Training Image Estimators \textit{without} Image Ground-Truth

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Imaging + ML = ❤️
Imaging + ML = ♥

Practical Measurements
Imaging + ML = ❤️

- Practical Low-Quality
- High-Quality Impractical
Imaging + ML = ❤️

Practical Measurements & High-Quality Images
Imaging + ML = 💖

At test time,
Imaging + ML = ❤

At test time,
Imaging + ML = ❤️
Imaging + ML = ❤️

Training requires high-quality ground-truth (impractical to measure)
Imaging + ML = ❤

Training requires many high-quality ground-truth images (impractical to measure)
Imaging + ML = 💘

Training requires many many high-quality ground-truth images (impractical to measure)
Unsupervised Learning

Standard Supervised Training

Our Training Approach
Unsupervised Learning

Standard Supervised Training

Our Training Approach
Unsupervised Learning

Standard Supervised Training

Our Training Approach
Unsupervised Learning

\[ y = x + \epsilon \]

Noise2Noise [Lehtinen et al., ICML 2018]
Unsupervised Learning

\[ y = x + \epsilon \]

Noise2Noise [Lehtinen et al., ICML 2018]
Unsupervised Learning

\[ y = \theta x + \epsilon \]

General Linear Measurement Model
Unsupervised Learning

Compressive Sensing
(different sensing matrices)

for images, videos, multispectral data ...

General Linear Measurement Model

\[ y = \theta x + \epsilon \]
Unsupervised Learning

In-painting
(different masked pixels)

\[ y = \theta x + \epsilon \]

General Linear Measurement Model
Unsupervised Learning

Deblurring
(different blur kernels)

\[ y = \theta \ x + \epsilon \]

General Linear Measurement Model
Unsupervised Learning

$\theta_1$  
\[ \theta_1 \]

Measurement 1

$\theta_2$

Measurement 2

Unsupervised Training

$y = \theta x + \epsilon$

General Linear Measurement Model
Unsupervised Learning

Measurement Parameters also unknown during training

Blind Unsupervised Training

\[ y = \theta x + \epsilon \]

General Linear Measurement Model
Sketch of Training Approach
Sketch of Training Approach

- measurement
- measurement
Sketch of Training Approach

measurement → [Image]
measurement → [Image] → [Network] → [Image]
measurement → [Image] → [Network] → [Image]
Sketch of Training Approach

Swap Loss

measurement

measurement
Sketch of Training Approach

Swap Loss

measurement

Assume measurement parameters are known
Sketch of Training Approach

Swap Loss

measurement

Assume measurement parameters are known

simulated measurement
Sketch of Training Approach

Swap Loss

measurement

simulated measurement
Sketch of Training Approach

Swap Loss
Sketch of Training Approach

Swap Loss

measurement

simulated measurement

Swap Loss
Sketch of Training Approach

If measurement parameters per image are *random* and *diverse*
across the training set,

swap loss provides *full* supervision
Sketch of Training Approach
Sketch of Training Approach: **Blind Setting**
Sketch of Training Approach: Blind Setting
Sketch of Training Approach: **Blind Setting**

Parameter Estimation Network

Image Estimation Network
Sketch of Training Approach: **Blind Setting**

Parameter Estimation Network → Image Estimation Network → Trained Simultaneously
Sketch of Training Approach: **Blind Setting**

- **Parameter Estimation Network**
- **Image Estimation Network**

*Trained Simultaneously*
Sketch of Training Approach: **Blind Setting**

Parameter Estimation Network

Image Estimation Network

*Trained Simultaneously*
Experiments

• Compressive Sensing Reconstruction
  Non-blind unsupervised training

• Blind Motion Deblurring of Face Images
  Non-blind and Blind unsupervised training
Experiments: Compressive Sensing
Experiments: Compressive Sensing

PSNR (dB)

<table>
<thead>
<tr>
<th>Compression Ratio</th>
<th>Supervised Baseline</th>
<th>Unsupervised</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>17.88</td>
<td>17.84</td>
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<tr>
<td>4%</td>
<td>22.61</td>
<td>22.20</td>
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<tr>
<td>10%</td>
<td>26.74</td>
<td>26.33</td>
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</tbody>
</table>
Experiments: Compressive Sensing

Ground Truth

Supervised Baseline

Unsupervised
Experiments: Blind Face Image Deblurring
Experiments: Blind Face Image Deblurring

- **Supervised Baseline**
- **Unsupervised**
- **Unsupervised Blind**

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Supervised Baseline</th>
<th>Unsupervised</th>
<th>Unsupervised Blind</th>
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</thead>
<tbody>
<tr>
<td>Helen</td>
<td>26.13</td>
<td>25.95</td>
<td>25.93</td>
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<tr>
<td>CelebA</td>
<td>25.20</td>
<td>25.09</td>
<td>25.06</td>
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Experiments: Blind Face Image Deblurring

Ground Truth

Blurry Input

Supervised Baseline

Unsupervised

Unsupervised Blind
Experiments: Blind Face Image Deblurring

Blurry Input

Ground Truth

Unsupervised Blind
Experiments: Blind Face Image Deblurring

Blurry Input  Ground Truth  Unsupervised Blind

[Images of blurry faces and corresponding ground truths and deblurred images]
Visit our poster for more details!

Project Page with Code & Models

https://projects.ayanc.org/unsupimg/