NablaFoil: a tool for the airfoil real-time aerodynamic prediction

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1. NablaFoil Overview

NablaFoil represents a new, innovative approach to the design of the airfoils. Concepts from different disciplines constitute the tool. Some algorithms allow to parametrize the airfoil shapes using the most advanced mathematical representations. Through an interactive mode the user can adapt, by hand, the shape of the airfoil and check in real-time the performance. A neural network runs in background in order to extrapolate the results from a huge database of airfoils. The database has been created using xFoil, one of the most accurate panel code developed by MIT.

The main features are:

- Real-time estimation of aerodynamic performance
- Choice the aerodynamic target in terms of Angle of Attack, Reynolds Number, Lift and Drag Coefficients
- Easy change of the parametrization techniques
- Over 150k airfoil shapes used to populate the airfoil map.

2. Parametrization Techniques

The parametrization techniques, allowable in **NablaFoil** make possible to reproduce all the most used airfoils and to generate new, innovative, shapes. The discretization methods include:

- Bezier curve
- B-Spline representation
- Nurbs curve
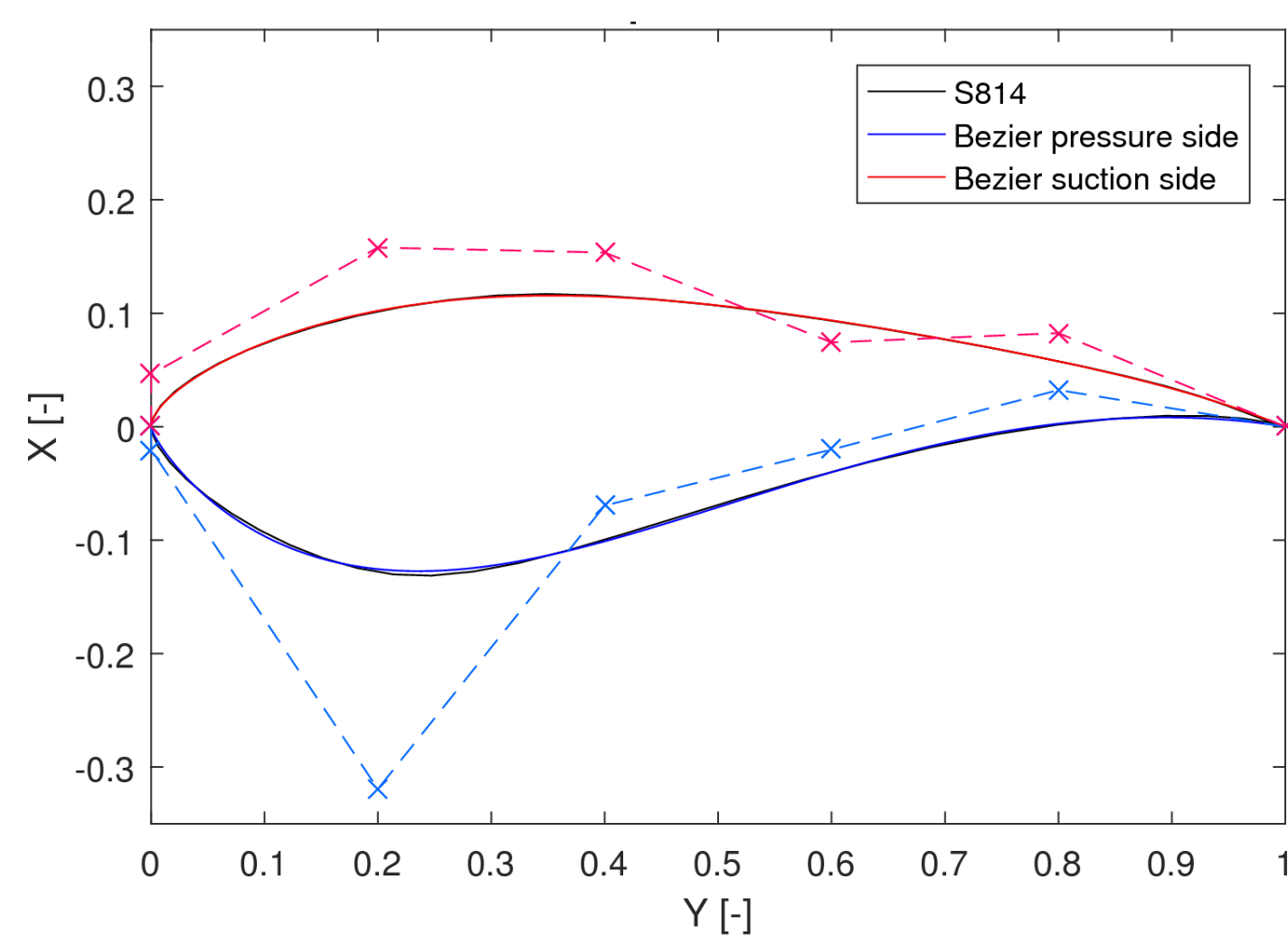
3. Neural Network

