

24658/42640 – IMAGE-BASED COMPUTATIONAL MODELING AND ANALYSIS
FALL 2022, 12 Units

Instructor: Jessica Zhang, jessicaz@andrew.cmu.edu
Lectures: MW 12:20-2:10pm, Remote only
Office Hour: M 2:10-3pm (zoom), or by appointment

Teaching Assistant: Kuanren Qian, kuanrenq@andrew.cmu.edu
TA Office Hour: By appointment via email

Course Description:

Image-based computational modeling and analysis play an important role in mathematical modeling and computer simulation of many physical and biological phenomena. This course integrates mechanical engineering, biomedical engineering, material sciences, computer science, and mathematics together. Topics to be studied include scanning techniques, image processing, geometric modeling, mesh generation, computational mechanics, as well as broad applications in biomedicine, material sciences and engineering. The techniques introduced are applied to examples of multi-scale modeling and simulations in various research fields.

Some homework and Project 1 have computing component. C/C++/Matlab/Python will be used throughout the course.

Learning Outcomes:

- Understanding the fundamentals of scanning techniques, image processing, computational geometry, mesh generation, and finite element analysis;
- Ability to analyze and solve interdisciplinary research problems in computational biomedicine, materials science and other engineering fields;
- Ability to develop new numerical algorithms for novel and advanced applications in engineering; and
- Enhanced programming skills in C/C++/Matlab/Python for scientific computing.

Textbook: Y. J. Zhang. Geometric Modeling and Mesh Generation from Scanned Images. CRC Press, Taylor & Francis Group. 2016 (available free online through CMU Library)

Grade: 40% Homework; 30% Project 1; 30% Project 2
90 ≤ A; 85 ≤ A- < 90; 80 ≤ B+ < 85; 70 ≤ B < 80; 60 ≤ B- < 70; R < 60

Homework: Due at 12pm on Monday/Wednesday. No credit for late homework unless arrangements are made in advance. Solutions should be neatly written and well organized. Program files need to be uploaded to the Canvas in a Zipped or single file (Lastname_Fristname_hw#.zip, replace # with a number like 1, 2, etc.). Students are encouraged to discuss their homework assignments with each other. However, students should not copy other students' homework solutions – you need to think through the details yourself. Copying work is against university regulations and will be penalized.

Exam: No exam will be given.

Project: There will be two projects. Project 1 needs some programming. Project 2 will be either programming or survey and it features both a report and a presentation. Students will pick their own topic. More details will be given later.

Course Outline:

- **Introduction and scanning techniques** (2 classes): CT (Computed Tomography), MRI (Magnetic Resonance Imaging), Ultrasound, Fluorescence, and Cryo-EM (Cryo-Electron Microscopy)

- **Image processing** (4): Contrast enhancement, filtering, classification, segmentation, and registration
- **Geometric modeling** (3): Fundamentals, objects, curves and surfaces, computer graphics and visualization
- **Mesh generation** (6): Image-based mesh generation, Delaunay triangulation and Voronoi diagram, triangular and tetrahedral mesh generation, unstructured quadrilateral and hexahedral mesh generation, quality improvement
- **Computational mechanics** (5): Finite element method, isogeometric analysis, XFEM, immersed FEM
- **Applications** (2): Biomedical, materials science and engineering applications
- **Project presentations** (3)

Approximate Plan of the Course:

Date	Topic	Assignments
Mon, Aug 29	Syllabus and Introduction	Hw1 post
Wed, Aug 31	Scanning Techniques	
Mon, Sep 5	No class* – Labor Day	
Wed, Sep 7	Image Processing	Hw1 due, Hw2 post
Mon, Sep 12		
Wed, Sep 14		Hw2 due
Mon, Sep 19		
Wed, Sep 21	Geometric Modeling	Hw3 post
Mon, Sep 26		
Wed, Sep 28		Hw3 due, Hw4 post
Mon, Oct 3	Guest Lecture	
Wed, Oct 5	Mesh Generation	
Mon, Oct 10		Hw4 due, Project 1 post
Wed, Oct 12		
Mon, Oct 17	No class* -- Fall Break	
Wed, Oct 19	No class* -- Fall Break	
Mon, Oct 24		
Wed, Oct 26		
Mon, Oct 31		Project 1 due, Project 2 post
Wed, Nov 2	Computational Mechanics	
Mon, Nov 7		
Wed, Nov 9		
Mon, Nov 14		
Wed, Nov 16		
Mon, Nov 21	Applications	
Wed, Nov 23	No class* -- Thanksgiving	
Mon, Nov 28		
Wed, Nov 30	Student presentations I	
Mon, Dec 5	Student presentations II	
Wed, Dec 7	Student presentations III	Project 2 due

Note: This is only an approximate plan. Please follow the announcements in class for any change on dates and deadlines.