UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

CEE 598

CONSTRUCTION ROBOTICS

SPRING 2024

SYLLABUS

Instructor:
Dr. Houtan Jebelli

Class Location: 2015 Civil & Envir Eng Bldg
Wednesdays 1:00 – 3:50 PM

I. CONTACT INFORMATION

Instructor – Houtan Jebelli, Ph.D.

Assistant Professor
Department of Civil and Environmental Engineering
University of Illinois Urbana-Champaign
2109 Newmark Civil Engineering Building
Email: hjebelli@illinois.edu
Office Hour:

1. Weekly office hours: will be scheduled.
2. By appointment (Please email me to set up an appointment. Please make sure all email correspondence has CEE 598-Construction Robotic in the subject heading)

II. COURSE OBJECTIVE

The objective of this course is to provide an understanding of the challenges faced by automation and robotics in the construction domain, a familiarity with the current state of automation and robotics technologies relevant to construction, a basic understanding of the principles, technologies, and applications of automation and robotics within the field of construction, and the fundamental skills necessary to begin programming for construction automation and robotics.

By the end of this course, students will:

- Gain an understanding of the specific challenges confronting automation and robotics in the construction domain
- Acquire knowledge about the past, present, and future innovations in construction automation and robotics
- Learn the fundamental concepts of what cutting-edge technologies used in construction automation and robotics are and how they function, including hardware and software
- Learn the theoretical knowledge required to analyze data relevant to construction automation and robotics
- Gain practical programming skills and hands-on experience in utilizing languages like MATLAB or Python for robot control and automation tasks.

This course provides an introduction to automation and robotics and their application to civil and construction engineering. The history, current state, and future of construction automation and robotics will be overviewed. The fundamentals of automation and robotics are described at a conceptual level to provide an understanding of what robots are and how they function. The course also includes spatial descriptions of robots, kinematics (mobile robots), and an introductory programming component. These topics provide students with essential knowledge and skills to initiate basic control and operation of robots.

III. COURSE ORGANIZATION

Lectures

The course materials will be taught through a series of lectures. Lectures are scheduled during the scheduled class time in 2015 Civil & Envir Eng Bldg.

Lecture times will be used for both teaching course materials and class discussion, as well as collecting data for the class term project. Classroom participation is strongly encouraged during lectures. A preliminary schedule is attached at the end of the syllabus.

With the exception of bottled water, all food and drink consumption is prohibited in lecture times. Justifying documentation to override this policy for medical reasons should be submitted to the Instructor.

Recommended Reading

Material for this class comes from several different sources. That is why there is no assigned textbook for the class. Specific reading portions (e.g., chapters) will be posted on the lecture slides if needed.

Most of the class material comes from the following four books:

- Site Automation: Automated/Robotic On-Site Factories by Thomas Bock and Thomas Linner.
- Principles of Robot Motion: Theory, Algorithms, and Implementations by Howie Choset, Kevin M. Lynch, Seth Hutchinson, George Kantor, and Wolfram Burgard
- Probabilistic Robotics by Sebastian Thrun, Wolfram Burgard, and Dieter Fox
- Automation and Robotics in the Architecture, Engineering, and Construction Industry by Houtan Jebelli and others, Springer.
- Construction Robots: Volume 3: Elementary Technologies and Single-Task Construction Robots by Thomas Bock and Thomas Linner.
- Robotic Industrialization: Automation and Robotic Technologies for Customized Component, Module, and Building Prefabrication by Thomas Bock and Thomas Linner.
- Robot-Oriented Design: Design and Management Tools for the Deployment of Automation and Robotics in Construction by Thomas Bock and Thomas Linner.

Canvas

All information will be available via Canvas. If you have a problem accessing it, please contact the Canvas team directly. I will make frequent announcements that will be automatically sent via email.

Grading

Your final grade will be calculated as follows (can be adjusted):

- **Participation** **5%**
    - Attendance: -1% per day absent (unexcused)
    - Lateness: -0.5% per day (unexcused)
    - Graded drop quizzes
        - All quizzes will be available in Canvas. Questions might be presented in different formats: multiple selection, multiple choice, blank completion, or short answers.
- **Paper Discussion** **20%**
    - Each student should select a journal or conference paper in the field of construction automation and robotics. The student is responsible is reading the article, writing a one-page summary of the paper, and presenting the paper to the rest of the class. Details about the required sections of the presentation and grading criteria will be discussed in the class.
- **HomeWorks (HWs)** **30%**
    - Five graded homework assignments are expected to be assigned throughout the semester. The dates for the assignments will be announced in Canvas. Typically, homework is due one week after the assignment date, as specified in the homework file. ***Please be aware*** that late submissions will receive a score of ZERO. However, we understand that unforeseen circumstances may arise. If you require an extension, do not hesitate to reach out to the Instructor for consideration. Also, if you have questions concerning your assignment marks, you only have a week after mark distribution to address them.
- **Term Project (TPs)** **30%**
    - Please refer to the Term Project subsection below.
- **Exam (date TBD)** **15%**
    - The specific date for the exam will be officially announced in Canvas. It's essential to adhere to the scheduled exam date to ensure a smooth process and timely evaluation. If you believe you have a valid reason for requesting an extension or rescheduling the midterm, please contact the ***Instructor*** as soon as possible. ***Please note*** that collaborative study and discussions with your peers are encouraged, but when it comes to the exam, you must demonstrate your individual understanding and application of the course concepts. Lastly, academic integrity remains of utmost importance throughout the examination process. Any form of cheating is strictly prohibited and will be considered a violation of Academic Integrity policies.

