CSCI 5636 Final Project Proposal

A finite element approach simulating flow over a Formula 1 car's wing using FEniCS

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In this project, I want to simulate the flow over a Formula 1 car's wing. I will probably choose the rear wing since it is aerodynamically simpler. I will also choose to model it after older cars since the modern ones have such complicated aerodynamic features. If I can find the technical regulations from this era, I will look at them to see if I can make the geometry as accurately as possible. Also, this simulation will ignore a lot of the important real life factors. The biggest is the lack of a whole car simulation. The flow over the rear wing of a car depends entirely on how the rest of the car shapes the air flowing around it before it hits the rear wing. I will just be simulating the flow over the rear wing on its own.

We will be looking at incompressible fluids governed by the Navier-Stokes equations. We let $\rho(x,t)$ be the density of the fluid at point x at times t. Likewise, let $u(x,t)$ be its velocity. We start with the mass continuity equation

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho u) = 0.$$

We also consider the Cauchy momentum equation

$$\frac{\partial \rho u}{\partial t} + \nabla \cdot (pu \otimes u) + \nabla p - \eta \Delta u - \left(\frac{\eta}{3} + \xi\right) \nabla(\nabla \cdot u) = f$$

where f are the external body forces (gravity etc.) p is the pressure and η and ξ are the first and second viscosities. Since we are concerned with incompressible flows where ρ can be treated as a constant, then, we get the Navier-Stokes equations:

$$\nabla \cdot u = 0$$
$$\frac{\partial u}{\partial t} + u\nabla u + \nabla p = f.$$

Using these equations, we will simulate how the air moves around a wing. I am note sure yet how to solve these equations with the geometry of the wing taken account of. Once I have results, I would also like to calculate the downforce (i.e. negative lift) and drag the wing generates. At the moment, I am not sure to calculate these values. I may also compare the downforce and drag on two or three different design of wings. I will be using FEniCS as my finite element software for this project.

References

[LMW12] Anders Logg, Kent-Andre Mardal, and Garth Wells, *Automated solution of differential equations by the finite element method: The fenics book*, Vol. 84, Springer Science & Business Media, 2012.

[PP89] Olivier Pironneau and Olivier Pironneau, *Finite element methods for fluids*, Wiley New York, 1989.