UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Course guide
295457 - 295TM114 - Data Science in Mechanical Engineering

Last modified: 26/06/2025

Unit in charge: Barcelona East School of Engineering
Teaching unit: 729 - MF - Department of Fluid Mechanics.

Degree: MASTER'S DEGREE IN MECHANICAL TECHNOLOGIES (Syllabus 2024). (Optional subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** Spanish

LECTURER

Coordinating lecturer: MARIO MIGUEL VALERO PÉREZ - JOAN CALAFELL SANDIUMENGE

Others: Primer quadrimestre:
JOAN CALAFELL SANDIUMENGE - Grup: T1
JAN MATEU ARMENGOL - Grup: T1
MARIO MIGUEL VALERO PÉREZ - Grup: T1

PRIOR SKILLS

Good understanding of basic statistics.
Scientific coding autonomy. Ability to autonomously create and run small functions and scripts in Python, Matlab, and/or similar high-level languages.
No previous experience in data science required.

LEARNING RESULTS

Knowledges:
K.08. Identify data analysis tools to characterise, synthesise, explain and predict the behaviour of physical systems in the field of mechanical engineering.
K.05. Identify emerging technologies, both in the mechanical domain and in the field of new information and communication technologies, that can be applied to mechanical engineering projects.
K.07. Define appropriate analytical, experimental and/or computational models to study relevant problems in mechanical engineering.

Skills:
S.02. Correctly apply the analytical, computational and/or experimental techniques best suited to the analysis of a case or project in the mechanical field.
S.08. Integrate knowledge from different areas of the mechanical field in the design and development of projects, systems and engineering solutions.
S.04. Incorporate sustainability and energy efficiency criteria into the design, planning, execution and operation phases of engineering projects.
S.05. Critically examine the results of the analysis of a process or product, taking into account the limitations of the techniques used.
S.07. Design flexible production/operation systems to improve the performance of industrial processes.
S.03. Use advanced numerical simulation and virtual prototyping techniques to solve complex mechanical problems.
S.06. Efficiently manage information collected during analytical, numerical and/or experimental studies and automate its analysis to facilitate knowledge extraction.

Competences:
C.03. Manage the acquisition, structuring, analysis and visualisation of data and information in the mechanical field and critically evaluate the results of this process.
C.02. Work as part of a multidisciplinary team, whether as a team member or in a leadership role, to contribute to the development of projects with pragmatism and a sense of responsibility, undertaking commitments with due regard to the resources available.
C.05. Propose advanced scientific and technological solutions to complex industrial challenges in the field of mechanical engineering.

TEACHING METHODOLOGY

This is a project-based course. The first part of the semester will introduce the student to the most important basic concepts of data science from an engineering perspective. Afterwards, students will pick or propose a project of their choice to develop in teams during the rest of the semester. The development of these projects will require the student to: (i) gain deeper knowledge in specific topics through a combination of autonomous work, teamwork and instructor guidance, (ii) design innovative solutions to engineering challenges using data science tools, (iii) present and defend their proposed solutions in front of the class, (iv) discuss and constructively evaluate others' solutions, proposing improvements, (v) implement and validate the proposed solutions, and (vi) self-assess and peer-assess their work at the end of the semester.

LEARNING OBJECTIVES OF THE SUBJECT

At the end of this course, the student will be able to:
1. Manage and visualize large datasets.
2. Implement data science workflows in a scalable fashion.
3. Design, implement, and evaluate the performance of advanced data analysis techniques, data-driven models or machine and deep learning schemes.
4. Select the most adequate methodologies to resolve data-related mechanical engineering problems.
5. Design, implement, and evaluate the performance of data science workflows in mechanical engineering frameworks.
6. Explain and discuss data science solutions, both orally and in writing.

STUDY LOAD

Type	Hours	Percentage
Hours large group	21,0	14.00
Self study	108,0	72.00
Hours small group	21,0	14.00

Total learning time: 150 h

CONTENTS

Topic 1: Basics of Data Science

Description:
Recap of basic statistics.
Optimization techniques.
Basics of software development.
Code and data management.
Scientific data visualization.
Cloud computing.
Distributed and Parallel systems for big data.

