ME520
Imaging-based Computational Hemodynamics for Cardiovascular Assessment

Credits:
3

Instructor:
Dr. Huidan (Whitney) Yu
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Class Hours:
MW 4:30-5:45pm**,** SL109

Office Hours:
MW: 3:30-4:30pm and 6:00-7:00 pm in SL260H Or via prior appointment

Textbook:
M. Thiriet, *Biology and Mechanics of Blood Flows Part II: Mechanics and Medical Aspects*, Springer.

Recommended reference books

- P. Galdi, R. Rannacher, A. M. Robertson, and S. Turek, *Hemodynamical Flows — Modeling, analysis, and Simulation*, Birkhauser Verlag, AG, 2000
- B. C. Lopez and E. Pena (eds), *Patient-specific Computational Modeling*, Springer

Note: these books can be downloaded from IUCAT

Prerequisite:
ME 31002, or BME 44200, or equivalent (consent of the instructor)

Course Description:
This course covers (1) fundamentals and imaging modalities for cardiovascular circulation; (2) image-based computational modeling techniques for hemodynamics; and (3) parametric analysis to assess the severity of cardiovascular diseases. Team projects on arterial stenosis provide the first-hand experience of how image-based computational hemodynamics can aid medical diagnostics and therapeutics.

Course outcomes:
Upon completion of the course, students are expected

1. To correlate hemodynamic abnormalities and cardiovascular diseases
2. To construct models of blood flows and boundary conditions based on vascular anatomy and hemodynamic physiology
3. To analytically solve Navier-Stokes equations for Womersley flows based on the pulsatile nature of blood flows
4. To assemble 3-D reconstructions of vessels from CT/MRI imaging data implementing appropriate modeling methods.
5. To critique image-based computational hemodynamics using open sources

6. To formulate non-invasive assessments of the severity of arterial stenosis based on patient-imaging data
7. To investigate the important role of computational modeling and analysis in modern clinical practice for non-invasive and patient-specific assessment of cardiovascular diseases

Grading Scale:

The course grade scale will follow the Latter Grades with +/- on Canvas.

Name:	Range:	
A+	100%	to 97.0%
A	< 97.0%	to 93.0%
A-	< 93.0%	to 90.0%
B+	< 90.0%	to 87.0%
B	< 87.0%	to 83.0%
B-	< 83.0%	to 80.0%
C+	< 80.0%	to 77.0%
C	< 77.0%	to 73.0%
C-	< 73.0%	to 70.0%
D+	< 70.0%	to 67.0%
D	< 67.0%	to 63.0%
D-	< 63.0%	to 60.0%
F	< 60.0%	to 0.0%

The instructor may or may not provide opportunities for students to earn extra credits based on the entire class performance. Grade upgrade requests based on personal expectation/imagination or special needs will not be issued.

Project -- 40 %
Homework -- 20%
Reading and in-class discussion ------------------ 20%
Final exam -- 20%

- **<u>Projects</u>** require students to numerically assess the severity of arterial stenosis in different arteries such as renal, iliac, coronary, etc. with provided CT and Doppler Ultrasound imaging data. Specific project topics and related instructions, requirements, and grading policies will be announced in the third week after the semester starts. Three milestones will ensure progress and the completion of the projects.
- **<u>Homework</u>** assignments will include project milestones. Both parts are not necessarily related and grading will be separate. **The due date and instructions on the assignment sheet need to be strictly followed.** Late HW submission will result in a 10% per day penalty point reduction. Once the HW assignment has been graded, no late HW will be accepted.

- **In-class discussion** enhances the lectures. Students are assigned research paper excerpts to read outside of the class and then share their learning and understanding during class through presentation and discussion. These reading assignments are related to computational modeling method and cardiovascular disease topics that specifically relate to the topics being covered on that day. The presentation is required to be uploaded to Canvas before the discussion. Student performance will be scored by both the instructor (75%) and peers (20%) using provided evaluation sheets; the remainder of the grade is determined by attendance (5%). On the rare occasion that a student is excused with valid written documents for an emergency (e.g. doctor notes or medicine purchase receipts for illness, evidence of vehicular failure, etc.) or a prior written request and approval for non-emergency, the instructor will credit the average score of the class excluding the 5% for the attendance.

Canvas:

All course-related communication outside of lectures and office hours will be through http://canvas.iu.edu.

