Paper Review: PULSE: Self-Supervised Photo Upsampling via Latent Space Exploration of Generative Models

Abdullah Mamun

June 28, 2021

About this paper

PULSE: Self-Supervised Photo Upsampling via Latent Space Exploration of Generative Models

Sachit Menon*, Alexandru Damian*, Shijia Hu, Nikhil Ravi, Cynthia Rudin
Duke University
Durham, NC
{sachit.menon,alexandru.damian,shijia.hu,nikhil.ravi,cynthia.rudin}@duke.edu

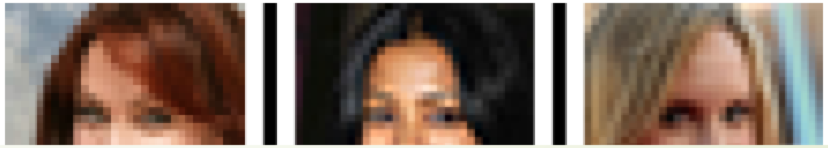
Abstract

The primary aim of single-image super-resolution is to construct a high-resolution (HR) image from a corresponding low-resolution (LR) input. In previous approaches, which have generally been supervised, the training objective typically measures a pixel-wise average distance between the super-resolved (SR) and HR images. Optimiz-

sible.

* denotes equal contribution

1. Introduction



About this paper

- Published in the **CVPR** conference in 2020.
- Cited by **54** as of June 28, 2021
- Main goal is to create realistic high-resolution images of people's faces from very low-resolution images.

