

*Course inspired by and adapted from Profs. Sonia Chernova, Frank Dellaert, Animesh Garg, Matthew Gombolay, Seth Hutchinson, Kevin Lynch, Matt Mason, and Russ Tedrake.*

# CS 4803 ARM: Advanced Robotic Manipulation

Fall 2026

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<b>TA</b>	TBD
<b>Lab Manager</b>	Dr. Soobum Kim [skim743@gatech.edu]
<b>Credits</b>	3
<b>Classroom</b>	TBD
<b>Lab</b>	TBD
<b>Time</b>	TBD

## Course Description and Expected Outcomes

This course intends to provide students with a rigorous and comprehensive understanding of the fundamental principles and modern techniques in autonomous robotic manipulation. The desired learning outcome is that, given a manipulation application and a hardware platform, the students that have taken the class will be able to build a software architecture that, when executed on the hardware, constitutes a working prototype for the desired application.

By integrating theory with intensive, project-based assignments focused on practical robotic challenges, this course ensures students develop not only conceptual understanding but also the practical engineering skills needed to design, implement, and analyze complex robotic manipulation systems.

**Context:** This course is part of a three-course curriculum design to prepare Georgia Tech undergraduate students for robotics positions in industry or as robotics researchers in academia. The three courses are 1) CS 3630 Introduction to Robotics and Perception, 2) CS 4803 ARM: Advanced Robotic Manipulation (this course), 3) CS 4803 AMR: Advanced Mobile Robotics. Students are strongly urged to complete CS 3630 before enrolling in either CS 4803 ARM or CS 4803 AMR.

This three-course sequence is designed to first give you a broad overview of robotics. CS 3630 by itself is a critical, foundational introduction but will not be enough for you to “get a job” in robotics. In CS 4803 AMR, you will go deeper into concepts of perception, planning, and controls in the real-world and be introduced to the Robot Operating System (ROS), a key software skill required for roboticists. CS 4803 AMR is essential for students interested in robotics and Autonomous Vehicles. In 4803 ARM, you will get hands-on experience with 6 degree-of-freedom (DoF) manipulator arms. This course will be critical for students interested in becoming a “full-stack” roboticist. Taken together,

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these three courses will offer complementary modeling and algorithm design skills required to perform mobile manipulation.

## Prerequisites

While we do not enforce formal prerequisites, we generally assume that students have prior knowledge of fundamentals of linear algebra (e.g., MATH 1554 Linear Algebra), applied probability (e.g., MATH 3215 Introduction to Probability and Statistics), algorithms and computational complexity (e.g., CS 3510 Design & Analysis of Algorithms), Artificial Intelligence (e.g., CS 3600 Introduction to Artificial Intelligence), and robotics (e.g., CS 3360 Introduction to Robotics and Perception).

Lastly, this course requires access to a laptop. If you don't have one, please contact the instructor ASAP. All programming assignments will be completed in Python.

## Reference Material

There is no assigned textbook for this course, but material covered in lectures has significant overlap with the following textbooks:

- Robotic Manipulation: Perception, Planning, and Control, R. Tedrake, Course Notes for MIT 6.421, 2025. [[Available online](#)]
- Modern Robotics: Mechanics, Planning, and Control, Kevin M. Lynch and Frank C. Park, Cambridge University Press, 2017 [[Available online](#)]
- Principles of Robot Motion: Theory, Algorithms, and Implementations, H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki and S. Thrun, MIT Press, Boston, 2005.
- Robot Motion Planning, Jean-Claude Latombe, Kluwer Academic Publishers, 1991.
- Planning Algorithms, Steven M. LaValle.

These books are available in digital form either online or through the [Georgia Tech Library](#).

## Course Logistics

**Office Hours:** Each teaching assistant (TA) will hold two weekly office hours for 1 hour each session (a total of 2 hours per week). In addition, the instructor will hold office hours weekly for one hour. Office Hours will be posted on Piazza and updated weekly.

**Modality:** Lectures will be **in-person** and **synchronous**. Lectures will NOT be recorded or live streamed.

*Note: You cannot take this class unless you can make the regularly scheduled class periods @ [Time].*

**Piazza:** All course-related communications will be handled through Piazza. Please do not email us! We will add all enrolled students to a dedicated Piazza page for this class. We do encourage students to try to answer each other's questions. We will review such "peer" responses and make sure they are accurate.

