Co-funded by
the European Union

FAAI:
The Future is in Applied Artificial Intelligence
Erasmus+ project 2022-1-PL01-KA220-HED-000088359

01.09.2022 – 31.08.2024

Competence framework : WP3

The production of this document has been possible thanks to the support of the ERASMUS+ project: The Future is in Applied Artificial Intelligence (2022-1-PL01-KA220-HED-000088359)

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the National Agency (NA). Neither the European Union nor NA can be held responsible for them.

Date
21.05.2023

Places of the development of the result
University of Bielsko-Biala, Bielsko-Biala, Poland
University of Library Studies and Information Technologies, Sofia, Bulgaria
University of Nis, Serbia
University of Ss. Cyril and Methodius in Trnava, Slovakia
University of Montenegro, Montenegro

Summary: This result outlines a learning initiative focused on developing a Competence framework within the field of AAI. The approach involves analyzing and incorporating various competency standards, such as ACM and IEEE. The content of the framework aims to encompass knowledge areas, specifying scope, competencies, and sub-domains. Sub-domains are further detailed through the inclusion of corresponding knowledge, skills, and dispositions. This comprehensive approach seeks to establish a robust foundation for competence development in the rapidly evolving field of AAI.

Keywords: applied artificial intelligence, good practices, training, FAAI

I. Content

II. Basic knowledge requirements

Combination of the plan in proposal with AI part of „Computing Competencies...“

• Machine learning • Neural networks • Robotics • Expert systems • Fuzzy logic • Natural language processing Changed their order in the proposed curriculum compared to proposal	Artificial Intelligence ● General ● Knowledge representation and reasoning – logic based ● Knowledge representation and reasoning – probability based ● Planning and search strategies Machine learning ● General ● Supervised learning ● Unsupervised learning ● Mixed methods ● Deep learning

Curriculum in 12 topics

Topic 1. Artificial intelligence 01
(only a broad overview)
Knowledge T1:

- History of AI
- Reality of AI (what it is, what it does) versus perception
- Major subfields of AI: knowledge representation, logical and probabilistic reasoning, planning, perception, natural language processing, learning, robotics (both physical and virtual)

AI-Knowledge Representation and Reasoning (Logic-based Models) T2:

- Predicate logic and example uses
- Automated reasoning: forward chaining, backward chaining
- Reasoning integrated into large-scale systems (e.g., Watson) (probable exercise – using some web based logical inference model to derive conclusion from premises)

Topic 2. Artificial intelligence 02

AI-Knowledge Representation and Reasoning (Probability-based Models) T1:

- Fundamental concepts: random variables, axioms of probability, independence, conditional probability, marginal probability
- Causal models T2:
- Bayesian networks
- Markov Decision Processes (MDPs)

(probable exercise – using a software like WinBUGS, BNFinder in Python, or bnlearn in R to build a simple Bayesian network and compute answers for relevant questions to the network)

Topic 3. Artificial intelligence 03

AI-Planning and Search Strategies Knowledge
T2:
- State space representation of possible solutions to a problem
- Breadth- and depth-first (i.e., uninformed) search of a state space
- Heuristic (i.e., informed) search of a state space (e.g., A* search)
- Data storage, processing.
- Necessity of project scaling

(probable exercise – Design a heuristic for a small problem.
Apply an informed search approach to a small problem, maybe a shortest path with constraints.)

Topic 4. Fuzzy logic (only briefly)

What is fuzzy logic and why is it useful?
Fuzzy sets, membership functions, fuzzy rules, and fuzzy inference Fuzzy control system architecture (Mamdani, Takagi-Sugeno) Design of fuzzy controllers
Fuzzy inference methods (e.g. max-min, product-sum) Defuzzification techniques
Real-world applications of fuzzy control systems (e.g. temperature control,
speed control)
Comparison of fuzzy control to traditional control methods
(probable exercise – simple system for health monitoring, autofocus camera or robotic manipulator, probably in matlab?)

Topic 5. Expert systems (only briefly)

Fundamentals of automated reasoning and deductive systems. Rule-based expert systems augmented with rule weighting, certainty factors, and fuzzy logic and Bayesian belief networks. Applications in technical systems synthesis, diagnostics, and process control.
(probable exercise – hands-on experience with prevalent expert system shells, e.g. Prover9/Mace4, CLIPS, FuzzyCLIPS, Matlab, HuginLite.)

