

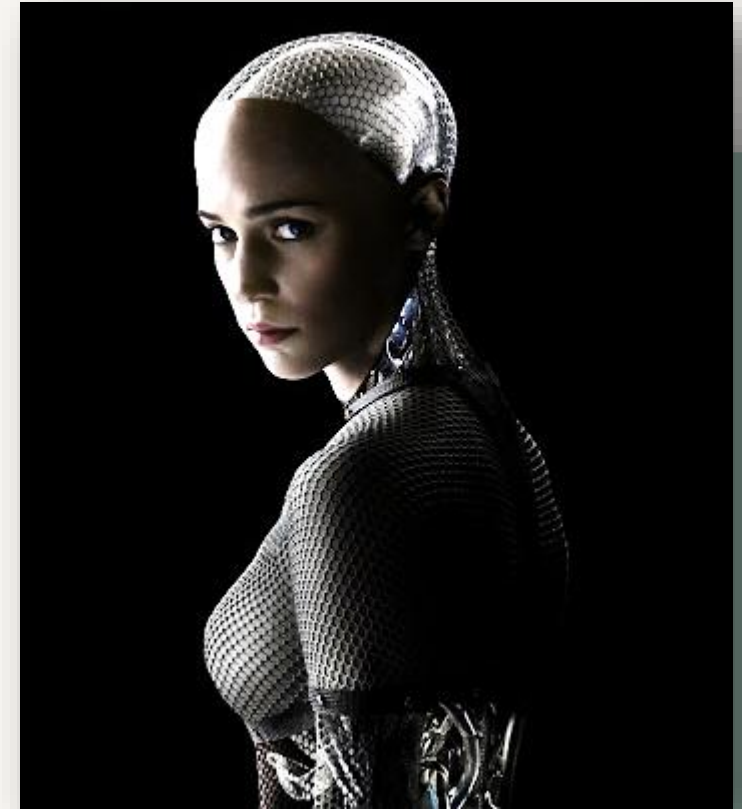
Advanced AI models in engineering

What will happen this semester?

dr hab. inż. Ziemowit Dworakowski

KATEDRA ROBOTYKI I MECHATRONIKI
WYDZIAŁ INŻYNIERII MECHANICZNEJ I ROBOTYKI

07/10/26



Before we begin...

Lecture presentations (and all other course materials) will be available on my webpage at least 2 days before a given lecture or laboratory:

<https://galaxy.agh.edu.pl/~zdw/Materials/AAIME/>

I recommend making notes only for stuff that is **NOT** on the slides. During lectures just focus on understanding relations and thought process. Knowledge will be easier to memorize after you see *the big picture*

In general, you can find plenty of useful materials on my webpage and on my YouTube channel. Unfortunately, the latter is only in Polish for now.

<https://galaxy.agh.edu.pl/~zdw>

<https://www.youtube.com/@ZiemowitDworakowski>



What this course is all about?



Assumptions:

- You are interested in AI for engineering design and problem solving
- You already have some knowledge regarding how to build and train AI models
- You are already focused on particular areas of interest
- You don't have an equal entry level of knowledge

so we will NOT give you another set of methods with basic examples...

...but we will focus on broad but important
meta-concepts regarding usage of AI in
engineering practice

...and ask you to invent and test examples by yourself...

... and reach out for knowledge (to us and to other sources)

Course team



dr hab. inż. **Ziemowit Dworakowski**, zdw@agh.edu.pl

(course coordinator, lecturer)

Office hours: D3, 4.17, Thursday, 9:00 AM – 11:00 AM

Area of expertise:

AI, decision systems, optimization signal & image processing, vision systems



dr inż. **Adam Machynia**, machynia@agh.edu.pl

Office hours: D3, 4.08, Thursday, 10:00 AM – 11:30 AM

Area of expertise:

