# Solving Aerodynamics and Aeroelastic Stability Problems through Data

Bibliography defense by

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11/05/2021

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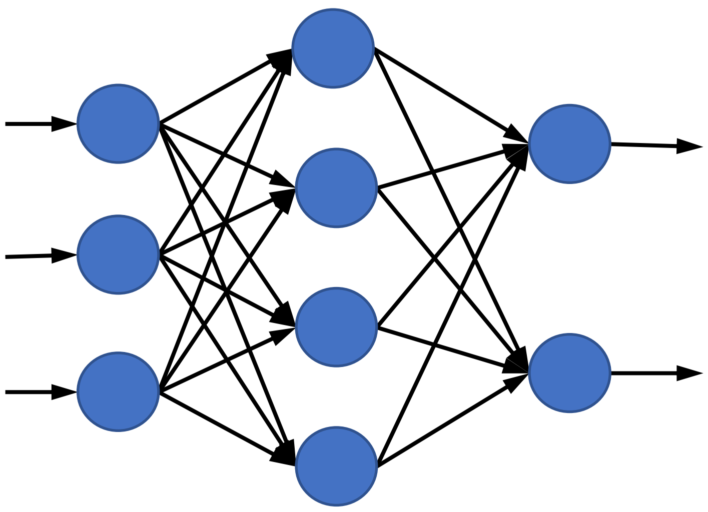
# Content

# Introduction

- airfoil geometry crucial part of design process
- obtaining of aerodynamic coefficients:
  - windtunnel
  - simulations

→ expensive and time consuming

- surrogate models
  - reproduce results from simulation
  - example artificial neural network




[1] A. I. J. Forrester, A. Sobester, and A. J. Keane. Engineering design via surrogate modelling. Wiley, 2008.
[2] D. P. Raymer. Aircraft design: A conceptual approach. AIAA, 1992
[3] J. Schmidhuber. Deep learning in neural networks: An overview. Elsevir, October 2014

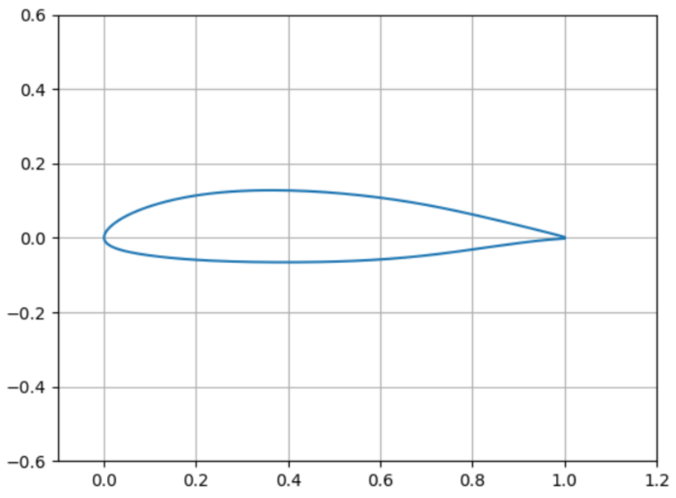
# Previous Work

- aeroelastic instability problem
  - airfoil morphing
- building of own Database of 1000 airfoils from the 4th NACA family
  - BEZIER Parsec 3434 parameters
  - Xfoil for calculation for the aerodynmic coefficients
- training of neural network
- building aeroelastic model
- coupling neural network and aeroelastic model

[1] R. Carreira Rufato and J. Morlier. Avoid aeroelasticity instabilities with a morphing airfoil using neural networks. ISAE SUPAERO, June 2020

# Database - Building

- singular value decomposition SVD of 1172 airfoils in UIUC database
  - mode shapes for three camber and thickness line
- database split in subsonic and transonic airofils
  - 81000 subsonic airfoils
  - 32400 transonic airfoils
- airfoils controlled by mode shapes
  - 14 mode shapes for the subsonic airfoils
  - 8 mode shapes for the transonic airfoils




