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10-799 Diffusion & Flow Matching

Yutong (Kelly) He
Class overview, Jan 13th, 2026

The year of 2025 is insane

ChatGPT, OpenAI

https://thunderdungeon.com/2025/03/28/studio-ghibli-memes-ghiblify-memes/

Veo, Google

https://www.youtube.com/shorts/Z8AOj5D70pA

Sora, OpenAI

https://www.tiktok.com/@longlive ai/video/7563640496497626390

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Absolutely the best thing that happened to me in 2025
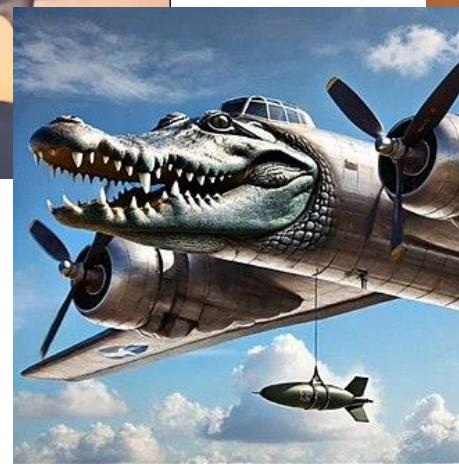
Besides memes, the industry is blooming in other directions too

All these advances are built based on the same underlying technology

This is what we are going to learn in this class

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In this class, we are going to learn about **diffusion & flow matching** – the technology behind the great AI ~~memes~~ advancements in image generation & beyond in recent years. In particular, we will learn

- The **intuitions and math** behind these algorithms

- How to **implement** basic diffusion & flow matching models in Python

- How to **train a good image generation model** using GPUs **?**

- **Techniques** that **improves** upon the vanilla models

- How to conceptually extend these frameworks to **discrete data**

- How to **demonstrate your thoughts** and **your work**

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What makes a good image generation model

Fidelity

Do the generated images look "real"?

- Do the people generated have 6 fingers?

- Are the images over/under saturated?

- Do the images have a lot of unnatural artifacts?

…

Controllability

Can I control what I generate in however way I want?

- Can I use text to describe the image I want to generate?

- Can I use other images to specify the image I want to generate?

- Can I generate my cat playing basketball?

- Can I personalize the model?

- Can I use other models to interact with the image generation model?

...
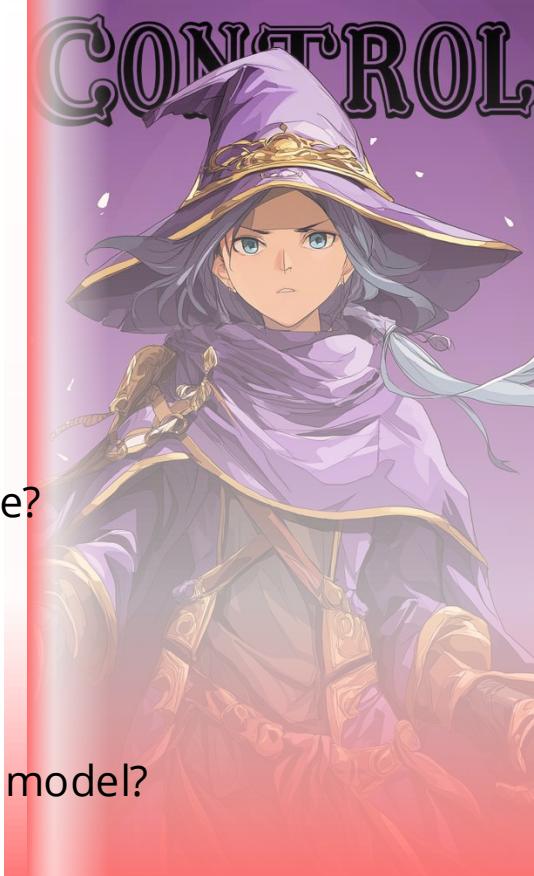
Speed

How fast is the generation?

- Is it possible to speed up the generation without quality degradation?

- Is it possible to speed up and improve the generation quality?

- Do I need extra training to speed things up or can I do it without training?

- Can I reduce the wall clock time with the same number of network evaluation?