Specific objectives:
Understand and apply basic statistics concepts used in data science.
Implement a variety of multiparametric optimization techniques.
Process data at scale.
Create reproducible and maintainable data workflows.

Related activities:
Short exercises on statistics, optimization, and other relevant mathematical tools.
Implement a simple data workflow.

Full-or-part-time: 26h 15m
Theory classes: 5h 15m
Laboratory classes: 5h 15m
Self study : 15h 45m

Topic 2: Data-Driven Modeling

Description:
Uncertainty quantification.
Model verification and model validation.
Bayesian inference.
Data assimilation (dynamic assimilation, gap filling, data-fusion).
Dynamical systems.
Reduced order models.
Intelligent control through learning and optimization.

Specific objectives:
Apply uncertainty propagation on basic mathematical operations.
Understand the underlying concepts of reduced order models and their implementation.
Build surrogate models from large databases and perform cross-validation.
Understand global sensitivity models and their implementation.
Implement Bayesian calibration algorithms.

Related activities:
Build a full Uncertainty Quantification workflow from a real-world application.

Full-or-part-time: 26h 15m
Theory classes: 5h 15m
Laboratory classes: 5h 15m
Self study : 15h 45m

Topic 3: Machine Learning. Deep Learning fundamentals

Description:
Deep learning in the context of Machine Learning.
Supervised vs. Unsupervised Learning.
Regression vs. Classification problems. Metrics.
Perceptron: single neuron model and activation functions.
Loss Function, Backpropagation, and Optimization.
Multilayer Perceptron.
Convolutional Neural Networks, Pooling Layers.
Neural Network training process. Regularization techniques.

Specific objectives:
Understand and apply fundamental concepts in deep learning (neural networks) development.
Implement basic neural networks for classification and regression problems.
Training basic models for classification and regression problems.

Related activities:
Complete missing but essential parts of a basic PyTorch code defining a neural network and its training functions.
Training a model following training guidelines including hyperparameter tuning and application of regularization techniques.

Full-or-part-time: 26h 15m
Theory classes: 5h 15m
Laboratory classes: 5h 15m
Self study : 15h 45m

Topic 4: Data analysis and Technological applications

Description:
Detection of anomalies (e.g. predictive maintenance).
Pattern recognition.
Image processing and computer vision.
Dimensionality reduction.
Regression.
Clustering and classification.

Specific objectives:
Obtain a general overview of the possibilities that data science techniques offer in various technological applications, emphasizing mechanical engineering.

Full-or-part-time: 26h 15m
Theory classes: 5h 15m
Laboratory classes: 5h 15m
Self study : 15h 45m

GRADING SYSTEM

Student competencies and skills will be assessed through formative and summative evaluation using the following methodology:
1. The initial theoretical part of the course will include short practice exercises and it will be followed by a test (30%).
2. Student project work will be monitored through in-person synchronous classroom work sessions. The instructors will keep notes on each student's progression throughout the semester. The project development phase includes intermediate milestones and deliverables that all students must meet. The degree of accomplishment of the planned project timeline will be graded (10%).
3. All students must prepare a compulsory final project report (20%) and deliver a project presentation (10%) at the end of the semester. Both items will be graded using previously published assessment rubrics.
4. Projects will be evaluated by student self assessment (10%) and peer review (10%). The peer review report will also be assessed by the instructor (10%).

Summary of evaluation items:
- Midterm theoretical test (30%)
- Project (70%)
· Group and individual self-evaluation (10%) guided by rubric
· Peer-evaluation (10%) guided by rubric
· Instructor evaluation (50%)
> Initial timeline: milestone achievement (10%)
> Final project document (20%)
> Oral presentation (10%)
> Peer-evaluation assessment (10%)

Total Score (100%) = 0,3 * Midterm Test + 0,1 * Project self evaluation + 0,10 * Project peer evaluation + (0,10 * Project milestones + 0,20 Project report + 0,10 * Project oral presentation + 0,10 * Assessment of peer evaluation).