**The project is used as application documentation supplement to presents some of the authors technical and problem solving skills.* *Author: Nikola Franic*

# Approximation of Cl based on shape, angle and Re

**Task:** The task is to develop a model that can predict Cl value based on shape of the airfoil, angle and Reynolds number.

**Description:** In the first part data process of getting, preparing and cleaning data is described. I the second part approximation model is built and results are described

## First part – Defining, finding and preparing data

To do an aerodynamic analysis current simulation software needs a lot of computational power to calculate forces that influence testing model. The main idea that is explored here is can machine learning model be built that could approximate forces and parameters of certain shape. Model would need a lot of computational power to train and develop but on the end it would be able to give user the results faster, without a lot of computation.

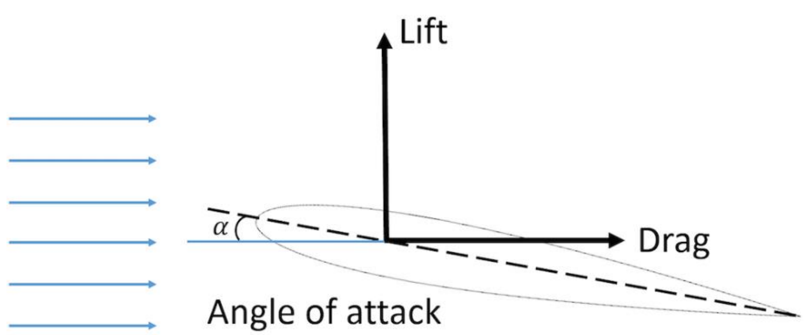


*Illustration of forces*

To explore this idea NACA database of airfoils is scripted and model is built upon it.

### Creating database

For data that is included in database is: coordinate points that define shape of airfoil and angle, Cl (lift coefficient), Cd (drag coefficient) and Re (Reynolds number). Other parameters that were considered where Ncrit = 9 (clean wind tunnel) and Re from 50 000 to one million. One of the main problems that occurred where how to describe shape of airfoil for all airfoils in some standardized way. Problem was solved by sorting, rotating points for certain angle and interpolating airfoil points. Then y coordinates for 1000 fixed x coordinates where extracted. In the end one input information row for one airfoil was organized in array with 1000 y coordinates followed by angle Cl, Cd, Re values. In the end around 800 000 airfoil examples where generated. Code of following procedure can be seen **here**.

## Second part – building and testing the approximation model

For approximation model simple neural network was built. Its architecture was consisted from one normalization layer, followed by three dense layers with 124, 64 and 16 neurons and ReLu activation function and on output layer with one neuron. Model was trained with Adam optimizer, learning rate 0.0001 and MAE (mean absolute error) loss function. Results gave us average MAE of 0.04 and we further took few examples tested them and where satisfied with results. Code of following procedure can be seen **here**.

**Results:**

2032c-il (0 degrees, Re 50 000), Real value (Cl): 0.6454, Predicted value (Cl): 0.6157

2032c-il (-6 degrees, Re 100 000), Real value (Cl): -0.249, Predicted value (Cl): -0.189

be50-il (6 degrees, Re 200 000), Real value (Cl): 1.1677, Predicted value (Cl): 1.1599

hq17-il (0 degrees, Re 500 000), Real value (Cl): 0.5444, Predicted value (Cl): 0.5474

m3-il (-3 degrees, RE 1 000 000), Real value (Cl): -0.3189, Predicted value (Cl): -0.3062

I have also took example of airfoil that was not included in NACA database but one that was experimentally tested at my home University. Results where also pretty accurate and showed good results even for Re values that where not in database, which means that model is interpolating good:

(0 degrees, Re 800 000) Real value (Cl): 0.843, Predicted value (Cl): 0.857

(6 degrees, Re 6 000 000) Real value (Cl): 1.245, Predicted value (Cl):1.213

Model was only trained with random 100 000 examples because it was trained on laptop that lacked computational power. So room for even better improvement exist. By building bigger network and training on whole database results would probably be even better.