arisa

D4.2 Specific Curriculum

MACHINE LEARNING ENGINEER EQF 7

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Project information

The Artificial Intelligence Skills Alliance (ARISA) fast-tracks the upskilling and reskilling of employees, job seekers, business leaders, and policymakers into AI-related professions to open Europe to new business opportunities. It is a four-year transnational project funded under the EU's Erasmus+ programme. For more information, contact info@aiskills.eu | aiskills.eu

Project Partners

List of abbreviations

AI	Artificial Intelligence
ARISA	Artificial Intelligence Skills Alliance
EQF	European Qualification Framework
EU	European Union

Table of contents

1. General information

Name	Machine Learning Engineer
EQF level	EQF 7
Goals	The intent of the EQF 7 Machine Learning (ML) Engineer curriculum is to provide a solid base in ML techniques, develop advanced machine learning and artificial intelligence (AI) skills, and ensure the ability to build and manage ethical and secure AI systems. Its aim is to produce graduates who are ready to lead and innovate as ML Engineers, capable of tackling complex problems and contributing to advancements in technology and society, as well as being capable of applying their knowledge to real-world problems.
Scope	The curriculum is aimed at people who intend to become ML Engineer practitioners. It can also be used to upskill or reskill individuals that already have a background in computer science and want to specialize in ML. It is also intended to both articulate how to instantiate for both microcredentials as well as conventional second-cycle courses, as both options are valid for aspiring ML Engineers (for example if they possess a master's degree already). It is also agnostic as regards platforms and APIs so to allow customisation to local requirements.
Entry requirements	As expected of a bachelor's degree in computer science or a related subject, specifically: • Python programming, basic data preprocessing, basic databases • Linear Algebra • Calculus • Probability theory Resources such as the following may be used for already competent programmers who wish to familiarise themselves with Python beforehand: • https://cs231n.github.io/python-numpy-tutorial/ • https://pandas.pydata.org/pandas-docs/stable/user_guide/10min.html
Programme learning outcomes (PLOs)	1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - ML Ops (EQF 7) 4 - Machine Learning (EQF 7) 5 - Explainable AI (EQF 7)

	6 - Big Data & Data Analytics (EQF 7) 7 - Human-Centered AI (EQF 7) 8 - AI Ethics (EQF 6) 9 - AI Awareness (EQF 6) 10 - Cyber and Data Security (EQF 5) 11 - Generative AI (EQF 7) 12 - Change Management (EQF 6) 13 - Soft Skills (EQF 6) 14 - HPC and Cloud services (EQF 7)

2. Description of the structure

The two learning units Machine Learning Foundations, Deep Learning comprise a base that covers the key concepts that underpin the role.

Thereafter there are two sets of extension learning units. The first set deepens and broadens ML technical knowledge and skills in important areas (Data Science, Machine Learning Operations [MLOps], Large-Scale AI Solutions, Generative AI). An AI Applications learning unit has also been articulated to allow customisable delivery in specific application areas such as cybersecurity and NLP.

Following from this, the second set of learning units are aimed at developing aspiring ML Engineers to be effective deliverers of technological solutions to clients (Human-Centred AI and User Experience, AI for Business, AI Law and Ethics, AI Transformation and Project Management).

It is worth noting that it is assumed that soft skills will be developed through the curriculum.

Though 5 ECTS is assumed as a default to support conventional second-cycle studies, a range is given. For example, a microcredential aimed at upskilling established developers might require fewer ECTS as some of the outcomes could be deemed to have been already met to some degree.

There is a capstone Project and Thesis Work learning unit. This supports both a traditional academic project typical of second-cycle studies, as well as a work-based or industrial project. It could also be used as a concluding unit in a microcredential-based scheme that leads to a larger award. A minimum of 5 ECTS is suggested to allow for an extended piece of work to be produced.

3. Overview of Learning Units

Learning unit title	Hours/ECTS	EQF level	Assessment(s)
Machine Learning Foundations	2-10 ECTS	EQF 6-7	Exam and/or Practical Assignment, Project work
Deep Learning	2-10 ECTS	EQF 6-7	Exam and/or Practical Assignment, Project work
Data Science	2-10 ECTS	EQF 6-7	Exam and/or Practical Assignment, Project work
Machine Learning Operations (MLOps)	2-5 ECTS	EQF 6-7	Exam and/or Practical Assignment, Project work
Large Scale AI Solutions (cloud/HPC)	2-5 ECTS	EQF 6-7	Exam and/or Practical Assignment, Project work
AI Applications (NLP, coding tools, CV, Speech, cybersecurity, etc.)	1-5 ECTS	EQF 5-6-7	Exam and/or Practical Assignment, Project work

