

# Training Image Estimators without Image Gound-Truth

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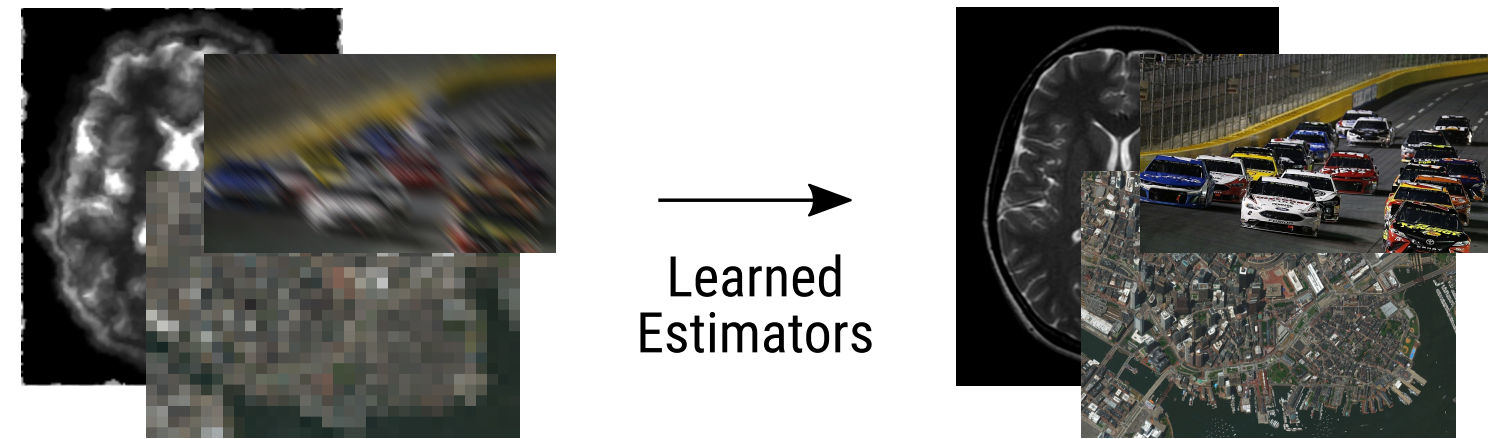
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<https://projects.ayanc.org/unsupimg>

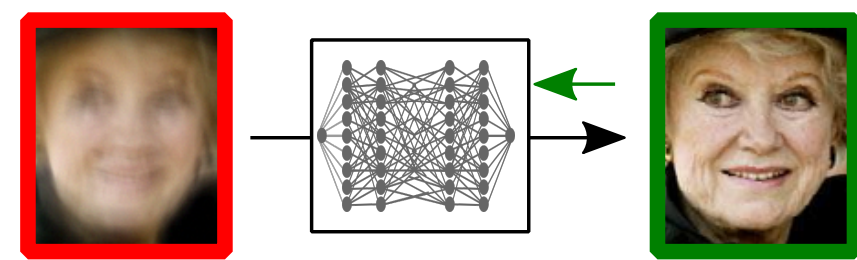
## Overview

### Motivation



Practical Measurements  
(Incomplete / Imperfect)

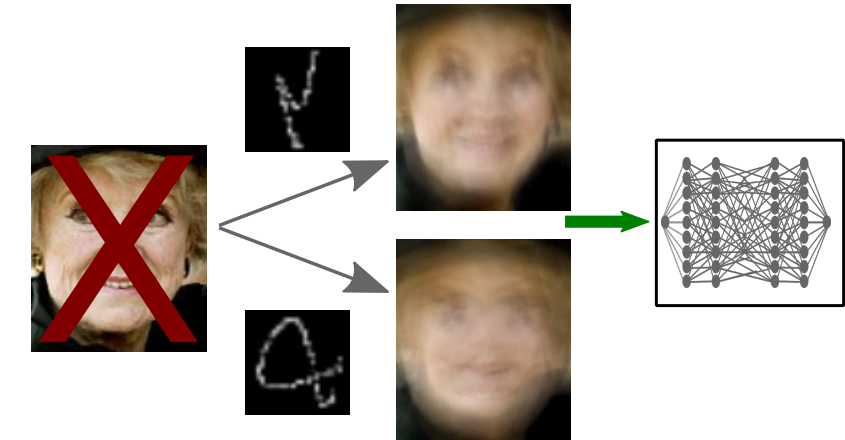
High-quality Images



Standard supervised training  
requires a large training set  
with ground-truth data.

