CS 4803 ARM: Advanced Robotic Manipulation (Fall 2026)

Instructor	Prof. Harish Ravichandar [harish.ravichandar@gatech.edu]
Lab Manager	Dr. Soobum Kim [skim743@gatech.edu]
Credits	3
Format	In person · synchronous
Meetings	Mon & Wed: 12:30pm to 1:45pm
Classroom	Skiles 255
Lab Location	Robotics Education Lab (CCB 030)
Lab Orientation	TBD

Acknowledgement: This course is inspired by similar courses by Profs. Russ Tedrake, Kevin Lynch, & Matt Mason. Some materials adapted from Profs. Animesh Garg, Sonia Chernova, Frank Dellaert, Matthew Gombolay, & Seth Hutchinson.

Course Description and Learning Outcomes

This course develops the mathematical and computational foundations of autonomous robotic manipulation. Topics include manipulator kinematics, RGB-D perception, grasp and motion planning, interaction control, and learning-based policies. Lectures and mini projects connect these ideas through a common interface in MuJoCo and on the AgileX PiPER platform.

By the end of the course, students should be able to model and reason about manipulator motion; build perception pipelines from depth data; synthesize grasps and collision-free motion; design motion and interaction controllers; train and evaluate learning-based policies; and integrate these components into a working manipulation system.

Context: CS 4803 ARM complements CS 3630 Introduction to Robotics and Perception and CS 4803 AMR Advanced Mobile Robotics. Because CS 3630 already covers much of the underlying rigid-body geometry, this course uses a brief refresher and moves quickly into manipulator-specific kinematics and algorithms.

Platforms and workflow: Students will develop in Python using course-provided environments. MuJoCo will be used as the simulation platform with standardized environments, designed to support the course projects. AgileX PiPER arms will be used to support hardware implementations, evaluations, and demonstrations for select projects.

Preparation

There are no enforced prerequisites, but CS 3630 Introduction to Robotics and Perception is strongly recommended. Students should be comfortable with linear algebra, probability, algorithms, introductory artificial intelligence, and Python programming.

A laptop is required for coursework. Students who do not have reliable access to one should contact the instructor as early as possible.

Reference Material

There is no required textbook. The following references overlap substantially with course topics:

- Robotic Manipulation: Perception, Planning, and Control, R. Tedrake, Course notes for MIT 6.421. Available online
- Modern Robotics: Mechanics, Planning, and Control, K. M. Lynch and F. C. Park, Cambridge University Press, 2017. Available online
- Principles of Robot Motion: Theory, Algorithms, and Implementations, H. Choset et al., MIT Press, 2005.
- Robot Motion Planning, J.-C. Latombe, Kluwer Academic Publishers, 1991.
- Planning Algorithms, S. M. LaValle, Cambridge University Press, 2006.

These books are available online or through the Georgia Tech Library.

Course Logistics

Office hours: Instructor office hours will immediately follow the lecture on Mondays (1:45pm to 3pm). Lab-support and lab space access windows will be announced on Ed Discussion.

Modality: Lectures are in-person and synchronous. They will not be recorded or live-streamed.

Attendance: Enrollment assumes that students can attend the regularly scheduled Monday and Wednesday class periods, required assessments, and required hardware activities.

Ed Discussion: Ed Discussion is the primary channel for questions and discussion. Students are encouraged to help one another; course staff will monitor discussions and correct inaccuracies.

Learning Activities

- **Participation:** The course includes in-class discussions, short exercises, and design critique. Participation is evaluated through regular and genuine engagement.

- **Laboratory work:** Students will safely develop, test, and demonstrate software on AgileX PiPER arms. The required, ungraded orientation (date TBD) covers lab policies and a walkthrough of the software and hardware infrastructure. Attendance and compliance with safety procedures are required for hardware access.

Out-of-class work: Activities are designed to support the learning outcomes above.

- **Readings:** Selected papers, notes, or documentation may be assigned before class.
- **Mini projects (individual):** MP1–MP4 assess perception, planning, control, and learning. MP0 is an ungraded quickstart.

Mini Projects (MPs)

MP0 is a required, ungraded quickstart with no submission. MP1–MP4 are individual projects worth 15% each. Each project specification will define its allowed tools, evaluation mode, and hardware-access requirements.

MP0: MuJoCo + lab quickstart (ungraded): Run the provided MuJoCo scene and common robot interface, then complete the required hardware lab orientation (date TBD).

MP1: Point clouds, pose & reach: Build and evaluate a point-cloud pose-estimation and reach pipeline in simulation.

MP2: Grasping & motion planning: Synthesize a feasible grasp and collision-free motion; this is the first graded hardware evaluation.

MP3: Contact-rich control: Design and evaluate a controller for stable, safe physical interaction in a live evaluation.

MP4: Learning for manipulation: Design and evaluate a learning-based manipulation system using the course-provided workflow. This mini project will be evaluated during a final demo on Dec 7th (Mon) during class hours.

Quizzes

There are five in-class quizzes, each approximately 30 minutes and held at the beginning of class. **Quiz 0 is an ungraded diagnostic on Monday, August 31—the first class after Georgia Tech's add/drop period.** Quizzes 1–4 are graded at 7.5% each and assess the preceding module. Make-up quizzes are available only for documented or otherwise approved extenuating circumstances; interviews and discretionary travel do not normally qualify.

