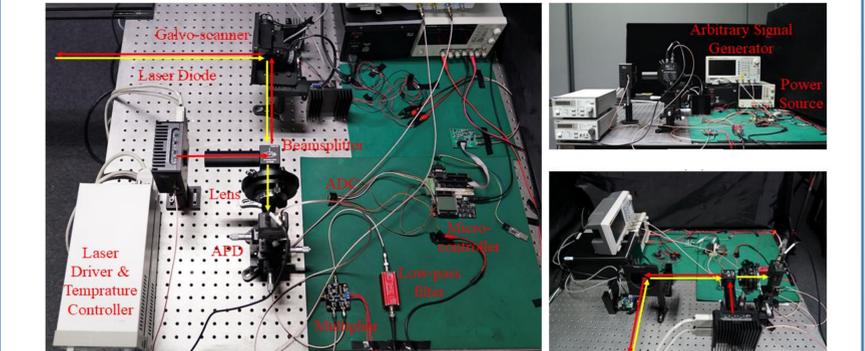
- **Overall comparisons in physical experiments**

Scene   Square + PS   Sine + DeepToF   Hamilton   Ours