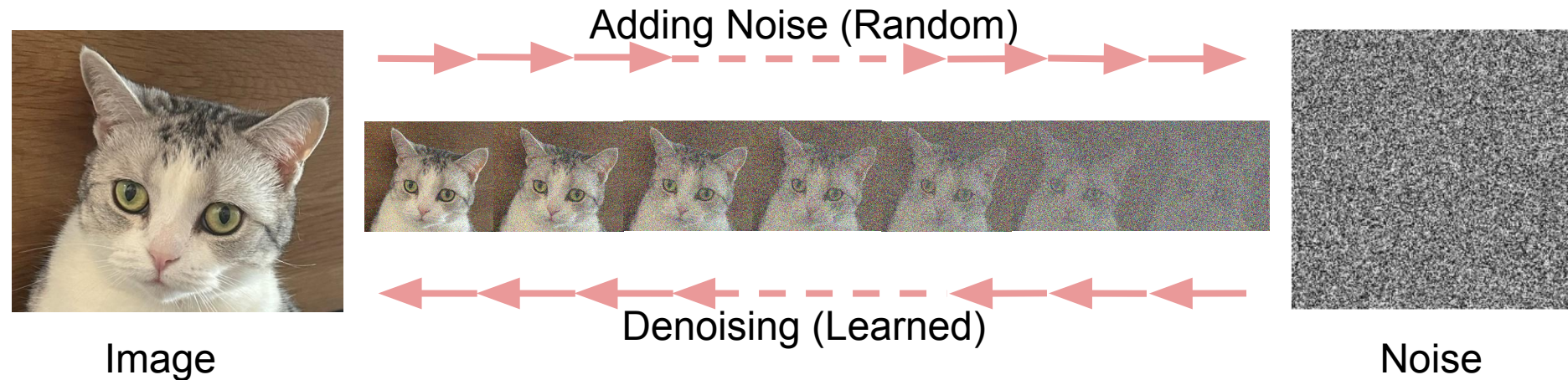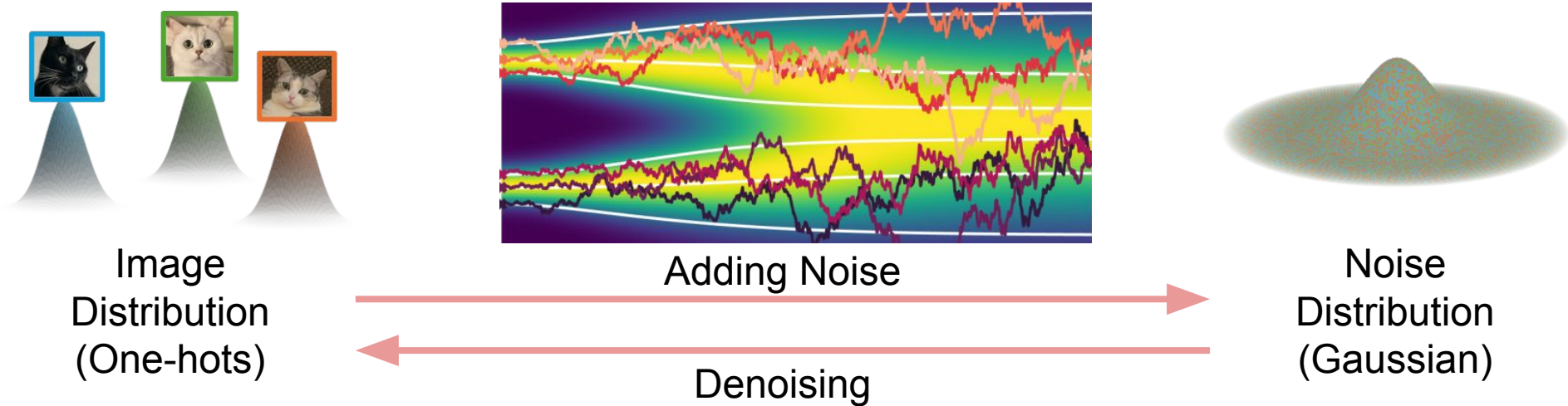# Immiscible Diffusion
Accelerating Diffusion Training with Noise Assignment
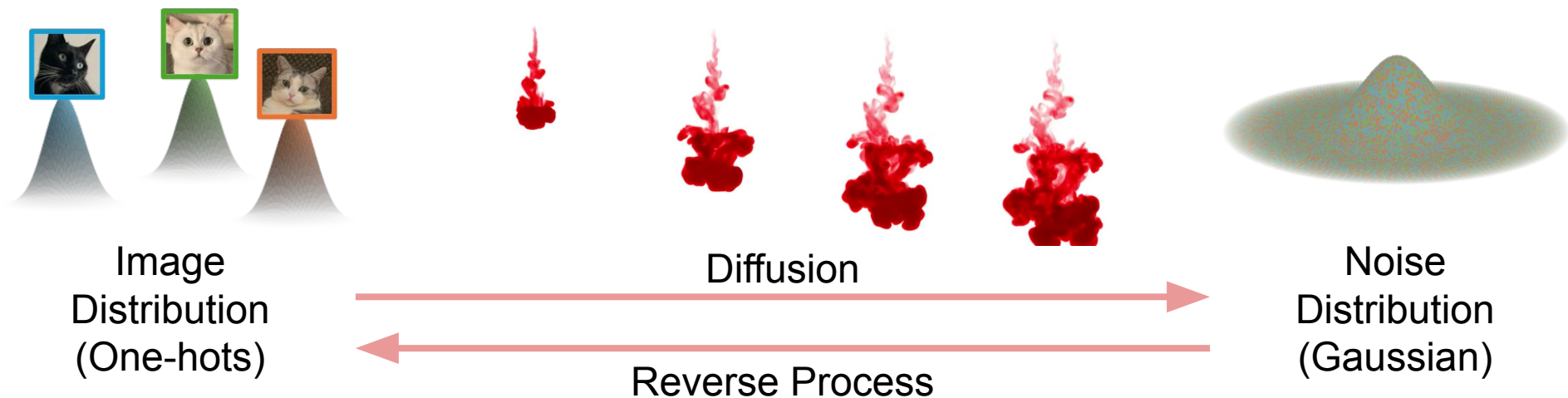
Yiheng Li, Heyang Jiang, Akio Kodaira
Masayoshi Tomizuka, Kurt Keutzer, Chenfeng Xu
2024/12

