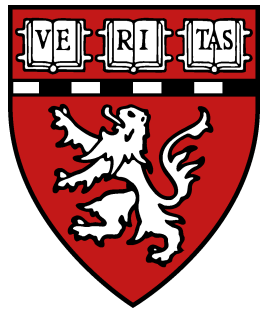

3D-StyleGAN: A Style-Based Generative Adversarial Network for Generative Modeling of Three-Dimensional Medical Images

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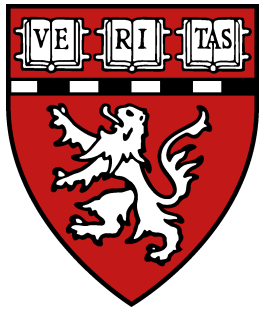
Anna Bonkhoff, MD (HMS)

Natalia S. Rost, MD, MPH (HMS)

Polina Golland, PhD (MIT)



Generative Modeling of 2D Natural Images

Randomly Generated Human Face Images*

* Karras, et al., “Analyzing and Improving the Image Quality of StyleGAN,” CVPR 2020.

Generative Modeling of 2D Natural Images

Expression Transfer Example*

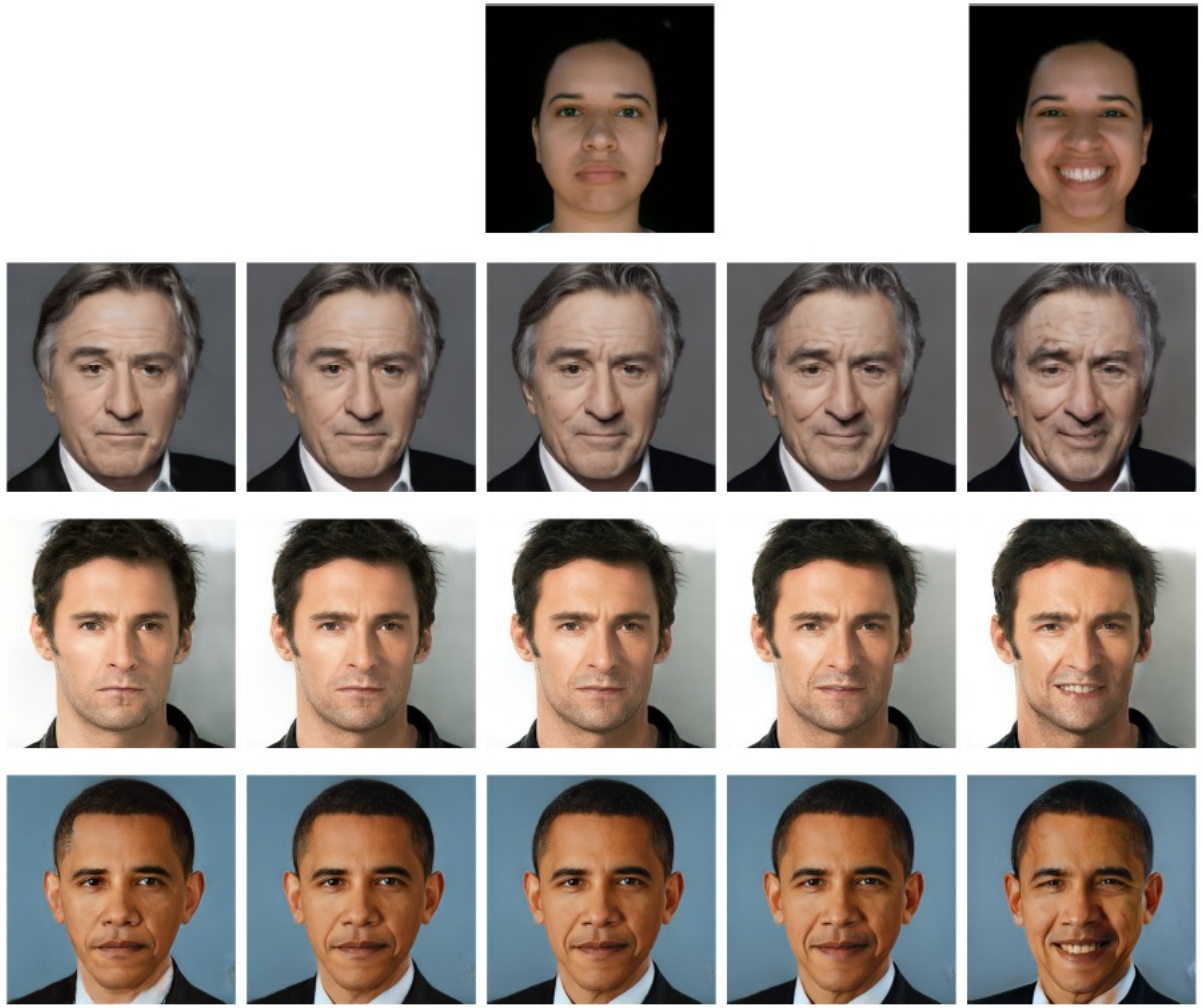
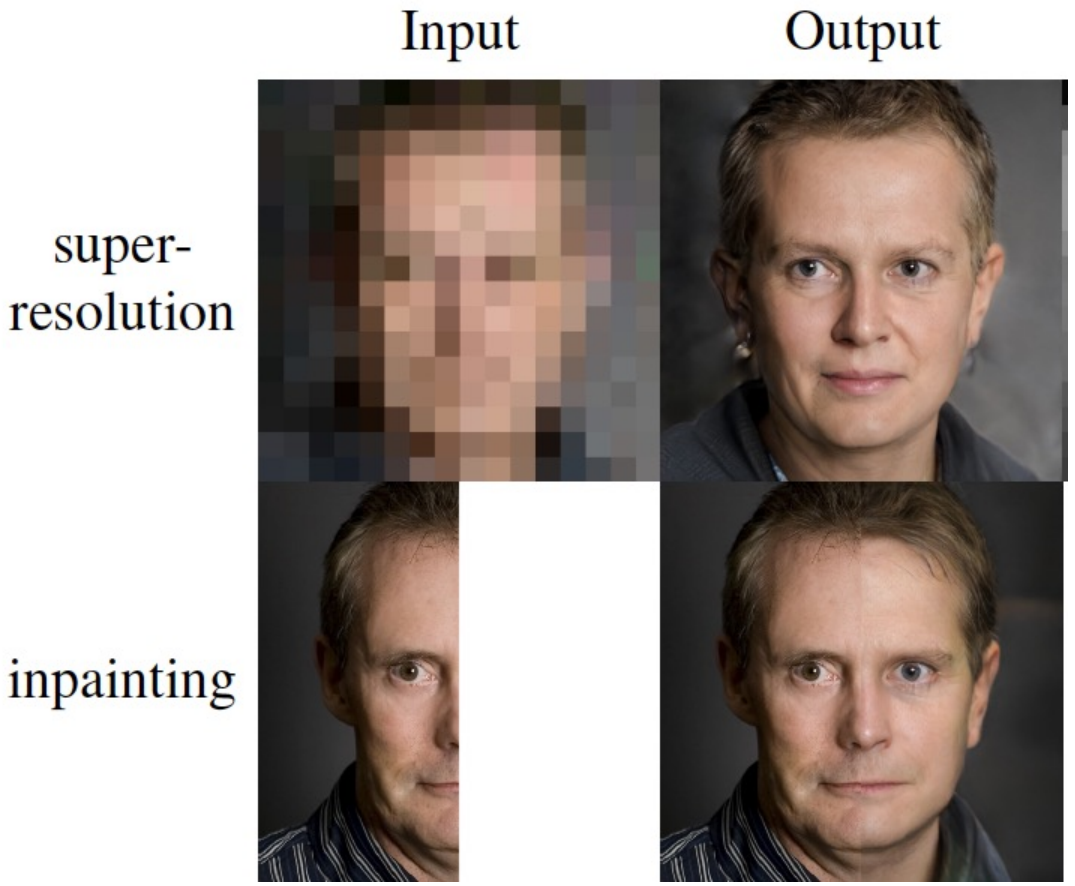


