CHEN E4150: Computational Fluid Dynamics

Syllabus

Description: Course is aimed at junior and senior undergraduate and graduate students. Covers fundamentals of numerical algorithms for modeling dynamics of fluid flow computationally. Includes various approaches to discretize time and space on structured and unstructured grids with a variety of boundary conditions. Involves programming of basic CFD codes in MATLAB or Python to test example problems in fluid mechanics with different discretization schemes. Uses open-source software OpenFOAM to investigate more complex geometries and numerical approaches. Introduction to simulation of multiphase flow. Course grade based on homework assignments and final project report and presentation.

Prerequisites: Undergraduate fluid mechanics

Lecture: Lectures are scheduled for MW from 5:40 to 6:55 pm. The lecture format will be primarily slides but will be augmented with excursions to the board (for derivations, etc.). The lecture slides as well as example codes will be made available on CourseWorks before the lecture, and you are ***strongly*** encouraged to bring these slides to the lectures. The slides will be partially incomplete with space for you to take notes on the discussion on the board and any other additional notes that you see fit.

Grading:

Two Homework Assignments	40%
Two 45-minute Closed Note Quizzes	20%
Individual Final Project	40%

Homework: Two smaller projects will be assigned during the course of the semester. The first will involve coding and analyzing a simple CFD code in either Matlab or Python. The second will involve studying flow and the effects of the CFD solution method on simulation output using an open-source CFD platform called OpenFOAM.

Quizzes Quizzes will be closed notes and last about 45 minutes. The quizzes will be held at the start of a class period, and the end of the class period will be devoted to part of a lecture. The quizzes which will cover concepts covered in lecture which are not as easily incorporated in to the assignments. Practice problems for quizzes will be given.

Final Project: In lieu of a final exam, the course will conclude with an individual final project. The topic of your final project is entirely up to you (in consultation with the instructor). A typical project will follow one of two prototypes: (1) implementation, verification, and application of complex numerical methods to simple fluid flows in Matlab or Python or (2) study of complex flows (multiphase, turbulent, complex geometry, etc.) using OpenFOAM. Other projects types are certainly possible and should be discussed with the instructor.

Deliverables for the final project will consist of a written report, a slides presentation in class and an archive of your source code or input scripts to OpenFOAM

References: The relevant texts for this course are provided in PDF format on CourseWorks. The material covered in the course is largely in-line with that covered in the following textbook:

- J.H. Ferziger, M. Perić, *Computational Methods for Fluid Dynamics*, 3rd Edition, Springer, 2002 [ISBN: 3-540-42074-6]. (Focuses primarily on finite difference and finite volume methods applied to incompressible flow. Some coverage of complex geometries, compressible flows and turbulence modeling.)

The following textbook may also be useful, especially for more in-depth discussion of the governing equations:

- J.F. Wendt, Ed. *Computational Fluid Dynamics, An Introduction*, 3rd Edition, Springer, 2009 [ISBN: 978-3-540-85055-7].

Additionally, the PhD thesis in which OpenFOAM was first formulated may be of use:

- H. Jasak, *Error Analysis and Estimation for the Finite Volume Method with Applications to Fluid Flows*. PhD Dissertation: Imperial College London, 1996.

Documentation for OpenFOAM is available here:
https://www.openfoam.com/documentation/

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Lecture and Assignment Schedule (Subject to Change)

Date	Lecture	Topic	Readings	Assignments
1/11	1	Introduction and CFD Overview 1	F+P 2.1-2.3; JFW 1	
1/13	2	Introduction and CFD Overview 2	JFW 2; F+P 1	
1/18		NO CLASS: MLK DAY		
1/20	3	Introduction and CFD Overview 3	JFW 4; F+P 1.8	
1/25	4 + PS1	Introduction and CFD Overview 4	F+P 2	
1/27	5	Spatial Discretization 1	F+P 3; JFW 5	
2/1	6	Spatial Discretization 2	F+P 4; JFW 11	
2/3	PS2	Spatial Discretization Problem Solving		
2/8	7 + PS3	Temporal Discretization + Problem Solving	F+P 6	
2/10	8	Solving Systems of Equations 1 + HW1 Introduction	F+P 6	
2/15	9	Solving Systems of Equations 2	F+P 6	
2/17	10	Solving Systems of Equations 3	F+P 5	
2/22	11	Solving Systems of Equations 4	F+P 5	
2/24	PS4	Solving Systems of Equations Problem Solving		
3/1		NO CLASS: SPRING BREAK		
3/3		NO CLASS: SPRING BREAK		
3/8	12	Introduction to OpenFOAM + HW2 Introduction	User Guide	HW1 Due
3/10	PS5	OpenFOAM Problem Solving + HW1 Review + Final Project Intro	User Guide	
3/15	13	Incompressible and Compressible Solvers 1	F+P 7	
3/17	14 + PS6	Incompressible and Compressible Solvers 2 + Problem Solving	F+P 10	Quiz 1 Due
3/22	15	Quiz 1 Review + Turbulence Modeling 1	F+P 9	
3/24	16	Turbulence Modeling 2	F+P 9	
3/29	17	Multiphase Flows 1		
3/31	18	Multiphase Flows 2		HW2 Due
4/5	PS7	Turbulence and Multiphase Flow Problem Solving +HW2 Review + Quiz 2 Intro		
4/7		Catchup/Help with Final Projects		
4/12		Catchup/Help with Final Projects		
4/14		Catchup/Help with Final Projects		Quiz 2 Due
4/19		Final Presentations		Final Projects Due: Noon
4/21		Final Presentations		