AI, image processing, signal processing



mgr inż. **Szymon Dziewic**, sdziewic@agh.edu.pl

Office hours: Thursday, 8:30 – 10:00 AM,

Location to be arranged through email

Deep learning, Generative AI, control theory

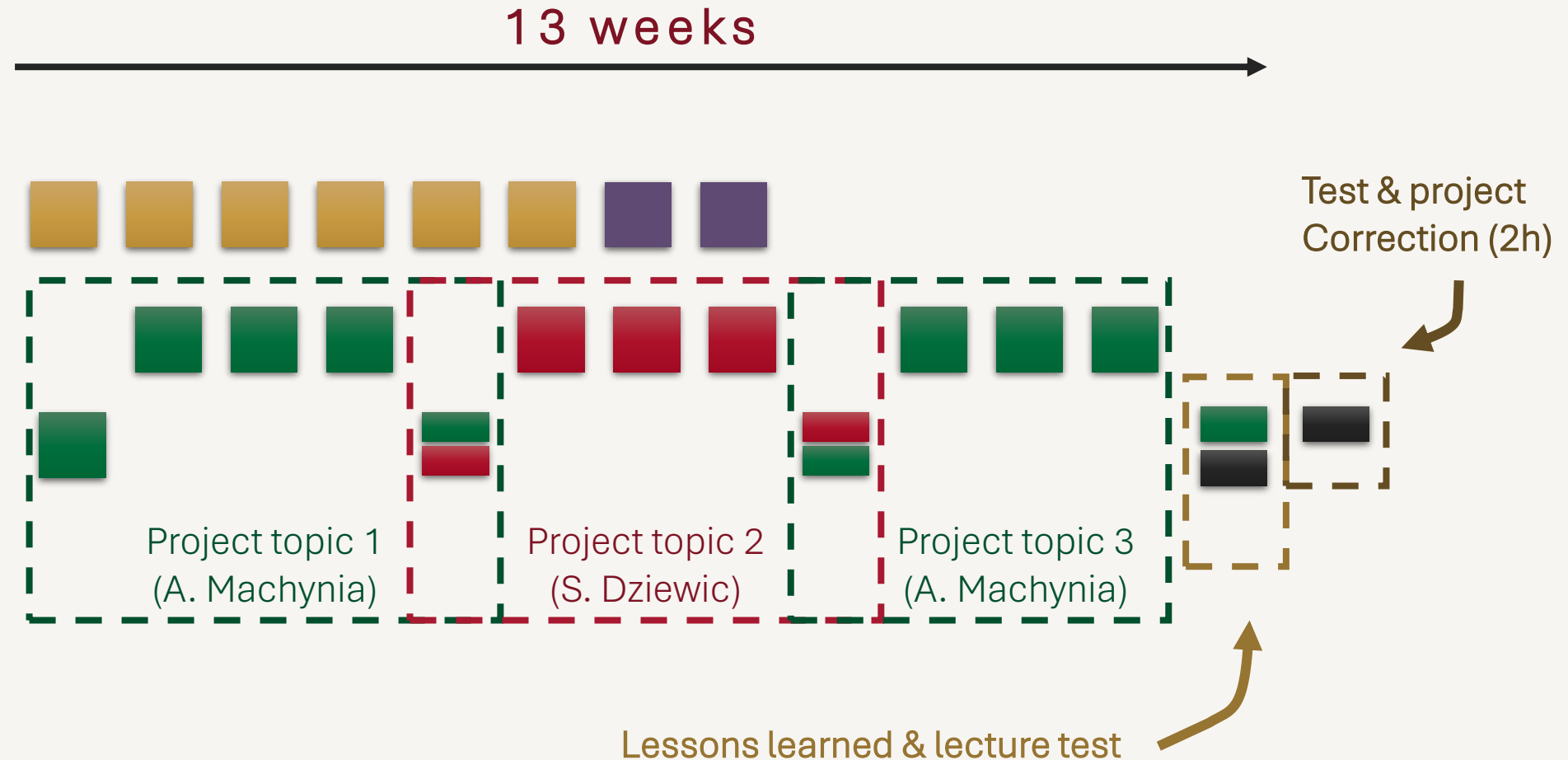
Please notify respective teacher via email at least a day before you plan to use office hours.

We have:

8 lectures

9 laboratories (4h)

4.5 projects (4h)



Grade (and course passing) is determined by **number of tokens**
 – separately for lectures (**knowledge**) and project/laboratories (**skills**)

Lecture activities: 20 tokens max,
grade as percentage, passing threshold is 10, 5.0 threshold is 18

You can choose from:

5 tokens - case study submission & description (*15 mins during the lecture, once*)

5 tokens - Lecture discussion (*Individual, at consultations or after the lecture, up to 2 times*)

5 tokens - Lecture participation (*1 token per lecture, up to 5*)

15 tokens – Final merit test (***note: you don't need it if you are active!***)

Lab & project activities, 40 tokens max, passing threshold is 15. 5.0 threshold is 25

0-3 tokens per lab – Laboratory activity (***„3” is considered „exceptional”, 27 max***)

3 tokens per project – group grade, project organization,
 discussion & conclusions (9 max)

4 tokens in total – correction of absences, tasks performed at home

Laboratories & projects use „student-design” approach:

- You declare what you want to do during laboratories
(and get teacher's acceptance for that!)
- Project work needs to focus on the main aspect of the project theme
- During laboratory-design and project-defence stages you are graded as a group
(0-3 tokens in total)
- During labs you are graded 0 – 3 tokens individually:
 - 3 – exceptional performance, initiative & understanding (hard to get!)
 - 2 – Good (well-done)
 - 1 – Acceptable
 - 0 – Not present, not-cooperative, not-prepared

What about ChatGPT (and all other GenAI models)?