Image Enhancement Example**



** Marinescu, et al., “Bayesian Image Reconstruction using Deep Generative Models,” ArXiv 2020.

* Abdal, et al., “Image2StyleGAN: How to Embed Images Into the StyleGAN Latent Space?,” ICCV 2019.

Generative Modeling of 2D Medical Images

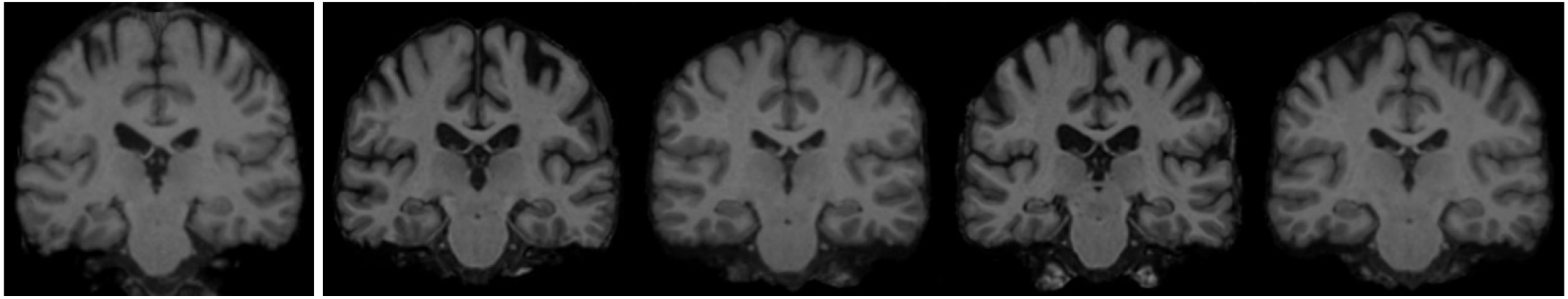
2D Medical Image Synthesis Examples*

Real

Generated (FID: 9.2)

Real

Generated (FID: 7.3)

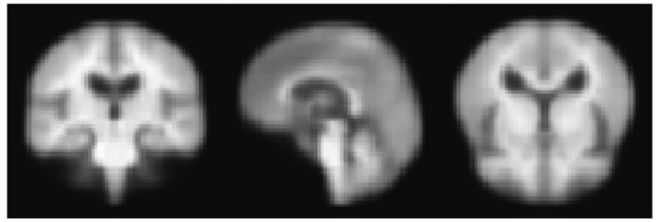


* Marinescu, et al., “Bayesian Image Reconstruction using Deep Generative Models,” ArXiv 2020.

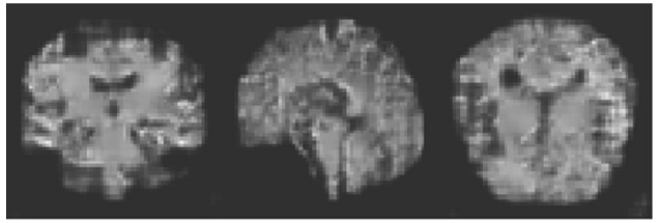
Generative Modeling of 3D Medical Images