Generative AI	2-5 ECTS	EQF 6-7	Exam and/or Practical Assignment, Project work
Human-Centred AI and UXUser Experience	1-5 ECTS	EQF 6-7	Exercises requiring the analysis, evaluation or UX design of AI systems (can be under exam conditions if required, also scope for groupwork)
AI for Business	1-5 ECTS	EQF 6-7	Exercises based on the analysis of case studies and/or realistic scenarios (can be under exam conditions if required, also scope for groupwork)
AI Law and Ethics	1-25 ECTS	EQF 6-7	Exercises based on the analysis of case studies and/or realistic scenarios (can be under exam conditions if required, also scope for groupwork)

AI Transformation and Project Management	1-5 ECTS	EQF 6-7	Exercises based on the analysis of case studies and/or realistic scenarios (can be under exam conditions if required, also scope for groupwork)
Project and Thesis Work	5+ ECTS	EQF 6-7	Project report, presentation/demonstration.

4. Details of Learning Units

4.1. Machine Learning Foundation

Description
The "Machine Learning foundations " learning unit is designed to provide students with a comprehensive understanding of both foundational and advanced machine learning techniques. Students will learn the fundamentals and practical use of predictive models for various classification, regression, and unsupervised learning tasks. The curriculum covers a wide range of topics, from classical algorithms to reinforcement learning methods. Modules: 1. Types of machine learning (e.g., supervised, unsupervised, self-supervised, reinforcement learning, semi-supervised learning, active learning) 2. Classical algorithms: k-NN, Linear and Logistic Regression, Decision Trees, Random Forest, XGBoost, and SVM 3. Advanced ensemble methods: Stacking, Boosting (AdaBoost, Gradient Boosting), and Bagging 4. Unsupervised learning: K-means, Hierarchical Clustering, DBSCAN, GMM, and Self-Organizing Maps (SOM) 5. Dimensionality Reduction and Feature Selection: PCA, t-SNE, UMAP, LDA, ICA, and Autoencoders 6. Probabilistic Graphical Models: Bayesian Networks, Markov Random Fields, and Hidden Markov Models 7. Deep Learning and backpropagation basics 8. Reinforcement Learning: Q-Learning and Deep Q-Networks (DQN) 9. Advanced Model Evaluation, Validation, and Interpretation
Related Programme Learning Outcome(s)
1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - ML Ops (EQF 7) 4 - Machine Learning (EQF 7) 5 - Explainable AI (EQF 7) 6 - AI Awareness (EQF 6) 7 - Soft Skills (EQF 6)
Unit learning outcomes
• Critically evaluates and understands the theoretical underpinnings of deep learning • Designs innovative deep learning models • Assesses the capabilities and limitations of different AI technologies

- Integrates AI technologies to create comprehensive systems that improve decision-making
- Implements AI solutions using best practices in software engineering and data management
- Disseminates findings and developments in AI technologies
- Designs robust ML Ops architectures
- Independently develops robust machine learning models using advanced algorithms
- Understands the mathematics of ML algorithms
- Critically evaluates the performance of machine learning models
- Optimizes machine learning algorithms and systems for improved performance
- Designs AI systems with a focus on explainability
- Critically assesses AI models for biases and ethical implications
- Understands the basic concepts and technologies underlying artificial intelligence
- Identifies key AI applications in the programming application market
- Assesses the strategic considerations for integrating AI into business operations
- Knowledge of current trends in AI technology
- Collaborates within teams, contributing positively to group efforts
- Solves problems creatively and efficiently
- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Thinks critically, analysing situations, evaluating diverse perspectives

Delivery method(s)

In-class / Blended learning

Materials

Learning materials: presentation slides and example practical exercises.

Suggested materials:

- Bishop, C. M., & Nasrabadi, N. M. (2006). Pattern recognition and machine learning (Vol. 4, No. 4, p. 738). New York: Springer.
- Géron, A. (2022). Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow. " O'Reilly Media, Inc.".
- Stuart Russell, Peter Norvig (2021), Artificial Intelligence: A Modern Approach, 4th edition, Pearson