What is mandatory:

- Clear and **unprompted** acknowledgement of form of AI usage (e.g. „*report was rewritten for clarity using ChatGPT*”)
- Storing prompts & response history for showing it to the teacher in case it is needed
- Taking responsibility for your codes and reports (so if any part of it was prepared using genAI, you still are required to understand it and explain it as if it was yours)

What is recommended:

- Conscious and transparent decision „**what do you intend to learn**” and planning usage of GenAI with this goal in mind (also: clear statement why and to what extend you are using GenAI)

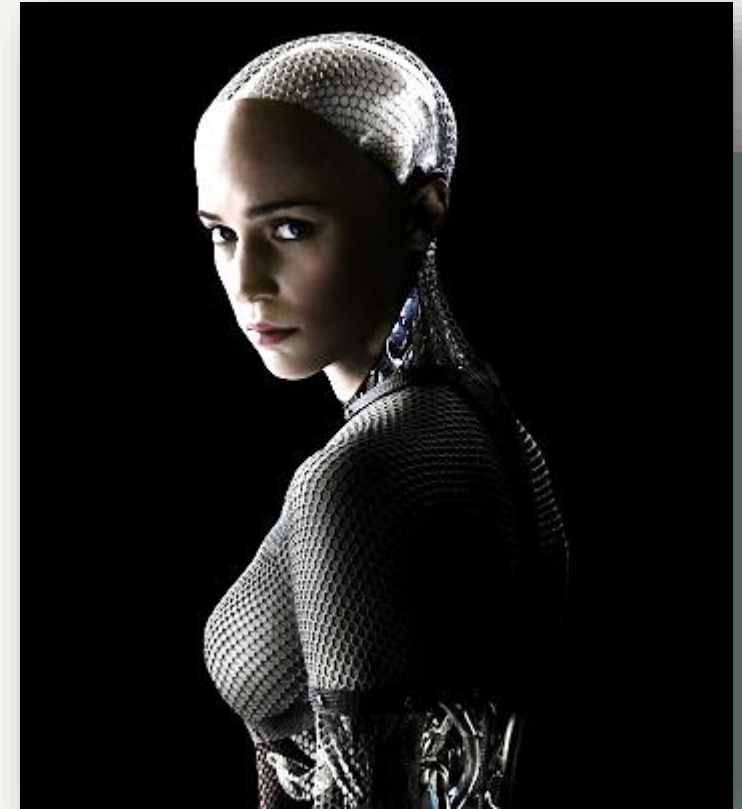
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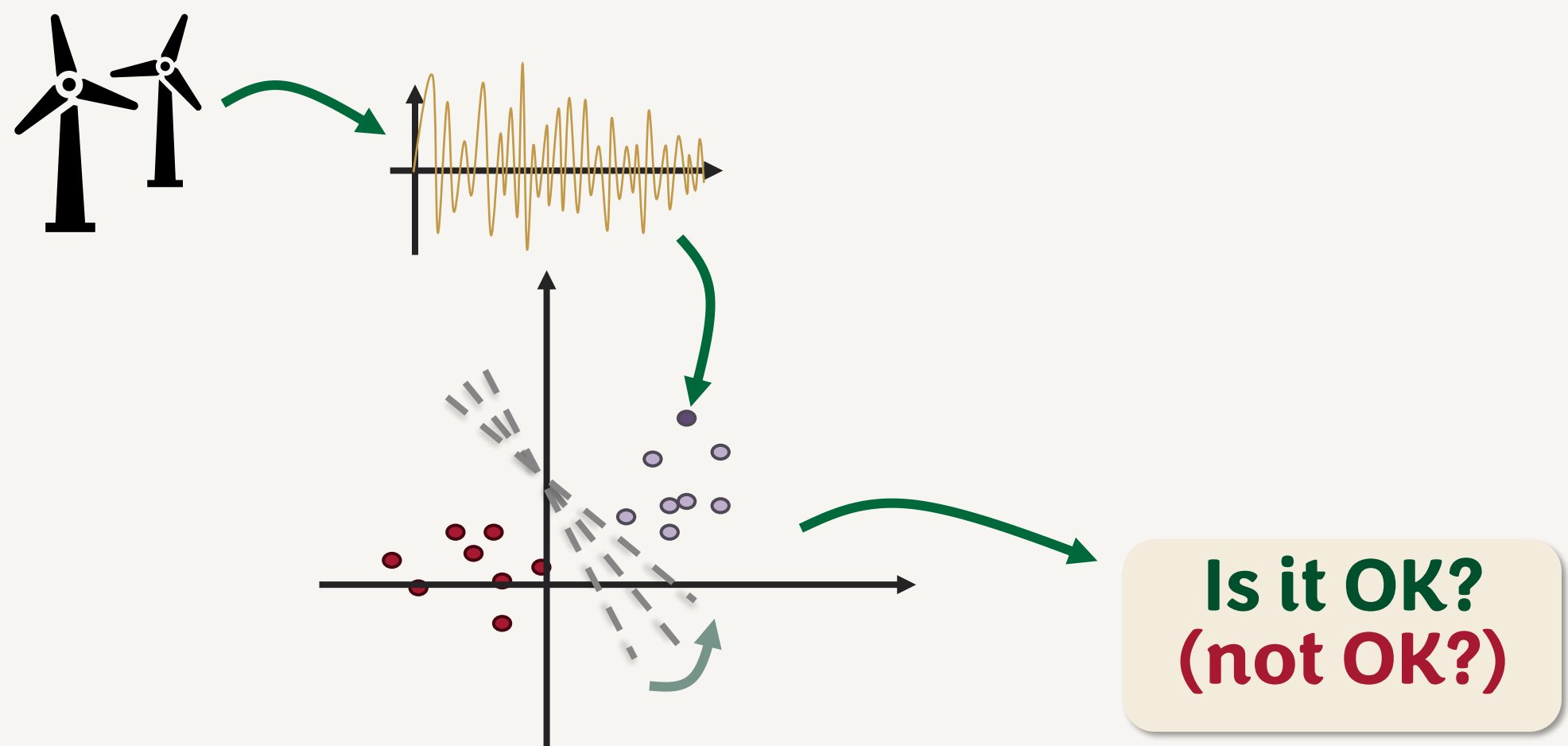
Who are we? What are we doing?