[1] M. A. Bouhlel, S. He, and J. R. R. A Martins. mSANN model benchmarks. Mendeley Data, 2019, http://dx.doi.org/10.17632/ngpd634smf.1
[2] J. Li, M. Amine Bouhlel, and J. R. R. A. Martins. Data-based approach for fast airfoil analysis and optimization. AIAA Journal, February 2019

# Database – First Surrogate Model

- approach:
  - Gradient enhanced kriging with partial least squares and a mixture of experts

Kriging

↓ Gradient enhanced kriging (GEK)

reduces number of evaluations

↓ partial  least squares method

solves the size problem of GEK

↓ mixture of experts

variable space split between multiple surrogate models

One surrogate model for every regime

[1] J. Li, M. Amine Bouhlel, and J. R. R. A. Martins. Data-based approach for fast airfoil analysis and optimization. AIAA Journal, February 2019
[2] M. A. Bouhlel and J. R. R. A. Martins. Gradient-enhanced kriging for high-dimensional problems. Springer-Verlag, February 2018

# Database – Second Surrogate Model

- approach:
  - modified artificial  neural network using Sobolev training (mSANN)

ANN

Sobolev training

Passes the gradient information into the loss function during training

modification

Gradient information is passed in gradually

One surrogate model for both regimes

[1] M. Amine Bouhlel, S. He, and J. R. R. A. Martins. Scalable gradientenhanced artificial neural networks for airfoil shape design in the subsonic and transonic regimes. ResearchGate, 2020

# Platforms – SMT and Keras

- SMT – surrogate modeling toolbox:
  - collection of neural network modelling methods
  - sampling and benchmark functions
- Keras:
  - deep learning API that uses the platform tensorflow
  - easy user interface
  - high flexibility

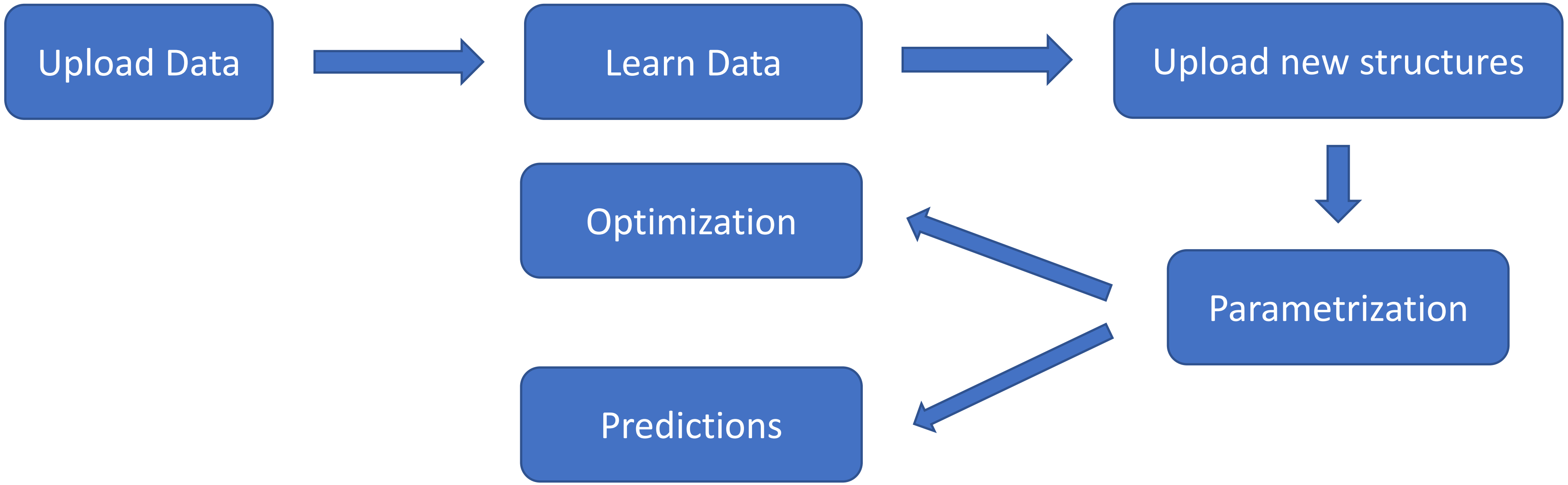
[3]

