# Deep Generative Model: A Statistical Perspective (STT 997)

**Instructor**: Younggeun Kim (kimyo145@msu.edu)

**Room and Time:** TT 12:40PM-2:00PM at WH C506

**Objective**: This course aims to provide a comprehensive understanding of generative models, machine learning methods for learning and synthesizing complex and large-scale data, and to enhance the ability to implement these models. Topics include latent variable models, statistical distances used to learn distributions, and advanced applications such as temporal, multi-modal, and medical data scenarios in generative model literature.

**Description**: Generative models are statistical models that learn high-dimensional data distributions and can generate realistic synthetic data. Key components include model classes that approximate data distributions, statistical distances that quantify discrepancies between real and model distributions, and inferences based on them. This course aims to deepen insight into and knowledge of the statistical principles behind these components, explore transitions in generative model literature, with a particular focus on deep generative models, and provide hands-on experience with popular algorithms.

Given the broader impact and growing importance of generative models in interdisciplinary fields, this course welcomes students interested in generative models from diverse backgrounds, including Computer Science and Engineering (CSE), Computational Mathematics, Science and Engineering (CMSE), and the Department of Mathematics. To make the course more inclusive, several lectures on preliminary statistical knowledge, such as likelihood maximization principles and information theory, as well as basics of Python and PyTorch programming, will be provided.

**Prerequisites**: There are no specific prerequisite courses; however, students interested in this course may review the slides from my STT 990 seminar talk, available at https://kyg0910.github.io/teaching/. This was a 3-hour talk that briefly introduced popular statistical distances and their roles in generative models for graduate students in the Department of Statistics and Probability. For example, the lecture on preliminary statistical knowledge in this STT 997 course will cover the basics of statistical distances to aid understanding of these slides.

**Textbook (not required)**: Goodfellow, Ian. "Deep learning" (2016); online access (free): https://www.deeplearningbook.org/

# Course Details

**Office Hours**: TBA

**Projects**: There is **one** group project and **one** personal project:

- **Group project**: Study one of the listed agendas on the broader impacts of generative models. Potential agendas include:
  1. Introducing AI into peer-reviewing processes (e.g., Pre-peer review screening): [1]
  2. Utilizing generative AI for psychotherapy (e.g., helping mourners cope with grief): [2] and [3]
  3. Regularizing generative AI research until the establishment of safeguards against misuse: [4] and [5]

  Group members will be designated according to **Assignment I**, which involves writing position papers that present personal stances (pros and cons) on the agendas.
- **Personal project**: Conduct one of the following projects:
  1. Reviewing generative model papers related to students' research interests
  2. Modifying or extending existing theoretical results
  3. Applying existing algorithms to solve new research problems

Repetitions of previous studies or summarizing existing review papers are not accepted.

**Assignments**: There are **four** assignments, **two** for writing articles (I and III) and **two** for solving problem sets (II and IV):

- **Assignment I**: Write position papers on the broader impacts of generative models (See **Group Project** above).
- **Assignments II & IV**: Solve sets of problems to assess understanding of the main content. Most of the problems are examples and proofs delivered in lectures.
- **Assignment III:** Write a review of learned papers and a meta-review of their peer-reviewing processes. Potential papers and their publicly available reviews include: Open reviews for Generative Adversarial Network [6] and Variational Autoencoder [7]

Assignments will be graded Pass or Resubmit (expected to be a rare situation). There is **Assignment 0** for preliminary knowledge, but **it is neither submitted nor evaluated**.

**Course Evaluation:** Four assignments (10% each, totaling 40%), personal project (40%), group project (20%). All reports must be passed.

# Lecture Plan

| Date | Topic | Coursework | Remark |
|---|---|---|---|
| **01/14** | Introduction | Assignment 0 released (no submission) | |
| **01/16 & 21** | Preliminary Knowledge I: Statistics | (01/16) Assignment I released | |
| **01/23 & 28** | Preliminary Knowledge II: Statistical Learning | (01/28) Assignment I due | |
| **01/30 & 02/04** | Preliminary Knowledge III: Python and PyTorch | (02/04) Assignment II released | |
| **02/06 & 02/11** | Linear Method and Auto-regressive Model | | |
| **02/13** | - | | **Class Not Held** |
| **02/18 & 20** | Energy-based Model | | |
| **02/25 & 27** | Variational Autoencoders | (02/27) Assignment II due & Assignment IV released | |
| **03/04 & 06** | - | | **Spring Break** |
| **03/11** | Variational Autoencoders | | |
| **03/13** | Group Project Presentation | | |
| **03/18, 20 & 25** | Generative Adversarial Networks | (03/18) Group project report due & Assignment III released | |
| **03/27** | PyTorch Implementation | | |
| **04/01, 03, & 08** | Optimal Transport-based Method | (04/01) Assignment III due | |
| **04/10, 15, & 17** | Score-based Method | (04/15) Assignment IV due | |
| **04/22 & 24** | Personal Project Presentation | | |
| **05/01** | - | Personal project report due | |

* Details can change depending on the class size and students' background.

**Reference**

[1] Checco, Alessandro, et al. "AI-assisted peer review." *Humanities and Social Sciences Communications* 8.1 (2021): 1-11.

[2] Chowdhury, Sibasish. Managing Grief with AI: Emerging Evidence and Ethical Considerations, https://www.linkedin.com/pulse/managing-grief-ai-emerging-evidence-ethical-sibasish-chowdhury-rtdhc, June 2024. Accessed: 2024-12-16

[3] CBS News, AI simulations of loved ones help some mourners cope with grief. https://www.cbsnews.com/news/ai-grief-bots-legacy-technology/, June 2024. Accessed: 2024-12-16

[4] Bengio, Yoshua. Slowing down development of AI systems passing the Turing test. https://yoshuabengio.org/2023/04/05/slowing-down-development-of-ai-systems-passing-the-turing-test/, April 2023. Accessed: 2024-12-16

[5] The White House. Executive order on the safe, secure, and trustworthy development and use of artificial intelligence. https://www.whitehouse.gov/briefing-room/presidential-actions/2023/10/30/executive-order-on-the-safe-secure-and-trustworthy-development-and-use-of-artificial-intelligence/, October 2023. Accessed: 2024-12-16

[6] NeurIPS 2014. Reviews for the submission “Generative Adversarial Nets” https://proceedings.neurips.cc/paper_files/paper/2014/file/5ca3e9b122f61f8f06494c97b1afccf3-Reviews.html, December 2014. Accessed: 2024-12-16

[7] ICLR 2014. Reviews for the submission “Auto-Encoding Variational Bayes” https://openreview.net/forum?id=33X9fd2-9FyZd, December 2013. Accessed: 2024-12-16