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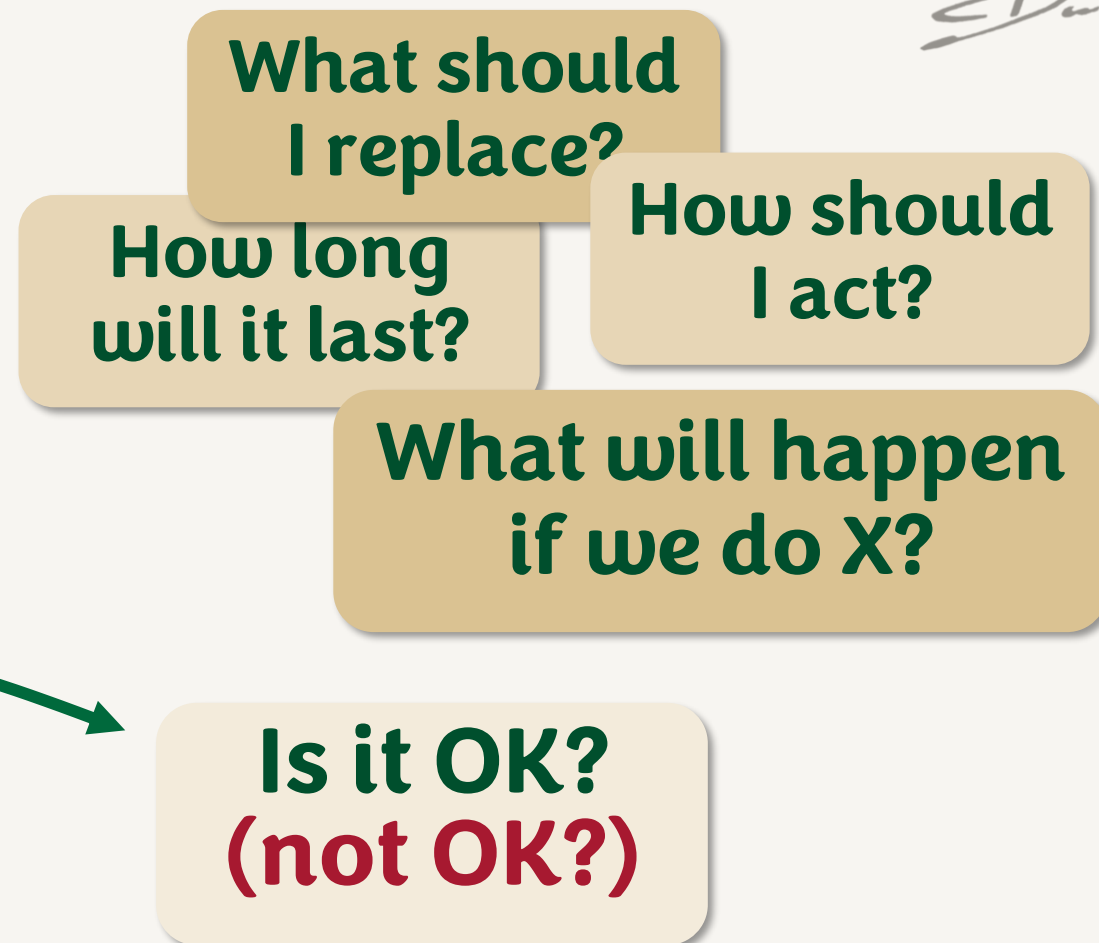