[1] M. A. Bouhlel, J. T. Hwang, N. Bartoli, R. Lafage, J. Morlier, and J. R. R. A. Martins. A python surrogate modeling framework with derivatives. page 102662, 2019
[2] Keras documentary. Online accessed on 05/05/2021. https://keras.io/about/.
[3] Keras logo. Online accessed on 07/05/202. https://keras.io/

# Platforms – Monolith AI

- online platform

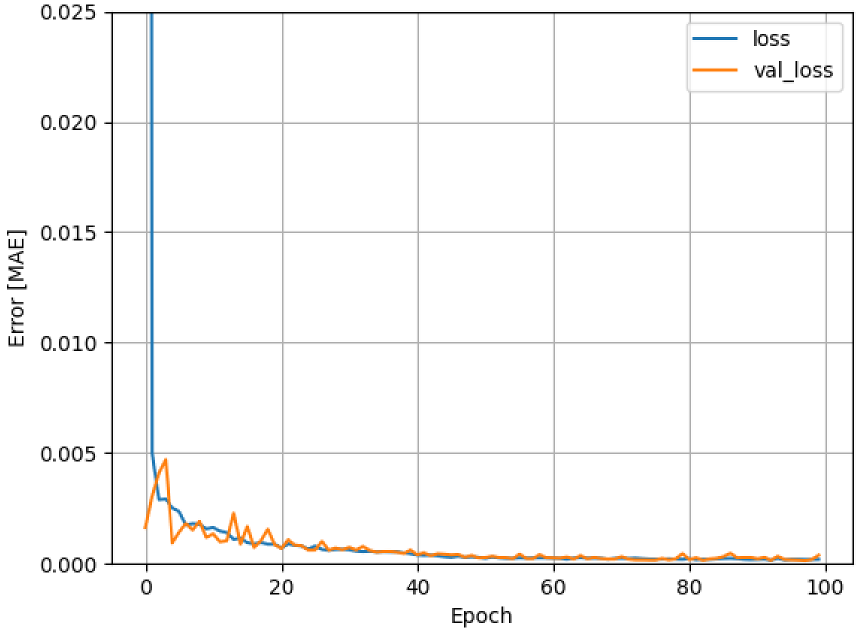
MONOLITH [2]

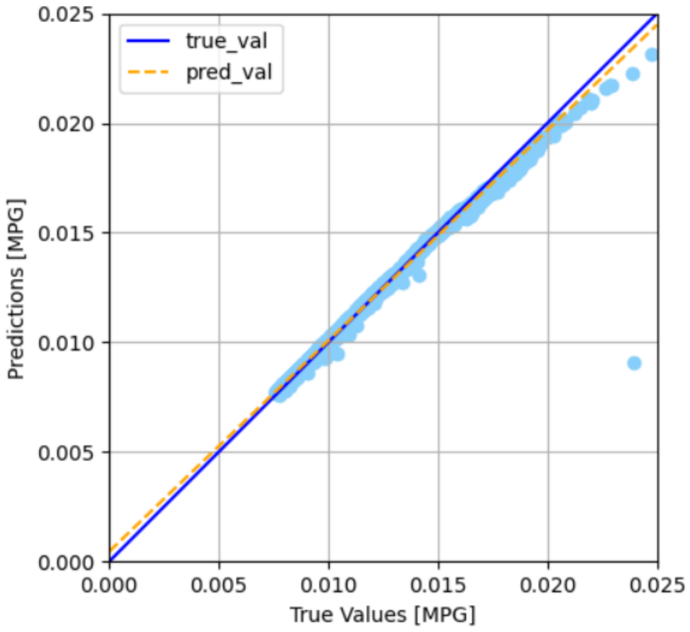



[1] Monolith. Online accessed on 05/05/2021. https://www.monolithai.com/industry/reduce-testing.
[2] Monolith logo. online accesed on 07/05/2021. https://www.monolithai.com/

# First Results

- visualization of Data
- first simple neural network using Keras



# Next Steps

- learning of the database by all three platforms
- gradually improving the built networks in Keras and SMT
- comparison of the results
- application on the aeroelasticity problem