Full 3D Medical Image Synthesis Examples*,**

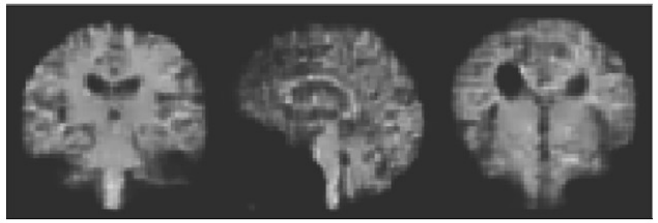
3D-VAE-GAN



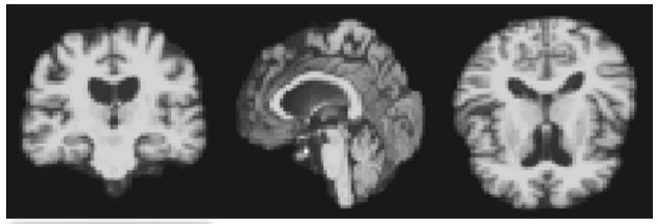
3D-α-GAN



Kwon, et al. MICCAI 2019



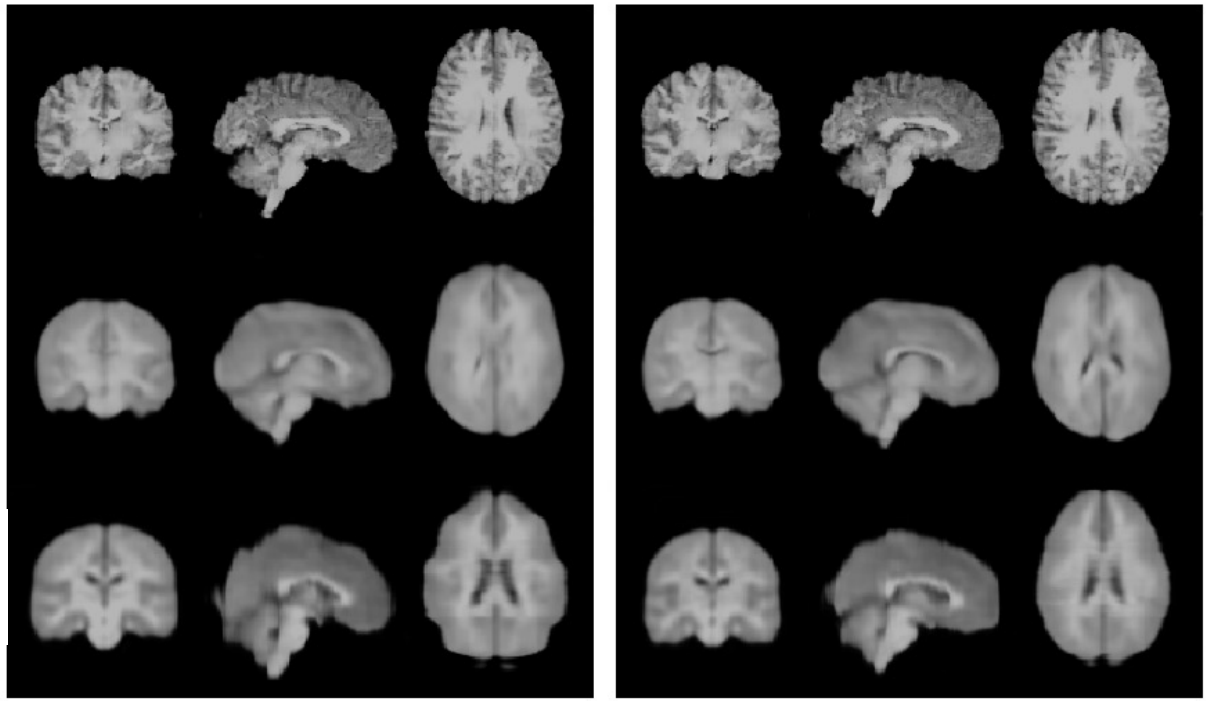
Real



Kwon, et al. MICCAI 2019

3D VAE

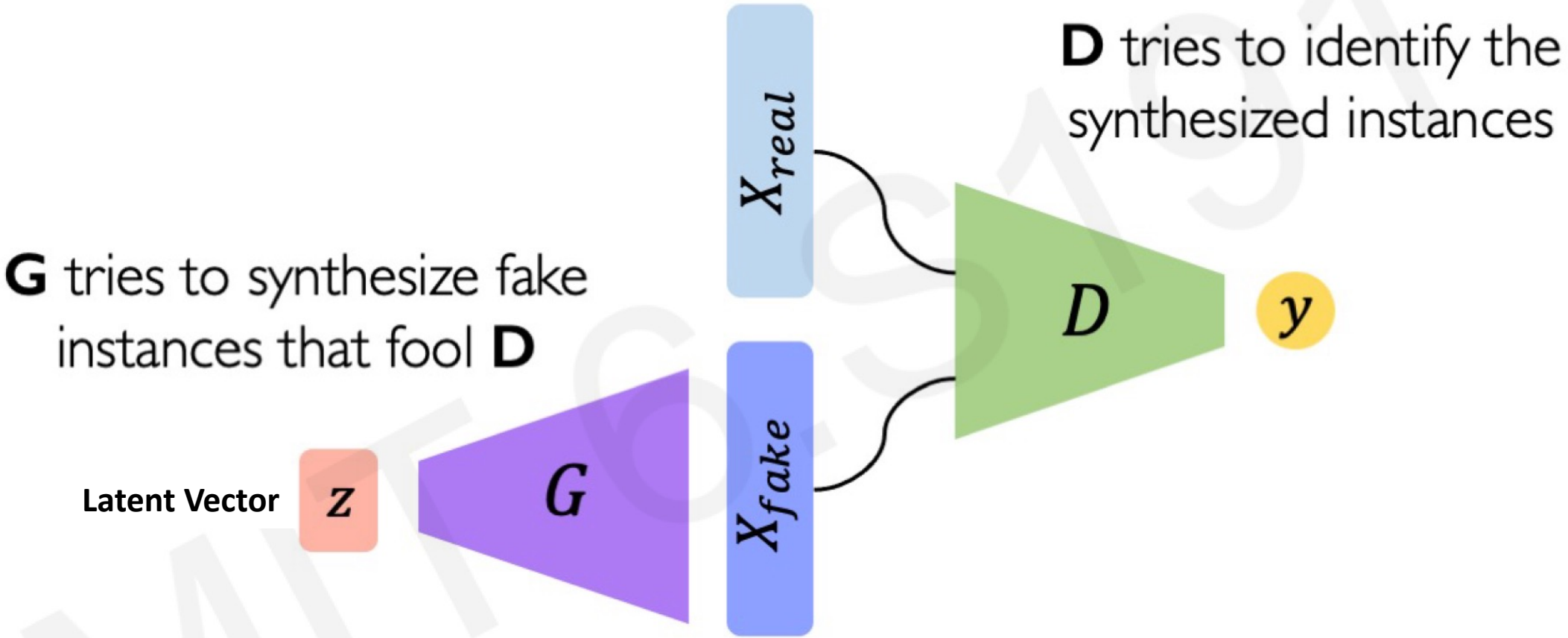
Volokitin, et al. MICCAI 2020



* Kwon, et al., "Generation of 3D Brain MRI Using AE GAN," MICCAI 2019

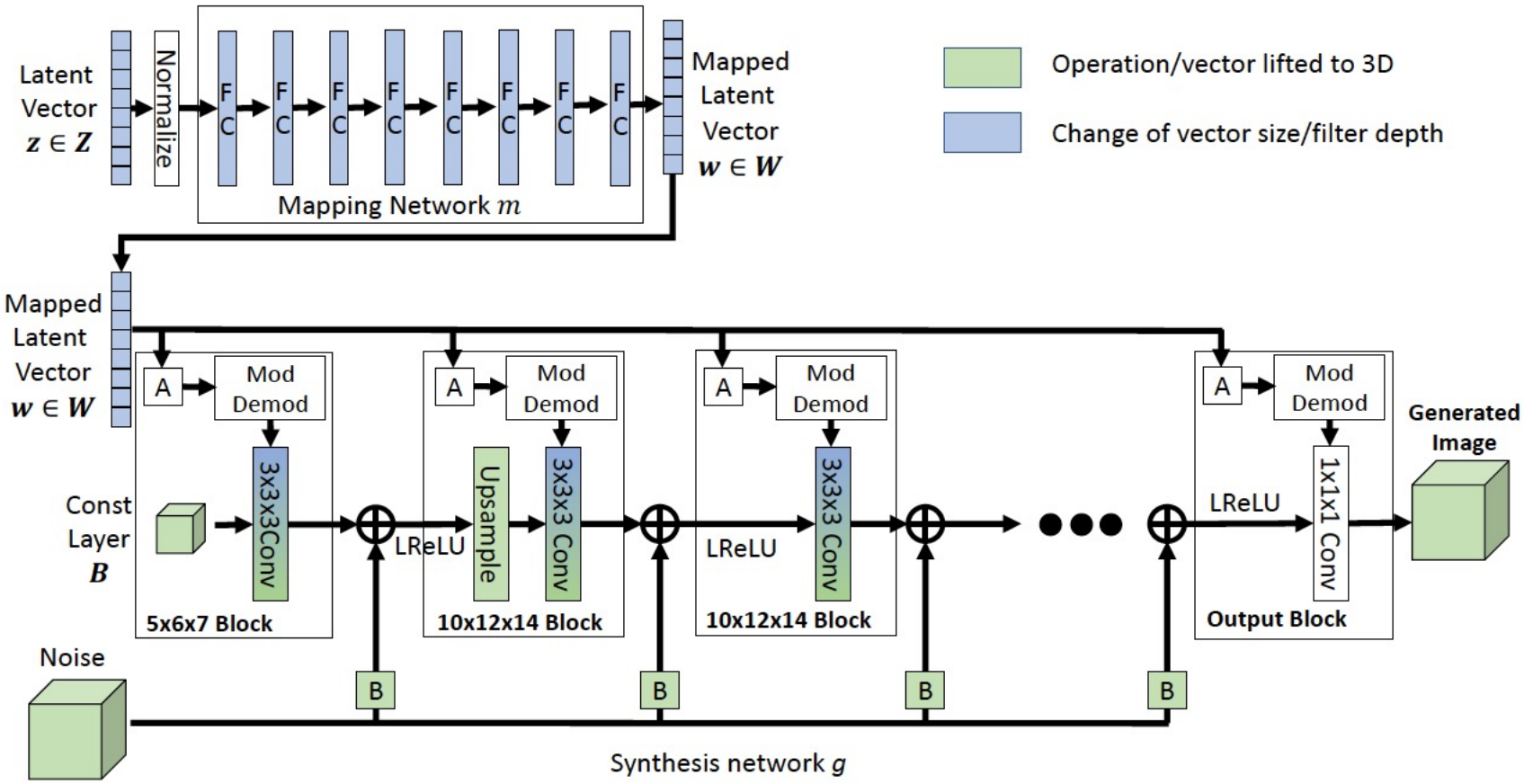
** Volokitin, et al., "Modelling the Distribution of 3D Brain MRI using a 2D Slice VAE," MICCAI 2020