**But these are hard to measure.**

### Proposed Method



Train on pairs of different  
measurements of same image,  
**without ground-truth for image !**

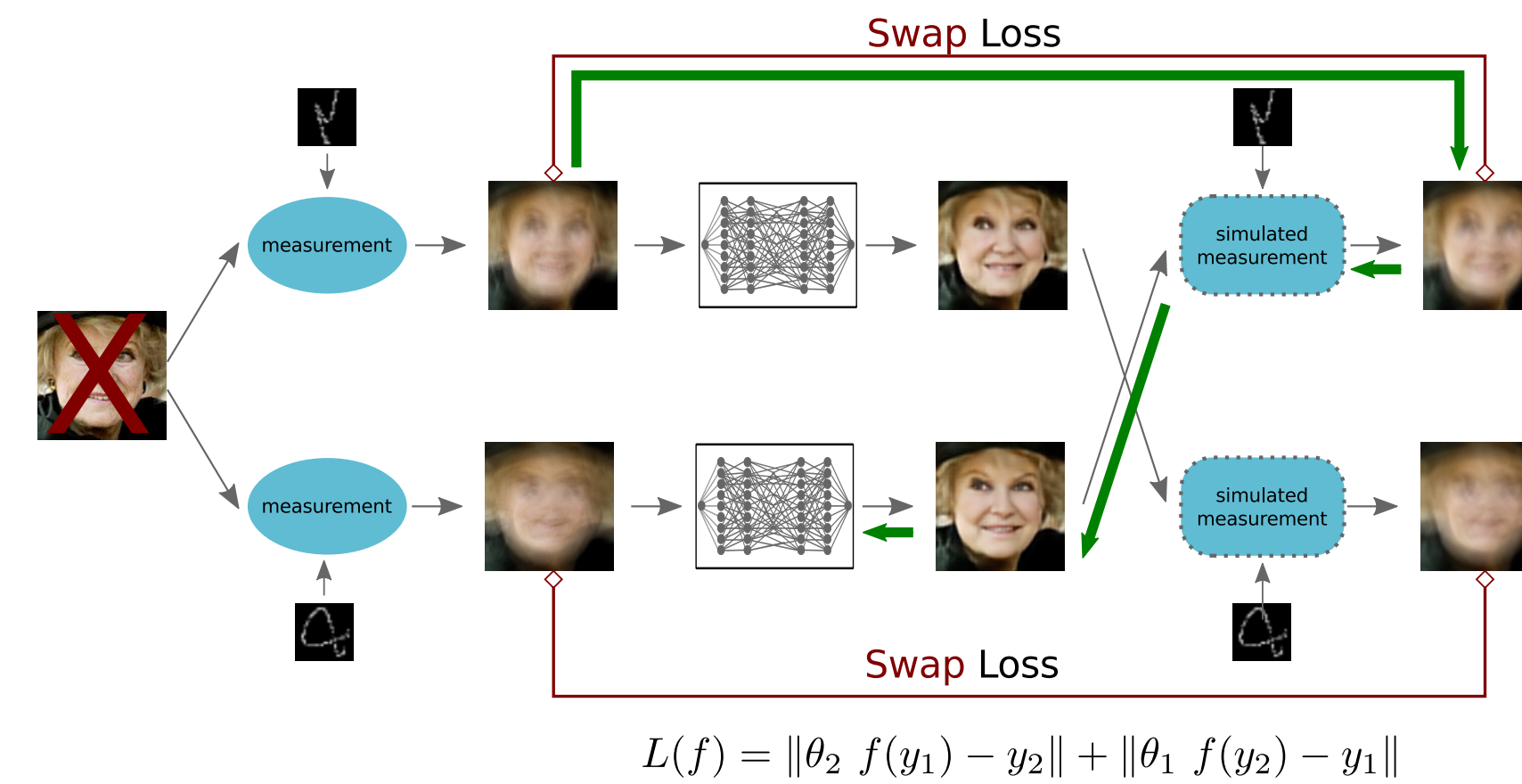
Noise2Noise [Lehtinen et al., 2018]: Train denoisers with noisy pairs.