Topic 6. Machine learning 01a (overwiew)
Knowledge T1:
- Major tasks of machine learning, including supervised, unsupervised,
reinforcement, and deep learning
- Difference between symbolic versus numerical learning
- Importance of robust evaluation, quality of data, need for regularization.

Topic 6. Machine learning 01b Supervised Learning
Knowledge T1:
- Major tasks of supervised learning: regression and classification
- The trade-off between bias and variance; Occam's razor for simple
models.
- The need for separation of training, test, and validation data. Define training error and testing error.

● Common evaluation metrics for classification tasks (e.g., accuracy, sensitivity, specificity, precision, recall, …) and regression tasks (e.g., root mean squared error,…)
● Classification and regression algorithms (e.g., linear regression/ classification, logistic regression, nearest neighbor, Naive Bayes, decision tree learning algorithms).
● Ensembles (e.g., bagged models, boosted models, random forests). (probable exercise – Execute at least classification and regression algorithm on a dataset.)

Topic 7. Machine learning 02 unupervised learning
Knowledge T1:
● Major tasks of unsupervised learning, including clustering and dimensionality reduction.
● Use cases for both tasks (e.g., data exploration/ summarization/ visualization, feature selection, data compression, data denoising, prototype learning, recommender systems, topic modeling).
● k-means, hierarchical clustering, density-based methods such as Gaussian mixture models (GMMs).
● Trade-offs of connectivity-based vs centroid-based clustering.
● Principal component analysis (PCA).
● (probable exercise – apply at least one clustering and one dimensionality reduction algorithm to a data set and e.g. face recognition with PCA.)

Topic 8. Neural networks 01

Knowledge T2:
● How multilayer neural networks (including non-deep networks) learn and encode higher-level features from input features.
● Common deep learning architectures, such as deep feedforward networks, convolutional neural networks (CNNs), recurrent neural networks (RNNs), and LSTMs; purpose and properties of each.
● Practical challenges of common deep learning approaches, e.g., choosing a deep learning architecture, having sufficient data / possibility of overfitting, length of learning time, interpretability.
● Examples of regularization methods for deep learning architectures, such as early stopping, parameter sharing, and dropout.
● Examples of methods for mitigating other challenges of deep learning, such as tools that work with GPUs or on distributed systems.
● (probable exercise – Use a deep learning toolkit (Keras, resp. PyTorch, Tensorflow) to study a learned model’s output from a dataset..)

Topic 9. Neural networks 02

● Selection of appropriate tools that scale with the size of the data -- specifically, processing Big Data calls for Deep Learning tools that run in a parallelized way.
● Be aware of the state-of-the-art deep learning tools available.
● At least one commonly used algorithm for learning in the context of deep networks, e.g., how backpropagation is used in a deep feedforward network or how backpropagation is used to learn higher-order features in a convolutional network; how backpropagation through time is used in recurrent networks.
● Convolution and its usefulness, e.g., detecting vertical edges in an image.
● Pooling; examples of functions such as max pooling and use cases.

● Challenge of long- vs short-term dependencies in recurrent neural networks; at least one solution, such as LSTMs.(probable exercise – Use a deep learning toolkit to for a dataset, including network, like image classification, object detection in images on a real use case.)

Topic 10. Deep reinforcement learning

Definition of reinforcement learning, rewards, agents, environments, applications (e.g. game-playing agents, robotics)
Markov Decision Processes (MDPs), Markov property, state transitions,
rewards, value functions (state-value and action-value)
Bellman equations and optimality conditions
Model-based RL: Learning a model of the environment (state transition and reward functions), dynamic programming (value, policy iteration)
Model-free RL: Temporal difference (TD) learning, Q-learning algorithm, SARSA algorithm
Policy-based RL: Representation and parameterization, gradient methods (REINFORCE, actor-critic)
Deep Reinforcement Learning, Deep Q-networks (DQNs), policy gradient with deep neural networks, actor-critic with deep neural networks, exploration-exploitation tradeoff
(probable exercise – learning for simple simulated robot, robot localization)

Topic 11. Natural language processing

Text Processing and Linguistic Analysis, text preprocessing techniques, linguistic analysis tools, part-of-speech tagging and parsing
Dialog systems and conversational agents, Natural Language Understanding (NLU), Natural Language Generation (NLG), Chatbot evaluation metrics
Deep Learning for NLP, Recurrent and convolutional neural networks, Attention-based models, Transformer architecture
Advanced NLP Topics: Named Entity Recognition (NER), Sentiment Analysis,
Topic Modeling, Text Summarization
Ethical Considerations in NLP, Bias and fairness in NLP, Privacy and security concerns, Responsible AI practices
(probable exercise – playing with a really small precursor of ChatGPT or
using more advanced intelligent chatbots.)