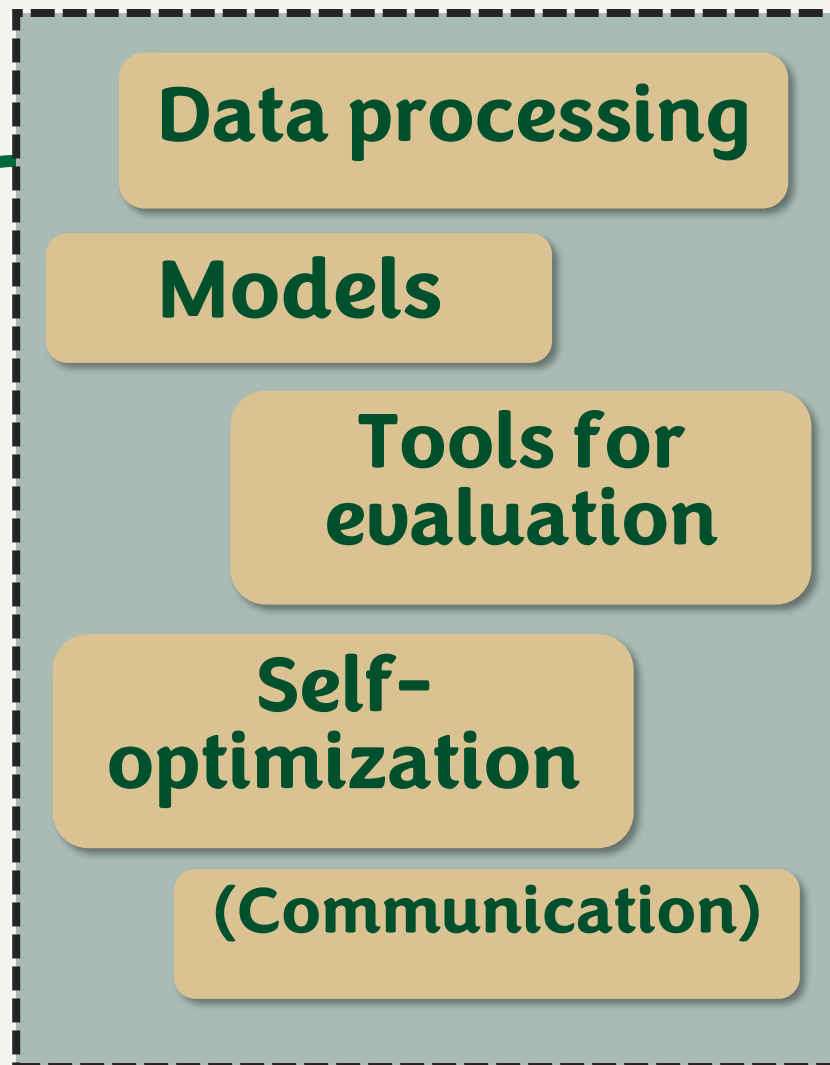
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2D