The grading in the class will **roughly follow** the rubric below (can be adjusted):

A+	100-97%
A	97-93%
A-	93-90%
B+	90-87%
B	87-84%
B-	84-80%
C+	80-77%
C	77-74%
C-	74-70%
D+	70-67%
D	67-64%
D-	64-60%
F	60-0%

Term Project

There will be one Term Project (TP). Instructions and required materials for the TP will be published in Canvas in the TP section.

Students should work on the TP as a team of three and perform all aspects of conducting a scientific research project, from collecting data, analyzing data, preparing a midterm and final report, as well as preparing a final presentation. All TP teams should be grouped by week 3. Beyond that date, I will assign the remaining students to the incomplete teams or create new teams.

For full credit, each delivery of the project should be submitted as a digital file on Canvas on its due date. Points will be deducted for files submitted that do not meet this criterion and are not well organized.

We will allocate time in the class session for you to work on the TP and discuss it with your peers or with the Instructor. Please come to the class session assigned for this activity prepared to make the most use of this time. It is designed to help you complete the term project efficiently and effectively.

Each student is expected to greatly collaborate with their team on the TP. Each team should produce its own solutions to the TP. Students may not copy or otherwise share other students' work or copy or otherwise use past students' solutions.

IV. General Information, Guidelines, and Tips for the Course

To do well in this course you should keep up with lectures, related readings (e.g., books and papers), and assignments. If you ever find yourself falling behind, we strongly encourage you to reach out to the TA and/or the Instructor at your earliest convenience for assistance.

Attendance in lectures is expected, and we recommend utilizing office hours for any questions or clarifications you may have.

Office hours will be conducted either in person or through Zoom. Office hours' Zoom link can be accessed from Canvas. These sessions are a great opportunity for you to engage directly with the Instructor. You are encouraged to make the most of office hours by utilizing them for inquiries regarding class materials, homework, grading procedures, or any related topics. They serve as the primary channel for direct interaction between the Instructor and students, so we encourage you to take advantage of this resource.

The course material on Canvas is organized according to the topic of each lecture. At the start of each week, we will have an overview of the main topics and activities to be covered. In addition, we advise dedicating a minimum of 5-6 hours per week to engage with all the weekly content, which includes assignments, paper discussions, and progress on the term project.

Assignments submitted online will be reviewed and graded by the course instructor/TA within two weeks from the submission date. If the instructor/grader is unable to meet this timeline, students will receive notification.

This syllabus is a guide and every attempt is made to provide an accurate overview of the course and its requirements. However, certain circumstances may make it necessary for the Instructor to modify the syllabus during the semester for your benefit and the changes may depend, in part, on course progress and our needs. I will announce any change to the syllabus as early as possible so that you can adjust your schedule. The department will also be notified of any change.

While this syllabus serves as a comprehensive guide, it's important to note that certain circumstances may make it necessary for the Instructor to modify the syllabus during the semester for the benefit of the course and your learning experience. These changes may be adjusted based on course progress and our evolving needs. Any alterations to the syllabus will be announced as early as possible, allowing you to adapt your schedule accordingly.

V. ABSENCE POLICY

General Attendance Requirement:

Attendance in all scheduled classes, including lectures, discussions, and lab sessions, is mandatory and crucial for success in this course. Regular participation is expected to ensure a comprehensive understanding of the course material.

Planned Absences:

If you anticipate missing a class due to a religious observance, athletic commitments, graduate school interviews, or other valid reasons, you are required to:

- Notify Prof. Jebelli at least one week prior to the absence.
- Arrange to complete any missed work before the absence.
- Submit assignments before their deadlines if they fall on the day of your absence.

Failure to comply with these conditions will result in the absence being marked as unexcused, and you may receive a zero for any work missed during this time.