Introduction

1. Introduction

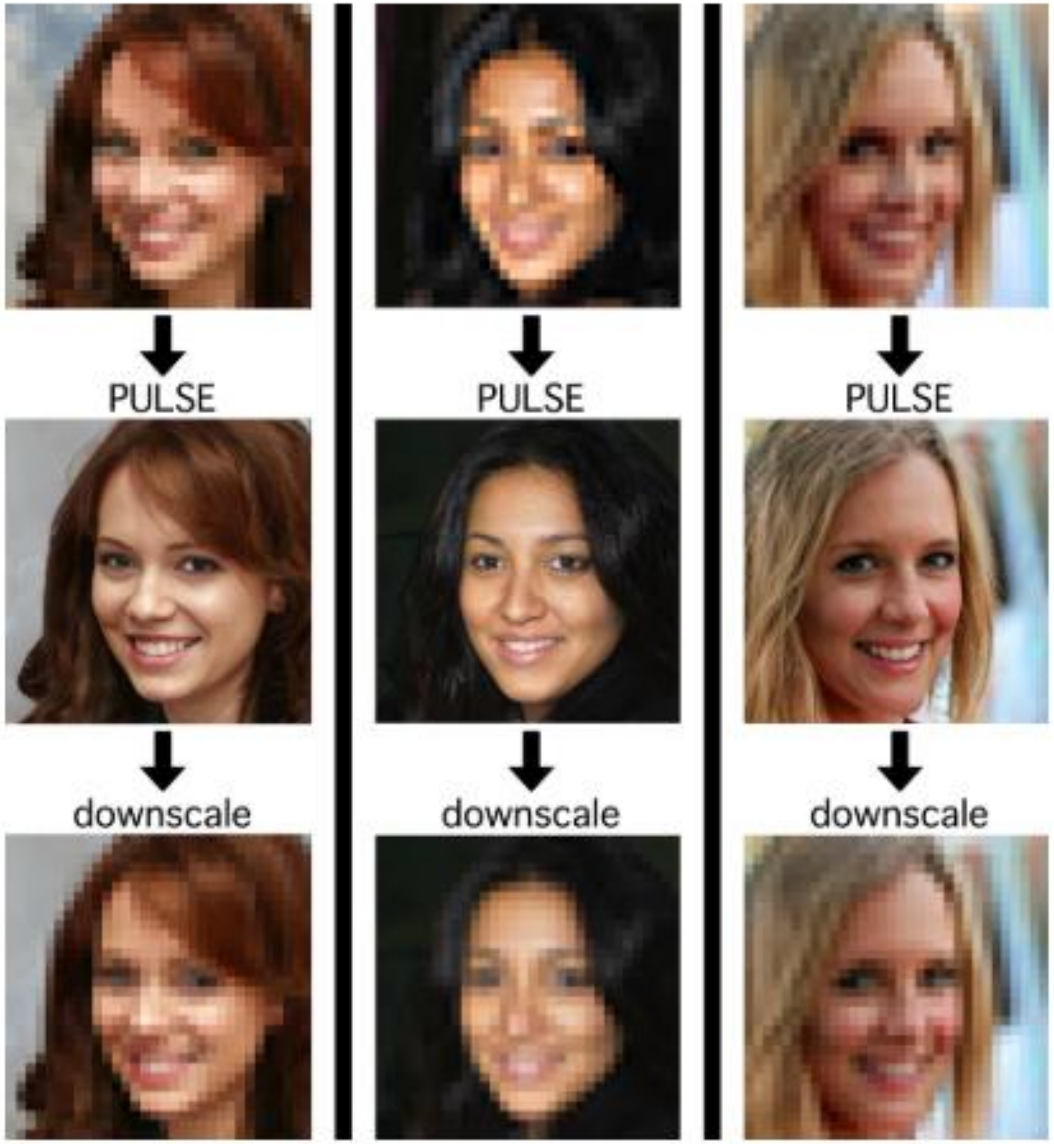


Figure 1. (x32) The input (top) gets upsampled to the SR image

Motivation

- High-resolution image data often difficult to obtain
- Consumer demand for high-resolution image capture higher than ever before
- Many downstream tasks require high-resolution images

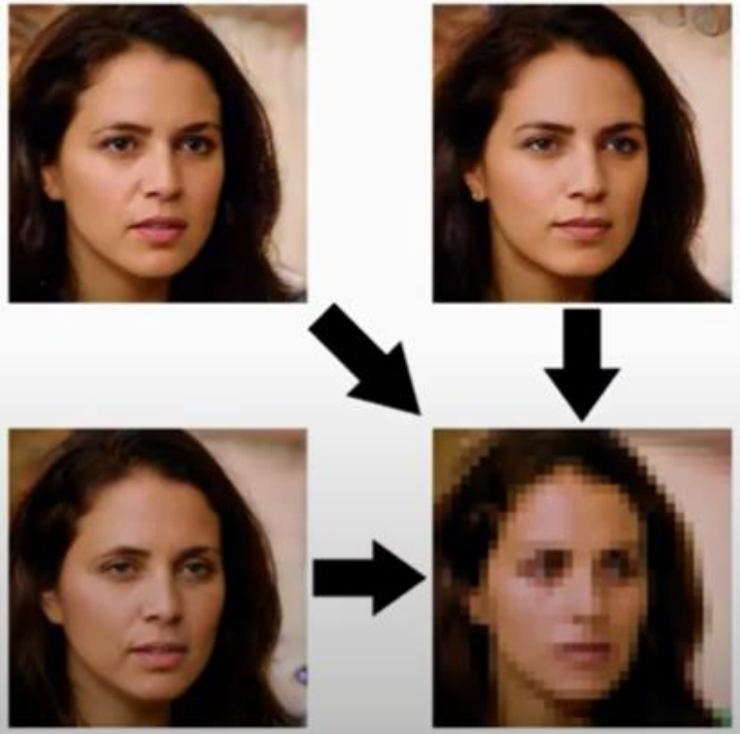
IMAGE SUPER-RESOLUTION

Construct high-resolution (HR) images from corresponding low-resolution (LR) input

Challenges

- Problem of recovering true HR image depicted by an LR input inherently ill-posed
  - Number of such images grows exponentially with scale factor (Baker and Kanade 2000)

