Generative Artificial Intelligence

Generative Künstliche Intelligenz

M. Sc. Angewandte Informatik

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But ...

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What is generative artificial intelligence?

A lecture at the right time

- Generative AI is one of the big trending technologies, and said to change the way we work and live.
- It is based on two key enablers:
  - The availability of large amounts of data and
  - The availability of compute.
- Both is not available for us, though ;-)

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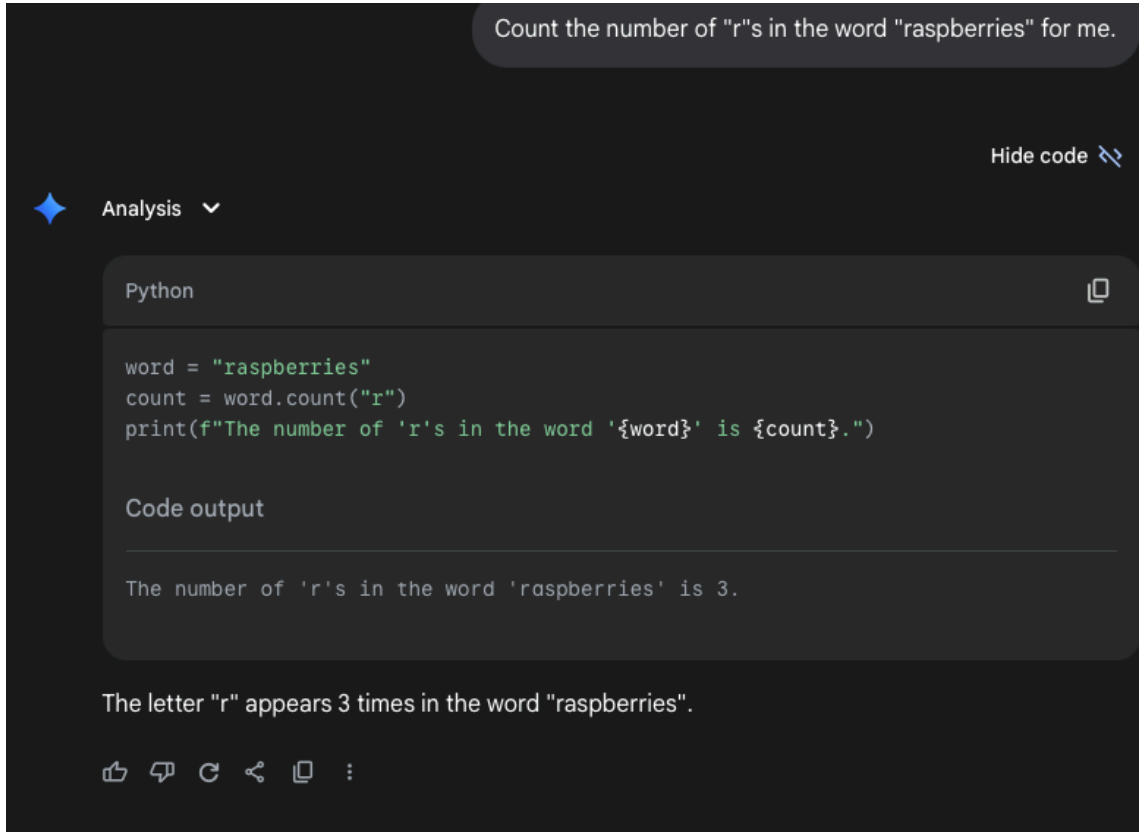
Examples of GenAI: LLMs

- Large Language Models as Chatbots



(gemini, Aug 2025)