The aerodynamic prediction technique of **NablaFoil** is based on a Neural Network.

- First, a huge number of parametrized airfoils (over 150k) has been generated
- Therefore, each airfoil has been simulated using the panel code xFoil and its performance recorded in a database
- Finally, a neural network has been set and trained on the database

The result of the procedure is a complex mathematical function, capable to instantaneously predict the polars of an airfoil from the coordinates of its control points.
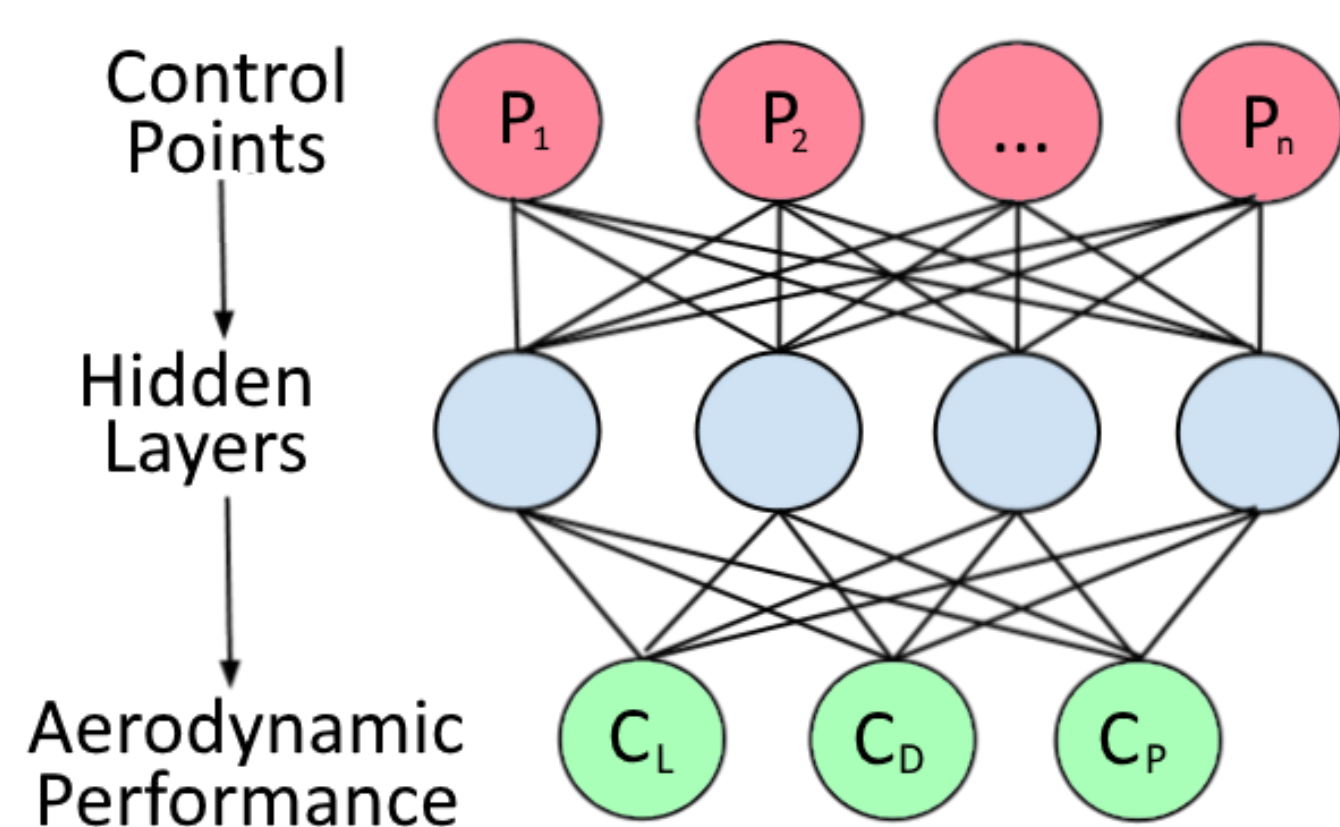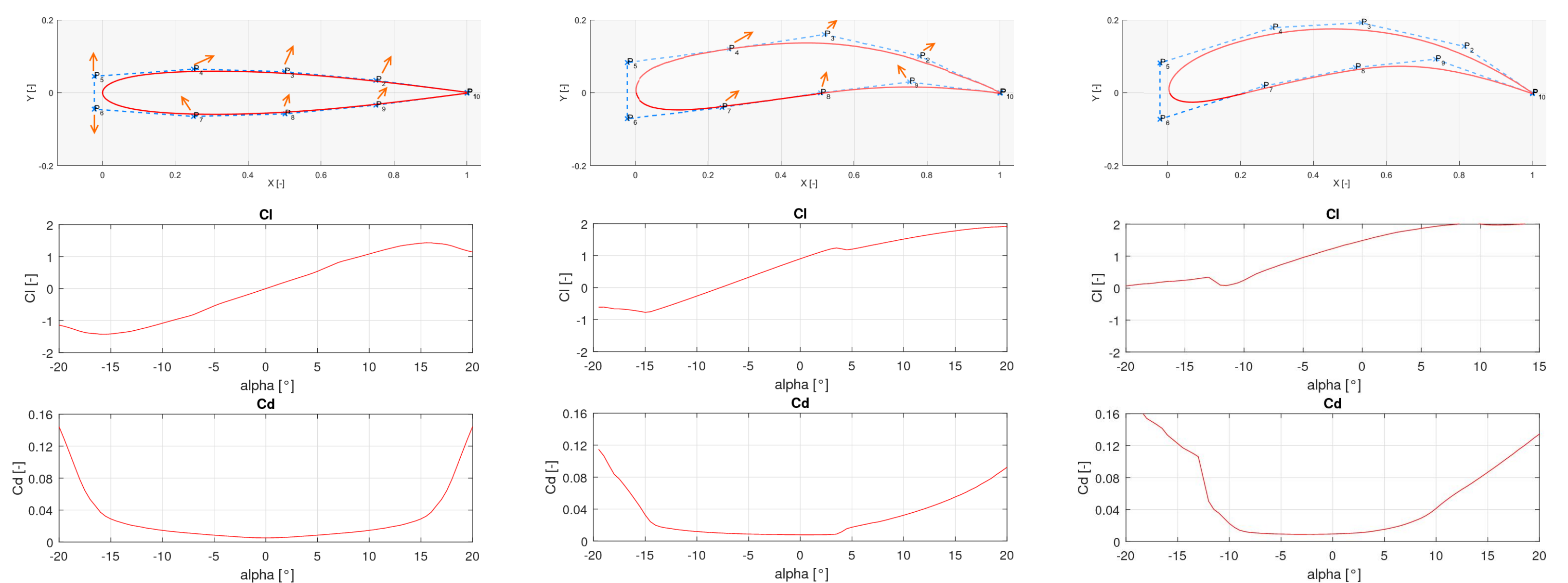