- Can I reduce the wall clock time with the same network and the same number of network evaluation?
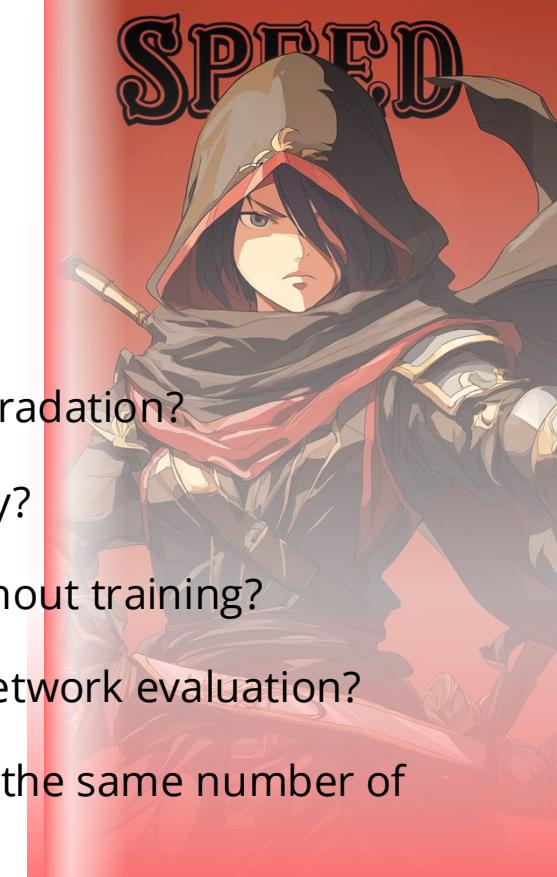
...

Choose your path and level up

I am going to be the best ~~Pokemon~~ AI trainer!

Learning in this class is the same as playing (RPG) video games!

- You start in the beginners' village to learn the basics

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Choose your path and level up

Learning in this class is the same as playing (RPG) video games!

- You start in the beginners' village to learn the basics

- Before leaving the village, you choose the path you want to focus on and start learning specialized skills

Images from Pokemon & Sekiro

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Learning in this class is the same as playing (RPG) video games!

- You start in the beginners' village to learn the basics

- Before leaving the village, you choose the path you want to focus on and start learning specialized skills

- During your exploration, you will fight (multiple) small bosses. These fights can help you improve your skills

Choose your path and level up

I am going to be the best ~~Pokemon~~ AI trainer!

Learning in this class is the s

- You start in the beginner

- Before leaving the village   d start learning specialized skills

- During your exploration,   hts can help you improve your sk

- At the end, you will defeat the final boss and obtain the holy grail

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Homework (70%): Choose your path and level up

- HW1: Set up environment & build your first diffusion model (DDPM)

- HW2: Build your first flow matching model & choose your path

- HW3: Implement your chosen baseline on your chosen path

- HW4: Implement your novel improvements & beat your baselines

Beginners' village

Choose your branch in the skill tree
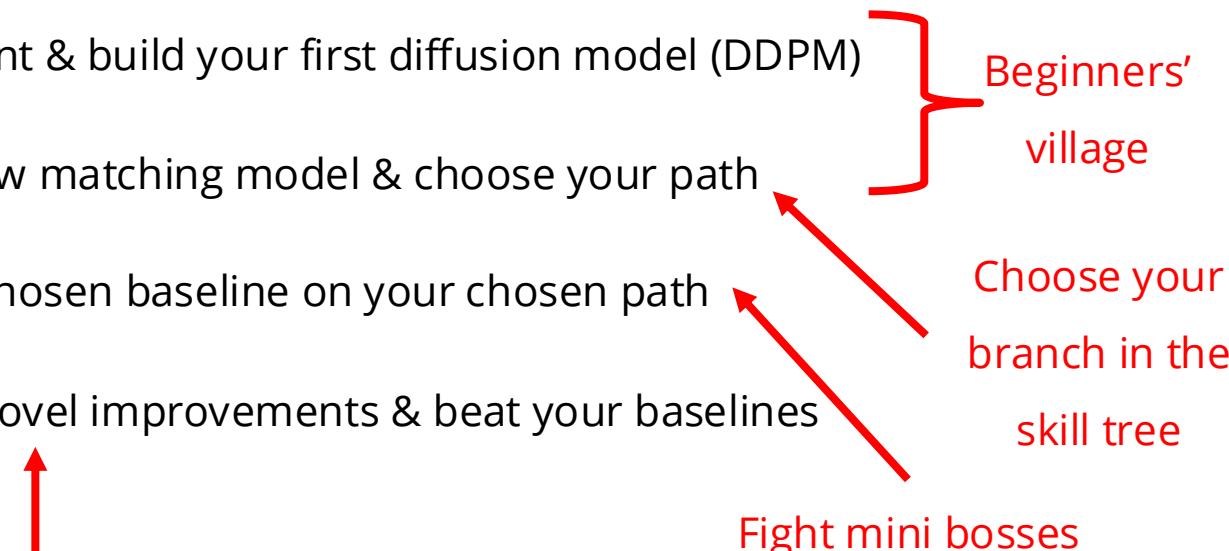
Fight mini bosses