Examples of GenAI: Text-to-Video

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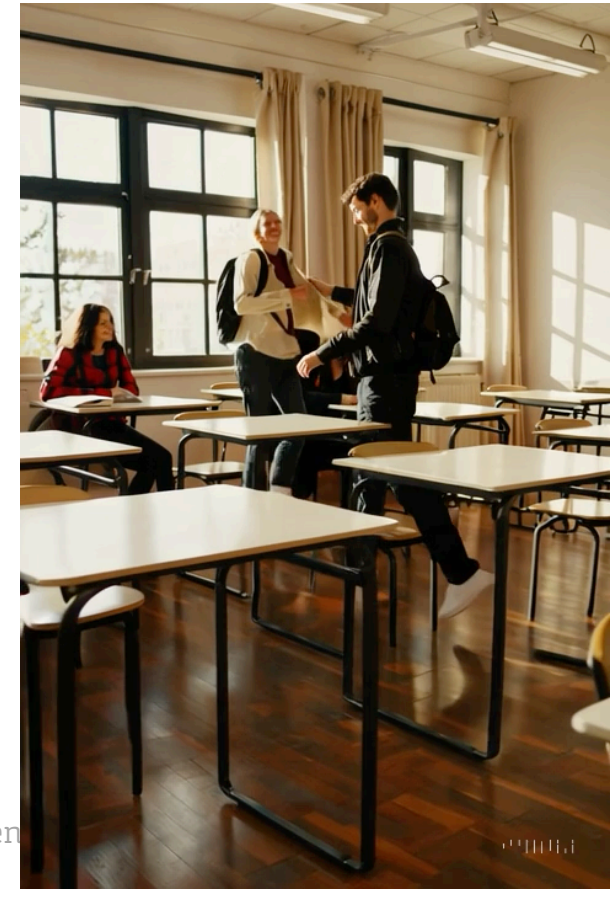
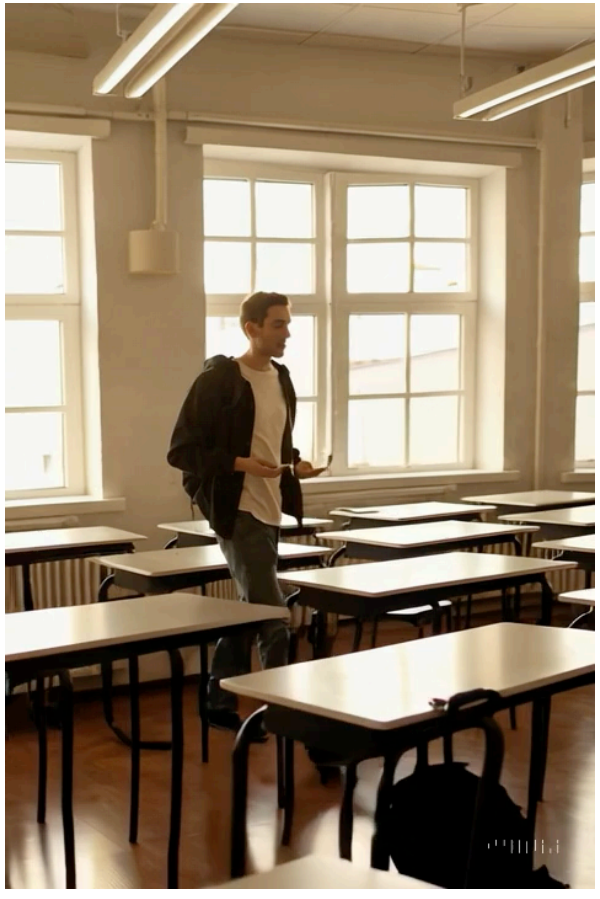
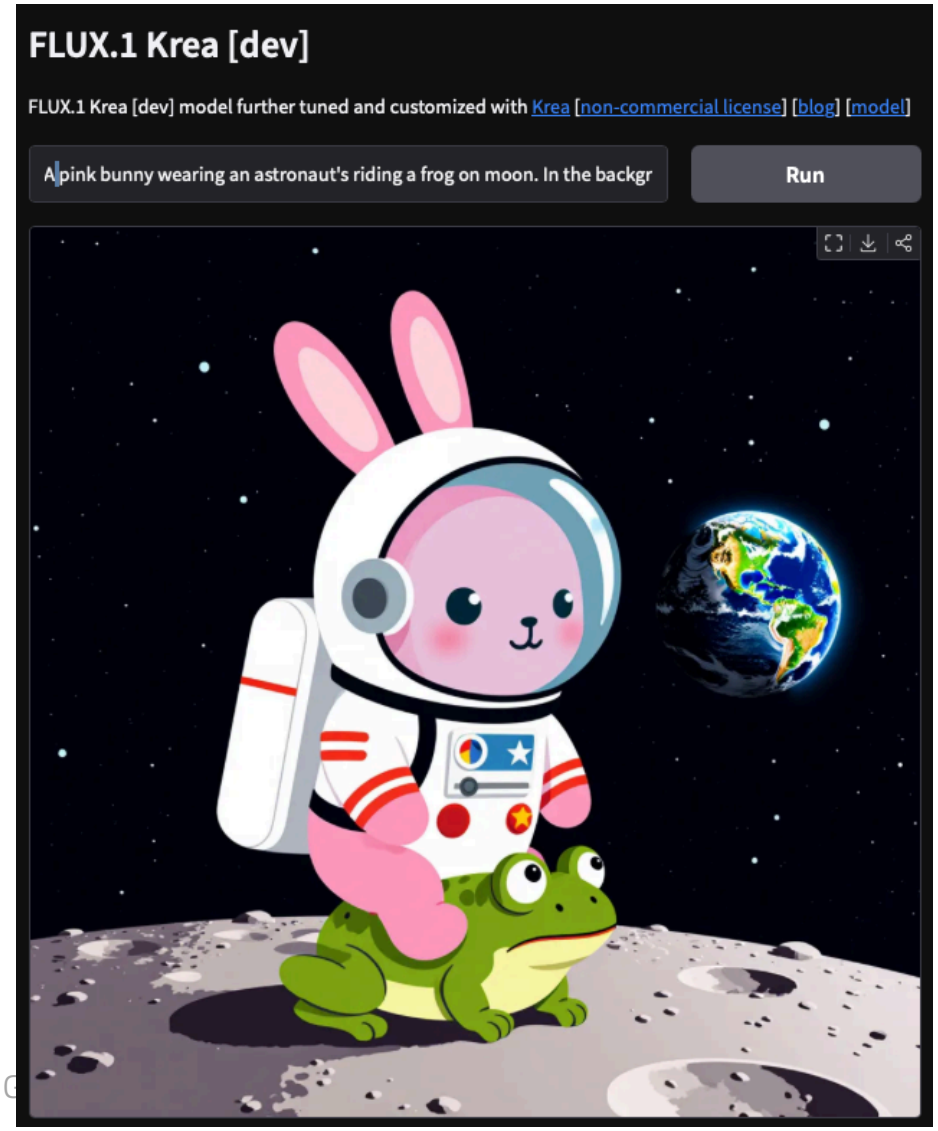
+ A student at HS Flensburg is coming late to class. To avoid the professor being angry, he presents a magic trick.