Standard GAN Architecture*



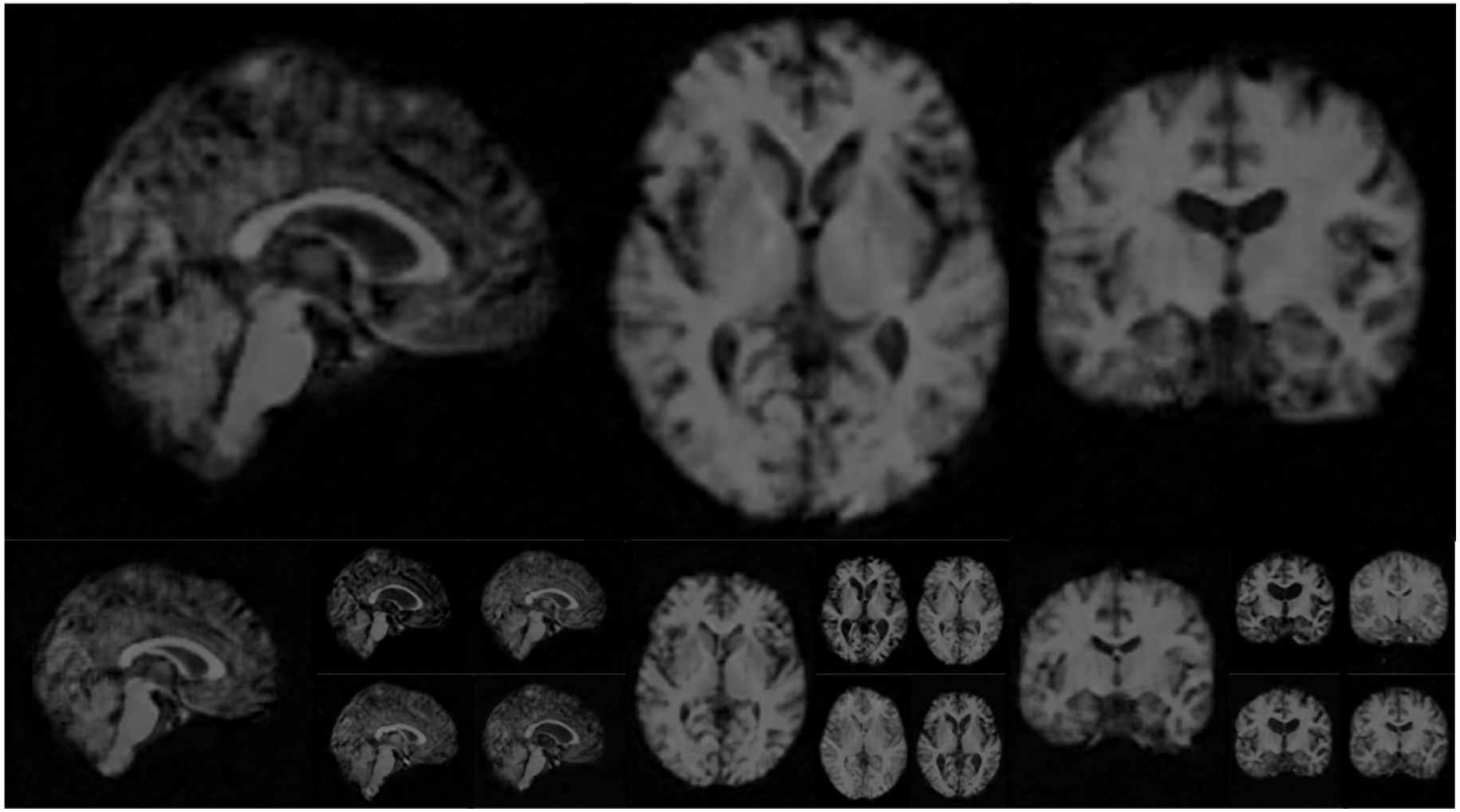
* Modified from Course Slide, Ava Soleimany, MIT 6.S191 Introduction to Deep Learning, Deep Generative Models.