NEURAL INFORMATION PROCESSING SYSTEMS

Berkeley
UNIVERSITY OF CALIFORNIA

BAIR
BERKELEY ARTIFICIAL INTELLIGENCE RESEARCH

MSC laboratory

Learning Step-by-step **Denoising** for Image Generation

Adding Noise (Random)

Denoising (Learned)

Image

Noise

Learning Step-by-step **Distribution Transfer** for Image Generation

Image
Distribution
(One-hots)

Adding Noise

Denoising

Noise
Distribution
(Gaussian)

https://yang-song.net/blog/2021/score/

Physics Understanding: Data (Particle) Diffusion & Reverse Process

Image
Distribution
(One-hots)

Diffusion →

Reverse Process ←

Noise
Distribution
(Gaussian)

Miscibility

Mixing during Diffusion in Physics

Miscibility Challenges the De-noising

Where to denoise to?

Diffusion

Reverse Process

Image
Distribution
(One-hots)

Noise
Distribution
(Gaussian)

???
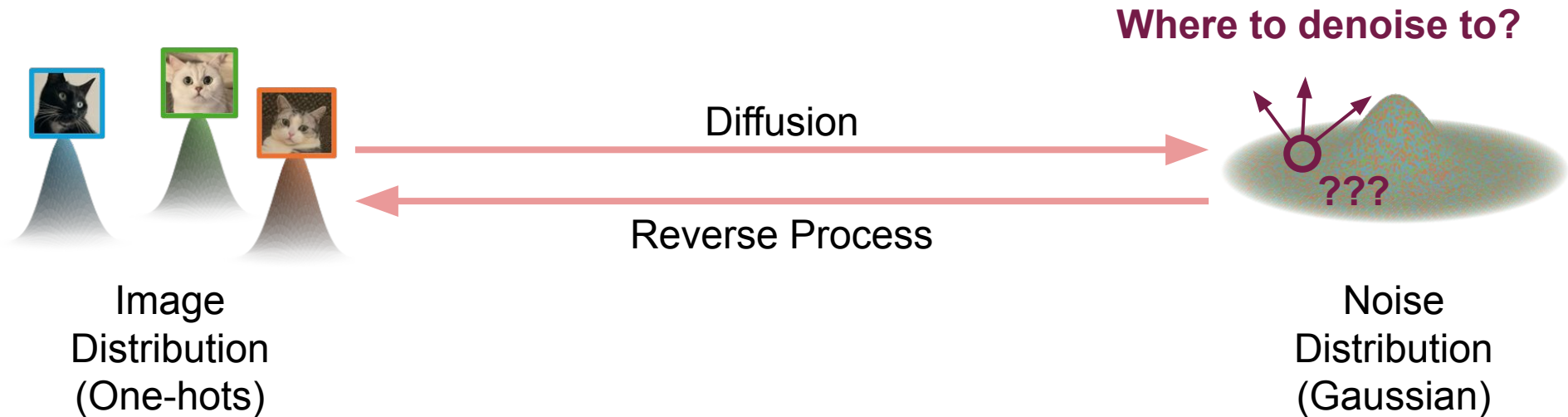
The last diffusion step provides **trivial information**.
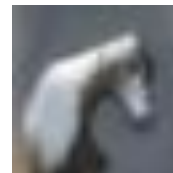
Denoising Direction

Predicted Image

True Image

Immiscibility
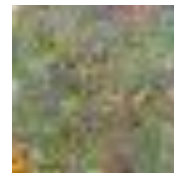
Restricted Diffusion of Each Solvent

Caused by Intermolecular Forces

Immiscible Diffusion

Image Distribution

Restrict Image Diffusion to Relatively **Separate** Areas

Noise Distribution

Immiscible Diffusion Implementation: **Assignment**
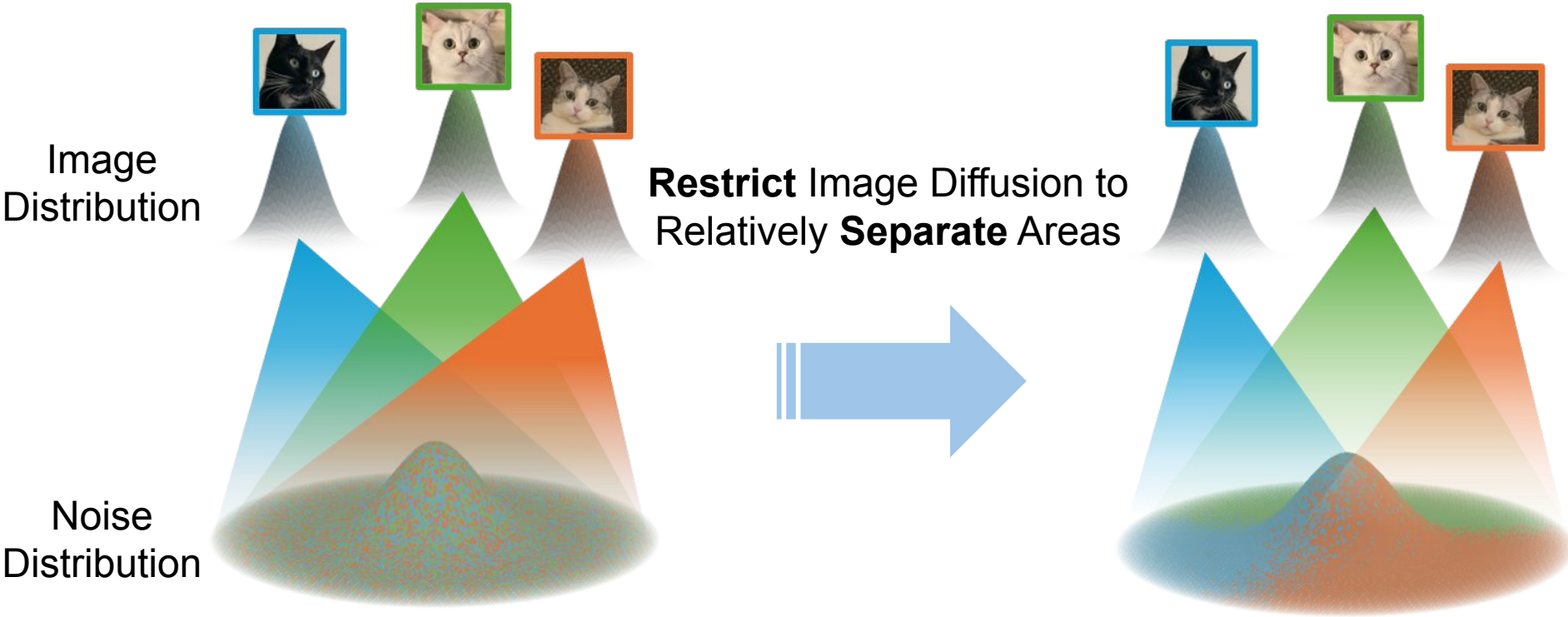
Method
Assign Noise to Nearby Image