Topic 12. Robotics

3D vision in robotics 3D coordinate frames,
raw pitch yaw, quaternions,
basics of SLAM (simultaneous localization and mapping), probabilistic robotics (Extended Kalman filter, Particle filter) Object perception for robot manipulation
Neural radiance fields for perception
Pose estimation and Robot grasp pose detection
Ethical considerations
(probable exercise – control of a simple simulated robot by fuzzy logic, neural networks, reinforcement learning, or by code produced by Chatbot from natural language commands, using

robotics simulation software for beginners, like Microsoft Robotics Developer Studio, Robotics Virtual Worlds, NVIDIA ISAAC Platform for Robotics...)

Advantages of the proposed topics

- Follows both the plan in the proposal and AI part of „Computing Competencies...“
- Logically follows the inner structure, i.e.

Artificial intelligence ⇒ Fuzzy logic as part of optional logic in AI ⇒ Expert systems (can use fuzzy logic) ⇒ Machine learning as part of AI ⇒ Neural networks as part of ML ⇒ Deep reinforcement learning ⇒ Natural language processing (using NN) ⇒ Robotics (with NN, NLP)

Disadvantages of the proposed topics

- AI part of „Computing Competencies...“ include some less interesting fundaments (like using classical logic)
- These topics take too great a chunk from syllabus, leaving too little for neural networks, and practically nothing for image processing, which for practical consideration leaves time only for simple exercises and likely not real- world applications

Alternative structure of topics?

- Topics 1-3 Artificial intelligence
- Topics 4 Fuzzy logic
- Topic 5 Expert systems
- Topics 6-7 Machine learning
- Topics 9-10 Neural networks, reinforcement learning.
- Topic 11 Natural language processing
- Topic 12 Robotics   Possibly include image processing?

III. Competence and Competency-based education

A. *Competence*[1]

Competence is the person’s knowledge, behavior, attitude, and skills that lead them to the ability to be successful in a job.

B. *Competency-based education*

CBE is a system of instruction, assessment, feedback, self-reflection, and academic reporting that is based on students demonstrating that they have learned the knowledge, attitudes, motivations, self-perceptions, and skills expected of them as they progress through their education[2].

CBE is a system[3] in which:

[1] Competence vs Competency
Competence is your ability to generally understand and perform anything at a basic level - knowledge and general state of being.
Competency refers to your ability to perform a specific task in which someone has trained you.
[2] https://www.aacnnursing.org/Essentials/Definition-of-Competency-Based-Education
[3] https://aurora-institute.org/our-work/competencyworks/competency-based-education/

- Students:
  - advance based on their ability to master a skill or competency at their own pace regardless of environment;
  - are empowered daily to make important decisions about their learning experiences, how they will create and apply knowledge, and how they will demonstrate their learning;
  - receive timely, differentiated support based on their individual learning needs;
- Rigorous, common expectations for learning are explicit, transparent, measurable, and transferable.
- Students' progress based on evidence of mastery, not seat time;
- Assessment is a meaningful, positive, and empowering learning experience for students that yields timely, relevant, and actionable evidence;

Changing paradigm:

- Credit hour -> **content mastery**
- Focus on teaching -> **focus on learning (**Shifts the primary focus of education to the desired outcomes (for learners) rather than the structure and process of the educational system**)**
- Time is constant/learning is variable **-> time is variable/learning is constant**
- **Greater focus on employer input** regarding knowledge, skill, and aptitude (KSA) needs of future employees

Basic principles of CBE

- Students' centered education
- A set of expectations that demonstrate what learners can do with and know
- Clear expectations are made explicit to learners, employers, and the public.
- Visibly demonstrated and assessed over time by multiple methods and multiple assessors.

Learning experiences in CBE must be:

- integrative and experiential
- self-aware and reflective
- active and interactive
- developmental
- transferable

CBE is not:

- A checklist of tasks
- A one-and-done experience or demonstration.
- Isolated in one sphere of care or context;
- Demonstrated solely on an objective test.

