Generative AI

1. **Course number and name:** 020GAIES5 Generative AI

2. **Credits and contact hours:** 4 ECTS credits, 2x1:15 contact hours

3. **Name of course coordinator:** Fares Maalouf

4. **Instructional materials:** Slides
   References:
   Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play" – David Foster (2nd Edition, O'Reilly, 2022)
   https://huggingface.co
   https://paperswithcode.com/task/text-generation

5. **Specific course information**
   a. **Catalog description:**
      This course provides engineering students with an in-depth understanding of generative artificial intelligence, focusing on the design, implementation, and deployment of advanced generative models. Students will explore foundational architectures such as Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), autoregressive models, diffusion models, and transformer-based systems like GPT. The course also introduces Retrieval-Augmented Generation (RAG), a powerful paradigm that enhances large language models by integrating external knowledge sources for grounded and context-aware generation. In addition to mastering core modeling techniques, students will examine recent trends such as foundation models, multimodal generation, and the integration of generative models within agentic AI systems (autonomous, goal-driven agents capable of reasoning, planning, and tool use). Hands-on projects will allow students to apply these concepts to real-world tasks involving text, image, audio, and cross-modal generation. Ethical considerations, including bias, misinformation, and responsible deployment will also be discussed. By the end of the course, students will be prepared to build, fine-tune, and evaluate generative AI systems in both industrial and research contexts.

   b. **Prerequisites:** 020NLPES3 Natural Language Processing

   c. **Required** for CCE Artificial Intelligence option students; **Selected Elective** for students in the CCE Software Engineering and Telecommunication Networks options.

6. **Educational objectives for the course**
   a. **Specific outcomes of instruction:**

- Explain the theoretical foundations and architectural principles of generative models including GANs, VAEs, autoregressive models, diffusion models, and transformer-based architectures.
- Implement generative models using open-source frameworks such as PyTorch or TensorFlow, and apply them to real-world data (text, image, audio, and multimodal).
- Analyze training challenges such as mode collapse, instability, and overfitting, and apply appropriate mitigation techniques.
- Evaluate the quality and performance of generative models using quantitative metrics (e.g., FID, BLEU) and qualitative assessments.
- Fine-tune pretrained generative models for domain-specific tasks and optimize them for deployment in constrained environments.
- Compare different generative architectures based on use case, complexity, and computational requirements.
- Apply generative models responsibly by identifying and addressing ethical concerns such as bias, misinformation, and synthetic content misuse.
- Design and document an end-to-end generative AI solution, demonstrating system-level thinking, performance analysis, and ethical compliance.

b. PI addressed by the course:

PI	1.1	1.2	1.3	2.1	2.2	2.3	2.4	2.5	4.1	4.2	7.1	7.2
Covered	x	x	x	x	x	x	x	x	x	x	x	x
Assessed	x	x	x	x	x	x	x	x			x	x

7. Brief list of topics to be covered

- Introduction to Generative AI, Foundation Models, and Probabilistic Modeling (2 lectures)
- Latent Variable Models and Variational Autoencoders (VAEs) (2 lectures)
- Generative Adversarial Networks (GANs) and Variants (2 lectures)
- Training Challenges and Evaluation in Generative Models (2 lectures)
- Autoregressive Models and Sequence Generation (2 lectures)
- Transformer Architectures and Attention Mechanisms (2 lectures)
- Generative Pretrained Transformers (GPT) and Large Language Models (LLMs) (2 lectures)
- Diffusion Models and Score-Based Generative Modeling (2 lectures)
- Multimodal Generation and Cross-Modal Models (2 lectures)
- Retrieval-Augmented Generation (RAG) and Knowledge-Augmented LLMs (2 lectures)
- Agentic AI: Goal-Directed Behavior, Tool Use, and Reasoning with Generative Models (2 lectures)
- Responsible and Ethical Deployment of Generative AI (2 lectures)