**16-665 – MRSD Robot Mobility on Air, Land, and Sea – Carnegie Mellon University**  
**Fall 2024 – D. Apostolopoulos, J. Dolan, H. Geyer, M. Kaess, G. Shi**

## Syllabus

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### General Information

**Instructors:**

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[Dr. John M. Dolan](http://www.ri.cmu.edu/people/dolan_john.html) ([Robotics](http://www.ri.cmu.edu/) and [Electrical and Computer Engineering](http://www.ece.cmu.edu/Home-Page.html))

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[Dr. Hartmut Geyer](https://www.ri.cmu.edu/ri-faculty/hartmut-geyer/) ([Robotics](http://www.ri.cmu.edu/))

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[Dr. Michael Kaess](https://www.ri.cmu.edu/ri-faculty/michael-kaess/) ([Robotics](http://www.ri.cmu.edu/))

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[Dr. Guanya Shi](https://www.ri.cmu.edu/ri-faculty/guanya-shi/) ([Robotics](http://www.ri.cmu.edu/))

Office & phone: TBD

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Office hours: TBD

**Lectures:**

Tuesdays and Thursdays 2:00 – 3:20 PM

Zoom: None, but lecture recordings from 2020 are available on Canvas

**Administrative Assistant:**

Ms. Christine Downey

Smith Hall 226, x8-4800

[cdowney@andrew.cmu.edu](mailto:cdowney@andrew.cmu.edu)

**Teaching Assistants:**

Dhruv Gupta: [dhruvg2@andrew.cmu.edu](mailto:dhruvg2@andrew.cmu.edu)  
Shivangi Gupta: [shivangi@andrew.cmu.edu](mailto:shivangi@andrew.cmu.edu)

**TA Office Hours:**

Dhruv Gupta: TBD

Shivangi Gupta: TBD

Location: TBD

**Required Text:** No required textbook

**Reference Texts:**

* Vehicle Dynamics and Control, Rajesh Rajamani, Springer Verlag, 2012
* Theory of Ground Vehicles, Jo Y. Wong, John Wiley & Sons, 4th Edition, 2008
* Fundamentals of Vehicle Dynamics, Thomas Gillespie, SAE, 2014
* Road Vehicle Dynamics, George Rill, CRC Press, 2012

**Prerequisites:**Basic knowledge of control theory and engineering math and physics.

#### Course Description

Many robots are designed to move through their environments. Three prevalent environments on earth are land, air, and water. This course will summarize the state of the art and explore the fundamentals of modeling, control, and navigation of ground-based (wheeled and legged), air-based (rotorcraft such as quadcopters), and water-based robots.

**Learning Objectives**

**Upon graduation, students should be able to…**

* Understand the state of the art in ground, air, and water robots;
* Perform basic modeling and control of ground, air, and water robots;
* Understand the key differences and similarities between the modeling (kinematics & dynamics) and control of robots in various domains.

#### Course Outline

Refer to the course schedule on Canvas under Syllabus🡪Schedule. The course schedule is provisional and the instructors reserve the right to modify it throughout the semester.

#### Course Assignments and Grading

There will be five problem sets, one for each of the major course segments (autonomous driving, legged, aerial, wheeled, marine).

|  |  |  |  |
| --- | --- | --- | --- |
| **Task** | **Percentage** | **Due Date** | **Description** |
| 1 Autonomous Driving assignment | 22% | 9/21 | Analyze various instances of the kinematic bicycle model, implement vehicle control strategies using the dynamic bicycle model in an example maneuver, implement pure pursuit control. |
| 2 Wheeled Robots assignment | 14% | 10/5 | Perform wheeled mobility configuration analysis and design studies. |
| 3 Aerial Robots assignment | 30% | 11/2 | Develop the dynamic model, feedback control and tracking, and trajectory generation capabilities required to enable an aerial robot to navigate (fly) through a cluttered simulated environment (in MATLAB). |
| 4 Legged Robots assignment | 24% | 11/28 | Perform hand analysis and MATLAB modeling of the basic walking, actuation, and control methods for legged locomotion. The assignment is structured in several parts that align with the weekly lecture content. Although these parts are posted as we progress in lecture content, only one submission is required on the due date comprising the answers to all parts. |
| 5 Marine Robots assignment | 10% | 12/14 | Discuss the utility and challenges associated with underwater robotics, demonstrate understanding of basic navigation, and think about the tradeoffs of different marine systems. |
| **TOTAL** | **100%** |  |  |

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The provisional final grading thresholds are listed below, though they may be adjusted depending on various factors:

|  |  |
| --- | --- |
| **Letter grade** | **Minimum %-age to achieve letter grade** |
| A+ | 98 |
| A | 93 |
| A- | 90 |
| B+ | 87 |
| B | 83 |
| B- | 79.5 |
| C+ | 76 |
| C | 73 |
| C- | 69.5 |
| D | 60 |

#### Policy on Late Assignments

Assignments are expected to be submitted on time, but 5 late days (reckoned by cumulative late time) may be used by students across all assignments without penalty. Once the late days have been exhausted, for each day after the due date an assignment is submitted, 5% will be deducted from the grade.

