

Diffusion Models

How AI Learns to Create Images from Noise

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February 20, 2026

CSE 200: Technical Writing and Presentation
Bangladesh University of Engineering and Technology

Outline

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Core Idea

Forward Process

Reverse Process

Training

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Applications

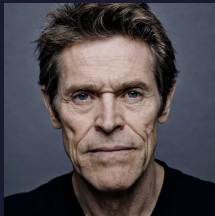
Limitations & Challenges

Conclusion

What Problem Are We Solving?



Real face

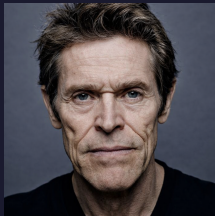


AI-generated face (*Sora*)

What Problem Are We Solving?



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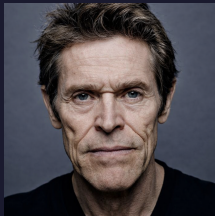
Generative Modeling

Can a machine learn to **create new, realistic samples** that are indistinguishable from real data?

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Generative Modeling

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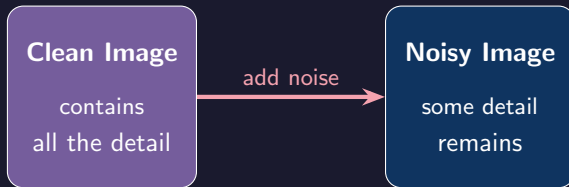
Diffusion models provide a stable, high-quality solution.

The Core Idea: Learning by Destroying

Clean Image

contains
all the detail

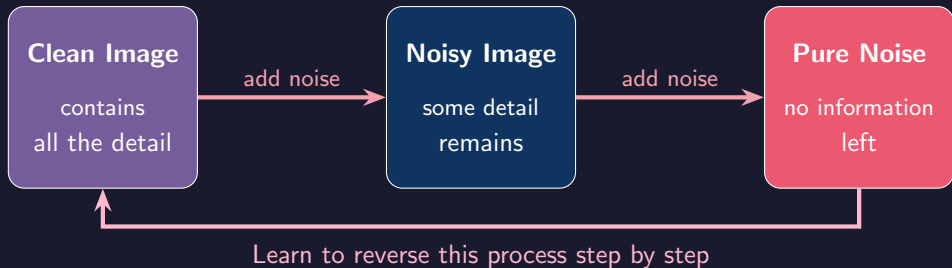
The Core Idea: Learning by Destroying



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The Core Idea: Learning by Destroying



The Forward Process: Adding Noise

Insert image: progressive noising sequence

Clean image \rightarrow slightly noisy \rightarrow more noisy $\rightarrow \dots \rightarrow$ pure noise

What Happens

Take a real image and add a *tiny* bit of random noise. Repeat this hundreds of times until only noise remains.

The Reverse Process: Removing Noise

Insert image: progressive denoising sequence

Pure noise → rough shape → clearer structure → final image

How Generation Works

- Start from **pure noise**
- Predict and remove a little noise at each step
- Repeat until a realistic image appears

How Do We Train It?

1. Take a real image from the training set

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2. Pick a random step and add the corresponding noise

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3. Ask the neural network: *“what noise was added?”*

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4. Compare the prediction to the **actual noise**, minimize the error

Key Insight & Why It Works

Key Insight

- We add **known** noise
- So we have exact labels
- Training target is clear and reliable

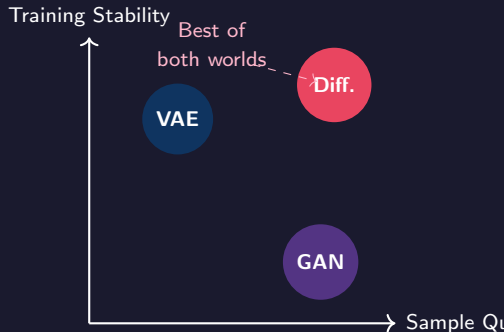
Why It Works

- Model learns many small denoising steps
- Small steps are easier to learn
- Chaining them builds a full image

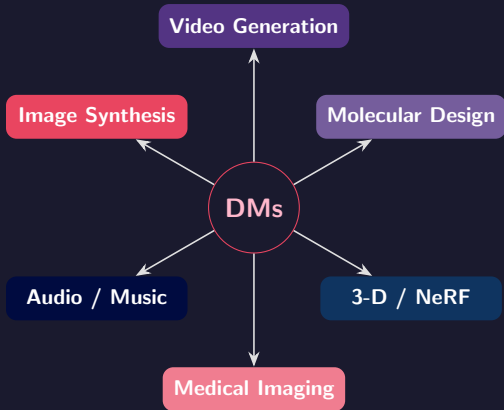
Why Diffusion Models Work So Well

Advantages

- **Stable training** no adversarial game; just predict noise
- **Small steps** each denoising step is a tiny, easy task
- **High quality** state-of-the-art image fidelity
- **Flexible** works on images, audio, video, 3-D, molecules...



Applications



Real-world tools powered by diffusion:

- **DALL·E 3** — text-to-image
- **Stable Diffusion** — open-source image generation
- **Midjourney** — art and design
- **Sora** — text-to-video

Limitations & Open Challenges

Current Limitations

- **Slow generation** — requires many denoising steps (hundreds to thousands)
- **High compute cost** — training requires significant GPU resources
- **Large model size** — not easy to run on consumer hardware

Open Questions

- Can we make generation **faster**? (Active research area)
- How do we ensure generated content is **safe and ethical**?
- Can we extend to **longer videos** and **interactive content**?



Thank You!

Questions?

References

- [1] J. Ho et al. **“Denoising diffusion probabilistic models”**. In: *Proceedings of the 34th International Conference on Neural Information Processing Systems*. NIPS '20. Vancouver, BC, Canada: Curran Associates Inc., 2020.
- [2] Y. Song and S. Ermon. **“Generative modeling by estimating gradients of the data distribution”**. In: *Advances in neural information processing systems* 32 (2019).
- [3] J. Song et al. **“Denoising diffusion implicit models”**. In: *arXiv preprint arXiv:2010.02502* (2020).
- [4] A. Q. Nichol and P. Dhariwal. **“Improved denoising diffusion probabilistic models”**. In: *International conference on machine learning*. PMLR. 2021, pp. 8162–8171.