Fight final boss

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Homework (70%): Choose your path and level up

- HW1: Set up environment & build your first diffusion model (DDPM) <- 15%

- HW2: Build your first flow matching model & choose your path <- 15%

- HW3: Implement your chosen baseline on your chosen path <- 20%

- HW4: Implement your novel improvements & beat your baselines <- 20%

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Final Presentation (15%): Showcase your work

In the last week of class, we will have two poster sessions for everyone to showcase the work they did for their homework. In order to receive full credits, you'll have to

- Submit your poster PDF the day before the first poster session <- 5%

- Actually present your poster at your assigned poster session <- 5%

- Attend the other poster session to check out other people's work <- 5%

We will also conduct a poll at the poster sessions for everyone to vote for their favorite posters. The best poster for each path will receive a small award :)

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AI as your companion on this journey

This class is AI-friendly and open everything!

You can use

- Any AI assistant/tools

- Any open source code

- Any pre-trained model

- Any research paper/book/tutorials etc

- You can also discuss with other human

I am going to be the best ~~Pokemon~~ AI trainer!

Your AI

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AI as your companion on this journey

This class is AI-friendly and open everything!

That being said, you should

- Complete all assignments on your own

- Cite all resources that you use (including AI)

- Do not copy from your classmates

- Do not claim other human or AI's work as your own

- Do not plagiarize any source without attribution

I am going to be the best ~~Pokemon~~ AI trainer!

Your AI

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Human companions that shall help you learn

Kelly He
Instructor

Russ Salakhutdinov
Advisor

Zico Kolter
Advisor

Nichelle Phillips
Education Associate

Douglas Chen
TA

Krish Vijayan
TA

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Office hours starts next week

Kelly He
Instructor

Douglas Chen
TA

Krish Vijayan
TA

Office hours (Kelly + TAs) starts next week

Schedule will be announced on the class website and Discord

TAs are your peers!

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I will provide some intuitions math, and pointers

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You & Your pikachu figure these out through experiments

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In-class 10-min Quizzes (15%): Sanity check

The most common concern we got about this fully AI-friendly setting is that, how do we **make sure that we are actually learning stuff** when AI helps us do homework?

In order to provide some sort of reference point, we will have **7 in-class 10-min quizzes** through out the class to benchmark learning in a traditional setting (so **everything closed**).

That being said, you should just treat these quizzes as sanity checks: they will all be **simple questions** with no tricks and they should not heavily impact your final grade. Doing bad on quizzes simply means that you need to catch up a bit and **you can drop the lowest two quizzes**.

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Extra Credits (1.5~5%): Tell us what you have learned (and what you have not learned)

We want your feedback!

Through out the class, we will release two optional surveys (1.5% each) and conduct one optional interview (2%) to collect feedback on your AI-assisted learning experience.

The extra credits will be applied upon completion in both cases.

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Lecture topics & schedule

- Week 1~2: Basics & foundational algorithms for diffusion & flow matching

- Week 3~4: Advanced algorithms for each path

- Week 5: SOTA models & industrial applications

- Week 6: Discrete variants

- Week 7: Final poster presentation

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Class website & Gradescope

Class website: https://kellyyutonghe.github.io/10799S26/

       One-stop-shop for all the resources and pointers you will need

Gradescope: https://www.gradescope.com/courses/1207241

       The place where you will submit your homework and view your grades

       (Everyone will be added on Friday)

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Discord server (CMU only)

Our main hub for all communication:

- General question answering

- Announcements

- Forum discussion

- Memes

- Virtual office hours

- Virtual study room

Computational resources

We are super grateful that Modal is sponsoring the compute resources for this class!

- Serviceless cloud compute, everything in code, super easy to use

- All registered students will get $500 credits for this class (instructions will be sent on Friday 1/16)

- Every month you also get $30 for free

- This should translate to ~280 GPU hours on L40S in total

- **Modal is giving a guest lecture on Friday 1/16 5 PM SH 105** (same time same location of the lecture) on how to use their service!

