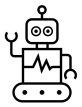

CEE 327: Construction Robotics Syllabus

Welcome!

Over the past few years, progress in mobility, autonomous manipulation skills, Artificial Intelligence reasoning, and physical interaction through multimodal sensing and environment modeling present new opportunities for the application of robotics in unstructured environments (Khatib et al., 2016). The International Federation of Robotics (IFR) has predicted a growing adoption of construction robots (IFR, 2018) and Bock and Linner (2016) outlined 24 categories of on-site task-specific construction robots. Tasks such as drilling, painting, brick-laying, and excavating are being automated and performed with the aid of robots (Brosque, C., & Fischer, M., 2022)).

However, construction companies do not have extensive experience working with robots, and therefore innovators in construction cannot rely on historical data to decide on the best solution for a given project compared to the traditional baseline. As these robotic construction methods are increasingly being prototyped and adopted in the field (Siciliano & Khatib, 2016; Cousineau & Miura, 1998), innovation leaders in construction must be able to consistently evaluate the impact of deploying robots on site compared to traditional construction methods. For instance, how does the robot impact the schedule, cost, quality, and health and safety, particularly for the workforce?

To answer these questions, our research developed a Robotics Evaluation Framework (REF) based on a literature review and in-depth industry case studies that compared the on-site robot to the manual construction method for a given project. The small-group class project carried out with industry partners applies the REF to compare the health and safety, quality, schedule, and cost performance of robotic and traditional construction methods for construction tasks like painting, drilling, and surveying.

Class sessions contrast the development of construction robots with manufacturing robots, showcase real-world applications of construction robots, and introduce state-of-the-art robot development in human-robot collaboration.

Students attending the class will gain a good understanding of the performance of robots available in the market through guest lectures, demos, and site visits. Special guest lectures by General Contractors, Stanford's Robotics Center, TUM, Autodesk, and Venture Capitalists will complement the analysis perspective.

Course Instructors

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Course Logistics

Meeting times Spring Quarter 2024:

Tu/Thu 9:00 AM - 10:20 AM at Y2E2 292A

3 Units: Letter (ABCD/NC)

1 Unit Seminar (Tuesdays only)

Glossary

Course Requirements[1]

1. **Participation (20%)**

   Class participation is a crucial aspect of this course[2]. We expect students to engage with the guest speakers and ask relevant questions. Lectures will be held in person unless otherwise noted.

   OH are optional.

   To receive credit for the seminar (1 unit Pass/Fail) students cannot have more than **one absence** and must complete reading assignments.

2. **Assignments (20%)**

   All assignments are due before class via link or document upload in Canvas (any format is valid). Seminar students enrolled for 1 unit will only complete the Assignments on Canvas due on Tuesdays before the Seminar class. 3-unit students must complete all Canvas Assignments.

3. **Industry Project (60%) - 3-unit students only**

   Pairs of students are matched with industry professionals who have used or are interested in using a robot application on a real-world project. This joint project is a significant part of the course performance. In our experience, the student-professional collaboration enriches both parties as students provide an objective lens to a robot evaluation problem and the industry professionals both on the robotics and the construction side can help connect the class concepts with reality.

   Project Instructions

   Working with industry partners

[1] Students must earn the equivalent of 'C-' or a 60% between requirements 1 to 3 with at least 50% in each category.

[2] Students may miss class due to illness, family crisis, or other extenuating circumstances. Please contact the instructors as soon as possible to notify them of the reason for the absence. To receive credit for the class (3 units) students cannot have more than **one** unexcused absence. Seminar students may only miss one class (excused or unexcused).

The robot companies will introduce their robot to the class in a meet and greet session at the beginning of the quarter and later on through a guest lecture. The time to work with the professionals is limited, so make the most out of each interaction.

Read available online material on the company website, public interviews, etc., to prepare insightful questions in advance and think of ways to work as a unified team with industry partners to co-generate ideas.

REF templates

Each student will receive a Google Drive folder with a blank REF template (one for the Assignments and one for the Project). Please work online (instead of downloading the Gdocs) so the teaching team can easily review your progress and the final project.

Once you start working on the project, you may select one folder to work together with your partner(s).

REF examples and case studies are available on Canvas:

Case 1: Drilling robot
Case 2: Drywall robot
Case 3: Layout robot (To be completed together during in-class assignments)
Case 4: Spot

Feel free to add/remove variables to the REF based on the feedback from the industry partners. Document the necessary changes and bottlenecks in the comparison.

As we progress with the course you will be able to apply more robot concepts and examples to develop your thinking about the robot evaluation problem. Weekly OH will help share your progress and get peer feedback.

The class is structured into four Modules:

Module 1	**Introduction to the framework** Introduction to on-site vs. off-site robots, basic robot principles, and construction robots' history. Robotics Evaluation Framework: Product, Organization, Process, Safety, Quality, Schedule, and Cost Analyses. Introduction to the class project.
Module 2	**Case Studies** On-site construction robot application examples. Discussion on the opportunities and challenges of robots. Guest lectures, demos, and site visits.
Module 3	**The Sustainable Perspective** Equity, Economic, and Ecological perspective (EEE framework).
Module 4	**Human-Robot Collaboration** Collaborative approaches in industry and academia. Reflection on the robot operator role.

Project Deliverables - with teammate(s)

1. Completed REF files
   - 00REF_Template
   - 01REF_Process Analysis
   - 02REF_Time Management (please track the project work hours for each part of the framework)
2. Final Presentation slides

   The presentation template can be downloaded here
3. Final Report

   The final report should include:
   - Introduction to the case study
   - POP analysis
   - SQSC analysis
   - Sensitivity analysis
   - Final reflections/recommendations

   Approximate length 5-6 pages of text without including figures/tables/diagrams
4. Complete CEE 327 Final Survey - individual (all students including seminar and project)

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