## **In-class Work**

- **Participation:** we want students to stay with the class, synchronously. While we understand some circumstances will cause you to miss a few classes here and there, we are conscious that the availability of recorded lectures might make you fall behind. To that end, we will have in class polls, administered through canvas, that will allow us to get real-time feedback on how well you understand the concepts taught. These will be graded for feedback purposes only. However, your participation in these will determine your participation grade.
- **Laboratories:** This course requires hands-on experience. You will participate in a mixture of structured and unstructured laboratory time, during which you will be trained on safely developing, testing, and demonstrating software and real robots (i.e, the AGILEX PiPER 6 DoF Arm). Attendance and adherence to best practices for safety are required.

**Out-of-class Work:** There are several activities designed to achieve the learning outcomes above.

- Reading and understanding research papers: we will occasionally assign papers or other materials to read before class.
- **Mini projects (individual):** There will be 4 mini projects on foundational concepts in manipulation: perception, planning, control, and learning.
- **Final Demo (teams):** In the final demo, you will assemble different modules (that you built for mini projects) together in a layered software architecture to build a fully integrated, operational manipulation system. You will work in teams to put together this demo.

## **Mini Projects (MPs)**

We have designed five mini projects. The first one is an ungraded project to get familiar with the basic software stack and the simulator that we will use. The next four will be graded and each corresponds to one of the modules in the class.

### **MP0: MuJoCo setup (ungraded)**

Setup a predefined scene in MuJoCo with a manipulator robot, cameras, and objects placed on a table. Run example code to move the robot in free space.

### **MP1: Point cloud-based object tracking**

Implement segmentation and Iterative Closest Point (ICP) algorithms to recognize and track a rigid object based on raw noisy point clouds.

### **MP2: Pick and Place**

Design grasp synthesis and motion planning algorithms to pick up an object and move it to a desired position and place it.

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### **MP3: Sliding**

Design a control algorithm to reliably slide along a tilted surface and follow a desired trajectory (e.g., wiping a whiteboard clean).

### **MP4: Behavior Cloning**

Collect demonstrations, and implement a behavior cloning algorithm to train the manipulator to perform the desired skill

### **Final Demo**

In the final demo, you will work in teams to assemble different modules (that you built for mini projects) together in a layered software architecture to build a fully integrated, operational manipulation system.

### **Quizzes**

There will be a total of five in-class quizzes, each lasting about 20 minutes. The first one, like the first MP, will not be graded and is designed to better understand the students' backgrounds and interests. The remaining four will be graded and will cover contents covered in class from the date of the previous quiz up until the class meeting preceding the date of the quiz. The quizzes will be held at the beginning of the class on the scheduled dates. We will not accommodate requests to reschedule quizzes, unless under extenuating circumstances. Note that interviews and travel will NOT be considered as extenuating circumstances.

### **Grading**

Your final grade in the course will be determined by the weighted components listed below. The first table shows the component breakdown, and the second table shows the final letter-grade scale.

Component	Number	Grade	Percentage
Mini Projects	4	15% each	60%
Demo	1	10%	10%
Quizzes	4	5% each	20%
Participation	N/A	10%	10%

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Final Grade	Percentage
A	90% – 100%
B	80% – 89.99%
C	70% – 79.99%
D	60% – 69.99%
F	0% – 59.99%

## Course Policies and Expectations

**Accommodations:** If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404) 894-2563 or <http://disabilityservices.gatech.edu/>, as soon as possible, to discuss your needs and to obtain an accommodations letter. Please e-mail me as soon as possible to set up a time to discuss your learning needs.

**Academic Integrity:** Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit [this link](#). Any student suspected of cheating or plagiarizing will be reported to the Office of Student Integrity.

**Student-Faculty Expectations Agreement:** At Georgia Tech, we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See [this agreement](#) for an articulation of expectations you can have of me, and I have of you. Respect for knowledge, hard work, and cordial interactions will help build the environment we seek.

**Piazza:** Behavior on piazza should be courteous, professional, and relevant to facilitate learning. Piazza is not a reddit or 4chan forum. Piazza is not a mechanism to express personal frustrations or to vent. Venting or attacks against any other student, TA, or instructor may result in consequences, including referral to the Office of Student Integrity. Please do your part to help make this course a safe learning environment for everyone. We do encourage students to try to answer each other's questions. We will review such "peer" responses and make sure they are accurate.