3D-StyleGAN Generator Architecture



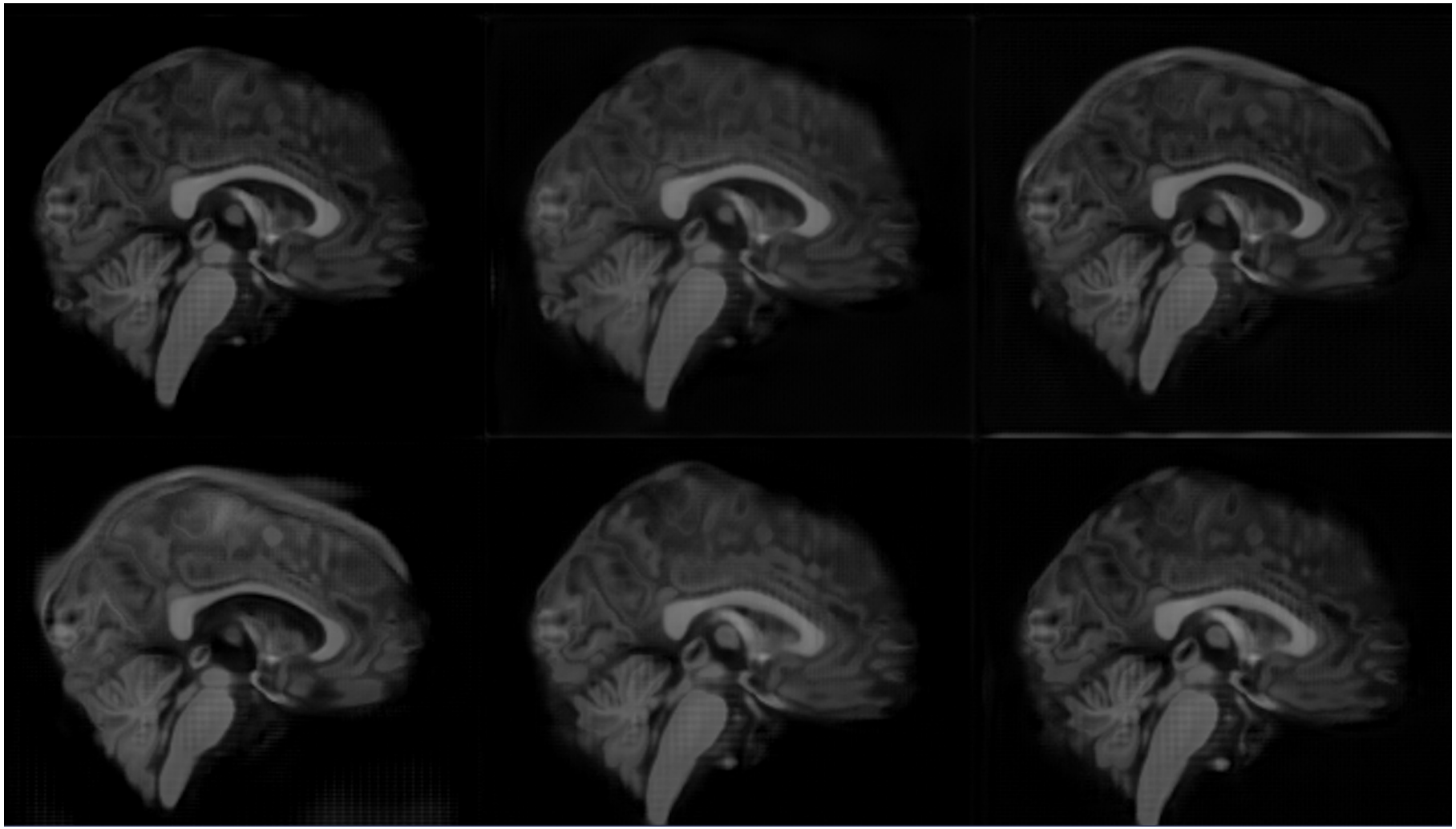
Results – Uncurated Generated Images

2mm Resolution



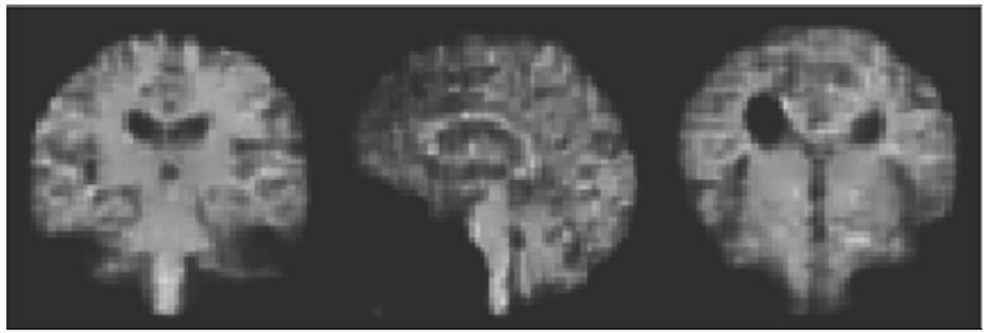
Results – Uncurated Generated Images

1mm Resolution

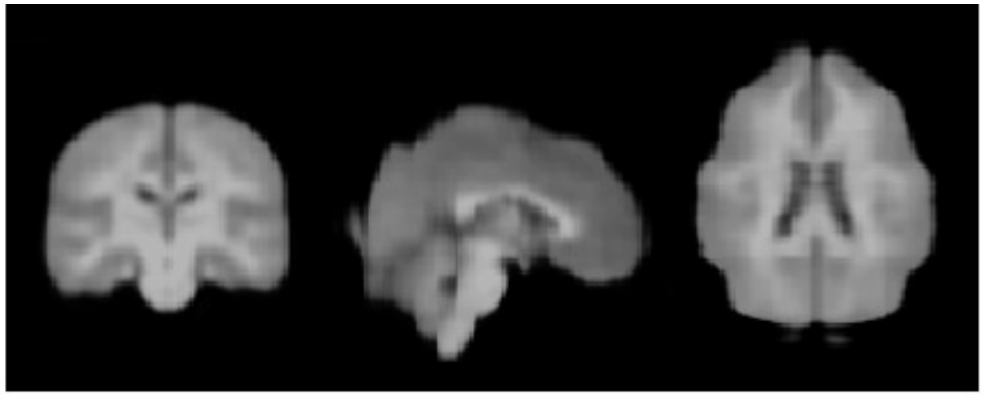


Qualitative Comparisons

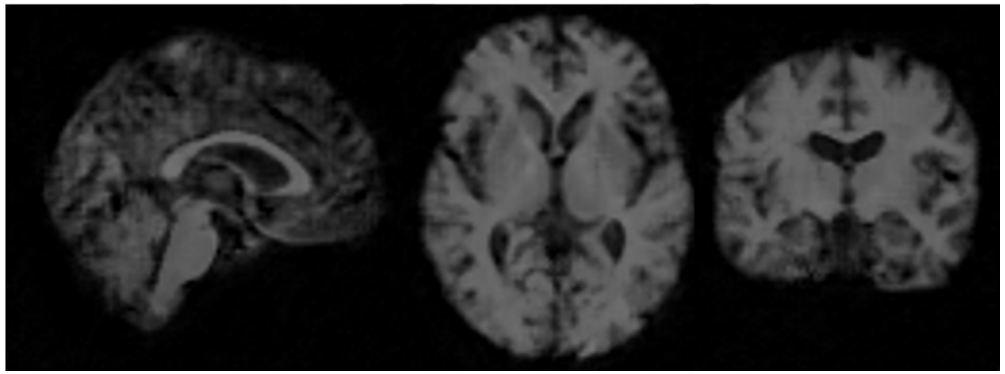
Kwon, et al.
MICCAI 2019*



Volokitin, et al.
MICCAI 2020*

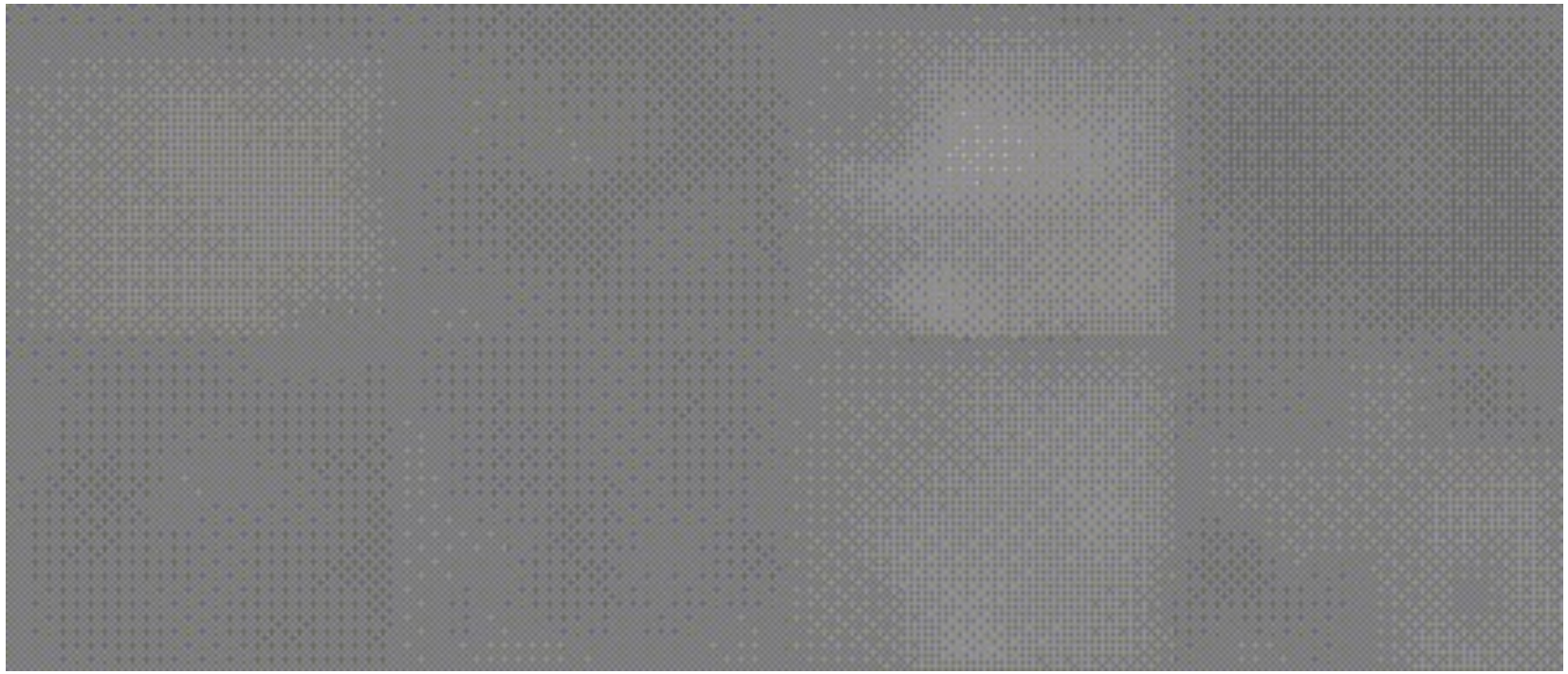