Image Data

Noise

Traditional (Miscible)   Immiscible
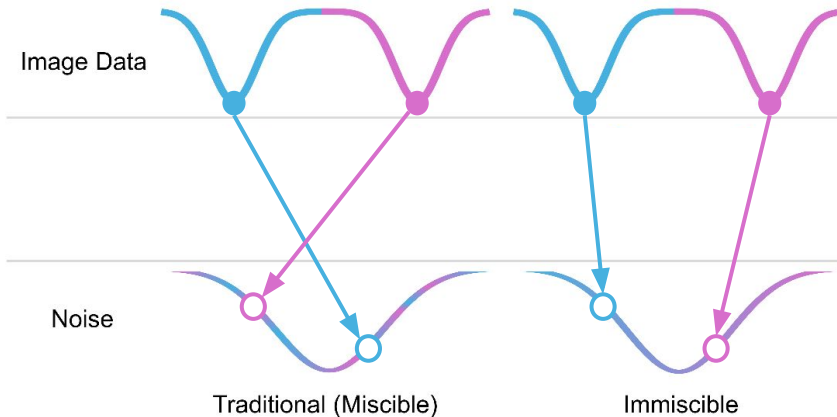
Performance
Efficient Execution & Little Image-Noise Average Distance Change

Batch Size	128	256	512	1024
Execution Time (ms)	5.4	6.7	8.8	22.8
ΔAve. Dist. (image, noise)	-1.93%	-2.16%	-2.32%	-2.44%

Immiscible Diffusion Solves the Denoising Challenge!

Diffusion

Reverse Process

Image
Distribution
(One-hots)

