AE 244: Assignment 2

Weightage: 15% of the total grades

Deadline: 9th March. 2025 (Sunday) 11:59 PM
(Submissions after this deadline will attract 5% penalty for each 30 minutes delay. For example, 15% will be deducted from the assignment grades if the submission happens at 1:30 AM)

A note on plagiarism:

This is an individual assignment. While discussion is encouraged, simply copying someone else's work will attract zero marks for all involved.

Overall Background

You wish to participate in the Short Take-Off and Landing Aircraft Competition and being an aerospace engineer, you have decided to design an aircraft to compete completely by yourself. You already have a Lycoming O-320 engine with you, which you plan on using in your aircraft. Considering that you are the one who is also going to pilot the aircraft, your aircraft is capable of carrying you considering your height and weight.

Goal for Assignment 2:

Simulating an airfoil in a CFD tool can take a significant amount of time and computational resources as noticed in the first assignment. Therefore, it is useful to have a tool that can give at least some approximate answers quickly, so that an iterative airfoil design process can be conducted efficiently.

The goal of the current assignment is to create a tool that can predict performance of any thin airfoil using the thin airfoil theory, and to compare its prediction capabilities against other tools. Later, use the tool to try out your own unique airfoil designs!

Tasks

1. Create a computer program comprising of the following functions to implement thin-airfoil theory (**In a team of 3**):
    a. A function to generate and plot points along the camber line based on user defined functions [y = f(x)], including the one for NACA airfoils.
    (Consider normalized airfoil with leading edge at x = 0 and trailing edge at x = 1.)
    b. A function to compute the slope of the camber line at any given point along the chord length.
    c. A function to compute C_l of the thin airfoil at a given α based on thin airfoil theory.
    d. A function to plot vector field around the airfoil based on circulation distribution, and compute circulation due to airfoil through line integral.
    e. A main function that takes user inputs and combines functionality of all the above functions.
2. Use the program to plot/find (**Individually**):
    a. Camber line ('y' vs 'x') for the NACA airfoil from assignment 1

b. Slope of the camber line along x (dy/dx vs x)
c. C_l vs α (α from -3° to 12^0) along with C_l vs α curves from CFD simulations from assignment 1 for the NACA airfoil on the same chart for comparison.
d. Vector field plot around the airfoil in a domain 4 times the chord length along x and 3 times the chord length along y.
e. Circulation around the entire airfoil using velocity line-integral approach
f. Bound circulation by integrating circulation distribution along camber line.

3. Come up with 3 custom-designed airfoils and plot for each design (**Individually**):
   a. Camber line ('y' vs 'x') for the three custom designed airfoils
   b. C_l vs α of the three airfoils (α = -3° to 12^0)
   c. Vector field.

Report Structure

1. Program development team introduction and work share

1.1. Table containing team member names, roll numbers, and contribution by each in programing the functions [1]

[Note: Contribution level marked against each team member will be used as a scaling factor while assigning marks for the team tasks]

Sr. No	Roll Number	Name	Contribution Level (0 to 5)	Specifics of Contribution
1				
2				
3				

<u>Contribution Level Rubrics</u>:

- **0**: Was completely unresponsive and did not put any effort.
- **1**: Responded, but didn't do the promised tasks, and didn't try to learn to do it either.
- **2**: Did the promised/assigned tasks only partially/incorrectly and didn't try to learn to do it completely/correctly.
- **3**: Did the promised/assigned tasks only partially/incorrectly but put some effort to learn to do it right.
- **4**: Did the promised/assigned tasks to just acceptable quality with or without guidance from the other team members.
- **5**: Did the promised/assigned tasks completely with or without guidance from other team members.

2. Algorithm

Describe the algorithm for each function in a stepwise manner. Include equations wherever relevant (snipped images of equations are acceptable).
Examples of algorithm : https://www.programiz.com/dsa/algorithm#quadratic

2.1. Algorithm for plotting camber line [3]
2.2. Algorithm for plotting camber line slope [5]
2.3. Algorithm for computing C_l [10]
2.4. Algorithm for plotting vector field [5]
2.5. Algorithm for calculating circulation through line integral. [5]

3. Airfoil Simulation and Results.

3.1. Camber line ('y' vs 'x') for the NACA airfoil from assignment 1 [2]
3.2. Slope of the camber line along x (dy/dx vs x) [2]
3.3. C_l vs α for the NACA airfoil from the program and CFD simulations on same chart [5]
3.4. Comment on/discuss the results obtained in 3.3. [4]
3.5. Vector field plot around the airfoil (domain size: 4c times 3c) at α = 3° [5]
3.6. Comment on/discuss the plot obtained in 3.5 [4]
3.7. Circulation around the entire airfoil using velocity line-integral approach at α = 3° [3]
3.8. Bound circulation by integrating circulation distribution along camber line. α = 3° [2]
3.9. Compare and comment on the values obtained in 3.7 and 3.8. [2]

4. Novel Airfoil Properties

4.1. Camber line ('y' vs 'x') for your 3 airfoils and the NACA airfoil on same chart [3]
4.2. C_l vs α of the three airfoils along with that of the NACA airfoil on same chart [6]
4.3. Comment on/discuss the results obtained in 4.2 [2]
4.4. Vector field plot around the three airfoils (domain size: 4c times 3c) at $\alpha = 3^0$ [3]
4.5. Comment on/discuss the results obtained in 4.4 [2]

5. Conclusion

5.1. Overall take on your code's performance as compared to Ansys simulation, and possible reasons for deviations, if any [4]
5.2. Overall take on the performance of your airfoil as compared to the NACA airfoil [4]

6. Code (marks common to the team members)

6.1. Proper working of the camber line plotting code [2]
6.2. Proper working of the camber line slope plotting code [3]
6.3. Proper working of C_l and C_m code [6]
6.4. Proper working of vector field plotting code [4]
6.5. Proper working of circulation calculation [3]

7. GUI (Bonus)

7.1. Build a working GUI with the following features [10]

Sr. No.	Features	Marks
1	Input of camber line in tabulated form + Input of velocity + Output of C_l and C_m	2
2	+ Graphical display of airfoil geometry and free stream direction	1
3	+ Display of vector field plot	2
4	+ Option to input camber line shape in equation form	2
5	+ Sliders for live variation in velocity magnitude and angle of attack (with all outputs responding near time)	3

Guidelines for the computer program: (-5% for not following these)

1. **Programming language**: Use only freely available ones. Python preferred
2. Make the code modular by splitting it into functions (preferably separate files). Add a preamble to each function file describing what the function is supposed to do, what inputs does it need, what does it output, and any assumptions that have been made. Remember, you will end up using some of the functions across more than one assignments, so doing this will save you from frustration later.
3. Add comment against each variable name to describe what the variable means
4. Add comment for each functional chunk of code to explain what it is supposed to do.
5. Have a separate user input function/file where a user can specify all necessary design details and flight condition.
6. Write a "Readme.txt" file with complete instructions on how to run your code.
7. <u>Submit the code in a way such that it is straightforward for any user to run it.</u>

8. Acknowledgement

Mandatory to acknowledge people you discussed with or took help for any part of the assignment.

9. References

List all references (books, paper, websites, etc.) used while doing the assignment