Our Approach:

- Estimators for general linear measurement models. Useful for *compressive sensing, deblurring, inpainting, ...*
- Trains on pairs with different measurement parameters.
- Supports blind training when these parameters unknown.

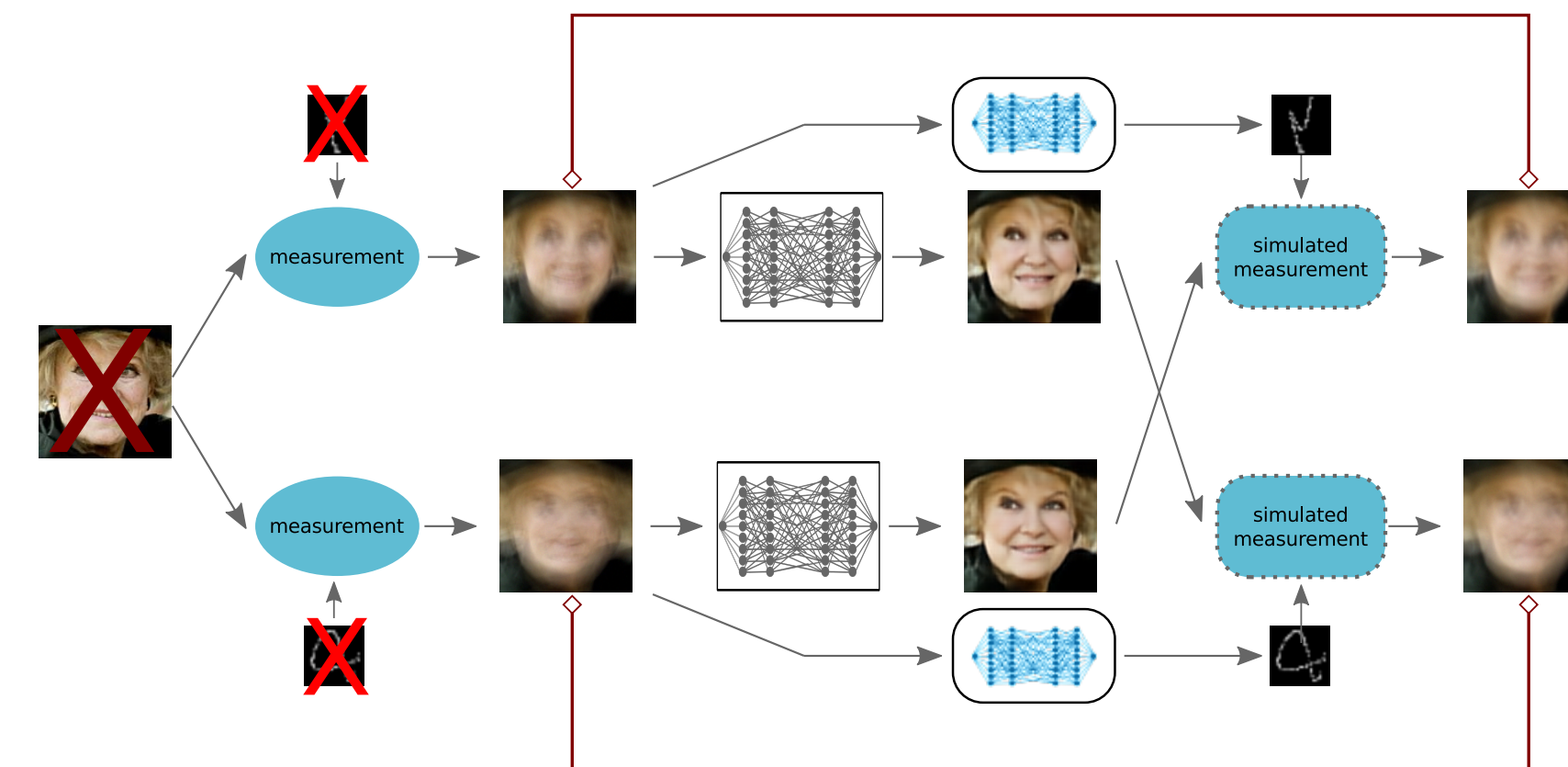
- Linear Measurement Model:  $y = \theta x + \epsilon$ ;  $\theta$  is low-rank and non-invertible.
- Train a network  $f$  to estimate image  $\hat{x} = f(y)$  from a single measurement.
- Train on measurement pairs  $y_1$  &  $y_2$ , made with parameters  $\theta_1$  &  $\theta_2$ . ( $[\theta_1^T, \theta_2^T]^T$  together is also non-invertible)
- Unsupervised:  $x$  is unknown during training.  
Blind Unsupervised:  $\theta_1$  &  $\theta_2$  also unknown.