4.2. Deep Learning

Description
The "Deep Learning" learning unit is focused on advancing students to deep learning models, methods and applications. The learning unit also introduces the necessary hardware architecture and software tools, as well as model development and deployment methods, with practical examples. Topics: 1. CRISP-DM methodology, its application to deep learning 2. Hardware architecture (from small to large scale) 3. Deep learning frameworks (e.g. PyTorch, TensorFlow, Keras) and related software tools (e.g. SLURM, Docker, Singularity, Kubernetes, KubeFlow, MLFlow, TensorBoard) 4. General deep learning architectures (e.g. fully connected, recurrent, convolutional, transformer layers) 5. Complex architectures (e.g. residual, skip connections, highway and dense networks, sequence-to-sequence models) 6. Self-supervised learning (SSL) and its application to different domains (e.g. text, vision) 7. Hyperparameter optimization 8. Graph neural networks 9. Deep reinforcement learning 10. Uncertainty and explainability in deep learning
Related Programme Learning Outcome(s)
1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - ML Ops (EQF 7) 4 - Machine Learning (EQF 7) 5 - Explainable AI (EQF 7) 6 - Big Data & Data Analytics (EQF 7) 7 - AI Awareness (EQF 6) 8 - Generative AI (EQF 7) 9 - Soft Skills (EQF 6) 10 - HPC and Cloud services (EQF 7)
Unit learning outcomes
• Critically evaluates and understands the theoretical underpinnings of deep learning • Designs innovative deep learning models • Develops advanced deep learning models using current frameworks and tools • Analyses complex datasets using deep learning models • Reflects on the ethical, legal, and social implications of deploying deep learning models • Manages the lifecycle of deep learning projects

- Assesses the capabilities and limitations of different AI technologies
- Integrates AI technologies to create comprehensive systems that improve decision-making
- Implements AI solutions using best practices in software engineering and data management
- Disseminates findings and developments in AI technologies
- Designs robust ML Ops architectures
- Independently develops robust machine learning models using advanced algorithms
- Understands the mathematics of ML algorithms
- Critically evaluates the performance of machine learning models
- Optimizes machine learning algorithms and systems for improved performance
- Designs AI systems with a focus on explainability
- Implements xAI techniques for such as feature importance scores, model-agnostic methods, and visualization of AI decision paths
- Evaluates the effectiveness of explainable AI models
- Researches and applies the latest advancements in explainable AI
- Critically assesses AI models for biases and ethical implications
- Develops and applies sophisticated data analytics algorithms and models to big data sets
- Understands the basic concepts and technologies underlying artificial intelligence
- Identifies key AI applications in the programming application market
- Assesses the strategic considerations for integrating AI into business operations
- Knowledge of current trends in AI technology
- Engages in continuous learning to keep pace with rapid advancements in AI
- Design and implement advanced generative AI models
- Optimize generative models for efficiency and scalability
- Collaborates within teams, contributing positively to group efforts
- Solves problems creatively and efficiently
- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Thinks critically, analysing situations, evaluating diverse perspectives
- Deploys complex applications on HPC and/or cloud platforms

Delivery method(s)

In-class / Blended learning

Materials

Learning materials: presentation slides and example practical exercises.

Suggested materials:

- Chollet, Francois. Deep learning with Python. Simon and Schuster, 2021. Online: https://www.manning.com/books/deep-learning-with-python-second-edition
- Ian Goodfellow and Yoshua Bengio and Aaron Courville, Deep Learning, 2016, MIT Press, online: http://www.deeplearningbook.org

- Bishop, C. M., & Bishop, H. (2023). Deep learning: Foundations and concepts. Springer Nature.

4.3. Data Science

Description
The "Data Science" learning unit is designed to introduce students to the fundamental concepts, techniques, and tools used in data science. This unit covers the process of extracting insights and knowledge from structured and unstructured data, with a focus on statistical analysis, data visualization, and data-driven decision-making. Topics: 1. Introduction to Data Science: data science lifecycle, types of data, and the role of data science in organizations 2. Data Collection and Acquisition: data sources, web scraping, APIs, and survey design 3. Exploratory Data Analysis (EDA): uni-, bi-, and multivariate analysis, statistical summaries, and data visualization 4. Data Preprocessing: data cleaning, transformation, integration, and handling missing data 5. Feature Engineering: feature selection, extraction, and transformation techniques 6. Data Visualization: principles of effective data visualization, tools (e.g., Matplotlib, Seaborn, Plotly), 7. Statistical Inference: probability distributions, hypothesis testing, confidence intervals, and sampling techniques, 8. Machine and deep learning for data science, 9. Big Data Technologies: introduction to big data concepts, distributed computing, and software tools,
Related Programme Learning Outcome(s)
1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - Machine Learning (EQF 7) 4 - Explainable AI (EQF 7) 6 - Big Data & Data Analytics (EQF 7) 7 - AI Awareness (EQF 6) 8 - Soft Skills (EQF 6)
Unit learning outcomes
• Critically evaluates and understands the theoretical underpinnings of deep learning • Assesses the capabilities and limitations of different AI technologies • Integrates AI technologies to create comprehensive systems that improve decision-making • Implements AI solutions using best practices in software engineering and data management • Disseminates findings and developments in AI technologies • Independently develops robust machine learning models using advanced algorithms

