



## **EE 599: Robotic Mobility**

**Units: 4**

**Fall2024—Tu/Th—2-4pm**

**Location: EEB B18**

**Instructor: Feifei Qian**

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**Office Hours: Tuesday 4-5pm**

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### **Course Description**

Applications involving mobile robots are becoming an increasingly important part of society and industry, including delivery, search and rescue, healthcare, and extraterrestrial explorations. How to achieve high mobility in the real world has been a key topic in robotics, and requires an integration of knowledge and skills from different fields including morphology design, kinematics control, dynamics modeling, sensing information analysis, and motion planning. This specialized course will combine lectures, student presentations, and hands-on lab projects to provide an overview of robotic locomotion control and analysis, and expose students to the latest challenges and progress associated with robotic mobility in complex environments. This course is primarily oriented towards 1<sup>st</sup> and 2<sup>nd</sup> year PhD students in ECE, AME, CS, and other relevant engineering programs.

### **Learning Objectives**

By the end of this course, students will be able to

1. implement state-of-the-art methods to design and optimize robot gaits, model complex terrains, and derive locomotion dynamics models.
2. obtain hands-on skills in actuator control, gait programming, kinematics control, and locomotion analysis
3. identify and investigate the latest robotics mobility challenges, and write conference paper style manuscripts to report scientific discoveries.

**Prerequisite(s):** N/A

**Co-Requisite(s):** N/A

**Concurrent Enrollment:** N/A

**Recommended Preparation:** Students will be expected to have taken linear algebra courses (e.g., has taken EE510 or equivalent). Students will also be expected to be able to program in C++. In addition, we will be using Arduino and servo motors for the hands-on labs and project, so familiarity with these hardware systems (e.g., has taken EE109) will be helpful.

### **Course Notes**

The course will be letter grade. Brightspace will be used to post assignments and release grades. Lecture slides (without notes) will be posted on Brightspace.

### Technological Proficiency and Hardware/Software Required

Hands-on labs require programming in Arduino IDE. Data analysis and plotting require Matlab or Python.

### Required Readings and Supplementary Materials

There will be no required textbook. Lectures will cover selected material drawn from the texts listed in "Optional Readings and Supplementary Materials" as well as relevant research articles.

### Optional Readings and Supplementary Materials

1. Sharbafi, Maziar Ahmad, and André Seyfarth, eds. *Bioinspired legged locomotion: models, concepts, control and applications*. Butterworth-Heinemann, 2017.
2. Lynch, Kevin M., and Frank C. Park. *Modern Robotics*. Cambridge University Press, 2017.
3. Choset, Howie M., et al. *Principles of robot motion: theory, algorithms, and implementation*. MIT press, 2005.

### Description and Assessment of Assignments

- **Homework:** Students will complete two homework assignments. Homework will consist of solving problems based on lecture topics.
- **Paper Reviews and Presentations** Each student will select two research papers from a list provided, and give a 10 min in-class presentation about each paper.

Examples of research papers:

1. Ozkan-Aydin, Yasemin, and Daniel I. Goldman. "[Self-reconfigurable multilegged robot swarms collectively accomplish challenging terradynamic tasks](#)." *Science Robotics* 6.56 (2021): eabf1628.
2. Choi, Suyoung, et al. "[Learning quadrupedal locomotion on deformable terrain](#)." *Science Robotics* 8.74 (2023): eade2256.
3. Badri-Spröwitz, Alexander, et al. "[BirdBot achieves energy-efficient gait with minimal control using avian-inspired leg clutching](#)." *Science Robotics* 7.64 (2022): eabg4055.

- **Hands-on labs and team project** There will be 3 hands-on lab sessions and 1 final project. Students will work individually as well as in groups to complete these hands-on assignments. For the project, students will form a team of 3. A few teams will have a 4<sup>th</sup> member upon instructor approval if class size cannot be divided by 3. Each team will propose a research topic on one mobility challenge task, and write a conference paper style report to describe the results and interpretations. Each team will present their findings in an oral presentation during the last week of the class.

Example project topics from previous semesters:

1. Tail-assisted locomotion and its impact on robotic mobility over a rocky slope
2. Directional compliance in flipper design to improve sand traversal performance
3. Multi-agent collaborated climbing via alternating anchoring

### Grading Breakdown

Assessment Tool (assignments)	% of Grade
Homework	20
Hands-on labs	30
Paper presentation	10
Project	40
<b>TOTAL</b>	100

## **Grading Scale**

Course final grades will be determined by applying a curve based on the class median.