## Unsupervised Training

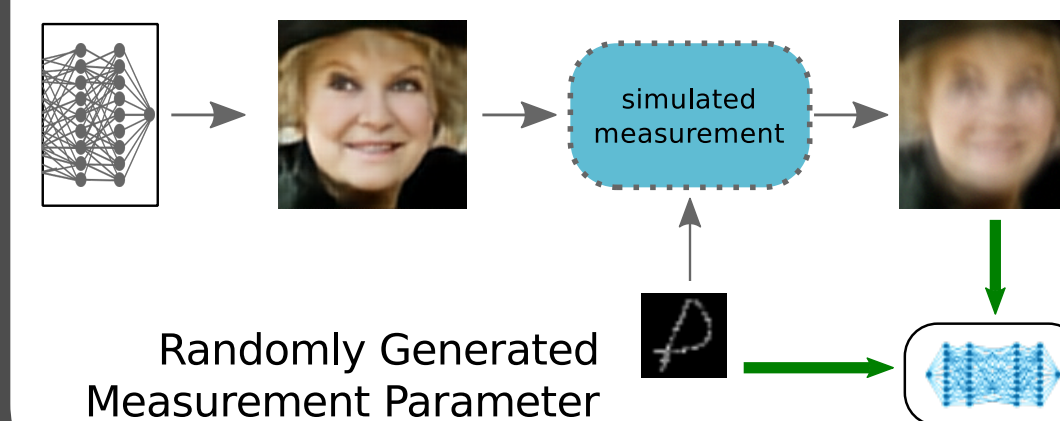


- Show that this provides "full supervision" if measurement parameter pairs are random, and *diverse*:  $\mathbb{E}(\theta\theta^T)$  is full-rank.

## Blind Unsupervised Training



- Use a second *parameter estimation* network. But how do we train this ?
- Train both networks simultaneously, using image network outputs to create **a synthetic proxy training set.**



- Generate measurements for which we know true parameter and image.
- Use to train paramater network, & augment training of image network.

