

MEC 529 - Introduction to Robotics: Theory and Applications

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Contact Information

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Instruction Mode

This is a synchronous online course. Course material will be delivered through lectures on Zoom. Although the lectures will be recorded and posted online, students are expected to attend the lecture online. For some topics, I will provide pre-recorded lectures that will be posted on Youtube and links will be available through Blackboard. Students must be mindful of all course expectations, deliverables, and due dates. All assignments and course interactions will utilize internet technologies. See Technical Requirements section for more information. Office hours will be held online through Zoom.

Online Lecture Hours

Time: Tuesday, 1 : 15 PM - 4 : 05 PM.

How will we communicate

There will be scheduled office hours on Monday and Thursday (4:00 PM – 5:30 PM). Office hours will be held online through Zoom. The zoom link for the office hours will be available on Blackboard. I will also be available after class if you have any questions. Apart from office hours, you can also contact me through email. I strive to respond to your emails as soon as possible, but please allow between 24-48 hours for a reply. Your Stony Brook University email must be used for all University related communications. You must have an active Stony Brook University e-mail account and access to the Internet. All instructor correspondence will be sent to your SBU e-mail account. Please plan on checking your SBU email account regularly for course related messages. To log in to Stony Brook Google Mail, go to <http://www.stonybrook.edu/mycloud> and sign in with your NetID and password.

Technical Requirements

This course uses Blackboard for the facilitation of communications between faculty and students, submission of assignments, and posting of grades. The Blackboard course site can be accessed at <https://blackboard.stonybrook.edu> If you are unsure of your NetID, visit <https://it.stonybrook.edu/help/kb/finding-your-netid-and-password> for more information. You are responsible for having a reliable computer and Internet connection throughout the term.

The following list details a minimum recommended computer set-up and the software packages you will need to have access to, and be able to use:

- PC with Windows 10
- Macintosh with OS 10.13 or higher
- Latest version of Chrome, Firefox or Explorer; Mac users may use Chrome, Firefox or Safari. (A complete list of supported browsers and operating systems can be found on the My Institution tab of the Blackboard website.)
- 8 GB RAM
- High speed internet connection
- Printer
- Word processing software (Microsoft Word, Pages, etc.)
- Speakers (either internal or external) or headphones
- Ability to download and install free software applications and plug-ins (note: you must have administrator access to install applications and plug-ins).
- Microphone and Webcam: needed for on-line interaction during class or office hours.
- Scanner or camera app: A scanner to scan HW, Quizzes, or Exams, as necessary or you can use a smartphone or tablet camera with an app for creating high quality, cropped pdf documents, such as free version of CamScanner (search for it in Google PlayStore or Apple iTunes store). It is your responsibility to ensure that your scans will be legible without being too large in size. This will be needed for submitting your HWs and cheat sheets, if any.

Technical Assistance

If you need technical assistance at any time during the course or to report a problem with Blackboard you can:

- submit a help ticket on the web at <http://it.stonybrook.edu/services/itsm>
- call (631) 632-9800 (technical support, log-in issues, computer support, wifi, software and hardware)
- call (631) 2-CELT [631-632-2358]

Course Description

This course will cover fundamental concepts in Robotics useful for applications ranging from traditional manipulators in industrial robotics to unmanned aerial robots for environmental sensing and cargo transport. This course is divided into approximately three parts. In the first part of the course, basic concepts will be discussed, including direct and inverse position kinematics and differential kinematics, dynamics, feedback and feedforward control, and state estimation. The above concepts will be discussed and illustrated within the context of robotic manipulators. The second part of the course will focus on applying the knowledge from the initial lectures to other types of robots including wheeled robots, aerial robots, robotic hands, and legged robots. The third part of the course will discuss motion planning, sensing, and actuation in different robotic systems. This course is intended for graduate students with interests in Robotics and Artificial Intelligence. Advanced undergraduates with a demonstrated interest in Robotics are also welcome. Prerequisites include a foundation in Linear Algebra and Calculus, and the ability to program in Matlab.

Books

- J. J. Craig, *Introduction to Robotics: Mechanics and Control*, 3rd Edition, Addison-Wesley, 2003.
- Richard M. Murray, Zexiang Li and S. Shankar Sastry, *A Mathematical Introduction to Robotic Manipulation*, CRC Press.
- Kevin Lynch and Frank Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press.
- S. Lavalle, *Robot Motion Planning*, Cambridge University Press.