C. Development of the AI Competency Framework

1) Existing Competency Frameworks

According to the ACM/IEEE Computing Competencies for Undergraduate Data Science Curricula (page 48), Artificial Intelligence (AI) includes the methodologies for modelling and simulating several human abilities that are widely accepted as representing intelligence. Perceiving, representing, learning, planning, and reasoning with knowledge and evidence are key themes.

Scope	Competencies
• Major subfields of AI • Representation and reasoning • Planning and problem solving • Ethical considerations	• Describe major areas of AI as well as contexts in which AI methods may be applied. • Represent information in a logic formalism and apply relevant reasoning methods. • Represent information in a probabilistic formalism and apply relevant reasoning methods. • Be aware of the wide range of ethical considerations around AI systems, as well as mechanisms to mitigate problems.
Sub-domains	
• AI-General • AI-Knowledge Representation and Reasoning (Logic-based models) • AI-Knowledge Representation and Reasoning (Probability-based models)	• AI-Planning and Search Strategies

From the other side the UNESCO Consultation on AI Competency Frameworks for Teachers includes:

- AI literacy,
- AI and pedagogy,
- ethics of AI,
- the use of AI for continuous professional development,
- the ability to foster AI competencies for students, etc.

According to Concordia University and Dawson College (2021) AI competence framework the **Competency Domains** could be structured in three main directions: Technical, Business and Human where the Ethical Competencies are horizontal and are integrated in each one of these three domains.

Technical	Business	Human
• Data • Mathematics and Statistics • Programming • Machine Learning • Deep Learning • Infrastructure • Libraries and Frameworks	• AI Initiative and Project Planning • AI Initiative and Project Scaling • AI Technologies	• Innovation • Teamwork • Professionalism • Ethics

2) FAAI Target Groups

To distinguish the main competences for the project is important to focus on direct target groups. They are:

- University students
- managers of SME
- researchers and experts

3) FAAI Competences Framework

The main twelve technical competencies selected are:

1. Recognize the breadth and utility of machine learning methods
2. Compare and contrast machine learning methods
3. Select appropriate (classes of) machine learning methods for specific problems.

4. Use appropriate training and testing methodologies when deploying machine learning algorithms.
5. Explain methods to mitigate the effects of overfitting and course of dimensionality in the context of machine learning algorithms.
6. Identify an appropriate performance metric for evaluating machine learning algorithms/ tools for a given problem.
7. Recognize problems related to algorithmic and data bias, as well as privacy and integrity of data.
8. Debate the possible effects -- both positive and negative -- of decisions arising from machine learning conclusions.
9. Describe major areas of AI as well as contexts in which AI methods may be applied.
10. Represent information in a logic formalism and apply relevant reasoning methods.
11. Represent information in a probabilistic formalism and apply relevant reasoning methods.
12. Be aware of the wide range of ethical considerations around AI systems, as well as mechanisms to mitigate problems.

In FAAI Competencies Framework the Ethics will be horizontal component.

IV. Modules of FAAI course

A. Modules V1

Part 1 - Introduction

- Module 1 - Basic principles of the application of Artificial Intelligence in science and in modern business solutions

Part 2 – Real cases for AI in life for support and innovative solutions

- Module 2 - AI in Agriculture
- Module 3 - AI in Healthcare
- Module 4 - AI in Ecology
- Module 5 - AI in Lifestyle and Smart City
- Module 6 - AI in Industry and Robots
- Module 7 – AI in Humanity

Part 3 – AI Software Solutions, Libraries and Modules

- Module 8 - Embedded Commercial Software: IBM, Microsoft, AWS, etc.
- Module 9 - Embedded Open-Source Software
- Module 10 - Conducting research related to the practical application of artificial intelligence
- Module 11 - Building software applications using AI
- Module 12 - Implementation of external AI modules in software applications

B. Modules V2

Part 1 - Introduction

- Module 1 - Basic principles of the application of Artificial Intelligence in science and in modern business solutions

Part 2 - Software implementation way

- Module 2 - Embeddable modules from IBM, Microsoft, Google, AWS, etc.
- Module 3 - Conducting research related to the practical application of artificial intelligence
- Module 4 - Building software applications using AI
- Module 5 - Implementation of external AI modules in software applications

Part 3 – Areas of Applied Artificial Intelligence

- Module 6 - AI-based solutions for Ecology
- Module 7 - AI-based solutions for Agriculture
- Module 8 - AI-based solutions for HealthCare
- Module 9 - AI-based solutions for Smart City
- Module 10 - AI-based solutions for Industry
- Module 11 - AI-based solutions in Robotics
- Module 12 - Application of other AI modules