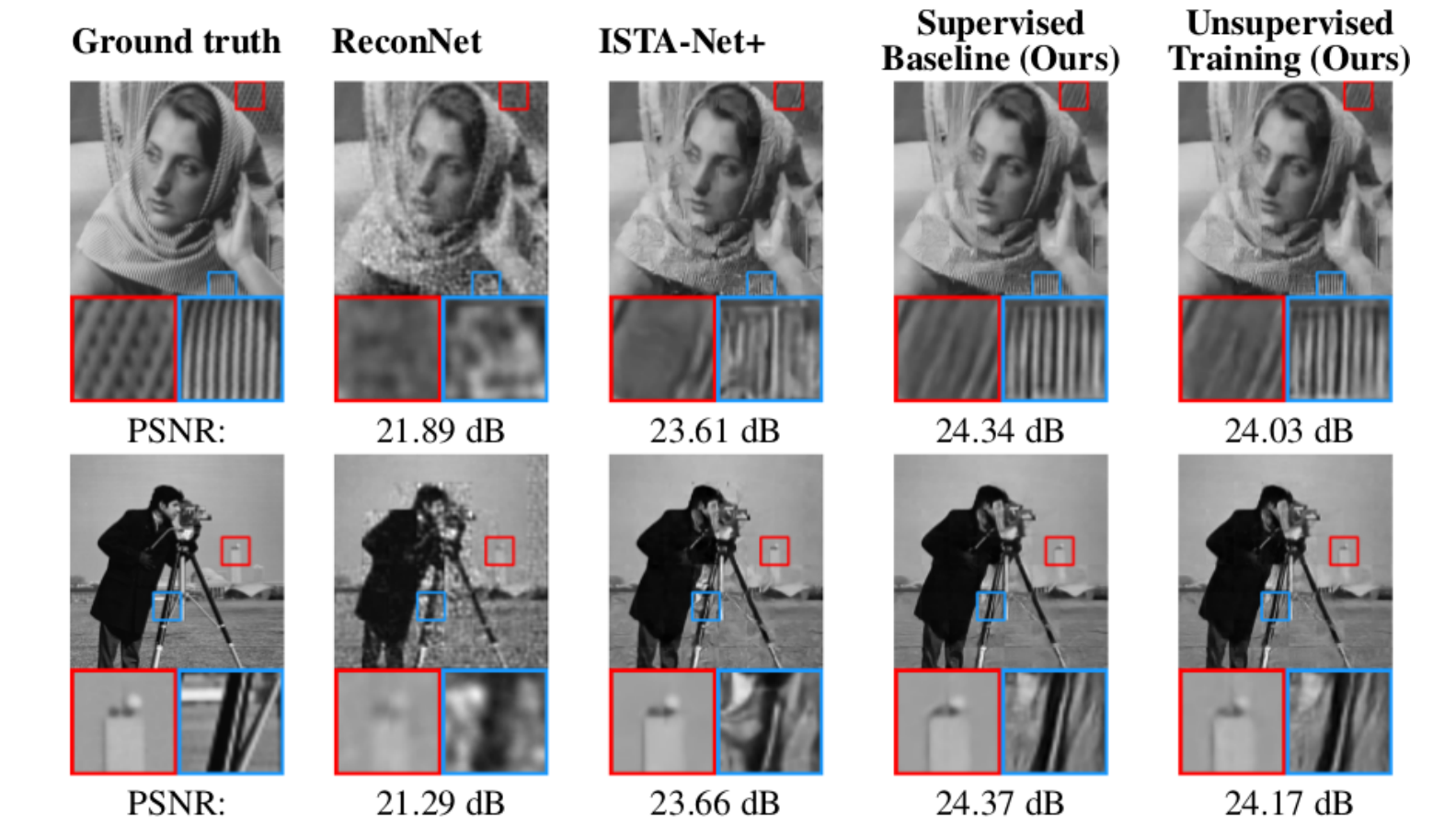
## Experimental Results

### Compressive Sensing

- Patch-wise Compressive Measurement: Linear low-rank matrices applied to 33x33 patches.
- Compression ratio = No. of measurements per patch / pixels in patch.
- Make two measurements using same matrix applied to randomly shifted patches.

Method	Supervised	BSD68			Set11		
		1%	4%	10%	1%	4%	10%
ISTA-Net+	✓	19.14	22.17	25.33	17.34	21.31	26.64
Supervised Baseline (Ours)	✓	<b>19.74</b>	<b>22.94</b>	<b>25.57</b>	<b>17.88</b>	<b>22.61</b>	<b>26.74</b>
Unsupervised Training (Ours)	✗	19.67	22.78	25.40	17.84	22.20	26.33

Reconstruction Quality in PSNR (dB)



### Blind Face Image Motion Deblurring

- Blind motion deblurring task for face images: blur kernel unknown at test time.
- Make measurements with different blur kernels.
- Consider both non-blind vs blind training: i.e., kernels known vs unknown during training.

Method	Supervised	Helen		CelebA	
		PSNR	SSIM	PSNR	SSIM
Xu et al.	✗	20.11	0.711	18.93	0.685
Shen et al.	✓	25.99	0.871	25.05	0.879
Supervised Baseline (Ours)	✓	<b>26.13</b>	<b>0.886</b>	<b>25.20</b>	<b>0.892</b>
Unsupervised Non-blind (Ours)	✗	25.95	0.878	25.09	0.885
Unsupervised Non-blind (Ours) without proxy loss	✗	25.47	0.867	24.64	0.873
Unsupervised Blind (Ours)	✗	25.93	0.876	25.06	0.883