Serious Illness or Family Emergency:

In cases of serious illness or family emergencies that prevent attendance:

- Inform Prof. Jebelli via email as soon as possible.
- If an extension on homework is needed due to these circumstances, contact Prof. Jebelli before the homework due date.
- Please note that late submissions cannot be accepted once the answer key is made available.

Unplanned Absences:

For absences not covered under 'Planned Absences' or 'Serious Illness/Family Emergency,' such as unexpected events or illnesses:

- Notify Prof. Jebelli as soon as feasibly possible.
- Provide valid documentation to support the reason for your absence.
- Discuss possible make-up work or extensions, which are subject to Prof. Jebelli's approval

Regular unexcused absences may negatively impact your grade. Participation points, if applicable, will be deducted for each unexcused absence.

Accommodation for Religious Observances:

As part of our commitment to inclusivity and respect for diverse religious practices, this course adheres to University's policy regarding the accommodation of religious observances. Students who require adjustments to their academic schedule for religious observances are encouraged to submit the "Request for Accommodation for Religious Observances" form. This is particularly pertinent for instances requiring an official absence letter due to religious commitments. Students are advised to make such requests at the earliest convenience, preferably at the start of the semester, to allow sufficient time for the necessary arrangements. Accommodations may include, but are not limited to, rescheduling exams or assignments, providing alternative assignments, or excusing absences. This would ensures that all students can participate fully in their academic pursuits without compromising their religious practices.

VI. Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should be considered as a part of this syllabus. Students should familiarize themselves with Article 1, Part 4: Academic Integrity, which can be accessed at the following URL:http://studentcode.illinois.edu/. Dishonesty of any kind will not be tolerated in this course. Dishonesty includes but is not limited to, cheating, plagiarizing, fabricating information or citations, facilitating acts of academic dishonesty by others, having unauthorized possession of examinations, submitting work of another person or work previously used without informing the Instructor or tampering with the academic work of other students. Academic dishonesty may result in a ***failing grade.*** Every student is expected to thoroughly review and adhere to the Academic Integrity Policy, available at: http://studentcode.illinois.edu/. Ignorance of this policy is not an acceptable excuse for any act of academic dishonesty. It is your personal responsibility to acquaint yourself with this policy to ensure full compliance and to avoid any potential misunderstandings. If you ever have questions or concerns regarding what constitutes plagiarism, cheating, or any other violation of academic integrity, please do not hesitate to seek clarification from the instructor(s).

- Unless explicitly directed otherwise by the Instructor, all assignments are expected to be the student's own original work completed individually without collaboration. Violations of this code of conduct can result in reduced grades and can be reported to the Department or University for disciplinary action.
- Students currently taking this class can work together to conceptualize general approaches to the term project sets. However, unless otherwise specified for a particular term project set, the work you submit must be done completely on your own. This includes text, numerical calculations, mathematical derivations, diagrams, graphs, computer programs, and output.
- For the term project sets to be worked as a team, each team does its own work on all team assignments. Teams do not work together.
- You are also expected to properly reference the source of any information used in a submission that is not your own. This includes any book, article, web page, MS PowerPoint presentation, or personal correspondence from someone in the industry that you used to create your work. It is recommended to use the American Society of Civil Engineers (ASCE) publication guidelines to properly reference all types of resources.
- Students are not allowed to look at assignments from prior terms. In general, students are not allowed to possess, use, or in any way derive advantage from the existence of assignments, solutions, or any work prepared by other students in this or past terms.
- The above applies to computer files as well. All work done by a student using a computer must be entirely his/her own, and a student must have entered every keystroke or mouse command for their work. Consequently, students must never leave computer files in directories where other students may have access to them. Doing so is equivalent to providing copies of their work to other students. Students should copy their files on other media and erase them from public areas on a computer's hard drive. If students find other people's files relating to this course on the computers in the Computer Labs, they should bring the matter to the attention of the Instructor immediately.
- Exams are individual efforts, not team efforts. All work during exams is completely independent.
- If you have any questions about this policy, please do not hesitate to contact the Instructor.

VII. Disability Accommodations

To request disability-related academic adjustments and/or auxiliary aids, students with disabilities should promptly reach out to both the course instructor and the Disability Resources and Educational Services (DRES). You can contact DRES by visiting 1207 S. Oak St., Champaign, calling 333-4603, emailing disability@illinois.edu, or visiting the DRES website (https://dres.illinois.edu/). If you are concerned you have

a disability-related condition that is impacting your academic progress, there are academic screening appointments available on campus that can help diagnose a previously undiagnosed disability by visiting the DRES website and selecting Sign-Up for an Academic Screening at the bottom of the page. To receive consideration for reasonable accommodations, you must contact the disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: See documentation guidelines (https://dres.illinois.edu/information-before-you-apply/documentation-requirements/). If the documentation supports your request for reasonable accommodations, your campus disability services office will provide you with an accommodation letter. Please share this letter with your instructors and discuss the accommodations with them as early as possible.

