Introduction to Robotics
Syllabus

Prof. Tron

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Course description: What this course is all about

The term *robot* was first used by a Czeck playwright in 1920, but the fascination of humans with machines that can sense, process and act in their physical environment was there since ancient civilizations. Today, the convergence of relatively cheap but powerful hardware with many years of research makes possible to (almost) build robots in different shapes and for a variety of applications: industrial robots, vacuum cleaners, delivery drones, self-driving cars, etc. While this is an active field of research, the basics of the building blocks for a robot (modeling, control, perception, mapping and planning) are well understood. Through both theory and practice, in this class you will learn these basics, and build a simple but complete system that will compete with the creations of your peers.

Course goals: What I hope you will remeber of the class in 5 years

After this class:

- You will be able to organize and document your work while you design of a large, complex system.
- You will know enough technical tools (Python/ROS/OpenCV/etc.) to be able to translate you ideas into code.
- You will be able to understand how the different subsystems in a robot work individually and together.

Course objectives: Why you should take this class

Foundational knowledge: What you will know

In this class you will learn:

Modeling Create a useful mathematical representation of a physical system.

Control Make the system follow a given trajectory and react to unexpected obstacles.

Perception and Machine Learning Use images, Inertial Measurement Units (IMUs) and other sensors to distill the environment into information that the robot can learn and use.

Planning Transform high-level tasks into trajectories that the robot can follow to achieve its tasks.

Mathematical tools You will learn how to use linear algebra, statistics, image processing, and optimization in a real system. These tools have many engineering applications beyond robotics.

Application: Learn how to think

You will gain intuition about what is realistically achievable in robotics, and how you can go about to achieve it. We will not build a T800, but this is a start.

Integration: How this class connects with the rest

You will learn why all those long hours used to study vector, matrices, and probability distributions can serve for an actual (and cool) practical application.

Interaction: Learn how to work together

Robotics systems can grow large and complex. You will learn how to tackle this complexity by building modular solutions, coordinate your work with others, and handling division of responsibilities.

Assessment: How we will know that you are learning effectively

The assessment of your progress during the class will be evaluated in different ways.

Formative assessments

These assessments will help you to reflect on the material covered, and help me to gain a sense of how your learning is going. These will be assigned at the end of each class or module, and be lightly graded or not graded at all.

Minute flashcards At the end of each class, you will prepare a small number of flashcard questions covering the main points of what we discussed in that session. You will receive a small fixed amount of points for simply completing this task. This activity has two functions: first, it will help you identify and recall the main points of the lecture (this type of immediate recall has been shown to improve retention); second, you will be able to import your flashcards in Anki, a free software for spaced repetition, which can be used to help you with studying for the exams. See Blackboard (Information → Useful software → Anki) for details.

Summative assignment feedback Associated to the submission of the homework assignments, you will have to submit a short commentary (one or two sentences) describing what was challenging, interesting or easy about the assignment, and how you would improve it. This will be weighted approximatively as a one of the questions in the homework.

In-class activities In most of the sessions, we will perform short exercises in class to reinforce the material. These exercises are given and mostly solved in class. However, you will have to write your own solution and submit it on Gradescope in the week following the end of lecture. These solutions are meant to be somewhat informal, so the "professionalism" required for the homework reports does not apply here (i.e., if you submit a scanned copy of your work, as long as it is legible, it will be fine).

Mini-hackatons Some classes will be organized as "mini-hackatons", where you will spend your time on a "coding challenge" related to the content of the homework. Completing the challenge is not required, but you will get a chance to make progress on your homework while having the opportunity to ask questions. However, as a "prize", the first two people that complete the challenge will be able, at the end of the semester, to increase their score by 50% on the homework of their choice. You can claim your prize up to 24 hours after the end of the mini-hackaton (i.e., after the end of that class).

Summative assessments

These assessments will be the basis on which I will gauge your learning and you will receive your grade.

Homework/Labs These guided exercises will involve mostly programming and some analytical derivations. You will submit your code, a short report explaining your work, and a video showing your results. You will be provided with some already-built basic blocks, and if you put in the effort to complete all the exercises well, you will gain a much more confident understanding of the theory. Each homework/lab focuses on a different aspect/component of a robot. The goal is to gain more intuition on what works and what does not. Each question will be associated to a fixed number of points. You will work on homework assignments in groups of two students. A single submitted report for the two students is sufficient.