How do we build the box
to get results we want?
(so it is smart enough)



Data processing

Data division, cleaning
& understanding for ourselves

Models

Decision trees,
distance classifiers,
ANNs, Probabilistic
classifiers

Tools for evaluation

Self- optimization

(Communication)

ROC graphs, measures
of accuracy, recall,
sensitivity, specificity,
confusion matrices

Grid search, Gradient method, 1+1
method, training (1st order) and
metaparameter optimization (2nd
order)

- Python in Machine Learning and Data Science course (1st stage, basics):

<https://galaxy.agh.edu.pl/~zdw/Materials/Python/>

- Practical Data Science Project and Engineering Statistics (2nd stage, advanced, ongoing)

Basics of AI and Deep Learning (1st stage):

<https://galaxy.agh.edu.pl/~zdw/Materials/BAIDL/>

MIT „Artificial Intelligence”

https://www.youtube.com/watch?v=TjZBTDzGeGg&list=PLUl4u3cNGP63gFHB6xb-kVBiQHye_4hSi

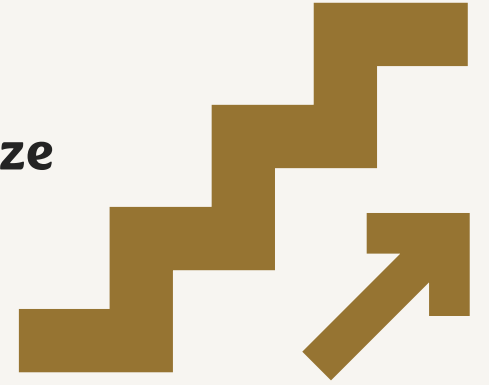
... And you'll look for sources once they are needed...

„Lets take measurements from the wind turbine and train neural network to predict remaining useful life of the drive train”

2D

US

„Lets build a decision system which will tell us how to optimize maintenance routines”



Now we think of how to design AI systems to meet specific, often challenging, requirements (higher level of abstraction)

You are not particularly good at designing and using advanced AI models

But you ARE good in understanding engineering context...

Evolutionary Optimization in Engineering Design: Application of evolutionary algorithms to complex, multi-objective engineering problems with simulation-based or experimental evaluation.

Physics-Informed and Context-Enriched Modeling: Integration of domain knowledge and physical laws into machine learning models to improve generalization and interpretability.

Data-Driven Process Modeling and Control: Modeling dynamic systems using learning-based approaches (e.g., LSTMs, neural-MPC) for prediction, simulation, or control.

Explainable and Trustworthy AI in Engineering: Exploration of techniques for improving transparency, robustness, and interpretability of AI models in safety-critical systems.

Surrogate Modeling and System Identification: Development of fast, approximate models to replace complex simulations or unknown systems using data-driven learning.

Learning from Sparse, Noisy, or Imperfect Data: Investigation of strategies such as data augmentation, transfer learning, and robustness techniques to handle real-world data limitations.

Consult laboratory instruction for further details

Lectures are not intended to introduce the methods and teach you about particular algorithms – you’ve got internet sources for that, your prior courses, books and, especially, your master thesis research.

Instead – I intend to give you „**conceptual vocabulary**” to be able to think about particular problems in terms of tradeoffs, risks, challenges and opportunities – and to attempt to teach you how to think around these systems and to **share my experience** in relations to the most complex problems you’ll face out there...

Think of them as **keynotes** rather than **lectures**

And feel free to submit case studies you’d like to share related to the lecture topic – send me an abstract at least a week before the lecture – and we’ll include case study into the lecture and give it together!

1. Foundational recap: Who are we and what are we doing here? What tools do we know already?

2. Modular thinking: System-level design, composability, constraints, parametrizations, problem division, goals of actions vs goals of decisions, model integration (errors piling up)

3. Advanced optimization solutions: Emergent systems, evolutionary optimization, alternatives, solution evaluation and choice.

4. Messy data: Pitfalls & challenges: noise, scarcity, non-uniform classes, how do we model data, how do we address these issues?

5. Complex systems: Explainability, digital twins, domain-informed tradeoffs, mimicking an expert vs surpassing an expert.

6. Design under constraints: Why solutions rarely fit the expectations. How to design models that are actually usable. Multi-objective problems and constrained environments. Ethical design

7. Integration and deployment: Practical integration of AI solutions, cloud/external/local computation, frameworks and pipelines, troubleshooting, practitioners view (Invited lecture, by Mateusz Heesch)

8. Agentic solutions and vibe coding: How's and why's, challenges, risks, costs, entry requirements. (Invited lecture, by Łukasz Wiatrak)

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Questions?

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