V. Cross Matrix Module Competencies

Topic / Competence	**Introduction -** Basic principles of the application of AI in science and in modern business solutions	**Real cases for AI in life for support and innovative solutions**						**AI Software Solutions – Commercial and Open Source**				
		Agriculture	Healthcare	Ecology	Lifestyle and Smart City	Industry and Robots	Humanities	Embedded Commercial Software	Embedded Open-Source Software	Conducting research related to the practical application of AI	Building software applications using AI	Implementation of external AI modules in software applications
Recognize the breadth and utility of machine learning methods												
Compare and contrast machine learning methods												
Select appropriate (classes of) machine learning methods for specific problems.												
Use appropriate training and testing methodologies when deploying machine learning algorithms.												
Explain methods to mitigate the effects of overfitting and course of dimensionality in the context of machine learning algorithms.												
Identify an appropriate performance metric for evaluating machine learning algorithms/ tools for a given problem.												
Recognize problems related to algorithmic and data bias, as well as privacy and integrity of data.												

Topic / Competence	**Introduction -** Basic principles of the application of AI in science and in modern business solutions	**Real cases for AI in life for support and innovative solutions**						**AI Software Solutions – Commercial and Open Source**				
		Agriculture	Healthcare	Ecology	Lifestyle and Smart City	Industry and Robots	Humanities	Embedded Commercial Software	Embedded Open-Source Software	Conducting research related to the practical application of AI	Building software applications using AI	Implementation of external AI modules in software applications
Debate the possible effects -- both positive and negative -- of decisions arising from machine learning conclusions.												
Describe major areas of AI as well as contexts in which AI methods may be applied.												
Represent information in a logic formalism and apply relevant reasoning methods.												
Represent information in a probabilistic formalism and apply relevant reasoning methods.												
Be aware of the wide range of ethical considerations around AI systems, as well as mechanisms to mitigate problems.												

VI. CROSS MATRIX "MODULE-COMPETENCE"

Module / Competence	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Describe major areas of AI as well as contexts in which AI methods may be applied.	x	x	x		x							x
Represent information in a logic formalism and apply relevant reasoning methods.		x			x							x
Represent information in a probabilistic formalism and apply relevant reasoning methods.		x			x							x
Be aware of the wide range of ethical considerations around AI systems, as well as mechanisms to mitigate problems.		x	x		x							x
Recognize the breadth and utility of machine learning methods	x		x									
Compare and contrast machine learning methods		x		x	x	x	x	x	x	x	x	x
Select appropriate (classes of) machine learning methods for specific problems.	x		x			x	x	x	x	x	x	
Use appropriate training and testing methodologies when deploying machine learning algorithms.	x			x		x	x	x	x	x	x	
Explain methods to mitigate the effects of overfitting and course of dimensionality in the context of machine learning algorithms.				x		x	x	x	x	x	x	
Identify an appropriate performance metric for evaluating machine learning algorithms/ tools for a given problem.				x		x	x	x	x	x	x	
Recognize problems related to algorithmic and data bias, as well as privacy and integrity of data.						x	x	x	x	x	x	
Debate the possible effects -- both positive and						x	x	x	x	x	x	

negative -- of decisions arising from machine learning conclusions.												

Modules:

M1 - Basic principles of the application of AI in science and in modern business solutions

M2 - Embeddable modules from IBM, Microsoft, Google, AWS, etc.

M3 - Conducting research related to the practical application of artificial intelligence

M4 - Building software applications using AI

M5 - Implementation of external AI modules in software applications

M6 - AI-based solutions for Ecology

M7 - AI-based solutions for Agriculture

M8 - AI-based solutions for HealthCare

M9 - AI-based solutions for Smart City

M10 - AI-based solutions for Industry

M11 - AI-based solutions in Robotics

M12 - Application of other AI modules

VII. Main module structure

1. Duration:

120 hours

- 12 module
  - 10 hours per module
    - 4 hours lecture
    - 6 hours learning activities

2. Module Design – structure

Course Curriculum

Lectures – 1

Demonstration, practical tasks in a team, Seminar assignment - 1 per lecture

Learning Scenarios – min 5

Guides, Tasks – 1

Resources

Questions for discussion – min 5

Quizze: 1 with ~40-50 close questions with 4 answers/distractors each
Presentations: 1 with min 30 slides
Demonstrators: 2
Learning Video: min 2
Content – 1
External URL - As needed