- Understands the mathematics of ML algorithms
- Critically evaluates the performance of machine learning models
- Designs AI systems with a focus on explainability
- Implements xAI techniques for such as feature importance scores, model-agnostic methods, and visualization of AI decision paths
- Designs and implements robust big data infrastructures
- Develops and applies sophisticated data analytics algorithms and models to big data sets
- Manages the entire lifecycle of data analytics projects
- Evaluates the performance of big data systems and analytics approaches
- Advocates, advises and implements for responsible data usage
- Understands the basic concepts and technologies underlying artificial intelligence
- Identifies key AI applications in the programming application market
- Analyses the implications of AI on business processes
- Assesses the strategic considerations for integrating AI into business operations
- Knowledge of current trends in AI technology
- Collaborates within teams, contributing positively to group efforts
- Solves problems creatively and efficiently
- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Thinks critically, analysing situations, evaluating diverse perspectives

Delivery method(s)

In-class / Blended learning

Materials

Learning materials: presentation slides and example practical exercises.

Suggested materials:

- *Joel Grus (2019). Data Science from Scratch: First Principles with Python. O'Reilly Media*
- *Wes McKinney (2023). Python for Data Analysis, 3rd Edition, online: https://wesmckinney.com/book/*

4.4. Machine Learning Operations (MLOps)

Description
The "MLOps" (Machine Learning Operations (MLOps) learning unit is designed to introduce students to the principles and practices of deploying, monitoring, and maintaining machine learning models in small-, medium- and large-scale production environments for students with prior experience in machine learning and software engineering. This unit covers the end-to-end lifecycle of machine learning projects, focusing on the operational aspects of ML systems. ModulesTopics: 1. Introduction to MLOps: ML lifecycle, challenges, and types of MLOps, 2. Scalable Data Engineering for ML: Data pipelines, feature stores, and data versioning, distributed feature engineering, real-time pipelines, 3. ML Model Development: automated model training and, hyperparameter tuning, and experiment tracking, 4. Model Evaluation and Validation: Performance metrics, cross-validation, and model selection, advanced testing techniques (e.g. A/B, metamorphic, property-based testing) 5. Model Deployment: Containerization, orchestration, and serving infrastructure, 6. Model Monitoring: Data drift, concept drift, and model performance monitoring 7. Model Maintenance: Model retraining, versioning, and continuous improvement, 8. ML Pipelines: Orchestrating end-to-end ML workflows, 9. ML Observability: Logging, tracing, and debugging ML systems, 10. CI/CD for ML: Continuous Integration and Continuous Deployment pipelines for ML 11. MLOps Governance and Best Practices: ML project management, team collaboration, and best practices for maintaining and evolving ML systems 12. MLOps Tools and Platforms: Overview of popular MLOps tools and platforms (e.g., MLflow, Kubeflow, TensorFlow Extended).
Related Programme Learning Outcome(s)
1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - ML Ops (EQF 7) 4 - Machine Learning (EQF 7) 5 - Big Data & Data Analytics (EQF 7) 6 - AI Awareness (EQF 6) 7 - Soft Skills (EQF 6)
Unit learning outcomes
• Critically evaluates and understands the theoretical underpinnings of deep learning • Assesses the capabilities and limitations of different AI technologies • Integrates AI technologies to create comprehensive systems that improve decision-making

- Implements AI solutions using best practices in software engineering and data management
- Designs robust ML Ops architectures
- Implements continuous integration and continuous delivery (CI/CD) pipelines
- Optimizes machine learning pipelines for performance and efficiency
- Evaluates the effectiveness and efficiency of ML Ops systems
- Understands the mathematics of ML algorithms
- Manages the entire lifecycle of data analytics projects
- Evaluates the performance of big data systems and analytics approaches
- Advocates and implements for responsible data usage
- Understands the basic concepts and technologies underlying artificial intelligence
- Identifies key AI applications in the programming application market
- Analyses the implications of AI on business processes
- Collaborates within teams, contributing positively to group efforts
- Solves problems creatively and efficiently
- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Thinks critically, analysing situations, evaluating diverse perspectives

Delivery method(s)

In-class / Blended learning

Materials

Learning materials: presentation slides and example practical exercises.

Suggested materials:

- Mark Treveil et al., Introducing MLOps: How to Scale Machine Learning in the Enterprise, O'Reilly, 2021
- MLOps: Continuous delivery and automation pipelines in machine learning (2023), online: https://cloud.google.com/architecture/mlops-continuous-delivery-and-automation-pipelines-in-machine-learning
- Mark Treveil, Nicolas Omont, Clément Stenac, Kenji Lefevre, Du Phan, Joachim Zentici, Adrien Lavoillotte, Makoto Miyazaki, Lynn Heidmann (2020). Introducing MLOps, O'Reilly Media, Inc.