3D-StyleGAN

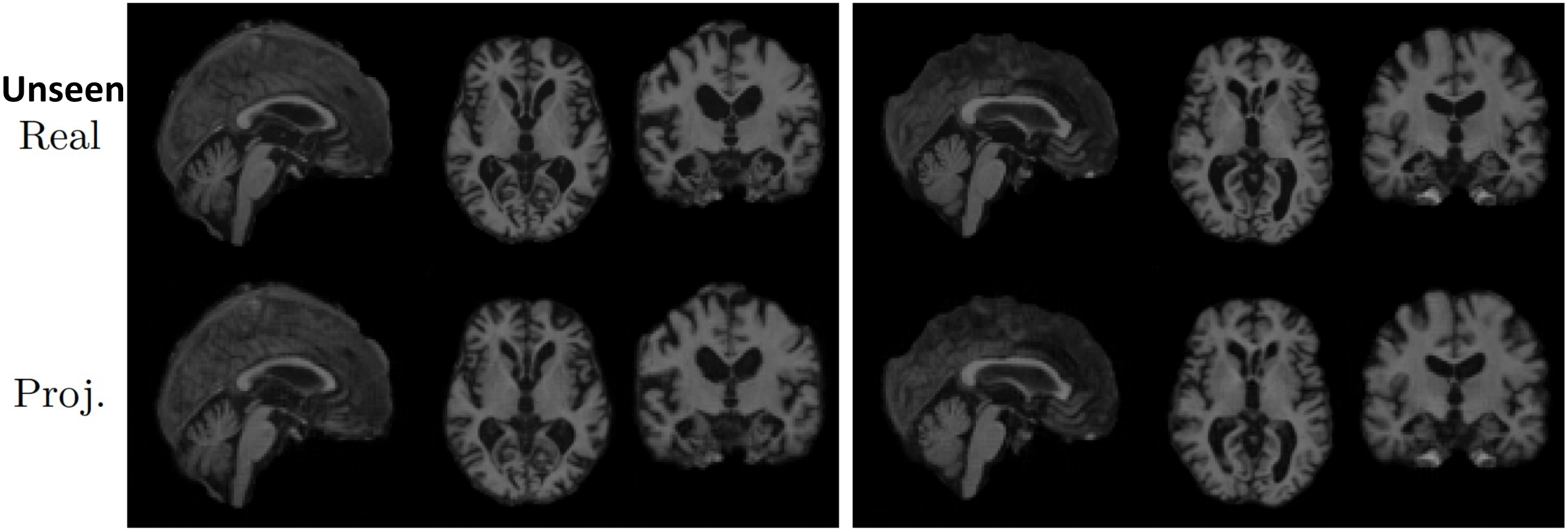


*** !! Figures captured from their original papers**

Image Synthesis over Training Iterations

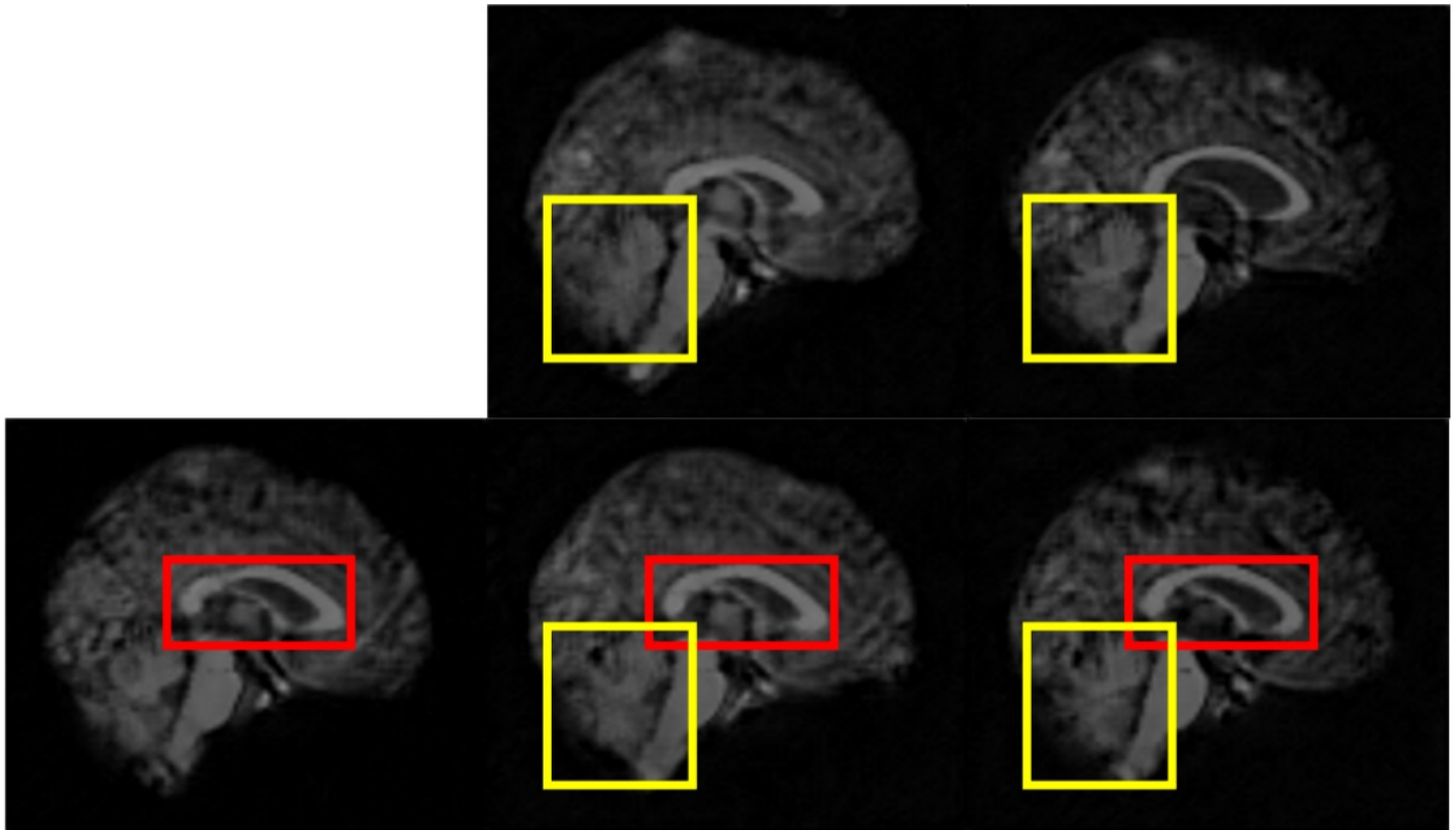


Latent Space Projection and Reconstruction



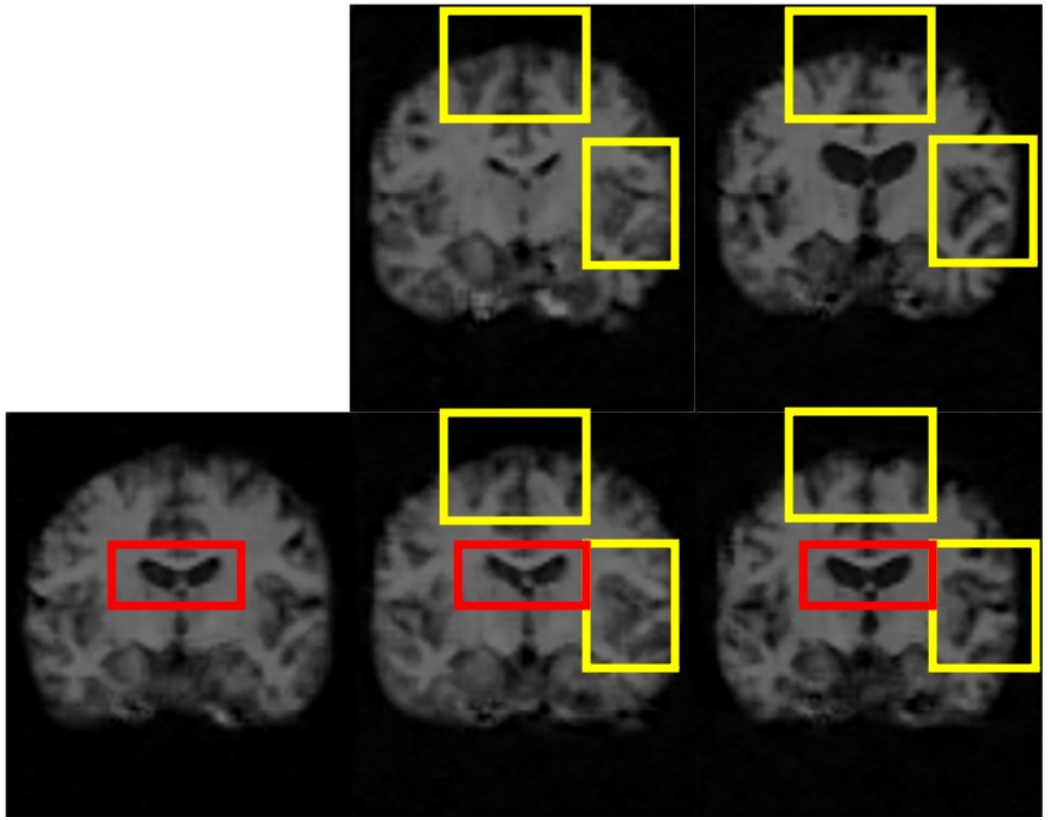
Style Mixing Examples

High Resolution Layer Projection



Low Resolution Layer Projection

High Resolution Layer Projection

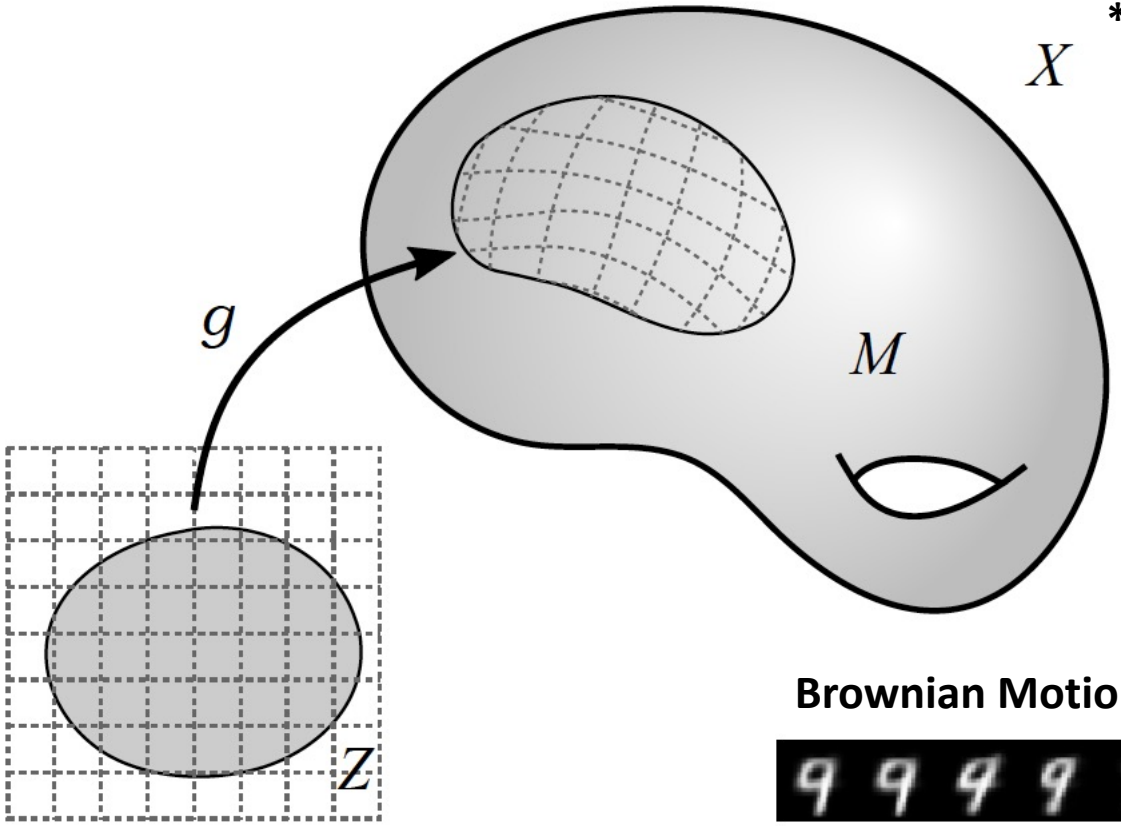


Low Resolution Layer Projection

Discussion

- We proposed 3D-StyleGAN for the generative modeling of full 3D medical images
- High quality generated brain T1 MR images
- The controllability and interpretability of 3D-StyleGAN
  - Latent Space Projection and Reconstruction
  - Style Mixing
- Can impact..
  - Downstream Tasks: Image Enhancement, Motion Correction, Disease Modeling
- GitHub Repo
  - https://github.com/sh4174/3DStyleGAN