VIII. EXAMPLES OF LEARNING ACTIVITIES

Lab work with low cost 3D sensors

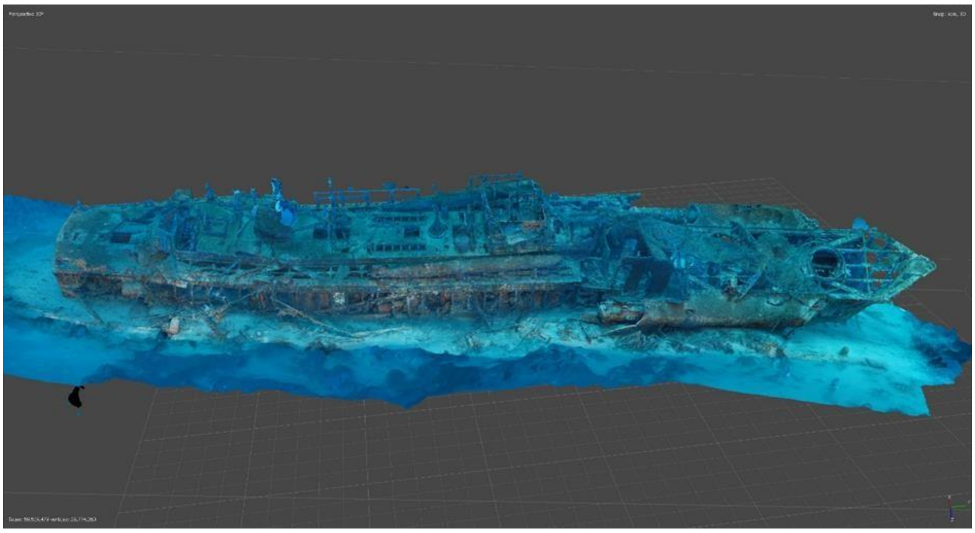
- Point cloud processing with 3D sensors

Collaboration with industry

- Point cloud processing with 3D sensors
- 2D image processing for defectcharacterization

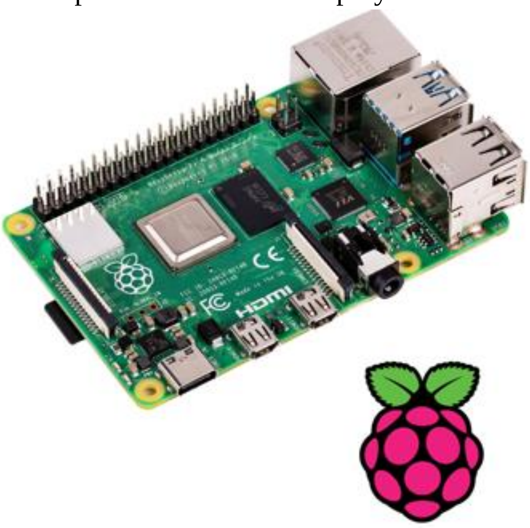
Photogrametry and 3D visualization (workshop for students)

- Collaboration with Faculty of maritime studies
- Learning goal: producing photorealistic 3D models and using them later in different AI applications: smart monitoring of the underwater cultural heritage, detecting garbage underwater, AR forunderwater museum



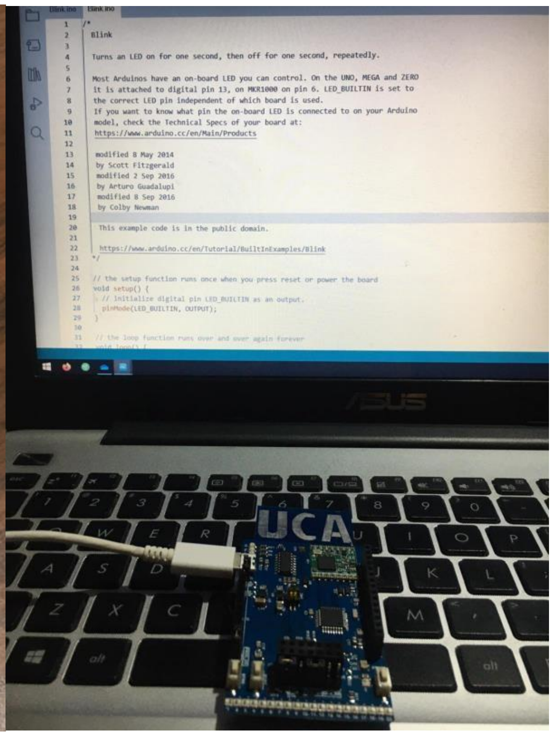
Focus on Edge AI

- AI computer vision models deployedon embedded systems



Lab work - connecting AI powered Raspberry Pi with Arduino to control an effector