4. NablaFoil GUI
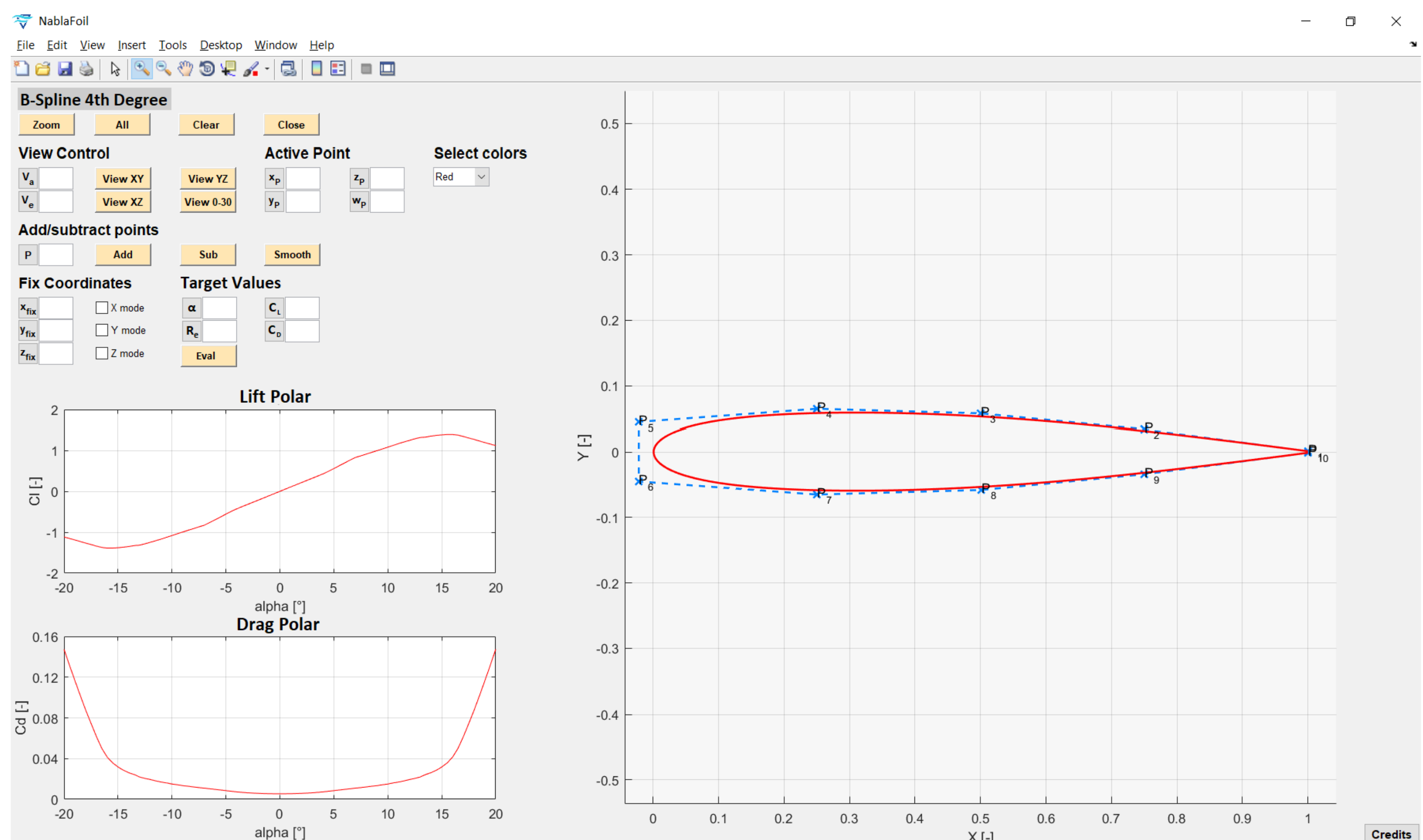
The **NablaFoil** Graphical User Interface shows an interactive draw-mode environment (on the right) linked to two dependent plots of the airfoil polars (on the left). Furthermore, the commands allows to:

- Change the view and color of the airfoil, zoom the shape
- Add/Subtract a point of the parametrization, move a point along a fixed coordinate
- Identify a random airfoil shape from a target value of α, R_e, C_L and C_D

5. Real-time Shape Modification

The hand-mode modification of the airfoil shape shows, in real-time, the change of the performance of the airfoil, in terms of C_L and C_D. A symmetric airfoil becomes a profile suitable for motorsport applications.

6. Applications

NablaFoil cuts across a broad range applications. Currently, it is used to generate high-performing airfoil shapes and it is easily coupled with 0-D and 1-D engineering codes for the estimation of machine performances. The main application fields are:

- **Wind Energy:** generation of the sequence of airfoils of an Horizontal Axis Wind Turbine, identification of the slightly non-symmetric airfoils, suitable for a Vertical Axis Wind Turbine
- **Axial Compressors**: the rotor blades can be easily optimized with NablaFoil algorithms.
- **Pumps**: coupled with a 1-D code to predict the performance of axial and radial pumps.
- **..........**: NablaFoil can be customized on-demand. Different parametrization techniques and target plots can be implemented. Airfoil performance maps of different accuracy (e.g. for stall predictions) can be used.