**Communication Policy:** If you have a question and want to ask an instructor/TA, please use Piazza first! Please do not email or use Canvas for communications about the normal function of the course (e.g., homework questions, project questions, syllabus questions, etc.). All course staff get notified when you post on Piazza. Piazza also allows you to ask questions anonymously and/or privately. Both email and canvas are relatively clumsy

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and noisy systems for responding to your questions, and we do not want to lose track of anything you ask. As such, please post everything to Piazza!

Outside of normal course questions, if you have an illness, mental health concern, emergency, ethics violation concerns, please email the instructor directly, or post privately on Piazza. If it is a life-threatening emergency, you should always call 9-1-1.

**Statement of Intent for Inclusivity:** As members of the Georgia Tech community, we are committed to creating a learning environment in which all students feel safe and included. Because we are individuals with varying needs, we are reliant on your feedback to achieve this goal. To that end, we invite you to enter a dialogue with us about the things we can stop, start, and continue doing to make our classroom an environment in which every student feels valued and can engage actively in our learning community.

**Use of AI:** We do not prohibit the use of AI in aiding your learning (e.g., requests for additional explanation of concepts or examples, exploration of related concepts outside the scope of the course, etc.). However, we will not allow the use of AI in completing coding assignments or projects. In each of your submission, students are required to indicate if and how they used AI regarding the assignment. We have automated tools to recognize flag suspected use of AI. Violating this policy will be considered as academic misconduct, lead to disciplinary actions, and referral to the Office of Student Integrity. Finally, please use AI-based tools with appropriate amounts of skepticism: verify answers, explicitly ask for sources and ensure that they are credible.

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## Approximate Schedule

This schedule is subject to change. Any changes will be notified immediately.

**Red Dates: Deadlines**

**Blue Dates: In-class quizzes**

Date	Day	Event / Topic	Deadlines & Quizzes
<b>Module 1: Foundations</b>			
8/24/2026	Monday	Introduction to Robotic Manipulation; Class	
8/26/2026	Wednesday	Rigid Bodies in Motion	
<b>8/31/2026</b>	<b>Monday</b>	Forward and Differential Kinematics	<b>Quiz 0</b>
9/02/2026	Wednesday	Inverse Kinematics	
9/07/2026	Monday	No Lecture (Labor Day)	
<b>9/9/2026</b>	<b>Wednesday</b>	Robot Dynamics	<b>MPO Due</b>
<b>Module 2: Perception</b>			
<b>9/14/2026</b>	<b>Monday</b>	Sensor Models: Cameras and Depth sensors;	<b>Quiz 1</b>
9/16/2026	Wednesday	Point Clouds: Pose Estimation, Segmentation	
9/21/2026	Monday	Manipulation-centric Perception	
<b>Module 3: Planning</b>			
9/23/2026	Wednesday	Motion Planning	
<b>9/28/2026</b>	<b>Monday</b>	Contact Dynamics	<b>MP1 Due</b>
<b>9/30/2026</b>	<b>Wednesday</b>	Planning for Contact; Grasping	<b>Quiz 2</b>
10/05/2026	Monday	No lecture (Fall break)	
10/7/2026	Monday	Trajectory Optimization	
10/12/2026	Wednesday	Task-level Planning	
10/14/2026	Wednesday	Task and Motion Planning	

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Module 4: Control			
10/19/2026	Monday	Trajectory Tracking	Quiz 3
10/21/2026	Wednesday	Introduction to Force Control	MP2 Due
10/26/2026	Monday	Operational Space Force Control	
10/28/2026	Wednesday	Stack of Tasks: Hierarchical Prioritization	
11/2/2026	Monday	Blending Planning & Control: MPC	
11/4/2026	Wednesday	No Lecture (Instructor travel)	
Module 5: Learning			
11/9/2026	Monday	Imitation Learning; Foundation Models	
11/11/2026	Wednesday	Reinforcement Learning	Quiz 4
11/16/2026	Monday	Manipulation-centric Learning	
11/18/2026	Wednesday	Learning for Detection, Segmentation, & Pose	MP3 Due
11/23/2026	Monday	Self-Supervised Learning	
11/25/2026	Wednesday	No Lecture (Thanksgiving)	
11/30/2026	Monday	Touch; Soft Robotics; Hands; Loco Manipulation	
12/2/2026	Wednesday	Open Problems in Robot Manipulation	
12/7/2026	Monday	MP 4 Demo (CCB 030 Lab)	MP 4 Due