Inverse Airfoil Design

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Supervised Learning Project

under the guidance of

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Overview

Objective

- To design an airfoil from its C_p distribution using Inverse Airfoil Design Approach
- Test the method for standard test cases like NACA Airfoils

Introduction

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- Inverse methods of aerodynamics determine the geometry of the aircraft elements for a given pressure distribution and are a powerful tool of aerodynamic design.
- An Inverse Airfoil Design method includes a solver and an optimization algorithm.

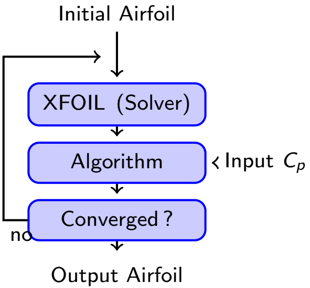


Figure – Inverse Airfoil Design

Solver

XFOIL

- Xfoil is an Open Source low fidelity, fast and reliable solver using Panel method to solve flow over an Airfoil
- XFOIL significantly reduces the computational requirements while retaining the ability to predict low Reynolds number flow
- Being open source it is easy to couple XFOIL with our algorithm using python scripts

Final Design

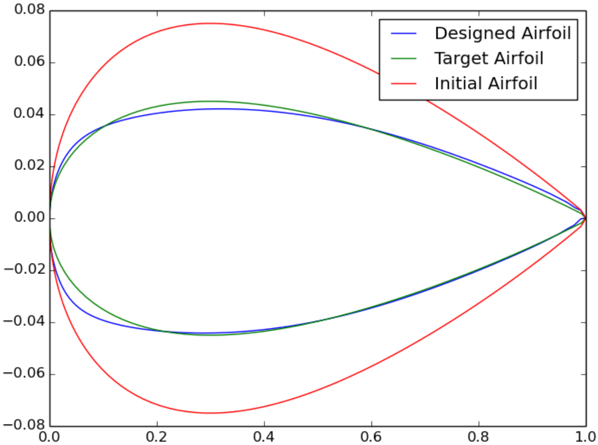
Final Design

- **Step 1 Initial Airfoil** : Wrote a custom python script to get NACA 0015 airfoil coordinates from UIUC Coordinate file and extract X-Y coordinates to feed XFOIL
- **Step 2 Running XFOIL** : A detailed python code was written to run XFOIL specify the flow conditions and extract the C_p distribution in a separate file to be further used
- **Step 3 Interpolation** : Since both the C_p distribution have different $\frac{x}{c}$, a separate linear interpolation function is ran to get C_p at same $\frac{x}{c}$ and compare both C_p distributions
- **Step 4 Algorithm** : The Algorithm is applied to the C_p distributions. Equating the momentum flux of initial and final airfoil gives the modified airfoil which is again fed to XFOIL and the procedure is applied again until $error \leq error_{desired}$

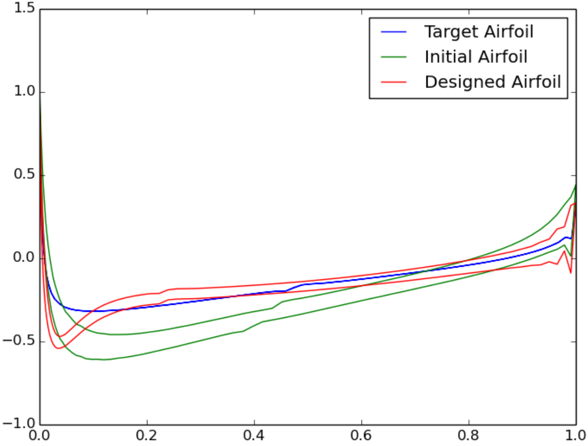
Results

Designed Airfoil

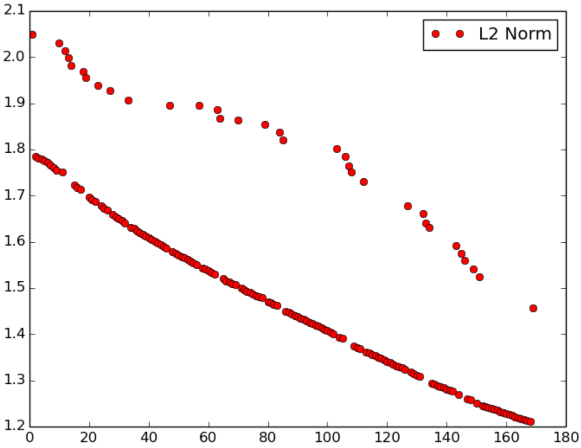
The code was tested to obtain NACA 0009 Airfoil where initial airfoil chosen was NACA 0015. The following Result was obtained :



Designed C_p Distribution



L2 Norm of Difference in C_p



Conclusion and Future Work

Conclusion

- As seen from the plots the algorithm work fairly well in case of symmetric airfoils in low Reynolds number
- There are some anomalies on the leading and trailing edge of the the designed and target airfoil which can be improved in the algorithm but could not be done due to time constraint

Future Work

- The algorithm can also further be improved to generate cambered airfoils
- Standard Optimization Algorithm like Genetic or PSO can be implemented to improve performance
- High fidelity solvers like OpenFOAM or MSES can be implemented to perform well for high Mach number for Transonic Design

Bibliography

- "A VISCOUS INVERSE DESIGN METHOD FOR INTERNAL AND EXTERNAL FLOW OVER AIRFOILS USING CFD TECHNIQUES" by Raja Ramamurthy, Benedikt Roidl and Wahid Ghaly
- XFOIL by Mark Drela, MIT
- Ansys by ANSYS, Inc.
- OpenFOAM by CFD Direct

The End