<u>**MANY**</u> HR images can correspond to same LR image



Goal

GOAL

Generate realistic images within the set of feasible solutions

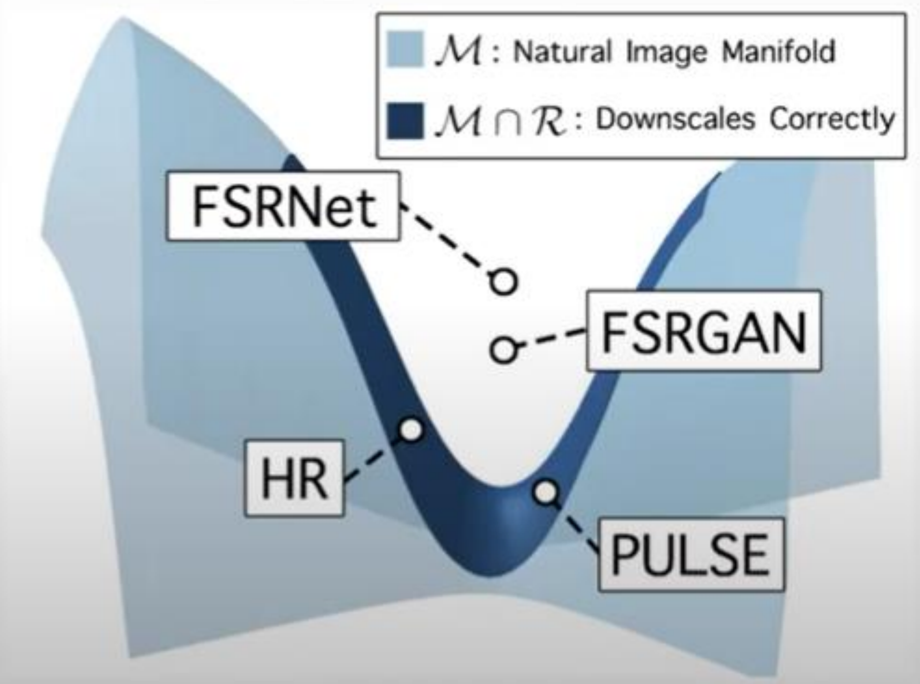
i.e., find points in $\mathcal{M} \cap \mathcal{R}$: points on $\mathcal{M}$ that also downscale correctly

$\mathcal{R}$: set of images that downscale correctly

Given I_{LR} & $\epsilon > 0$, want $I_{SR} \in \mathcal{M}$ s.t.

$$\|DS(I_{SR}) - I_{LR}\|_p \leq \epsilon$$

$DS(\cdot)$: Downscaling operator



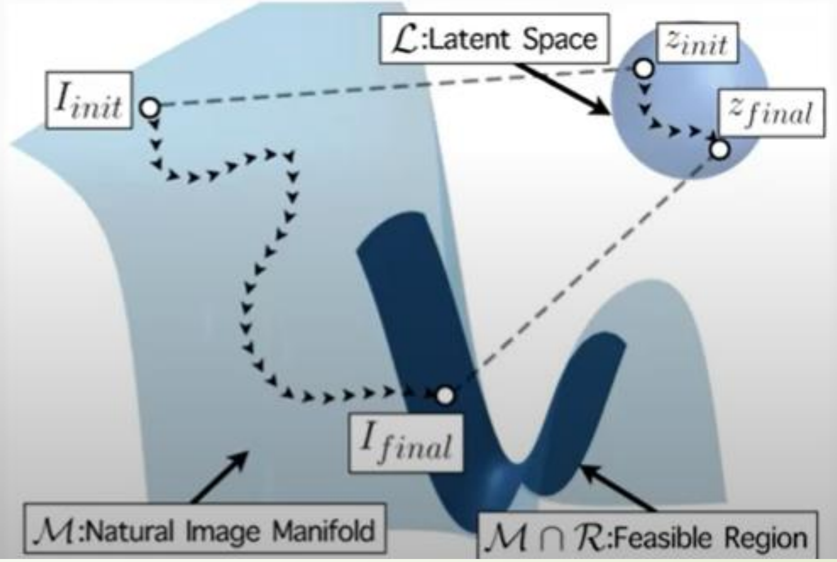
Idea

IDEA

Use generative models!

