Program: PGE5 Academic year: 2025-2026 Semester: 1 UE: …

Generative AI

24 H

I- Pré-requis / Prerequisite(s)

Students should be comfortable with basic deep learning concepts, optimization, and basic probability.

- Basic Deep Learning: MLPs (Multi-Layer Perceptrons), CNNs (Convolutional Neural Networks), and backpropagation.
- Optimization: Stochastic Gradient Descent (SGD) or Adam, and understanding of loss functions.
- Basic Probability: Concepts such as random variables, distributions, and expectation.

II- Répartition des heures / Learning Hours Analysis

Type d'heures d'apprentissage / Type of learning hours	Heures / Hours
Face à Face / Face to Face	24h
Activités en ligne / On-line activities	0
Travail individuel / Individual work	3h
Travaux de groupes / Group work	10-12h
Evaluation / Assessment	3h
TOTAL	**36h**

III- Course description

This course covers the theoretical foundations, core architectures, and practical deployment of modern Generative AI systems. It is structured across four key areas: foundational models (GANs and VAEs), large language models (LLMs), visual generation (Diffusion Models), and responsible deployment (Evaluation, Alignment, and Applications).

The course emphasizes tying equations to implementation intuition and empirical behavior. Students will move from understanding probabilistic foundations to implementing state-of-the-art architectures and building an end-to-end generative pipeline.

IV- Objectifs d'apprentissage / Learning objectives

By the end of the course, students should be able to:

- Explain Core Foundational Models: Derive and explain the GAN minimax loss and the VAE Evidence Lower Bound (ELBO), comparing their trade-offs regarding sample sharpness, mode coverage, and training stability.
- Master the Transformer Architecture: Derive and explain the scaled dot-product attention formula and describe the components of a Transformer block.
- Adapt Large Language Models (LLMs): Explain the LLM training pipeline, describe the process of alignment via RLHF, and choose and justify a Parameter-Efficient Fine-Tuning (PEFT) strategy, such as LoRA, for domain specialization.
- Implement Diffusion Models: Define the forward and reverse diffusion processes, explain the simplified noise-prediction training objective, and describe the Stable Diffusion pipeline utilizing VAE, U-Net, and cross-attention.
- Evaluate Generative Quality: Select and apply appropriate automated metrics for generated content, including FID (for images), CLIP similarity (for image-text alignment), and ROUGE/BERTScore (for text), understanding their limitations.
- Assess and Mitigate Risks: Conduct systematic probes for safety issues, including bias, toxicity, and hallucinations, and propose engineering mitigations such as Model Cards, Red Teaming, and Retrieval-Augmented Generation (RAG).

V- Contenu du cours / Sequences description, learning activities and assignments

	Contenus / content	Séance / Session	
1.	Generative AI: From Core Concepts to Foundational Models	1	Lecture #1
2.	Hands-on Implementation: Implement and train a simple GAN and a VAE using PyTorch (e.g., on MNIST), perform latent space interpolation, and compare sample quality and training stability.	2	Lecture #2
3.	LLMs & Fine-Tuning	3	Lecture #3
4.	Hands-on Implementation: Load a causal LM (e.g., DistilGPT2), prepare data for training, compare Full Fine-Tuning vs LoRA (PEFT), and run prompt engineering experiments (zero-shot, few-shot).	4	Lecture #4
5.	Diffusion & Multimodality	5	Lecture #5
6.	Hands-on Application: Run and control Stable Diffusion generation, experiment with CFG scale and inference steps, and perform image editing tasks like inpainting.	6	Lecture #6
7.	Evaluation, Alignment & Applications	7	Lecture #7
8.	Pipeline & Evaluation: Build an end-to-end LLM→Diffusion creative pipeline, compute CLIP-based alignment scores, design and perform a bias/safety probe, and propose mitigations.	8	Lecture #8

- Ethical, Social, and Environmental Issues: Throughout the course, particularly on Day 4, there is a systemic focus on the ethical, societal, and environmental impact of Generative AI. Specific issues addressed include:
- Bias and Fairness: Analyzing stereotypical associations in models (gender, race, profession) and the need for systematic bias evaluation.
- Toxicity and Misuse: Measuring and mitigating the generation of harmful, abusive, or violent content using Red Teaming and output filters.
- Misinformation and Hallucinations (LLMs): Understanding why models produce factually incorrect but fluent output and implementing grounding techniques like RAG.
- Intellectual Property and Artist Rights: Discussions relating to training data sources for Diffusion Models and the ethical implications of style mimicry.

- Responsible Frameworks: Introducing Model Cards and Datasheets for transparency and governance in deployment.

VI- Méthodes pédagogiques / Pedagogical methods

The course employs a deep learning methodology combining theory and practical application:

- Theoretical Foundations: Detailed derivations and intuitive explanations of core mathematical concepts underpinning VAEs, GANs, Transformers, and Diffusion.
- Learning by Doing (Focus): Extensive practical sessions (Labs 1–4, 3 hours each) focused on implementing models and controlling generation using industry-standard libraries (PyTorch, Hugging Face transformers and diffusers, PEFT).
- Practical Application: Building an operational end-to-end pipeline (LLM prompt generation feeding into a Diffusion Image model) to simulate real-world Generative AI products.
- Case Studies: Integration of real-world applications across science, robotics, and software engineering to contextualize evaluation and safety constraints.

VII- Méthodes d'évaluation / Grading procedure

- **Contrôle continu / Continuous assessment** : 50% in class quizzes
- **Examen final individuel / Individual Final sitting Exam :** 50% on paper

VIII- Bibliographie / Required and additional readings / resources (books, articles, vidéos, links, etc.)

The course draws heavily on fundamental and modern Generative AI literature, implemented through PyTorch and Hugging Face ecosystems:

- Fundamental Works: Original papers on GANs (Goodfellow et al., 2014), VAEs (Kingma & Welling, 2014), and The Transformer (Vaswani et al., 2017).
- LLM Adaptation: Works covering Scaling Laws (Kaplan et al., Chinchilla), Alignment (RLHF), and PEFT techniques like LoRA.
- Diffusion & Multimodality: DDPM (Ho et al., 2020), DDIM (Song et al.), CLIP (Radford et al.), and Latent Diffusion Models (Rombach et al.).
- Practical Tools & Resources: PyTorch documentation, Hugging Face transformers and diffusers libraries, and PEFT library documentation.
- Safety & Ethics: Resources covering Model Cards, Red Teaming, and evaluation benchmarks.

IX- Biographie de l'intervenant / Faculty bios

Dr. Antoun Yaacoub is an Associate Professor at aivancity, where he leads the MSc in Generative Artificial Intelligences. A recognized expert in language models (LLMs) and in the application of AI to education, his career is dedicated to the convergence between technological innovation and pedagogical engineering.

He holds a PhD in Computer Science from Paul Sabatier University (IRIT, Toulouse). His research focuses on the design of intelligent and adaptive learning environments. He is the author of numerous scientific publications and notably developed OneClickQuiz, a generative-AI–based tool for creating quizzes, perfectly illustrating his hands-on learning approach.