Assigned Noise
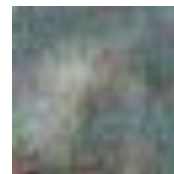Distribution
(Gaussian)
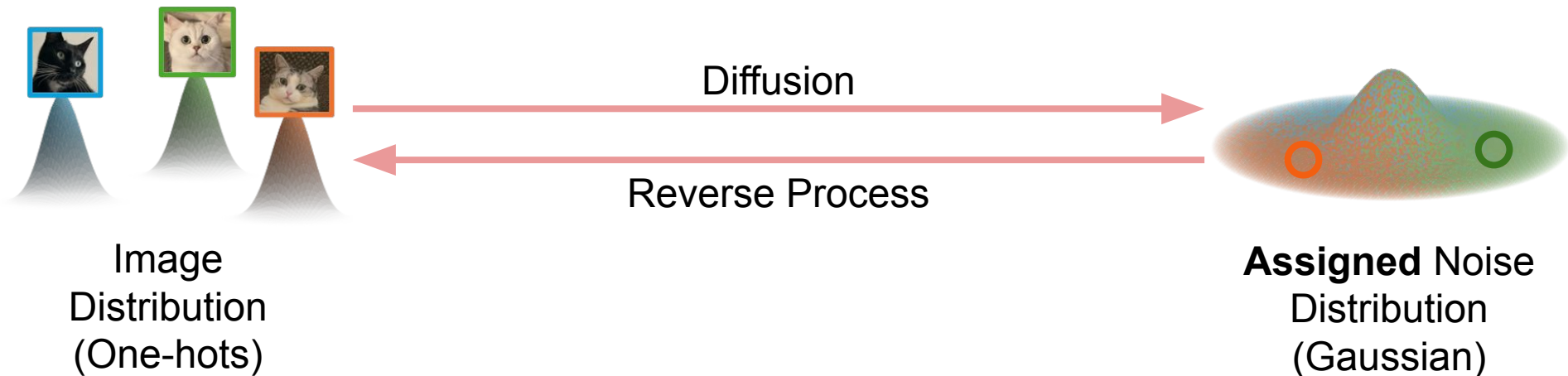
Then **the last diffusion step** provides **clear denoising results**!
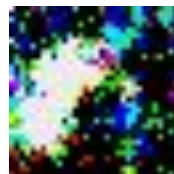
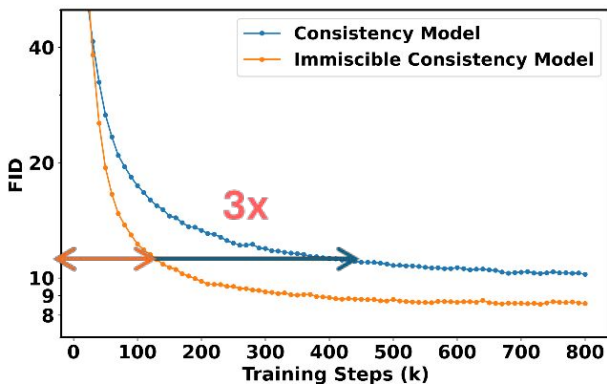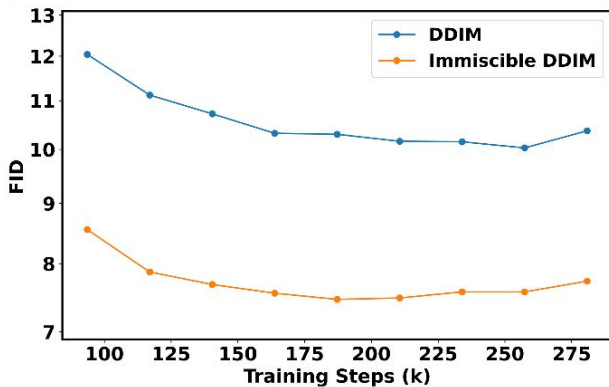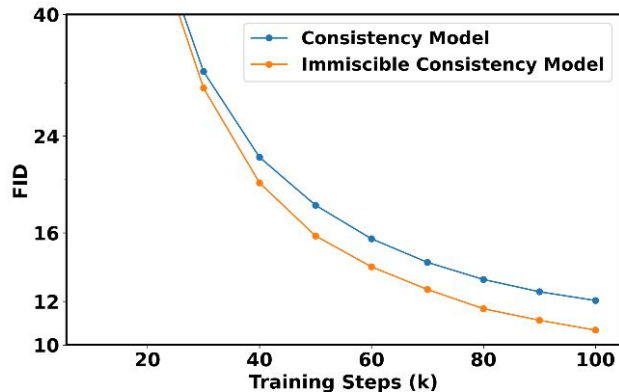| Denoising Direction	Predicted Image	True Image
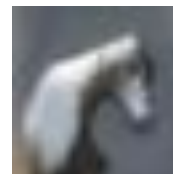
Unconditional Generation

Consistency Model + CIFAR10

DDIM + CIFAR10

Consistency Model+ CelebA

Unconditional Generation
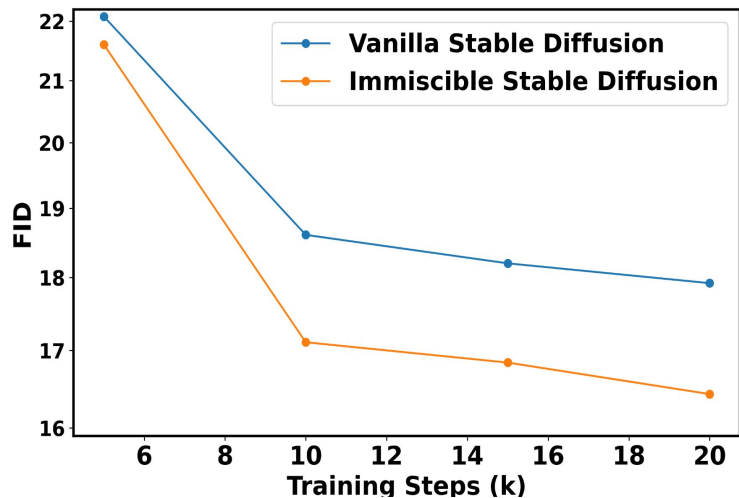
Stable Diffusion + ImageNet