**Student Wellness**

**Take care of yourself.**  Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at <http://www.cmu.edu/counseling/>. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

**CaPS: 412-268-2922**

**Re:solve Crisis Network: 888-796-8226**

**If the situation is life-threatening, call the police:**

**On campus: CMU Police: 412-268-2323**

**Off campus: 911**

If you have questions about this or your coursework, please let the course instructors know.

[**Student Academic Success Center (SASC)**](https://www.cmu.edu/student-success/)

SASC focuses on creating spaces for students to engage in their coursework and approach learning through a variety of group and individual tutoring options. We offer many opportunities for students to deepen their understanding of who they are as learners, communicators, and scholars. Our [workshops](https://www.cmu.edu/student-success/programs/workshops/index.html) are free to the CMU community and meet the needs of all disciplines and levels of study. SASC programs to support student learning include the following (program titles link to webpages):

* [Academic Coaching](https://www.cmu.edu/student-success/programs/coaching.html)--This program provides holistic, one-on-one peer support and group workshops to help undergraduate and graduate students implement habits for success. Academic Coaching assists students with time management, productive learning and study habits, organization, stress management, and other skills. Request an initial consultation [here](https://docs.google.com/forms/d/e/1FAIpQLSfMAnCWkyPdXRb0zOsMar7nzpUau8hqN_gIFm3OISY5QMWwyw/viewform).
* [Peer Tutoring](https://www.cmu.edu/student-success/programs/tutoring.html)--Peer Tutoring is offered in two formats for students seeking support related to their coursework. Drop-In tutoring targets our highest demand courses through regularly scheduled open tutoring sessions during the fall and spring semesters. Tutoring by appointment consists of ongoing individualized and small group sessions.You can utilize tutoring to discuss course related content, clarify and ask questions, and work through practice problems. Visit the [webpage](https://www.cmu.edu/student-success/programs/tutoring.html) to see courses currently being supported by Peer Tutoring.
* [Communication Support](https://www.cmu.edu/student-success/programs/communication-support/index.html)--Communication Support offers free one-on-one communication consulting as well as group workshops to support strong written, oral, and visual communication in texts including IMRaD and thesis-driven essays, data-driven reports, oral presentations, posters and visual design, advanced research, application materials, grant proposals, business and public policy documents, datavisualisation, and team projects. Appointments are available to undergraduate and graduate students from any discipline at CMU. Schedule an [appointment](https://www.cmu.edu/student-success/programs/communication-support/make-an-appointment.html)  on our website (in-person, zoom synchronous, or recorded video), attend a [workshop](https://www.cmu.edu/student-success/calendar.html), or consult [handouts or videos](https://www.cmu.edu/student-success/other-resources/index.html) to strengthen communication skills.
* [Language and Cross-Cultural Support](https://www.cmu.edu/student-success/programs/language-support/index.html)--This program supports students seeking help with language and cross-cultural skills for academic and professional success through individual and group sessions. Students can get assistance with writing academic emails, learning expectations and strategies for clear academic writing, pronunciation, grammar, fluency, and more. [Make an appointment](https://docs.google.com/forms/d/e/1FAIpQLSfMAnCWkyPdXRb0zOsMar7nzpUau8hqN_gIFm3OISY5QMWwyw/viewform) with a Language Development Specialist to get individualized coaching.
* [Supplemental Instruction](https://www.cmu.edu/student-success/programs/supp-inst.html) (SI)--This program offers a non-remedial approach to learning in historically difficult courses at CMU. It utilizes a peer-led collaborative group study approach to help students succeed and is facilitated by an SI leader, a CMU student who has successfully completed the course. SI offers a way to connect with other students studying the same course, a guaranteed weekly study time that reinforces learning and retention of information, as well as a place to learn and integrate study tools and exam techniques specific to a course. Visit the website to see courses with SI available [here](https://www.cmu.edu/student-success/programs/supp-inst.html).

[**Accommodations for Students with Disabilities**](https://www.cmu.edu/disability-resources/)

If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at [access@andrew.cmu.edu](mailto:access@andrew.cmu.edu).

#### Academic Integrity Policies:

**CMU Academic Integrity Policy (**<http://www.cmu.edu/academic-integrity/index.html>)**:**

In the midst of self-exploration, the high demands of a challenging academic environment can create situations where some students have difficulty exercising good judgment. Academic challenges can provide many opportunities for high standards to evolve if students actively reflect on these challenges and if the community supports discussions to aid in this process. It is the responsibility of the entire community to establish and maintain the integrity of our university.