- All information and materials will be accessed on this system throughout the semester: messages and announcements, syllabus and course schedule, supplementary handouts, assignments, grades, . . .
- Students are required to **send course-related messages through Canvas/Inbox**.
- Students are responsible to set up notifications on Canvas and check both their e-mail as well as the course website on Canvas for any course information.
- Students are encouraged to discuss course issues on Canvas/Discussion.

~~~~~~~~~~~~~~~~~~~~~ IMPORTANT POLICY NOTES ~~~~~~~~~~~~~~~~~

- Students should not enroll in the course unless they have met the prerequisite requirements.
- Students are required to show appropriate behaviors in the classroom. During class all electronic devices e.g. cell phone, computer, mp3, etc. should be turned off unless special permission has been granted. Food and drinks should not be consumed. Any student who is found to be a distraction to the instructor or other students will be dismissed immediately.
- Students are aware of the statements made regarding cheating in the IUPUI "Student Rights and Responsibilities" booklet. Such academic misconduct will be handled according to the guidelines in that booklet. Penalties for such misconduct include lowering of a student's grade as well as dismissal from school. A quote from the above mentioned booklet is worthwhile: "It is the responsibility of the student not only to abstain from cheating but, in addition, to guard against making it possible for others to cheat. Any student who helps another student to cheat is as guilty of cheating as the student he/she assists." Website for student code of conduct: http://www.iu.edu/~code/code/index.shtml.
- Students who need any special accommodations or assistance due to a disability, should

please contact Adaptive Educational Services (AES) at (317)-274-3241. The office is located in Joseph T. Taylor Hall (UC), Room 100. The AES website is http://aes.iupui.edu/services.html. No qualified individual with a disability shall, by reason of such disability, be either excluded from participation in or denied the benefits of the services, programs, or activities of Indiana University-Purdue University Indianapolis."

Course schedule

The following schedule is tentative and will be subjected to modify or change without prior notice. Students should follow the specific assignment sheet for any course task.

Lecture	Day	Topics	Notes
1	M	Syllabus and introduction	
2	W	Blood vessels and functionalities (Ch1)	Reading assignment 1
	M	Martin Luther King Jr. Holiday	No class
3	W	Anatomical and morphological features of cardiovascular system (Ch1)	
4	M	Physiology of systemic circulation (Ch2)	
5	W	In-class discussion 1: Modeling of blood flows in human arteries	Reading assignment 2
	M	Relationship among flow, pressure, and resistance in blood flow (Ch2)	
	W	Project Assignment	
7	M	Medical imaging modalities for cardiovascular diseases (Ch 3)	HW1 due
8	W	3-D re-construction from imaging data (Ch 3)	
	M	Project mentoring	
	W	In-class discussion 2: Open-sources for image-based computational hemodynamics	Reading assignment 3
11	M	Governing equations of blood flow and hemodynamics parameters (Ch4)	
12	W	Womersley flow and analytical solutions (Ch4)	HW2 due
13	M	Project mentoring	
14	W	Modeling of unsteady and turbulent blood flow (Ch4)	
	M	In-class discussion 3: multiscale modeling of cardiovascular flows	Reading assignment 4
	W	Modeling flow-vessel interaction (Ch 4)	
	M	Spring Break	No class
	W	Spring Break	No class
15	M	Hemodynamic abnormalities vs. cardiovascular diseases (Ch 5)	
16	W	Overview of Image-based computational hemodynamics and state of the art method (Ch 5)	

	M	In-class discussion 4: learning about renal arterial stenosis	Reading assignment 5
	W	Project mentoring	HW3 due
17	M	Volumetric lattice Boltzmann method (Ch 5)	
18	W	Inflow/outflow boundary conditions (Ch 5)	
19	M	Computational analysis for severity of cardiovascular disease (Ch 5)	
20	W	Validation and verification for image-based computational hemodynamics (Ch5)	
21	M	Project mentoring	
22	W	In-class discussion 5: learning about arterial aneurysms	
23	M	Applications of non-invasive and patient-specifics assessment (Ch 5)	
	W	Project wrap-up	HW4 due
	M	Project oral presentation	
		Final Exam	

Lectures are based on Textbook "M. Thiriet, Biology and Mechanics of Blood Flows Part II: Mechanics and Medical Aspects, Springer."
Chapter 1 Modeling basics I: Anatomical and morphological features of cardiovascular system (2 lectures)
Chapter 2 Modeling basics II: Physiology of blood flow (2 lectures)
Chapter 3 Modeling basics III: 3-D reconstruction of CT/MRI images (2 lectures)
Chapter 4 Advanced hemodynamics and related modeling (4 lectures)
Chapter 5 Image based computational he (7 lectures)

<u>Reading and in-class discussion</u>
Reading 1
- "Blood Flow in Arteries" by David N. Ku

Reading 2
- "SimVascular: An Open Source Pipeline for Cardiovascular Simulation"by Adam Updegrove *et al*
- "A re-engineered software interface and workfow for the open source SimVascular cardiovascular modeling" by Hongzhi Lan, Adam Updegrove, et al.
- "Computational blood flow simulations in Kawasaki disease patients: Insight into coronary artery aneurysm hemodynamics" by NG Gutierrez, A Kahn, et al

Reading 3
- "Multiscale Modeling of Cardiovascular Flows" by A. L. Marsden and E. Kung

Reading 4
- "Revascularization versus Medical Therapy for Renal-Artery Stenosis" by The ASTRAL Investigators.
- "Stenting and Medical Therapy for Atherosclerotic Renal-Artery Stenosis" by C. J. Cooper and T. P. Murphy, et al
- "Renal Artery Stenosis: New Findings from the CORAL Trial" by Rajesh Gupta, Salem Assiri, and Christopher J. Cooper

Reading 5

- “The Biomechanics of Arterial Aneurysms” by Lasheras
- “Experimental validation of more realistic computer models for stent-graft repair of abdominal aortic aneurysms, including pre-load assessment” by David Roy et al.
- “Off-the-shelf fenestrated and branched stent graft designs for abdominal aortic aneurysm repair”by Mendes et al