Vanilla
(Baseline)

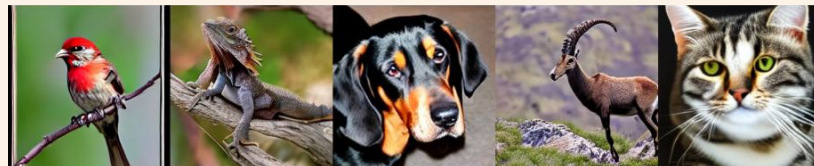Immiscible

Class-Conditional Generation
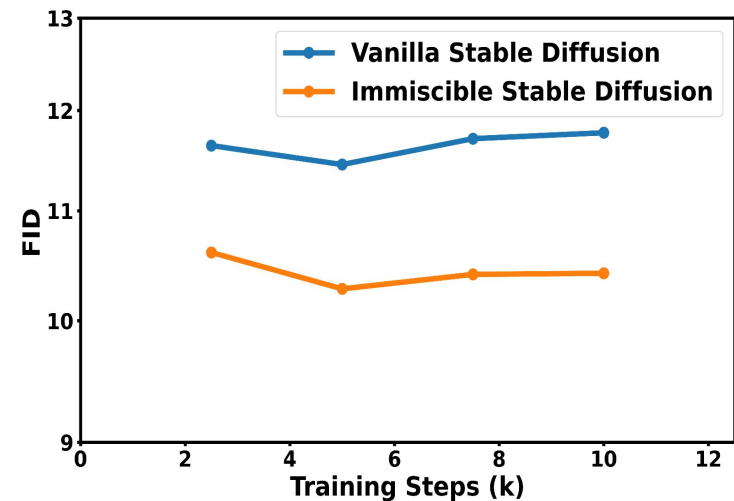
Stable Diffusion + ImageNet

Vanilla

Immiscible

Class-Conditional **Fine-tuning**

Stable Diffusion v1.4 + ImageNet

Summary

1 line

of code:
image-noise assignment*
*Only one immiscible diffusion method;
Excluding Image Normalization for Some Baselines

**One Line of Code
& Running Efficiently**

```
noise_immiscible =
linear_sum_assignment
(image, noise)
```
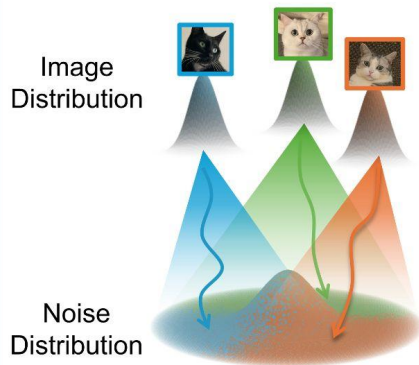
6.7 ms*
Execution Time
*For Batch Sizes = 256

2 %

image-noise data point
distance reduction
For Batch Sizes in [128, 1024]

**Assignments of Corresponding
Images in Gaussian Noise Space**
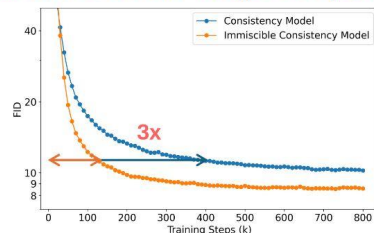
Image
Distribution

Noise
Distribution

3 x

training efficiency
enhancement
On Consistency Model + CIFAR Dataset
On unconditional / conditional generation & fine-tuning

**Effectiveness Observed
Both in FID and in Image Comparison**

Unconditional Conditional Fine-tuning

Immiscible
Stable
Diffusion

Stable
Diffusion

GitHub Site

Thank you!

NEURAL INFORMATION
PROCESSING SYSTEMS

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