

Is synthetic data from generative models ready for image recognition?

GISLab Short-Term Course 2025 Summer

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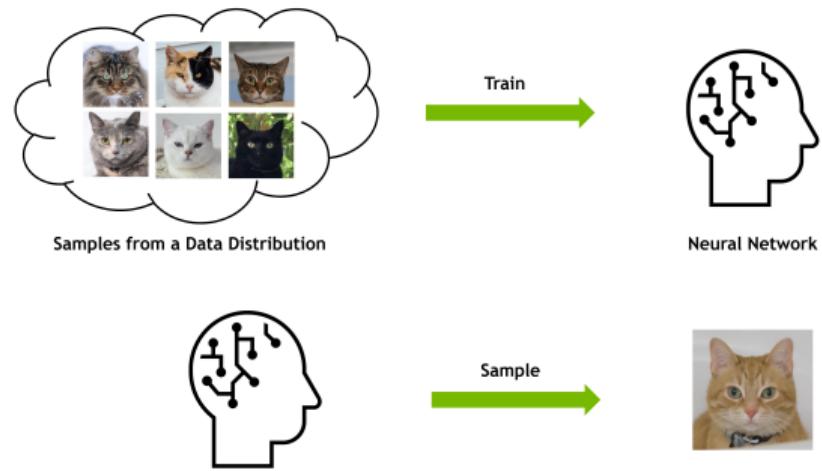
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Outline

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- ▶ Background: Generative Models
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- ▶ Applications in Remote Sensing
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Generative Modeling

Deep Generative Learning Learning to generate data



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Figure: Illustration of generative modeling (Vahdat Arash, Song, and Meng, 2023).

The Landscape of Deep Generative Learning



Figure: Image Derived from (Vahdat Arash, Song, and Meng, 2023).

Background: Diffusion Models

- ▶ **Diffusion models** generate data by iterative denoising (Sohl-Dickstein et al., 2015; Ho, Jain, and Abbeel, 2020).
- ▶ Add noise to data and learn to reverse the process.
- ▶ Achieve state-of-the-art image quality and diversity.

Diffusion models are the current frontier in generative modeling.

Diffusion Schematic

Figure: *

Stepwise denoising in diffusion models.

Preliminaries: Diffusion Models in Image Synthesis

- ▶ Diffusion models generate images by iterative denoising (Ho, Jain, and Abbeel, 2020).
- ▶ High fidelity, diverse image generation.
- ▶ Now state-of-the-art for many generative tasks.

Diffusion steps visual

Figure: Stepwise denoising in diffusion models.

Applications: Generative Models for Remote Sensing

- ▶ **CRS-Diff:** Controllable remote sensing image generation (Tang, Li, et al., 2024)
- ▶ **DiffusionSat:** Large-scale remote sensing text-to-image generation (Khanna et al., 2024)
- ▶ **Text2Earth:** Foundation model for text-driven Earth observation (Liu et al., 2025)

Example: Text-to-image synthesis

Figure: *

Results from state-of-the-art remote sensing generative models.

Tang, et al. CRS-Diff: Controllable Remote Sensing Image Generation with Diffusion Model. TGRS. 2024.

Khanna, et al. DiffusionSat: A Generative Foundation Model for Satellite Imagery, ICLR, 2024.

Liu, et al. Text2Earth: Unlocking text-driven remote sensing image generation with a global-scale dataset and a foundation model. GRSM. 2025.

Evaluation: Synthetic Data in Downstream Tasks

- ▶ ICLR 2023: Synthetic data from generative models boosts image recognition, but does not fully replace real data (Cherti et al., 2023).
- ▶ Text2Earth: Synthetic augmentation improves classification accuracy in remote sensing (Liu et al., 2025).

Performance: Synthetic vs. Real

Figure: *

Quantitative evaluation in downstream tasks.

Project Assignment

- ▶ Use checkpoints from **DiffusionSat** (Khanna et al., 2024) and **Text2Earth** (Liu et al., 2025).
- ▶ Tasks: Text-image alignment, image classification, super-resolution.
- ▶ Metrics: Accuracy, PSNR, SSIM.
- ▶ Reference SOTA model: DSCLoRA (Chai et al., 2025).

Khanna, et al. DiffusionSat: A Generative Foundation Model for Satellite Imagery, ICLR, 2024.

Liu, et al. Text2Earth: Unlocking text-driven remote sensing image generation with a global-scale dataset and a foundation model. GRSM. 2025.

Chai, et al. Distillation-Supervised Convolutional Low-Rank Adaptation for Efficient Image Super-Resolution, CVPRW 2025, 2025.

Q&A

Thank you for your attention!