4.5. Large Scale AI Solutions (cloud/HPC)

Description
The "Large Scale AI Solutions (cloud/HPC)" learning unit is designed to introduce students to develop, deploy, and manage large-scale AI solutions using cloud computing and High-Performance Computing (HPC) technologies and infrastructure. This unit covers the principles, architectures, and best practices for building scalable and efficient AI systems. Topics: 1. Introduction to Large Scale AI: Challenges, opportunities, and use cases, 2. Cloud Computing for AI: Cloud service models, providers, and AI platforms, 3. HPC for AI: HPC architectures, parallel computing, and accelerators (e.g., GPUs, TPUs), the EuroHPC framework. 4. Scalable Data Processing: Big data platforms, data lakes, and distributed data processing frameworks (e.g., Apache Spark, Dask), 5. Distributed Machine Learning: Data parallelism, model parallelism, and distributed training frameworks, 6. AI Workload Management: Resource allocation, scheduling, and orchestration in cloud and HPC environments, 7. Serverless computing, function-as-a-service (FaaS), 8. AI Infrastructure Optimization: Performance tuning, cost optimization, and efficiency best practices, 9. Scalable Model Serving: Model serving architectures, inference optimization, and scalable serving frameworks (e.g., TensorFlow Serving, NVIDIA Triton).
Related Programme Learning Outcome(s)
1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - Machine Learning (EQF 7) 4 - Soft Skills (EQF 6) 5 - HPC and Cloud services (EQF 7)
Unit learning outcomes
• Critically evaluates and understands the theoretical underpinnings of deep learning • Designs innovative deep learning models • Develops advanced deep learning models using current frameworks and tools • Assesses the capabilities and limitations of different AI technologies • Integrates AI technologies to create comprehensive systems that improve decision-making • Implements AI solutions using best practices in software engineering and data management • Disseminates findings and developments in AI technologies • Independently develops robust machine learning models using advanced algorithms • Collaborates within teams, contributing positively to group efforts

- Solves problems creatively and efficiently
- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Thinks critically, analysing situations, evaluating diverse perspectives
- Architects scalable and/or secure HPC and cloud infrastructures
- Conduct detailed performance monitoring and tuning
- Deploys complex applications on HPC and/or cloud platforms
- Manages HPC and/or cloud environments
- Analyses the performance of HPC and/or cloud-based AI solutions systems
- Innovates with emerging technologies in HPC and/or cloud computing
- Evaluates new HPC and/or cloud technologies and services for potential adoption

Delivery method(s)

In-class / Blended learning

Materials

Learning materials: presentation slides and Jupyter notebooks

Suggested materials:

- Robey, R., & Zamora, Y. (2021). Parallel and high performance computing. Simon and Schuster.
- Ted Hunter, Steven Porter, Legorie Rajan PS (2019). Build cost-effective and robust cloud solutions with Google Cloud Platform (GCP) using these simple and practical recipes, Packt Publishing Ltd,
- John Culkin, Mike Zazon (2022). AWS Cookbook: Recipes for Success on AWS 1st Edition. O'Reilly Media, Inc.

4.6. AI Applications (NLP, coding tools, CV, Speech, cybersecurity, etc.)

Description
This learning unit has been articulated to allow customisable delivery in specific AI application areas and upskill to current state-of-the-art. The broad aim of the learning unit is to showcase engender a deep appreciation of how AI is transforming products and services. The narrower aim of the learning unit is to introduce immerse students to in the latest AI solutions, mainly based on advanced deep learning models, and to give them practice in developing project-based AI solutions. Application areas within this learning unit may include • conversational AI applications, • natural language processing (NLP) aided applications and coding tools, • computer vision-based applications, • speech and audio processing, • cybersecurity, • anomaly detection.
Related Programme Learning Outcome(s)
1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - Machine Learning (EQF 7) 4 - Human-Centered AI (EQF 7) 5 - AI Awareness (EQF 6) 6 - Cyber and Data Security (EQF 5) 7 - Generative AI (EQF 7) 8 - Soft Skills (EQF 6)
Unit learning outcomes
• Critically evaluates and understands the theoretical underpinnings of deep learning • Designs innovative deep learning models • Manages the lifecycle of deep learning projects • Assesses the capabilities and limitations of different AI technologies • Integrates AI technologies to create comprehensive systems that improve decision-making • Implements AI solutions using best practices in software engineering and data management • Disseminates findings and developments in AI technologies • Understands the mathematics of ML algorithms • Evaluates AI systems from a human-centered perspective • Critically assesses societal impacts of AI • Understands the basic concepts and technologies underlying artificial intelligence

- Identifies key AI applications in the programming application market
- Analyses the implications of AI on business processes
- Assesses the strategic considerations for integrating AI into business operations
- Collaborates with technical and non-technical teams to explore AI opportunities
- Knowledge of current trends in AI technology
- Engages in continuous learning to keep pace with rapid advancements in AI
- Analyses the landscape of cyber threats and vulnerabilities
- Implements advanced security measures, such as encryption, firewalls, and intrusion detection systems
- Develops and tests robust cybersecurity policies and procedures
- Manages incident response and recovery operations
- Evaluates the effectiveness of security protocols through regular audits and updates
- Design and implement advanced generative AI models
- Apply generative AI in novel applications
- Stay abreast of technological advancements in the field of generative AI
- Advocate for responsible use of generative AI technologies
- Collaborates within teams, contributing positively to group efforts
- Solves problems creatively and efficiently
- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Thinks critically, analysing situations, evaluating diverse perspectives

Delivery method(s)

In-class / Blended learning

Materials

Lecture Slides, example practical exercises, resources document.

