

**MACHINE LEARNING AND STATISTICAL VALIDATION IN AERONAUTICS**  
**23 - 26 of May 2023**

**Room A-026 -Technical School of Aeronautical and Space Engineering.Pl. del  
Cardenal Cisneros, 3, 28040 Madrid**

- **Theory sessions: every morning 9:30h - 13:30h**  
Main concepts and ideas will be presented.
- **Independent hands-on sessions: every afternoon 15h - 18h**

These are sessions where participants will be able to work with template notebooks (that will be provided) to implement specific algorithms and apply the concepts learned during the morning session. Participants will be able to work independently or in groups.

**Requirements and comments:**

Some basic experience in programming in Python is desired. All electronic materials will be provided on the course. Participants are highly encouraged to bring their own laptop.

**The course will be delivered in English.**

## Syllabus of the course

Tuesday, 23<sup>st</sup> of May

### BRIEF OVERVIEW OF MACHINE LEARNING

09:30	13:30	<ol style="list-style-type: none"> <li>1. Supervised Learning <ul style="list-style-type: none"> <li>* Regression</li> <li>* Classification</li> <li>* Examples, including aeronautical examples</li> <li>* Overview of feature-based methods for regression and classification (logistic regression, k-NN, SVM, etc)</li> </ul> </li> <li>2. Neural Networks <ul style="list-style-type: none"> <li>* Feed-Forward and other architectures</li> <li>* Universal approximation theorem</li> <li>* Neural network optimization (loss function and regularization, stochastic gradient descent and backpropagation)</li> </ul> </li> <li>3. Unsupervised learning <ul style="list-style-type: none"> <li>* Clustering methods (k-means, hierarchical clustering)</li> <li>* Dimensionality reduction</li> </ul> </li> <li>4. Design of surrogate models' pipeline: from data curation to model evaluation</li> </ol>
15:00	18:00	<ol style="list-style-type: none"> <li>5. Applications and hands-on</li> </ol>

Wednesday, 24<sup>nd</sup> of May

### STATISTICAL METHODS FOR VALIDATION OF AERONAUTICAL SURROGATE MODELS

09:30	13:30	<ol style="list-style-type: none"> <li>1. Types of Data <ul style="list-style-type: none"> <li>* Continuous vs categorical variables.</li> <li>* One-hot encoding</li> </ul> </li> <li>2. Basic data representation and Visualization</li> <li>3. Basic statistics and metrics</li> <li>4. Linear and nonlinear correlations</li> <li>5. Hypothesis test: H0 and p-value, t-test, Kolmogorov-Smirnov, ANOVA</li> <li>6. Fitting via least squares optimization</li> <li>7. Outliers &amp; Outlier detection via z-score</li> </ol>
15:00	18:00	<ol style="list-style-type: none"> <li>8. Applications and hands-on</li> </ol>

## Syllabus of the course

**Thursday, 25<sup>th</sup> of May**

### VALIDATION PIPELINE OF SURROGATE MODELS

09:30	13.30	<ol style="list-style-type: none"> <li>1. Pipeline overview and concrete aeronautical examples</li> <li>2. Test-Train split: The interpolating character of neural networks. Convex hull, Distribution analysis and detection of isolated regions</li> <li>3. Model evaluation I: Global error analysis <math>P(E)</math>: true vs predicted distributions, error metrics and error distribution</li> <li>4. Model evaluation II <math>P(E Y)</math>: Error-output biases, how to detect and quantify</li> <li>5. Model evaluation III: <math>P(E X)</math>: Error-input biases, how to detect and quantify</li> <li>6. Model interpretability: feature importance</li> </ol>
15:00	18:00	<ol style="list-style-type: none"> <li>7. Applications and hands-on</li> </ol>

**Friday, 24<sup>th</sup> of June**

### UNCERTAINTY AND APPLICABILITY MODELS

09:30	13.30	<ol style="list-style-type: none"> <li>1. Merging sources of error into a complete uncertainty model. Training, test, validation and coverage</li> <li>2. The concept of applicability and its different layers</li> <li>3. Applicability classifiers</li> <li>4. Full picture of uncertainty and applicability in aeronautical examples</li> </ol>
15:00	18:00	<ol style="list-style-type: none"> <li>5. Applications and hands-on</li> </ol>

**The end**