VIII. Mental Health

Significant stress, mood changes, excessive worry, substance/alcohol misuse or interferences in eating or sleep can have an impact on academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings which are covered through the Student Health Fee. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources provided below. Getting help is a smart and courageous thing to do for yourself and for those who care about you.

- Counseling Center (217) 333-3704
- McKinley Health Center (217) 333-2700
- National Suicide Prevention Lifeline (800) 273-8255
- Rosecrance Crisis Line (217) 359-4141 (available 24/7, 365 days a year)

If you are in immediate danger, call 911.

*This statement is approved by the University of Illinois Counseling Center

IX. Community of Care

As members of the Illinois community, we each have a responsibility to express care and concern for one another. If you come across a classmate whose behavior concerns you, whether in regards to their well-being or yours, we encourage you to refer this behavior to the Student Assistance Center (217-333-0050 or http://odos.illinois.edu/community-of-care/referral/). Based on your report, the staff in the Student Assistance Center reaches out to students to make sure they have the support they need to be healthy and safe.

Further, as a Community of Care, we want to support you in your overall wellness. We know that students sometimes face challenges that can impact academic performance (examples include mental health concerns, food insecurity, homelessness, personal emergencies). Should you find that you are managing such a challenge and that it is interfering with your coursework, you are encouraged to contact the Student Assistance Center (SAC) in the Office of the Dean of Students for support and referrals to campus and/or community resources.

X. Disruptive Behavior

Behavior that persistently or grossly interferes with classroom activities is considered disruptive behavior and may be subject to disciplinary action. Such behavior inhibits other students' ability to learn and an instructor's ability to teach. A student responsible for disruptive behavior may be required to leave class pending discussion and resolution of the problem and may be reported to the Office for Student Conflict Resolution (https://conflictresolution.illinois.edu; conflictresolution@illinois.edu; 333-3680) for disciplinary action.

XI. Sexual Misconduct Policy and Reporting

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX and Disability Office. In turn, an individual with the Title IX and Disability Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options. For those seeking confidential guidance and support, a list of designated University employees, such as counselors, confidential advisers, and medical professionals, who do not have reporting responsibilities and can maintain confidentiality, can be found here: http://wecare.illinois.edu/resources/students/#confidential. Other information about resources and reporting is available here: http://wecare.illinois.edu.

XII. Schedule

Please see below for a **preliminary** schedule diagram. ***It will be changed (updated) based on the student's background and needs*** (will be discussed over the first week of the class). Also, the order of the sessions is flexible per class progress/interest.

XIII. Preliminary Lecture Schedule

Topics	Schedule
Course Introduction – Construction Automation and Robotics	Week 1-2
• Definition and scope of robotics and construction robotics (Overview)	W1
• Benefits and challenges of integrating robotics in construction (Overview)	W2
• Overview of all topics for this course	W2
Emergence and Applications of Construction Robots	Week 3-4
• Single-task construction robots	W3
• Applications of single-task construction robots o Bricklaying and masonry robots o Robotic 3D printing and additive manufacturing	W4
Robotic Perception and Sensing in Construction I – *Vision-based Robotic Perception*	Week 5-6
• Fundamentals of Computer Visions	W5
• Applications of vision-based robotic perception in construction o Pose estimation o Object detection	W5, W6
Robotic Perception and Sensing in Construction II – *Proximity-based Robotic Perception*	Week 7-8
• Proximity sensing for collision avoidance	W7
• Proximity sensing for robot navigation	W7

• SLAM algorithm	W8
• Bug algorithms for path planning	W8
Robotic Perception and Sensing in Construction III – *Physiologically-based Robotic Perception*	Week 9-10

• The framework of establishing a physiologically-based robotic perception system
  ○ Feature engineering
  ○ Machine learning
  ○ Robot adjustment
	W9-10

Human-Robot Collaboration and Safety in Construction	Week 10-12
• Human-robot interaction	W10

• Key features of human-robot interaction
  ○ Collaborative workspaces
  ○ Safety mechanisms
  ○ Role specialization
	W11, W12

• Safe human-robot collaboration methods in construction	W12
Advanced Robot Control System in Construction	Week 13-14
• Basic robotic components for control	W13
• Proportional-Integral-Derivative (PID) controller	W13, W14
• Application of PID for construction robots	W14
The Integration of Exoskeleton Technology in Construction Safety and Efficiency	Week 15-16

• Different types of exoskeletons
  ○ Passive exoskeletons
  ○ Active exoskeletons
	W15

• Components of exoskeletons (Powered)
  ○ Control unit
  ○ Actuators
	W16

Multi-agent Robotic Systems in Construction	Week 15-16