This site is offered as a comprehensive and accessible resource compiling and organizing the multitude of information pertaining to academic integrity that is available from across the university. These pages include practical information concerning policies, protocols and best practices as well as articulations of the institutional values from which the policies and protocols grew. The Carnegie Mellon Code, while not formally an honor code, serves as the foundation of these values and frames the expectations of our community with regard to personal integrity.

**The Carnegie Mellon Code**

Students at Carnegie Mellon, because they are members of an academic community dedicated to the achievement of excellence, are expected to meet the highest standards of personal, ethical and moral conduct possible.

These standards require personal integrity, a commitment to honesty without compromise, as well as truth without equivocation and a willingness to place the good of the community above the good of the self. Obligations once undertaken must be met, commitments kept.

As members of the Carnegie Mellon community, individuals are expected to uphold the standards of the community in addition to holding others accountable for said standards. It is rare that the life of a student in an academic community can be so private that it will not affect the community as a whole or that the above standards do not apply.

The discovery, advancement and communication of knowledge are not possible without a commitment to these standards. Creativity cannot exist without acknowledgment of the creativity of others. New knowledge cannot be developed without credit for prior knowledge. Without the ability to trust that these principles will be observed, an academic community cannot exist.

The commitment of its faculty, staff and students to these standards contributes to the high respect in which the Carnegie Mellon degree is held. Students must not destroy that respect by their failure to meet these standards. Students who cannot meet them should voluntarily withdraw from the university.

*This policy applies, in all respects, to this course.*

**Carnegie Mellon University's Policy on Cheating** (<http://www.cmu.edu/academic-integrity/cheating/index.html>) states the following:

According to the University Policy on Academic Integrity, cheating "occurs when a student avails her/himself of an unfair or disallowed advantage which includes but is not limited to:

* Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
* Use of an alternate, stand-in or proxy during an examination.
* Copying from the examination or work of another person or source.
* Submission or use of falsified data.
* Using false statements to obtain additional time or other accommodation.
* Falsification of academic credentials.”

*This policy applies, in all respects, to this course.*

**Carnegie Mellon University's Policy on Plagiarism** (<http://www.cmu.edu/academic-integrity/plagiarism/index.html>) states the following:

According to the University Policy on Academic Integrity, plagiarism "is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to:

* Text, either written or spoken, quoted directly or paraphrased.
* Graphic elements.
* Passages of music, existing either as sound or as notation.
* Mathematical proofs.
* Scientific data.
* Concepts or material derived from the work, published or unpublished, of another person."

*This policy applies, in all respects, to this course.*

**Carnegie Mellon University's Policy on Unauthorized Assistance** (<http://www.cmu.edu/academic-integrity/collaboration/index.html>) states the following:

According to the University Policy on Academic Integrity, unauthorized assistance "refers to the use of sources of support that have not been specifically authorized in this policy statement or by the course instructor(s) in the completion of academic work to be graded. Such sources of support may include but are not limited to advice or help provided by another individual, published or unpublished written sources, and electronic sources. Examples of unauthorized assistance include but are not limited to:

* Collaboration on any assignment beyond the standards authorized by this policy statement and the course instructor(s).
* Submission of work completed or edited in whole or in part by another person.
* Supplying or communicating unauthorized information or materials, including graded work and answer keys from previous course offerings, in any way to another student.
* Use of unauthorized information or materials, including graded work and answer keys from previous course offerings.
* Use of unauthorized devices.
* Submission for credit of previously completed graded work in a second course without first obtaining permission from the instructor(s) of the second course. In the case of concurrent courses, permission to submit the same work for credit in two courses must be obtained from the instructors of both courses."

*This policy applies, in all respects, to this course.*

**Carnegie Mellon University's Policy on Research Misconduct** (<http://www.cmu.edu/academic-integrity/research/index.html>) states the following:

According to the University Policy For Handling Alleged Misconduct In Research, “Carnegie Mellon University is responsible for the integrity of research conducted at the university. As a community of scholars, in which truth and integrity are fundamental, the university must establish procedures for the investigation of allegations of misconduct of research with due care to protect the rights of those accused, those making the allegations, and the university. Furthermore, federal regulations require the university to have explicit procedures for addressing incidents in which there are allegations of misconduct in research.”

The policy goes on to note that “misconduct means:

* fabrication, falsification, plagiarism, or other serious deviation from accepted practices in proposing, carrying out, or reporting results from research;
* material failure to comply with Federal requirements for the protection of researchers, human subjects, or the public or for ensuring the welfare of laboratory animals; or
* failure to meet other material legal requirements governing research.”

“To be deemed misconduct for the purposes of this policy, a ‘material failure to comply with Federal requirements’ or a ‘failure to meet other material legal requirements’ must be intentional or grossly negligent.”

To become familiar with the expectations around the responsible conduct of research, please review the guidelines for Research Ethics published by the Office of Research Integrity and Compliance.

*This policy applies, in all respects, to this course.*