## **Assignment Submission Policy**

Assignments are to be submitted in class or through email on the due date. Late homeworks will not be accepted unless prior approval for late submission has been obtained.

## **Grading Timeline**

Grading and feedback will usually be released through Brightspace within 2 weeks of submission due date.

## **Academic Integrity**

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the [USC Student Handbook](#). All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

If found responsible for an academic violation, students may be assigned university outcomes, such as suspension or expulsion from the university, and grade penalties, such as an "F" grade on the assignment, exam, and/or in the course.

For more information about academic integrity see the [student handbook](#) or the [Office of Academic Integrity's website](#), and university policies on [Research and Scholarship Misconduct](#).

## **Course Content Distribution and Synchronous Session Recordings Policies**

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via

email, on the internet, or via any other media. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

## Course Schedule

	<b>Topics/Daily Activities</b>	<b>Deliverables</b>
<b>Week 1</b>	Overview. Structure of the course; Topics to be covered; Presentation topics; Lab and project overview	Lab 0 assigned (mainly HW/SW setup, no submission required) Introducing Project tasks
<b>Week 2</b>	Types of mobility: walking, running, hopping, climbing, crawling, digging, brachiating, burrowing, swimming, flying.	Lab 1 assigned
<b>Week 3</b>	Robot gait generation and control (legged and legless)	HW1 assigned
<b>Week 4</b>	Forward and Inverse kinematics for controlling multi DoF legs	Lab 1 due Lab 2 assigned
<b>Week 5</b>	Motion planning: using geometric mechanics to design optimized gaits	HW1 due
<b>Week 6</b>	Dynamics of walking: Inverted pendulum; Templates and anchors for analyzing locomotion of complex systems	Lab 2 due Lab 3 assigned Project team formation due
<b>Week 7</b>	Walking as a Rimless Wheel; Dynamics of running: SLIP model.	Project assigned, Discuss project ideas with teams
<b>Week 8</b>	Vertical hopper control; Raibert's hopper	Lab 3 due HW2 assigned
<b>Week 9</b>	Planar hopper control	Project checkpoint 1 (literature review and hypothesis) due
<b>Week 10</b>	Adaptation on soft terrain (legged)	HW2 due Discuss robot design and experiment plan with project teams
<b>Week 11</b>	Adaptation on soft terrain (non-legged)	Project checkpoint 2 (robot design and experiment setup) due
<b>Week 12</b>	Adaptation on rough terrain (legged)	Discuss preliminary results with project teams
<b>Week 13</b>	Adaptation on rough terrain (non-legged)	Progress checkpoing 3 (results and discussion) due
<b>Week 14</b>	Course wrap-up: locomotion architecture; sensory feedback; where to go from here	
<b>Week 15</b>	Project demo and presentation	Project final report due
<b>FINAL</b>	N/A	

## Statement on Academic Conduct and Support Systems

### Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at [osas.usc.edu](https://osas.usc.edu). You may contact OSAS at (213) 740-0776 or via email at [osasfrontdesk@usc.edu](mailto:osasfrontdesk@usc.edu).

### Support Systems:

#### [Counseling and Mental Health](#) - (213) 740-9355 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

#### [988 Suicide and Crisis Lifeline](#) - 988 for both calls and text messages – 24/7 on call

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

#### [Relationship and Sexual Violence Prevention Services \(RSVP\)](#) - (213) 740-9355(WELL) – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

#### [Office for Equity, Equal Opportunity, and Title IX \(EEO-TIX\)](#) - (213) 740-5086

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

#### [Reporting Incidents of Bias or Harassment](#) - (213) 740-5086 or (213) 821-8298

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

#### [The Office of Student Accessibility Services \(OSAS\)](#) - (213) 740-0776

OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

#### [USC Campus Support and Intervention](#) - (213) 740-0411

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

#### [Diversity, Equity and Inclusion](#) - (213) 740-2101

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

[USC Emergency](#) - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

[USC Department of Public Safety](#) - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call

Non-emergency assistance or information.

[Office of the Ombuds](#) - (213) 821-9556 (UPC) / (323-442-0382 (HSC)

A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

[Occupational Therapy Faculty Practice](#) - (323) 442-2850 or [otfp@med.usc.edu](mailto:otfp@med.usc.edu)

Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.