- Collaboration with Faculty of mechanical engineering

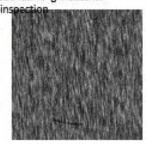


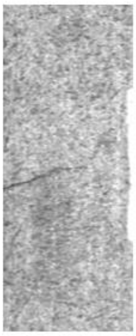
Small scale european projects defect detection

Autori: Jakob Božič, Domen Tabernik,
Danijel Skočaj, Kolektor Group d.o.o

Matthias Wieler, Tobias Hahn, Fred. A. Hamprecht. (2007) Weakly supervised learning for industrial optical inspection. [Dataset]. Retrieved from: https://hci.iwr.uni-heidelberg.de/content/weakly-supervised-learning-industrial-optical-inspection

Tobias Schlagenhauf, Magnus Landwehr, Industrial machine tool component surface defect dataset,Data in Brief,
Volume 39,2021,
107643,
ISSN 2352-3409,
https://doi.org/10.1016/j.dib.2021.107643

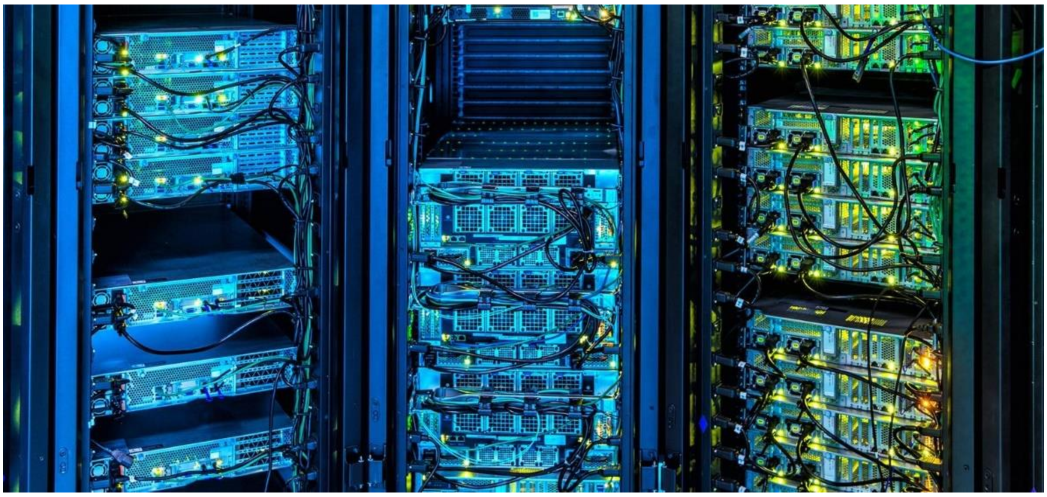




Autori: Jakob Božič, Domen Tabernik,
Danijel Skočaj, Kolektor Group d.o.o

Source:https://www.micro.ai/resources/case-studies/ai-enabled-defect-detection-solutions-in-manufacturing

HPC for most advanced master projects



Source of illustration: https://www.kingston.com/en/blog/servers-and-data-centers/4-things-data-centers-can-learn-from-hpc

IX. Conclusions

Aside from cultivating fundamental competencies in computing and statistics, students pursuing data science should be equipped to effectively apply these skills to practical scenarios. Integrating authentic datasets within a relevant context is essential for a holistic data science education.

It proves advantageous to structure certain courses within a disciplinary framework, fostering an understanding among students that data science is not merely an abstract set of methodologies. Possible application disciplines encompass physics, biology, chemistry, the humanities, or other relevant areas. This approach enhances the students' appreciation for the real-world implications and diverse applications of data science.

X. References

1. Danyluk, Andrea and Leidig, Paul, "**Computing Competencies for Undergraduate Data Science Curricula: ACM Data Science Task Force**" (2021). *Peer-Reviewed Publications*. 8. https://scholarworks.gvsu.edu/cispeerpubs/8