# Data-Driven Engineering

**Lecturers**
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**Course mnemonic**
MECA-H419

**ECTS credits**
4 credits

**Language(s) of instruction**
English

**Course period**
Second term

**Campus**
Solbosch

## Course content

The objective of the present course is to explore methods at the intersection between data-driven methods, applied optimization. The increasing availability of data is a shared trait of several research fields and opens up great opportunities to advance our understanding of physical processes and lead to disruptive technological innovations. Historically, the scientific method has progressed generating hypotheses and theories and collecting data to validate or confute them. These were later translated into computer models for problems that have soon become too complex to be solved analytically. The massive data from both experiments and simulations requires technologies so distinctive that it is worth distinguishing the emerging data-intensive science as a new paradigm for scientific exploration. While it is clear that data-driven methods are here to stay, the key question is how to incorporate them within the different scientific disciplines to drive the advances we need. The present course aims to present and future trends in the application of data-driven methods in various engineering fields, including Aeronautics, Energy, Mechatronics-Construction, Vehicle Technology and Transport, Operations Engineering and Management.

Specifically, the course content includes:

1. Introduction to data-driven modelling
2. Common Optimization Techniques
   - Introduction to Optimization
   - Problems admitting closed form solution
   - Convex Optimization
3. Machine learning methods: encoders, regression and classification
   - Manipulation of large data sets, data processing, outlier removal, variable selection in large data sets
   - Clustering and Classification
   - Regression and Model Selection
   - Neural Networks and Deep Learning
4. Reduced Order Models, model fidelity and digital twins
   - Data-driven reduced-order models for optimization
   - Physics-based, data-driven reduced-order models
5. Seminars and specific modules in Energy, Aerospace, Mechatronics and robotics, Vehicle and transport, Operation engineering and management

## Objectives (and/or specific learning outcomes)

The objectives of the present course are:

1. to get familiar with data-driven approaches.
2. to understand the potential and limitations of data-driven methods in engineering applications.
3. to be able to select and use data-driven methods appropriate for specific applications.

Specific learning objectives include being able to:

1. Analyse and reduce the dimensionality of large-scale data sets.
2. Extract the main features of large-scale data sets.
3. Perform classification and regression tasks.
4. Developed robust reduced-order models.
5. Use advanced computer codes to implement data-driven approaches and algorithms.

## Pre-requisits and co-requisits

### Required knowledge and skills

Background in linear algebra, (partial) differential equations, scientific computing, control theory.

## Teaching method and learning activities

Lectures, exercises under supervision, seminars, project report, personal work.

### Contribution to the teaching profile

This teaching unit contributes to the following competences:

- In-depth knowledge and understanding of exact sciences with the specificity of their application to engineering

- In-depth knowledge and understanding of the advanced methods and theories to schematize and model complex problems or processes
- Reformulate complex engineering problems in order to solve them (simplifying assumptions, reducing complexity)
- Conceive, plan and execute a research project, based on an analysis of its objectives, existing knowledge and the relevant literature, with attention to innovation and valorization in industry and society
- Correctly report on research or design results in the form of a technical report or in the form of a scientific paper
- Present and defend results in a scientifically sound way, using contemporary communication tools, for a national as well as for an international professional or lay audience
- Collaborate in a (multidisciplinary) team
- Develop, plan, execute and manage engineering projects at the level of a starting professional
- Think critically about and evaluate projects, systems and processes, particularly when based on incomplete, contradictory and/or redundant information
- A creative, problem-solving, result-driven and evidence-based attitude, aiming at innovation and applicability in industry and society
- A critical attitude towards one's own results and those of others
- Consciousness of the ethical, social, environmental and economic context of his/her work and strives for sustainable solutions to engineering problems including safety and quality assurance aspects
- The flexibility and adaptability to work in an international and/or intercultural context
- An attitude of life-long learning as needed for the future development of his/her career
- Has a broad scientific knowledge, understanding and skills to be able to design, produce and maintain complex mechanical, electrical and/or energy systems with a focus on products, systems and services.
- Has an in-depth understanding of safety standards and rules with respect to mechanical, electrical and energy systems.

## References, bibliography and recommended reading

Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control, by Steven L. Brunton and J. Nathan Kutz. Publisher: Cambridge University Press. ISBN: 9781108380690.

## Course notes

Podcast and Université virtuelle

# Other information

## Place(s) of teaching

Solbosch

## Contact(s)

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# Evaluation method(s)

Oral presentation, Group work and written examination

## Evaluation method(s) (additional information)

Multiple choice questions (40%) and oral presentation of a group-based study case (60%).

*Criteria for evaluation ofÂ the case study*

- Clarity of presentation, 40%, for a presentation of 20 minutes, showing the main steps of the work and how each member of the group contributed to the case study.
- Understating of the theoretical concepts, 30%, measuring the ability of making connections between the practical work and the theory.
- Critical assessment, 30%, measuring the ability to justify the results taking into account the potential and limitations of the approaches used.

## Determination of the mark (including the weighting of partial marks)

Multiple choice questions (40%) and oral presentation of a group-based study case (60%).

## Main language(s) of evaluation

English

# Programmes

## Programmes proposing this course at the Brussels School of Engineering

MA-IREM | Master of science in Electromechanical Engineering | finalité Professional/unit 1 and finalité Operations engineering and management/unit 1