4.7. Generative AI

Description
The "Generative AI" learning unit focuses on creating new data instances that resemble training data or that interacts with the user. This area includes techniques that allow models to generate novel images, texts, music, and other forms of media, simulating human-like creativity. the principles, techniques, and applications of generative artificial intelligence models. This unit covers the fundamentals of generative models, their architectures, and their use cases in various domains. Modules: 1. Introduction to Generative AI 2. Autoregressive Models: Autoregressive model architectures, training, and generation processes (e.g., PixelRNN, WaveNet), 3. Autoencoders (AEs) and Variational Autoencoders (VAEs), latent space representation, 4. Generative Adversarial Networks (GANs): Generator-discriminator architecture, adversarial training, and GAN variants (e.g., DCGAN, CycleGAN, StyleGAN), 5. Diffusion Models: Denoising diffusion probabilistic models, reverse diffusion process, 6. Transformer-based Generative Models: Attention mechanism, self-attention, and transformer architectures for generative tasks (e.g., GPT, BERT), 7. Evaluation Metrics for Generative Models: Inception Score, Fréchet Inception Distance (FID), and Kernel Inception Distance (KID), 8. Applications of Generative AI: Image and video synthesis, text, speech, music generation, and data augmentation. 9. Deep learning for generative AI: a. Generative Adversarial Networks b. Variational Autoencoders c. Diffusion 10. Natural language and code generation 11. Image and vdeo generation 12. Audio generation.
Related Programme Learning Outcome(s)
1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - Human-Centered AI (EQF 7) 4 - Generative AI (EQF 7) 5 - Soft Skills (EQF 6)
Unit learning outcomes
• Critically evaluates and understands the theoretical underpinnings of deep learning • Designs innovative deep learning models • Manages the lifecycle of deep learning projects • Assesses the capabilities and limitations of different AI technologies

- Integrates AI technologies to create comprehensive systems that improve decision-making
- Implements AI solutions using best practices in software engineering and data management
- Disseminates findings and developments in AI technologies
- Designs AI solutions that incorporate human-centered design principles
- Implements interactive AI systems that facilitate effective human-AI collaboration
- Evaluates AI systems from a human-centered perspective
- Design and implement advanced generative AI models
- Evaluate the effectiveness and safety of generative AI models
- Optimize generative models for efficiency and scalability
- Knowledge in fine tuning and customizing generative models and use of transfer learning
- Apply generative AI in novel applications
- Stay abreast of technological advancements in the field of generative AI
- Advocate for responsible use of generative AI technologies
- Collaborates within teams, contributing positively to group efforts
- Solves problems creatively and efficiently
- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Thinks critically, analysing situations, evaluating diverse perspectives

Delivery method(s)

In-class / Blended learning

Materials

Learning materials: presentation slides and Jupyter notebooks

Suggested materials:

- David Foster (2019). Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play, O'Reilly Media, Inc.
- Chris Fregly, Antje Barth, Shelbee Eigenbrode (2023). Generative AI on AWS: Building Context-Aware Multimodal Reasoning Applications 1st Edition, O'Reilly Media, Inc.

4.8. Human-Centred AI and User Experience

Description
This learning unit focuses on the integration of human-centred principles into the design, development, and deployment of artificial intelligence systems. This unit explores how AI can be developed to be more supportive of human needs. Skills developed will be around designing and evaluating AI systems that are not only technically proficient but also aligned with human goals. Topics include: (1) Introduction to Human-Centred AI, (2) Design for User Experience: Inclusivity and accessibility (3) Evaluation of AI systems for UX and human-centredness.
Related Programme Learning Outcome(s)
1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - Human-Centered AI (EQF 7) 4 - AI Awareness (EQF 6) 5 - Soft Skills (EQF 6)
Unit learning outcomes
• Critically evaluates and understands the theoretical underpinnings of deep learning • Designs innovative deep learning models • Assesses the capabilities and limitations of different AI technologies • Integrates AI technologies to create comprehensive systems that improve decision-making • Implements AI solutions using best practices in software engineering and data management • Disseminates findings and developments in AI technologies • Designs AI solutions that incorporate human-centered design principles • Implements interactive AI systems that facilitate effective human-AI collaboration • Evaluates AI systems from a human-centered perspective • Innovates by applying the latest research in psychology, cognitive science, and user experience design to AI development • Critically assesses societal impacts of AI • Understands the basic concepts and technologies underlying artificial intelligence • Identifies key AI applications in the programming application market • Analyses the implications of AI on business processes • Assesses the strategic considerations for integrating AI into business operations • Collaborates with technical and non-technical teams to explore AI opportunities • Knowledge of current trends in AI technology • Engages in continuous learning to keep pace with rapid advancements in AI • Collaborates within teams, contributing positively to group efforts • Solves problems creatively and efficiently

- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Thinks critically, analysing situations, evaluating diverse perspectives

Delivery method(s)

Lectures either online or in-person, and/or case-study based seminars

Materials

Lecture Slides, example case-studies, resources document.

Suggested Reading:

- *Human-Centered AI, Ben Shneiderman*
- *Converging Minds: The Creative Potential of Collaborative AI, Aleksandra Przegalinska, Tamilla Triantoro*

4.9. AI for Business

Description
ML Engineers need to be able to articulate their technological expertise into the language and needs of business to be truly effective. This learning unit looks in detail as to possibilities for ML exploitation in business. It will offer case studies for analysis so that learners are able to identify and communicate them clearly to clients. Topics include: (1) overview of ML successes and failures in business and what the critical factors are (2) common ML use cases (3) analysis of business processes for automation possibilities (4) making a business case for ML and communicating with business clients.
Related Programme Learning Outcome(s)
1 - AI Technologies (EQF 7) 2 - Machine Learning (EQF 7) 3 - Explainable AI (EQF 7) 4 - AI Awareness (EQF 6) 5 - Change Management (EQF 6) 6 - Soft Skills (EQF 6)
Unit learning outcomes
• Assesses the capabilities and limitations of different AI technologies • Integrates AI technologies to create comprehensive systems that improve decision-making • Implements AI solutions using best practices in software engineering and data management • Disseminates findings and developments in AI technologies • Critically evaluates the performance of machine learning models • Designs AI systems with a focus on explainability • Critically assesses AI models for biases and ethical implications • Understands the basic concepts and technologies underlying artificial intelligence • Identifies key AI applications in the programming application market • Analyses the implications of AI on business processes • Assesses the strategic considerations for integrating AI into business operations • Collaborates with technical and non-technical teams to explore AI opportunities • Knowledge of current trends in AI technology • Understands the principles and theories of change management • Assesses organizational readiness for change • Collaborates within teams, contributing positively to group efforts • Leads (interdisciplinary) teams and projects • Solves problems creatively and efficiently

- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Communicates effectively across a variety of platforms and media
- Thinks critically, analysing situations, evaluating diverse perspectives

Delivery method(s)
Lectures either online or in-person, and/or case-study based seminars
Materials
Lecture Slides, example case-studies, resources document. *Selected readings from business literature, for example HBR.*

4.10. AI Law and Ethics

Description
ML Engineers need to be aware of their legal and professional responsibilities and this unit aims to deliver this in a manner accessible to technologists. Topics include: (1) The dark side of AI: what can go wrong (1) The legal framework in the EU (AI Act, GDPR, Digital Services Act), (2) Ethical Considerations: Fairness, Explainability and Robustness, (3) AI Governance and Regulation, (4) AI Ethics in Generative AI and Machine Learning (5) Compliance in practice and the responsibilities of an ML practitioner. Though this is a short learning unit, in the context of a larger second-cycle program it may be extended by additional related material as required by professional bodies.
Related Programme Learning Outcome(s)
1 - AI Technologies (EQF 7) 2 - AI Ethics (EQF 6) 3 - AI Awareness (EQF 6) 4 - Soft Skills (EQF 6)
Unit learning outcomes
• Assesses the capabilities and limitations of different AI technologies • Integrates AI technologies to create comprehensive systems that improve decision-making • Implements AI solutions using best practices in software engineering and data management • Identifies ethical considerations and challenges in AI development and deployment • Develops ethical guidelines and frameworks for AI projects • Implements strategies to mitigate ethical risks in AI applications • Assesses AI projects for ethical implications • Knowledge of industry-specific laws (national and international) • Understands the basic concepts and technologies underlying artificial intelligence • Identifies key AI applications in the programming application market • Analyses the implications of AI on business processes • Knowledge of current trends in AI technology • Collaborates within teams, contributing positively to group efforts • Communicates effectively across a variety of platforms and media • Thinks critically, analysing situations, evaluating diverse perspectives
Delivery method(s)
Lectures either online or in-person, and/or case-study based seminars
Materials

Lecture Slides, example case-studies, resources document.