Given generator G with latent space $\mathcal{L}$ (i.e., $G : \mathcal{L} \to \mathbb{R}^{M \times N}$), find $z \in \mathcal{L}$ with $\|DS(G(z)) - I_{LR}\|_p^p \leq \epsilon$

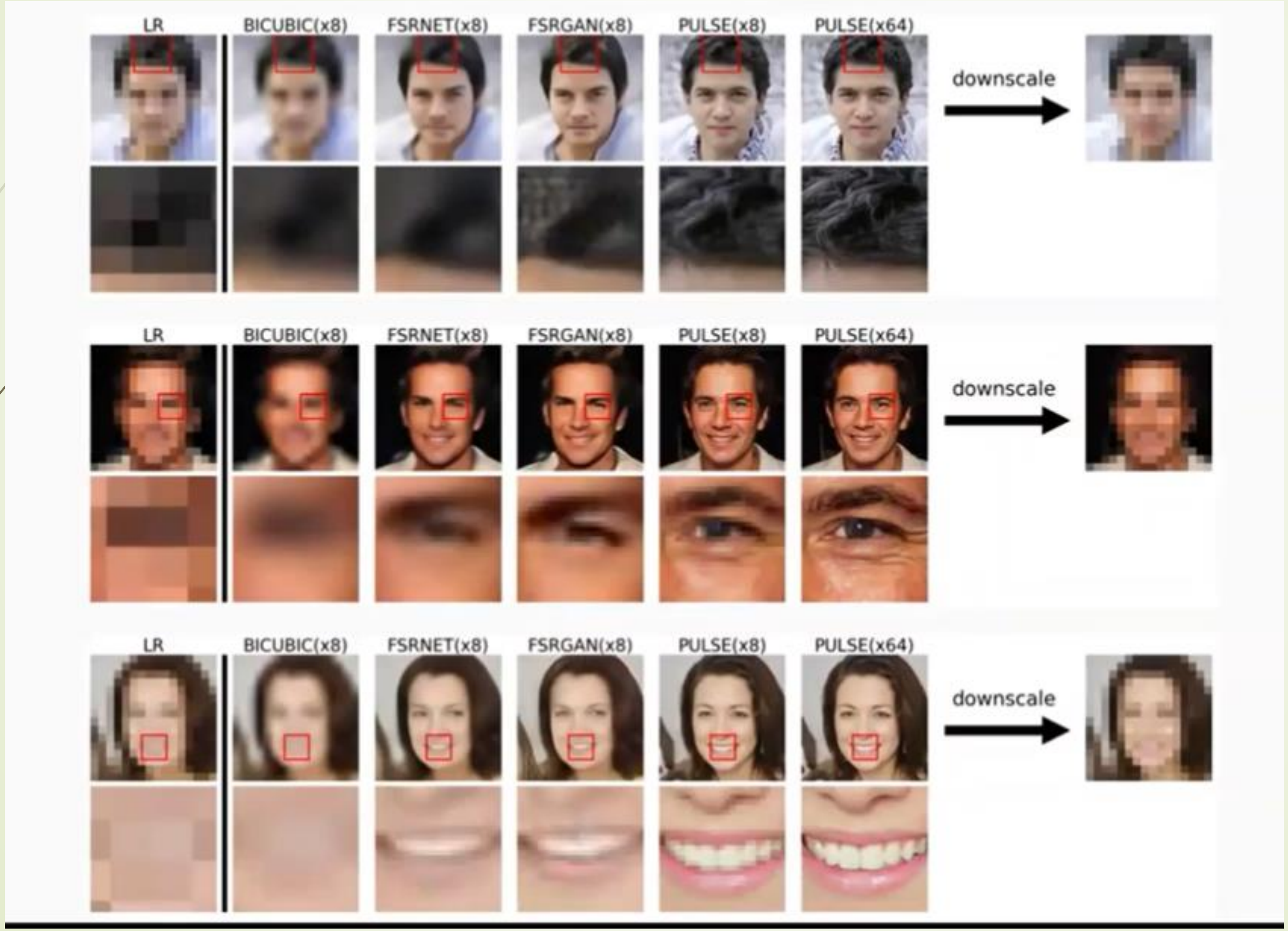
Simply requiring $z \in \mathcal{L}$ does <u>**NOT**</u> guarantee $G(z) \in \mathcal{M}$!