Latent Space Statistics with Deep Generative Models



*

Latent Space Interpolation Examples*,**

*

Linear

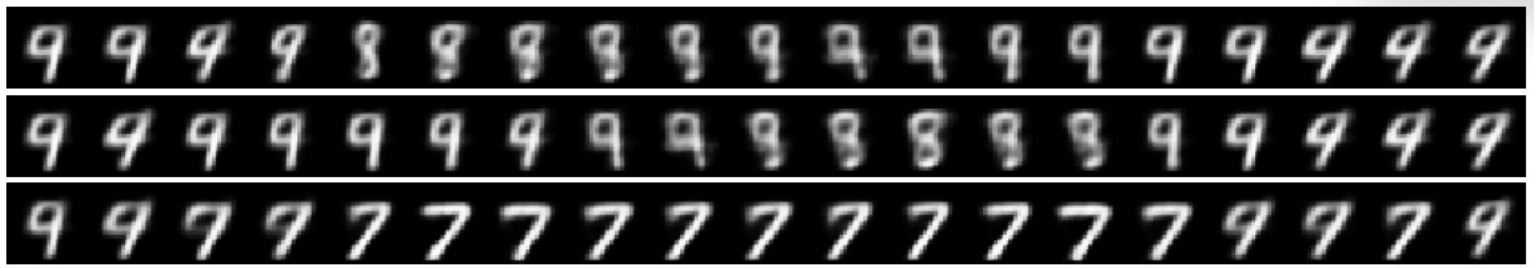
Geodesic

Linear

Geodesic

Brownian Motion Bridge

**



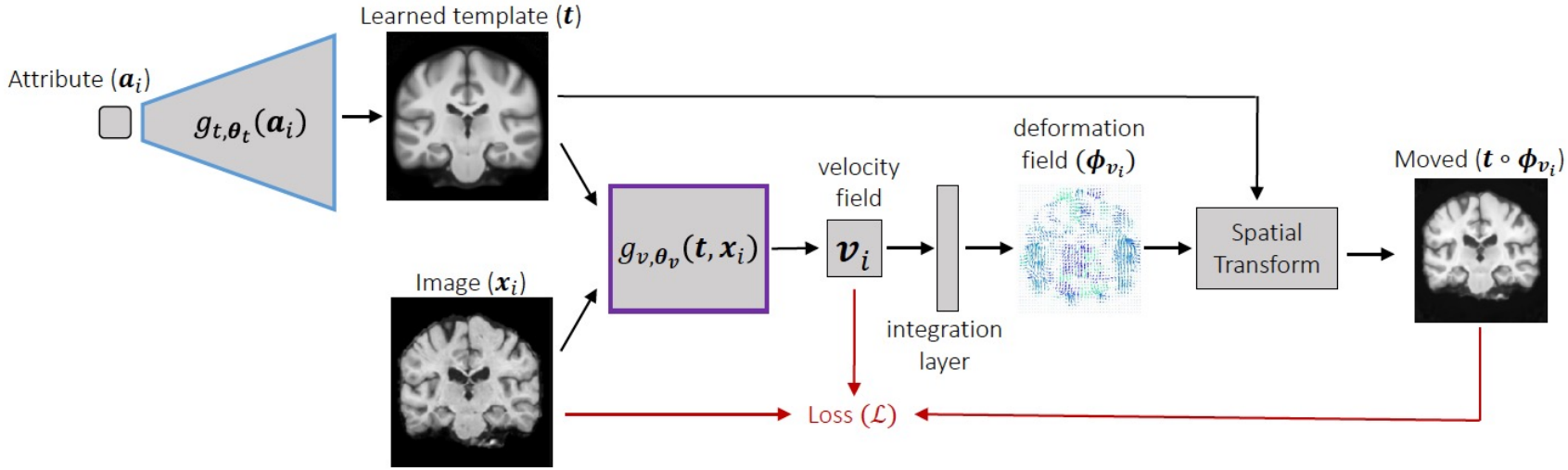
* Shao, et al., “The Riemannian Geometry of Deep Generative Models,” CVPR Workshops, 2018

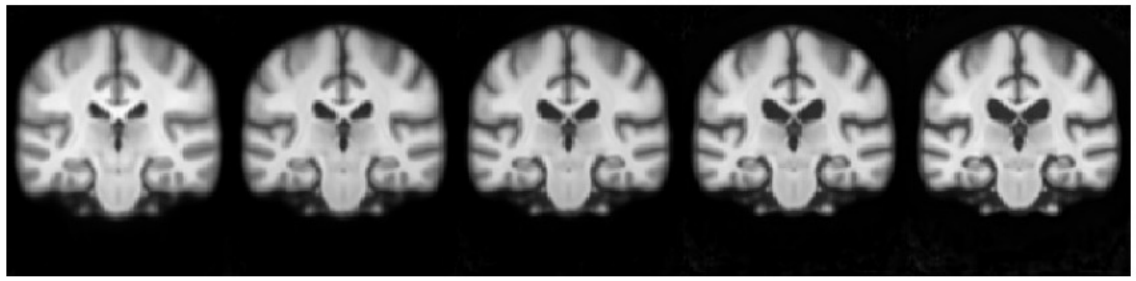
** Kuhnel, et al., “Latent Space Non-Linear Statistics,” ArXiv, 2018.

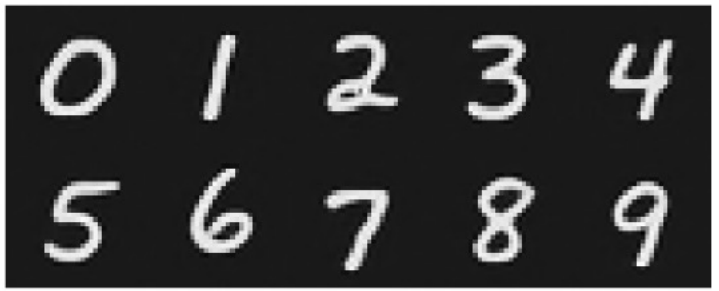
Latent Space Statistics with Deep Generative Models

- Atlas / Intrinsic Mean
- Conditional Atlas / Regression

Geometric Atlas Estimation*







* Dalca, et al., "Learning Conditional Deformable Templates with Convolutional Networks," NeurIPS 2019.

Latent Space Statistics with Deep Generative Models

- Atlas Estimation for Brain Images with Pathology
- Geometric atlas estimation does not reflect non-geometric pathological lesions in images.