(OpenAI sora, Aug 2025)

Examples of GenAI: Text-to-Image



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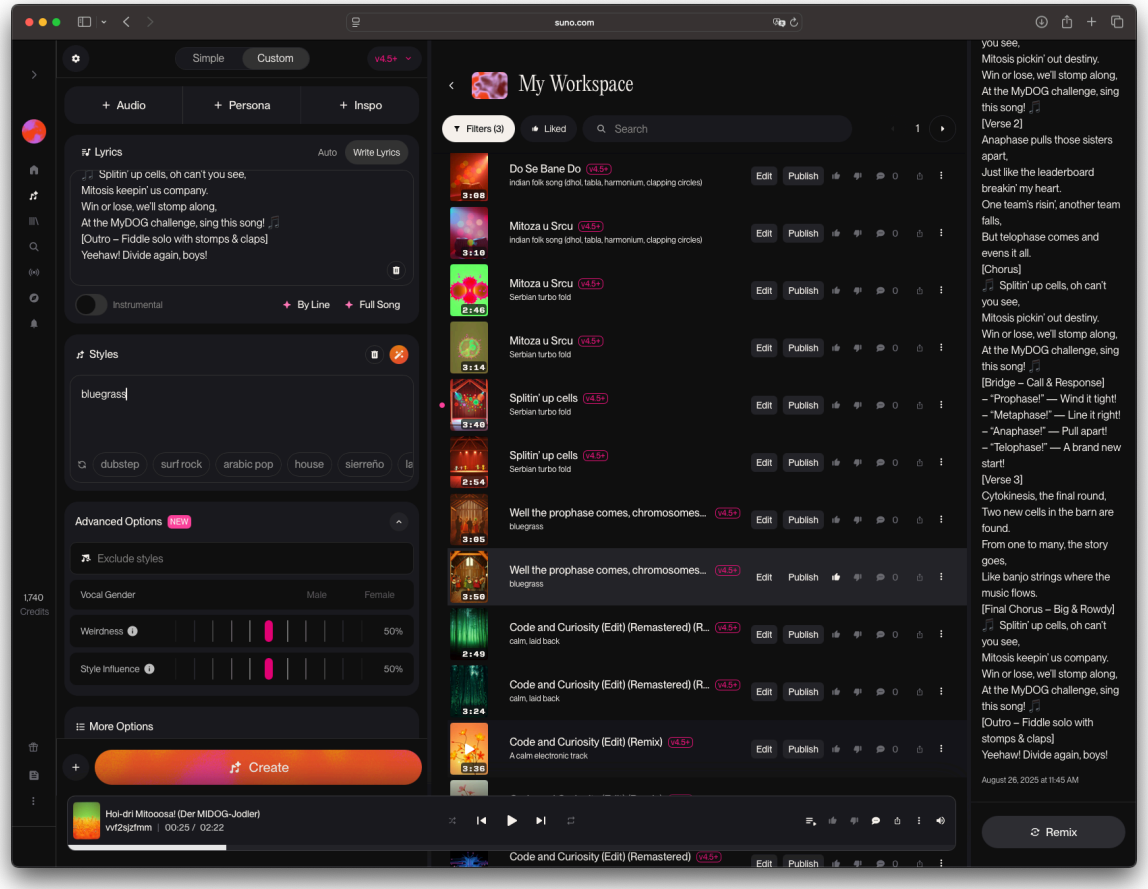
Examples of GenAI: Text-to-Music

- suno.ai Music Generation



Some examples:

"Divide and Conquer"

Hoi-dri Mitooosa!
(Der MIDOG-Jodler)

(gemini, Aug 2025)

Generative Artificial Intelligence: Definition

- Generative Artificial Intelligence Systems are models that can generate new and realistic data from pure entropy (randomness).