Assignments, Exams, and Projects

- **Homeworks:** There will be weekly homeworks and homeworks have to be submitted through Blackboard. The homeworks will include Matlab coding. You are allowed to discuss with your colleagues but you have to submit your individual work. Any discussion or help that you have taken from your colleagues or other sources should be acknowledged. In other words, you should write the name of the individuals you have worked with and also state explicitly the kind of help you have received.
- **Paper Critique:** There will also be one paper review report that you have to submit. You have to select one paper from a list of papers that I will provide (or you can choose your own paper based on your final project) and you have to write a critical review of the paper. You will get one week for the paper review.
- **Midterm Exam:** There will be one take home midterm exam. The exam will be open book, open notes. You will have approximately three days to complete your exam. You are not allowed to consult with your colleagues for the exam. (Tentative Date: 4\06\2020 to 4\10\2020).
- **Final Project and Presentation:** There will be one final project that will be done in groups of at most 2 students. You have to do one presentation and one report for the final project. The final report and presentation will be a comprehensive description of your work. The final presentation will be on the last day of class. **The final presentation will be done online through Zoom. It will be on the last day of classes and all students are expected to attend for the entire duration.** Details will be communicated through Blackboard.

Grading Breakdown and Policy

Your overall grade will be based on your performance in all the class work mentioned above. The weight distribution on grades for the different components are given below.

- Homeworks (30%).
- Take Home Midterm Exam (35%).
- Paper Critique (5%).
- Final Project and Project Presentation (30%).

The GRADING SCALE will be an accumulation of your course work, as follows (there will probably be no curves): A (100-90), A- (89-85), B+ (84-80), B (79-75), B- (74-70), C+ (69-65), C (60-64), F (59 or below).

Late Assignment Policy: Assignments are due in class unless otherwise stated or you have made prior arrangements with me. You are allowed at most two late days for each homework or paper critique. If you

submit your homework late you will be penalized 20% of the points. Assignments will not be accepted after the late days expire. No late submission is allowed for the mid-term exam or the final project report.

Collaboration Policy: You are allowed and encouraged to collaborate with your fellow students on homeworks. However, you are required to turn in your own work and you should not copy the work of another person. Any collaboration or help should always be acknowledged explicitly. **No collaboration is allowed** on the take home midterm exam.

Course Learning Objectives

Upon completion of this course students will be able to

- Convert description of points and vectors among different reference frames.
- Know about different representations of configuration of a rigid body and how to convert between them.
- Solve direct and inverse position and velocity kinematics problem of a manipulator.
- Form a manipulator Jacobian and use it in singularity analysis and control.
- Form a grasp Jacobian and use it in grasp analysis.
- Know how to write down the equations of motion of a manipulator using Lagrangian mechanics.
- Understand the different feedback control schemes for controlling a manipulator.
- Write the kinematics of wheeled robots and use it for solving mobile robot localization/control problems.
- Know basic motion planning techniques for manipulators and mobile robots.
- Know how to formulate and solve a robot control problem.
- Implement kinematic analysis, dynamic analysis, and control algorithms for manipulators in computer programs.

Lecture Topics (Tentative)

1. Introduction, Overview of course with a simple example.
2. Rigid Body Rotation
3. Combined Rigid Body Rotation and Translation
4. Direct Position Kinematics of robotic systems.
5. Differential Kinematics of Rigid Bodies.
6. Direct Velocity Kinematics of robotic systems.
7. Inverse Position and Velocity Kinematics of robotic systems.
8. Deterministic Techniques for Manipulator Motion Planning.
9. Robotic Grasping and Manipulation.
10. Dynamics and Inverse Dynamics of robotic systems.
11. Feedback Control of Manipulators.

Student Participation and Attendance

Students are expected to attend every class, report for examinations and submit major graded coursework as scheduled. If a student is unable to attend lecture(s), report for any exams or complete major graded coursework as scheduled due to extenuating circumstances, the student must contact the instructor as soon as possible. Students may be requested to provide documentation to support their absence and/or may be referred to the Student Support Team for assistance. Students will be provided reasonable accommodations for missed exams, assignments or projects due to significant illness, tragedy or other personal emergencies. In the instance of missed lectures, the student is responsible for reviewing posted slides, recorded lectures, and class notes). Please note, all students must follow Stony Brook, local, state and Centers for Disease Control and Prevention (CDC) guidelines to reduce the risk of transmission of COVID. For questions or more information click <https://www.stonybrook.edu/commcms/comingback/students.php>.

Disability Support Services (DSS) Statement

If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Disability Support Services, ECC (Educational Communications Center) Building, Room 128, (631)632-6748. They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential.

Academic Integrity Statement

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the academic judiciary website at http://www.stonybrook.edu/commcms/academic_integrity/index.html. Important Note: Any form of academic dishonesty, including cheating and plagiarism, will be reported to the Academic Judiciary.

Critical Incident Management

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of University Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.

Understand When You May Drop This Course

It is the students responsibility to understand when they need to consider disenrolling from a course. Refer to the Stony Brook Academic Schedule for dates and deadlines for registration: http://www.stonybrook.edu/commcms/registrar/calendars/academic_calendars.

Incomplete Policy

Under emergency/special circumstances, students may petition for an incomplete grade. Circumstances must be documented and significant enough to merit an Incomplete. If you need to request an incomplete for this course, contact me for approval as far in advance as possible.