Grading

Final grades are determined by the weighted components below.

Component	Count	Weight each	Course total
Mini projects (MP1–MP4)	4	15%	60%
Quizzes (Quiz 1–4)	4	7.5%	30%
Participation	—	—	10%

Final Grade	Percentage
A	≥ 90%
B	≥ 80% and < 90%
C	≥ 70% and < 80%
D	≥ 60% and < 70%
F	< 60%

Final assessment: MP4 and its in-class demonstration together constitute the course's alternative final assessment. There is no separate final examination.

Late Policy: Late submissions will be accepted (with a penalty) for up to 4 days past the due date. Late submissions incur a 15% penalty for each day past the due date: 1 day past due → 15% penalty, 2 days past due → 30% penalty, 3 days past due → 45% penalty, 4 days past due → 60% penalty, 5 or more days past due → no credit. These penalties will be strictly enforced, except in extenuating circumstances for which the student has received explicit accommodation.

Course Policies and Expectations

Accommodations: Students who require academic accommodations should register with the Office of Disability Services and provide the instructor with the official accommodation letter as early as possible. Please contact the instructor to discuss how approved accommodations will be implemented in this course.

Collaboration: Students may discuss course concepts and general debugging strategies but may not share or inspect another student's solution code, written answers, or project-specific outputs unless explicitly permitted by the project specification.

Academic Integrity: Students are expected to follow the Georgia Tech Academic Honor Code. Suspected cheating, plagiarism, unauthorized collaboration, fabrication, or other academic misconduct will be handled through the Institute's established procedures.

Student–Faculty Expectations: The course follows Georgia Tech's Student–Faculty Expectations Agreement. Mutual respect, responsibility, and professional communication are essential to the learning environment.

Ed Discussion conduct: Posts should be courteous, professional, and relevant to learning. Questions, answers, and critiques should address ideas and evidence rather than individuals. Harassment or personal attacks may be referred through appropriate Institute channels.

Communication policy: Use Ed Discussion for questions about lectures, projects, grading, and course logistics so that answers are visible and trackable. For illness, mental-health concerns, emergencies, accommodations, or other sensitive and personal issues, please use a private Ed Discussion post. In a life-threatening emergency, call 911.

Statement of intent for inclusivity: We are committed to a learning environment in which all students feel safe, included, and able to engage. Students are invited to share constructive feedback about changes that would improve access, belonging, and participation.

Use of AI: AI tools may be used to support learning (e.g., to explain concepts, background material, documentation, or error messages) but may not be used to produce or modify code, analyses, written answers, or other project work submitted for credit unless a project specification explicitly permits it. Each submission must include a brief AI-use statement, including 'No AI tools used' when applicable. Students remain responsible for verifying outputs and citing credible sources. Uses that violate these rules will be treated as potential academic misconduct.

Course Schedule

This schedule is subject to change; revisions will be announced promptly.

Red = project deadlines Blue = in-class quizzes

Date	Day	Event / Topic	Milestones
Module 1: Foundations of Manipulation			
Aug 24	Mon	Introduction to manipulation & Course logistics	
Aug 26	Wed	Geometry refresher & Forward kinematics	
Aug 31	Mon	Differential kinematics	Quiz 0
Sep 2	Wed	Inverse kinematics & Motion execution	
Sep 7	Mon	No class — Labor Day	
Module 2: Perception for Manipulation			
Sep 9	Wed	RGB-D geometry & Point clouds	Quiz 1
Sep 14	Mon	Point-cloud preprocessing	
Sep 16	Wed	Rigid registration	
Sep 21	Mon	Robust pose estimation and tracking	
Module 3: Planning for Manipulation			
Sep 23	Wed	Grasping & Contact planning	Quiz 2
Sep 28	Mon	Grasp mechanics	
Sep 30	Wed	Grasp synthesis	
Oct 4	Sun		MP1 due
Oct 5	Mon	No class — Fall Recess	
Oct 7	Wed	Configuration-space & Collision checking	
Oct 12	Mon	Motion planning for manipulation	
Oct 14	Wed	Trajectory optimization	
Oct 19	Mon	Task and motion planning	
Module 4: Control for Manipulation			
Oct 21	Wed	Robot dynamics & Control architectures	Quiz 3
Oct 25	Sun		MP2 due
Oct 26	Mon	Joint-space control	
Oct 28	Wed	Operational-space control	
Nov 2	Mon	Force control	
Nov 4	Wed	Impedance & Admittance control	
Nov 9	Mon	Intersections of planning and control	

Date	Day	Event / Topic	Milestones
Module 5: Learning for Manipulation			
Nov 11	Wed	Learning from demonstrations (BC)	
Nov 15	Sun		MP3 due
Nov 16	Mon	Distribution shift & Evaluation	
Nov 18	Wed	Learning from interaction (RL)	Quiz 4
Nov 23	Mon	Self-supervised learning & World models	
Nov 25	Wed	No class — Student Recess	
Nov 30	Mon	Learning for perception (Vision and Touch)	
Dec 2	Wed	Frontiers & Open problems	
Dec 6	Sun		MP4 due
Dec 7	Mon	Demo Day	MP4 Demo