- In particular, they
  - combine randomness with patterns learned from training data, and
  - use conditioning signals (priors), such as textual descriptions, to guide the generation process.

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But …

How does this all work?

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Plan for this semester

(might change a little bit, it's the first time I give this lecture)

Part 1: Introduction / Model Families

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- 1. Foundations & Core Concepts
  - Generative vs. discriminative models
  - Latent variable modeling & representation learning
  - Dimensionality reduction & interpretability: PCA, t-SNE, UMAP, linear probing
  - Learning paradigms: supervised, unsupervised, self-supervised

- 2. Generative Model Families (Compact History → Modern Focus)
  - Autoregressive models (RNNs, Transformers → GPT)
  - VAEs (concepts, posterior collapse)
  - GANs (core idea, conditional GANs, StyleGAN, but kept concise)
  - Diffusion models (denoising, latent diffusion, scaling to large models)

Part 2: Text and Image Generation

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- 3. Text Generation (LLMs)
  - Pretraining objectives: autoregression, masked LM, causal vs. bidirectional models
  - Fine-tuning strategies: supervised fine-tuning, RLHF, instruction tuning, parameter-efficient tuning (LoRA, adapters)
  - Scaling laws & data efficiency
  - Mixture of Experts (MoE) and sparse models
  - Current trends: retrieval-augmented generation, tool use, agents

- 4. Image Generation
  - Latent Diffusion Models (Stable Diffusion, Imagen, DALL·E)
  - Multi-scale & hierarchical models (e.g., Würstchen)
  - Flow matching models
  - Control & conditioning: text-to-image, inpainting, ControlNet
  - Beyond still images: image editing, personalization, style transfer
  - Limitations: compute intensity, training instability, evaluation metrics (FID, CLIP score)

Part 3: Video and Audio Generation

- 5. Audio Generation
  - Autoregressive approaches
  - Diffusion models for audio (AudioLDM, MusicLM)
  - Music generation (Jukebox, MusicGen)
  - Cross-modal links: text-to-speech, speech-to-speech, text-to-music
- 6. Video Generation
  - Extension of diffusion models to temporal dimension (e.g., Imagen Video, Pika, Runway Gen-2)
  - Consistency challenges (temporal coherence, motion dynamics)
  - Multi-scale spatio-temporal modeling
  - Emerging architectures (latent video diffusion, transformers for video)

Part 4: Multimodal Models & Discussion

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- 7. Cross-Modal & Multimodal Generation
  - Joint embeddings (CLIP, ALIGN)
  - Multimodal foundation models (Flamingo, Gemini, Kosmos)
  - Agentic AI

- 8. Challenges, Ethics & Future Directions
  - Training cost, scaling vs. efficiency (distillation, quantization)
  - Evaluation challenges (quality, diversity, alignment with human intent)
  - Risks: deepfakes, bias, misuse, copyright
  - Future: world models, scientific discovery, personalized generative AI

This will be fun.

- We will also not forget to have a look a some epic outcomes of generative AI.
- And of course, these lecture slides are full of it.

- So, get strapped - this is going to be quite a ride.

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How this lecture works

- The first part of the semester is me giving talks about various topics in the field of GenAI (see slides later).
- Occasionally, I will also bring papers for you to read and present.
- Then, it's your turn:
  - Select a topic of your own choice.
  - Write your own code, do your own experiments
  - Prepare a presentation
  - Finally, submit a summary report of your findings.

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Expected time investment

- One ECTS point accounts for 25 wall-clock hours (60 minutes) of effort.
- This lecture has 4 SWS = 6 ECTS
- You can thus expect to plan for an effort of $25 \cdot 6 = 150$ hours for this lecture.
- We have 13 on-site events (lectures), each being 180 minutes, so that's 39 hours.
- The rest of the time is:
  - Preparing and Follow-Up
  - Your own project

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Selection of a topic

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- I know: Selecting your own topic is hard.
- But on the other hand: You probably don't want me to select the topic for you. ;-)

- You can be totally free in the choice of topic, of course you will find inspiration in the lecture.
- Be aware: The level of complexity you choose influences the grade.
- There is a scheme for the grading (available on StudIP).
- I expect from you, until **November 1st**:
  - The topic of your talk (can be modified if it turns out to be not viable)
  - A rough time estimate

Peer review

- We also want to practice reviewing of reports / papers together.
- Reason:
  A critical but well-meaning view on the works of others will make you a better writer.
- Focus:
  How could this work have been improved?
  What's great about this work?

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