Course Materials and Copyright Statement

Course material accessed from Blackboard, SB Connect, SB Capture or a Stony Brook Course website is for the exclusive use of students who are currently enrolled in the course. Content from these systems cannot be reused or distributed without written permission of the instructor and/or the copyright holder. Duplication of materials protected by copyright, without permission of the copyright holder is a violation of the Federal copyright law, as well as a violation of Stony Brook's Academic Integrity.

Online Communication Guidelines and Learning Resources

Maintain Professional Conduct Both in the Classroom and Online: The classroom is a professional environment where academic debate and learning take place. I will make every effort to make this environment safe for you to share your opinions, ideas, and beliefs. In return, you are expected to respect the opinions, ideas, and beliefs of other students both in the face-to-face classroom and online communication. Students have the right and privilege to learn in the class, free from harassment and disruption. The course follows the standards set in the Student Code of Conduct, and students are subject to disciplinary action for violation of that code. If your behavior does not follow the course etiquette standards stated below, the grade you receive for a posting may suffer. I reserve the right to remove any discussion messages that display inappropriate language or content.

Online Post Etiquette

- Offensive language or rudeness will not be tolerated. Discuss ideas, not the person.
- Avoid cluttering your messages with excessive emphasis (stars, arrows, exclamations).
- If you are responding to a message, include the relevant part of the original message in your reply, or make sure to refer to the original's contents so as to avoid confusion;
- Be specific and clear, especially when asking questions.
- Use standard punctuation and capitalization. Using all UPPERCASE characters gives the appearance of shouting and makes the message less legible;
- Remember that not all readers have English as their native language, so make allowances for possible misunderstandings and unintended discourtesies.

Online Classes Require Better Communication

It is important to remember that we will not have the non-verbal cues that occur in a face-to-face classroom. I cannot see the confused, frustrated, or unhappy expressions on your face if you encounter problems. You **MUST** communicate with me so that I can help. To make the experience go smoothly, remember that you're responsible for initiating more contact, and being direct, persistent, and vocal when you don't understand something. My Role as the Instructor: As the instructor, I will serve as a guide in terms of the Discussion Board. While I will not respond to every post, I will read what is posted, and reply when necessary. Expect instructor posts in the following situations:

- To assist each of you when it comes to making connections between discussion, lectures, and textbook material.
- To fill in important things that may have been missed.
- To re-direct discussion when it gets out of hand.
- To point out key points or to identify valuable posts.

Student Learning Resources

- Academic and Transfer Advising Services: Have questions about choosing the right course? Contact an advisor today. Phone: (631) 632-7082 (option 2); email: advising@stonybrook.edu; website: <http://www.stonybrook.edu/commcms/advising/>
- Amazon @ Stony Brook: Order your books before classes begin. Phone: (631) 632-9828; email: BookstoreLiaison@stonybrook.edu; website: <http://www.stonybrook.edu/commcms/bookstore/>
- Bursar: For help with billing and payment. Phone: (631) 632-9316; email: bursar@stonybrook.edu; website: <http://www.stonybrook.edu/bursar/>
- Career Center: The Career Center's mission is to support the academic mission of Stony Brook University by educating students about the career decision-making process, helping them plan and attain their career goals, and assisting with their smooth transition to the workplace or further education. Phone: (631) 632-6810; email: sbucareercenter@stonybrook.edu; Website: <http://www.stonybrook.edu/career-center/>
- Counseling and Psychological Services: CAPS staff are available by phone, day or night. <http://studentaffairs.stonybrook.edu/caps/>
- Disability Support Services: Students in need of special accommodations should contact DSS. Phone: (631) 632-6748; email: dss@stonybrook.edu; <http://www.stonybrook.edu/commcms/studentaffairs/dss/>
- Library: Access to online databases, electronic journals, eBooks, and more!
 - Library Instruction Website
<http://library.stonybrook.edu/workshops-this-week-citation-skills-worldcat-and-endnote-the-hsc/>
 - SBU Library Research Guides and Tutorials
<http://library.stonybrook.edu/research/research-basics/>
- Registrar: Having a registration issue? Let them know. Phone: (631) 632-6175; email: registrar_office@stonybrook.edu; <http://www.stonybrook.edu/commcms/registrar/>
- Writing Center: Students are able to schedule face-to-face and online appointments. <https://www.stonybrook.edu/writingcenter/>
- Support for Online Learning <http://www.stonybrook.edu/commcms/onlineed/student.html>
- Ombuds Office The Stony Brook University Ombuds Office provides an alternative channel for confidential, impartial, independent and informal dispute resolution services for the entire University community. We provide a safe place to voice your concerns and explore options for productive conflict management and resolution. The Ombuds Office is a source of confidential advice and information about University policies and procedures and helps individuals and groups address university-related conflicts and concerns. <http://www.stonybrook.edu/ombuds/>