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Computational resources

We are super grateful that AWS is also sponsoring this class!

• Classic cloud compute service, many tutorials online

• Details are still being finalized but we are expecting to give each student $100~$300 AWS credits as well (will be available later)

• AWS is also sponsoring pizza for our final poster sessions :)

Computational resources

There are other compute resources available

- CMU clusters: Babel, FLAME, etc

- Your lab's cluster

- Renting other cloud compute service

  (https://kellyyutonghe.github.io/10799S26/self-study/#computational-resources)

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Waitlist, unofficial auditing & self-study

- If more students drop from this class, we will gradually admit students from the waitlist until Friday 1/16 noon

- If you are a CMU student, please join the discord server regardless

- You can feel free to unofficially audit in any form you'd like

- No need to submit the official audit form

- Guides on auditing and self-studying can be found here:
  https://kellyyutonghe.github.io/10799S26/self-study/

Class recording & Zoom

This course will entirely be recorded and streamed on Zoom.

- You can watch the lecture from home via Zoom (although I'd say coming to class shall be fun too ☐), link shared on Discord (CMU only)

- You can access the lecture recordings in the following way

    - Panopto (CMU only for now): link shared on Discord

    - YouTube (Public): link can be found on the class website later (will have some delay)

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Books, tutorials, papers & other helpful resources

Full list here: https://kellyyutonghe.github.io/10799S26/resources/

📚 Books

The Principles of Diffusion Models

Chieh-Hsin Lai, Yang Song, Dongjun Kim, Yuki Mitsufuji, Stefano Ermon

2025

Comprehensive monograph covering diffusion models, flow matching, and transport-based generative modeling from first principles.

Website · arXiv · PDF · Blog Post

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Books, tutorials, papers & other helpful resources

🎓 Courses

Stanford CS236: Deep Generative Models

Stefano Ermon, Aditya Grover

2023

Stanford course on generative models including VAEs, GANs, EBMs, normalizing flows, diff autoregressive models.

Course Website · Lecture Notes · Video Recordings

CMU 10-423/10-623: Generative AI

Matt Gormley, Yuanzhi Li, Henry Chai, Pat Virtue, Aran Nayebi

2025

CMU course on generative models including LLMs, GANs, and diffusion models.

Course Website · Video Recordings

CMU 18-789: Deep Generative Modeling

Beidi Chen, Xun Huang

2025

CMU course on generative models including LLMs, VAEs, and diffusion models.

Course Website

MIT 6.S184: Introduction to Flow Matching and Diffusion Models

Peter Holderrieth, Ezra Erives

2025

MIT class on diffusion and flow matching from a flow-based theoretical perspective.

Course Website · Lecture Notes · Video Recordings

CMU 10-708: Probabilistic Graphical Models

Andrej Risteski, Albert Gu

2025

CMU course that focuses on probabilistic modeling (including some deep generative models fro perspective).

Course Website

Stanford CS228: Probabilistic Graphical Models

Stefano Ermon

2024

Stanford course that focuses on probabilistic modeling.

Course Website · Lecture Notes

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Books, tutorials, papers & other helpful resources

📝 Tutorials

Generative Modeling by Estimating Gradients of the Data Distribution

Yang Song

2021

Introduction to score-based generative models and their connection to diffusion models.

What are Diffusion Models?

Lilian Weng

2021

Comprehensive introduction to diffusion models with clear explanations and intuitive visualizations.

Understanding Diffusion Models: A Unified Perspective

Calvin Luo

2022

Unifies VAEs, hierarchical VAEs, and diffusion models under a single framework.

arXiv · Blog Post

Flow Matching Guide and Code

Yaron Lipman, Marton Havasi, Peter Holderrieth, Neta Shaul, Matt Le, Brian Karrer, Ricky T. Q. Chen, David Lopez-Paz, Heli Ben-Hamu, Itai Gat

2024

Comprehensive guide to flow matching with code examples and applications.

arXiv · PDF

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The only goal in this class is to help you learn & build

This is why

- Lecture attendance is not required, feel free to join on Zoom, watch recordings later or disregard lectures all together if you dislike going to class
    - You still need to take the quizzes in person, lmk ahead of time if you have any emergency/need accommodation
- Your grade will only be curved up and never curved down, and if everyone does well, everyone gets an A/A+ (cutoffs will be announced mid-class)
- Feel free to use any and all resources you can find

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