Suggested Readings:

- *AI Ethics, Michael Coeckelbergh; The Cambridge Handbook of Artificial Intelligence, chapter 15 (Nick Bostrom, Oxford University, Eliezer Yudkowsky)*
- *EU Artificial Intelligence Act: The Essential Reference, Lex Press.*

4.11. AI Transformation and Project Management

Description
In practice, ML projects are often also business change projects. This learning unit sets out how ML Engineers can interface with other stakeholders to ensure that their technical interventions are properly executed and achieve the desired impact on the organisation. It will examine and evaluate what methods and tools are available to ML practitioners, as well as what kinds of interventions work in practice and how the odds can be stacked in favour of success.
Related Programme Learning Outcome(s)
1 - AI Technologies (EQF 7) 2 - Machine Learning (EQF 7) 3 - Explainable AI (EQF 7) 4 - AI Awareness (EQF 6) 5 - Change Management (EQF 6) 6 - Soft Skills (EQF 6)
Unit learning outcomes
• Assesses the capabilities and limitations of different AI technologies • Integrates AI technologies to create comprehensive systems that improve decision-making • Implements AI solutions using best practices in software engineering and data management • Disseminates findings and developments in AI technologies • Critically evaluates the performance of machine learning models • Designs AI systems with a focus on explainability • Critically assesses AI models for biases and ethical implications • Understands the basic concepts and technologies underlying artificial intelligence • Identifies key AI applications in the programming application market • Analyses the implications of AI on business processes • Assesses the strategic considerations for integrating AI into business operations • Understands the principles and theories of change management • Assesses organizational readiness for change • Designs change management strategies • Communicates change effectively, using clear, persuasive messaging • Engages stakeholders throughout the change process • Implements change management plans • Manages resistance to change • Evaluates the effectiveness of change management efforts • Cultivates resilience and adaptability in teams

- Collaborates within teams, contributing positively to group efforts
- Communicates effectively across a variety of platforms and media
- Thinks critically, analysing situations, evaluating diverse perspectives

Delivery method(s)

Lectures either online or in-person, and/or case-study based seminars

Materials

Lecture Slides, example case-studies, resources document.

Suggested Reading: Artificial Intelligence and Business Transformation, Alba Yela Aránega, Domingo Ribeiro-Soriano, María Teresa Del Val Núñez (Eds).

4.12. Project and Thesis Work

Description
Aspiring ML Engineers benefit from an opportunity to exercise their acquired knowledge and skills in an extended piece of work. To this end, a synoptic capstone Project and Thesis Work learning unit may be offered. This unit supports both a traditional academic project typical of second-cycle studies, as well as a work-based or industrial project. It could also be used as a concluding unit in a microcredential-based scheme that leads to a larger award. The scheme should give clear guidance as to what constitutes a suitable project in the context of the final award as well as providing support in appropriate methodological issues (eg. referencing). The focus and the regulations of the awarding institutions and overall purpose of the study programme will determine the type and shape of the project. That said, a minimum of 5 ECTS is suggested to allow for an extended piece of work to be produced.
Related Programme Learning Outcome(s)
1 - Deep Learning (EQF 7) 2 - AI Technologies (EQF 7) 3 - Machine Learning (EQF 7) 4 - AI Awareness (EQF 6) 5 - Soft Skills (EQF 6)
Unit learning outcomes
• Critically evaluates and understands the theoretical underpinnings of deep learning • Designs innovative deep learning models • Assesses the capabilities and limitations of different AI technologies • Integrates AI technologies to create comprehensive systems that improve decision-making • Implements AI solutions using best practices in software engineering and data management • Disseminates findings and developments in AI technologies • Independently develops robust machine learning models using advanced algorithms • Understands the mathematics of ML algorithms • Critically evaluates the performance of machine learning models • Optimizes machine learning algorithms and systems for improved performance • Understands the basic concepts and technologies underlying artificial intelligence • Identifies key AI applications in the programming application market • Analyses the implications of AI on business processes • Assesses the strategic considerations for integrating AI into business operations • Knowledge of current trends in AI technology

- Engages in continuous learning to keep pace with rapid advancements in AI
- Solves problems creatively and efficiently
- Delivers impactful presentations
- Cultivates an innovative mindset, embracing and fostering creativity
- Communicates effectively across a variety of platforms and media
- Thinks critically, analysing situations, evaluating diverse perspectives

Delivery method(s)

As this is self-directed, it could be supported in a number of ways: lectures, seminars and well as consultations with a project supervisor. These could be conducted either online or face-to-face.

Materials

Generic project guideline document, presentation of scheme/guidance, resources document.

Suggested Reading: Thesis Projects: A Guide for Students in Computer Science and Information Systems, Mikael Berndtsson, Jörgen Hansson, Björn Olsson, Björn Lundell

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