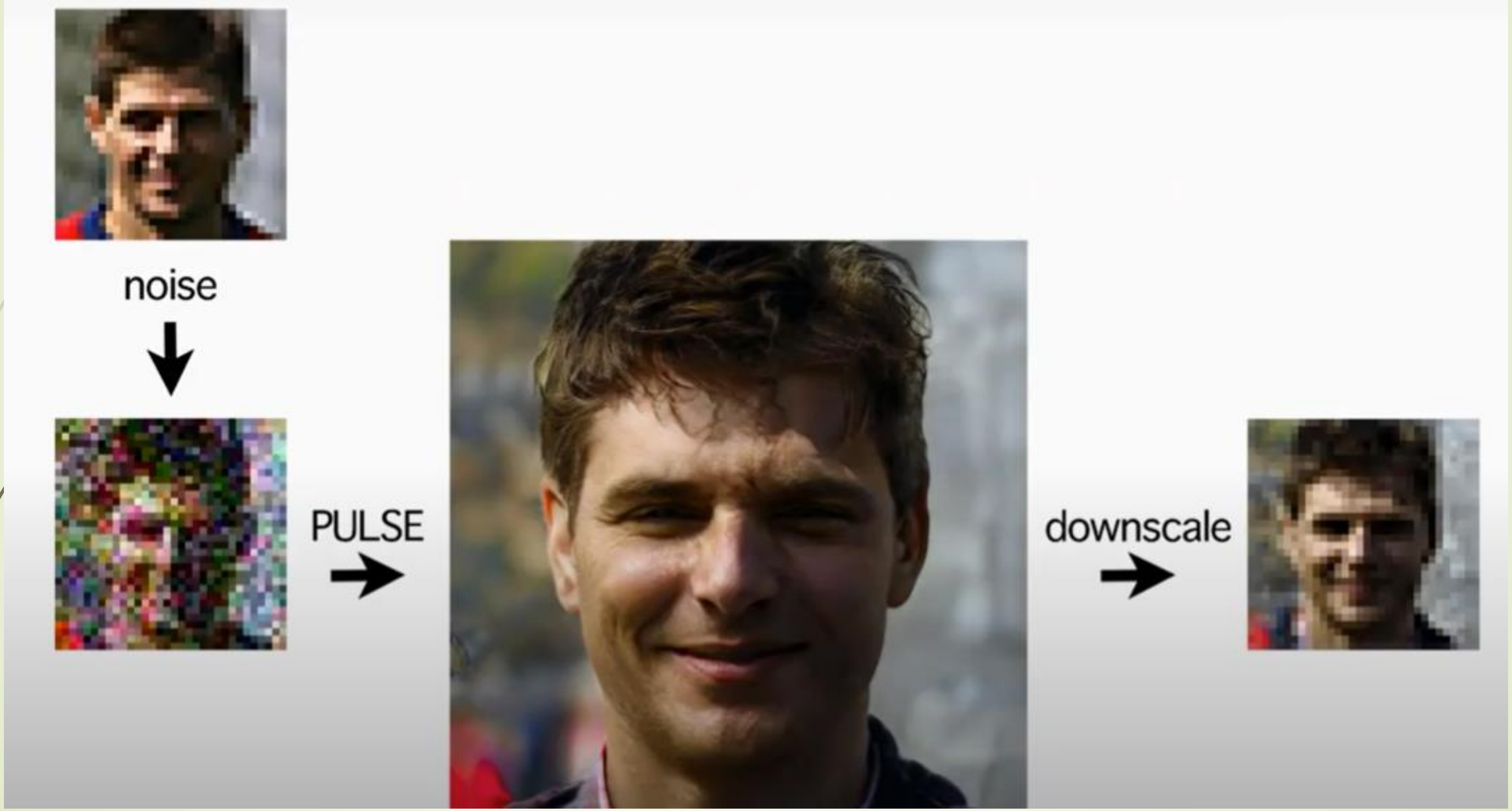
Methods

- Used StyleGAN (Karras et al. 2019) as generative model due to capacity to generate sharp images
- Used 100 steps of spherical gradient descent with a learning rate of 0.4 starting with random initialization
- Can generate samples with global variation using new initializations and with fine-level variation using inherent stochasticity of StyleGAN

Results


LR
BICUBIC(x8)
FSRNET(x8)
FSRGAN(x8)
PULSE(x8)
PULSE(x64)
downscale
LR
BICUBIC(x8)
FSRNET(x8)
FSRGAN(x8)
PULSE(x8)
PULSE(x64)
downscale
LR
BICUBIC(x8)
FSRNET(x8)
FSRGAN(x8)
PULSE(x8)
PULSE(x64)
downscale

Noise Tolerence



Contributions

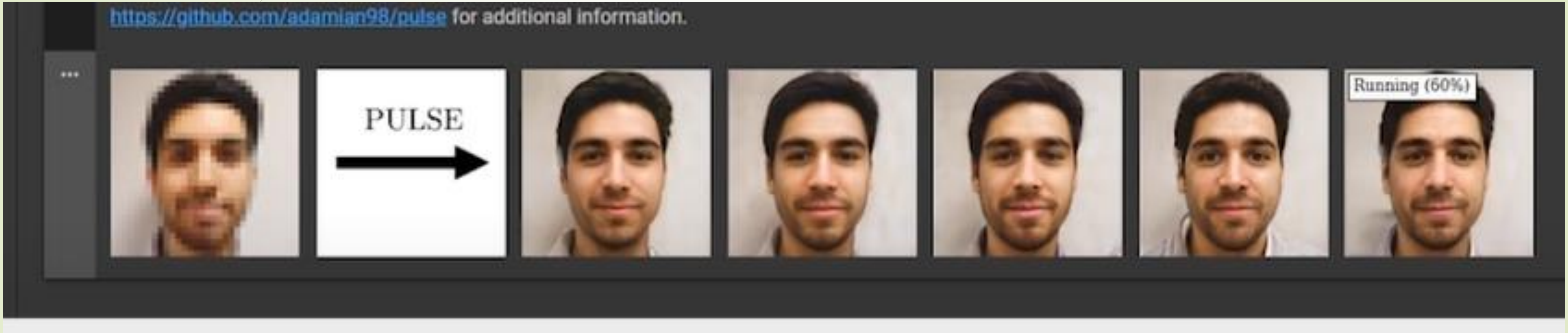
- New problem formulation for super-resolution
- Novel algorithm for addressing the super-resolution problem
  - Creates high-quality images at higher resolutions (1024×1024 vs 128×128) and higher scale factors ($32\times$ vs $8\times$) than state-of-the-art
  - Keeps up with advances in generative modeling without fundamental changes

Issue with privacy and security (below is a notice from their blog page)

We have noticed a lot of concern that PULSE will be used to identify individuals whose faces have been blurred out. We want to emphasize that this is impossible - PULSE makes imaginary faces of people who do not exist, which should not be confused for real people. It will **not** help identify or reconstruct the original image.

We also want to address concerns of bias in PULSE. **We have now included a new section in the paper and an accompanying model card directly addressing this bias.**

Issue with privacy and security



Thank You!

Contact: abdullahal.mamun1@wsu.edu