Midterm and Final Exams The exams will give you a chance to put together the material covered in the quizzes and homework/labs in a more integrated manner. The type of questions will be in line with those in the quizzes and the homework.

Guided collaboration

For this class, we will use a somewhat atypical approach to collaboration, in the sense that you will be collaborate on your homework assignments with different classmates during the semester. In particular, you will work in pairs. Different pairs are permitted to discuss the assignments at a high level, but sharing code or report sections outside the pair before the assignment deadline is not allowed. Midterm and final exams will be taken individually (in-class, closed books).

Weighting of the assignments on the final grade

The weight of each assessment on the final grade will be (approximately) as follows: quizzes (including in-class activities) 18%, homework 27%, midterm and final exams 20% each, minute papers 5%, contributions to the wiki 10%. I might decide to tweak the weights as the course progresses, but I will notify you if I am planning any changes. I reserve the right to adjust the final grade by ±5% points to reflect aspects that are not captured by the assignment (e.g., class participation and overall class performance).

Instructor information: How I make myself available to you

Instructor Prof. Roberto Tron

Office Room 301, 110 Cummington Mall.

Email tron@bu.edu

Office hours You can also just stop by my office, but if you schedule an appointment I can guarantee that you will have enough time reserved for you. For best results, come together as small studying group; I enjoy a lot small group discussions.

Instructor $\Longleftrightarrow$ Students communication In addition to office hours and class, we will communicate using online platforms.

- **Blackboard** I will use the class' Blackboard website to make announcements, to post material from the class and to post and collect assignments. Please let me know as soon as possible if you cannot find something.
- **Discussion boards** I will likely *do not answer* questions on the course's content or assigments through individual emails, unless they are personal in nature. Instead, you will have to ask your questions (anonymosly if you would like) on the Discussion boards on Blackboard, and I will answer there. In this way, every question will potentially benefit every student. Please subscribe to the forum, so that you will receive notifications

Prerequisites: What you need to know already

You will need linear algebra: modeling the position and orientation of a robot and its components requires using vectors and matrices. You will also need probability: often the state of the robot or of the environment cannot be known with 100% certainty, and we will need to take this into account. If you know dynamics, you will already have an intuition of why we need to consider the constraints on how the robot moves. If you do not know dynamics, we will review the relevant material, but you will have to put a little extra effort to understand it. Finally, and most importantly, you will need to know how to program: you will work with a simplified system whose intelligence, as with most real-life systems, is 90% given by the algorithms running it.

Formal prerequisite list

- MA225: Multivariate Calculus
- EK127/128: Introduction to Engineering Programming
- EK301: Engineering Mechanics 1
- ME366/EC381/BE200: Probability

Suggested prerequisite list

- ME302: Mechanics 2 (Dynamics)
- EC401/BE402/ME404: Signal and Systems or Control

Resources: What materials we will use

Wiki

Unfortunately there is no book that covers well the material in this class. As such, the main reference for the content of the course will be a set of Wiki pages that I will start with the most fundamental notions. However, as part of your assessment, you will be asked to integrate and improve these pages. Think of this as a collaborative study guide.

Virtual Machine

You will have access to a virtual machine (roslab.bu.edu) containing Linux and ROS. The setup is very similar to the one for your ROSBot, but it is faster and it will be always available. You can use this VM to practice while learning Liinux, Python, and ROS.

Book (for reference)

Optional book Peter Corke, Robotics, Vision and Control, Springer, 2011

Optional book Kelly, A, Mobile Robotics: Mathematics, Models, and Methods, Cambridge

Optional book Roland Siegwart, Illah R. Nourbakhsh and Davide Scaramuzza, Introduction to Autonomous Mobile Robots, Second Edition, MIT Press 2011

Grading criteria: How the results of the assessment is evaluated

Homework/Lab

Each exercise will count a fixed amount of points. For the programming part of each assignment, we will provide you with "interfaces" that you need to follow, and we will validate your code using automated tests. The final grade for each assignment can be adjusted with up to +/- 3 "beauty-contest" points that I will add/remove to my discretion. This will be based on how clear and professional the explanation of your work is. I will put my best effort to evaluate the correctness of your work, but I will reward you if you make my job easier. To give you an idea, these could be two extreme situations:

- You do not include any comment in your code, you do not explain why you are doing the derivations, and I have to spend more than a reasonable amount of time to understand your work: subtract 3 points, even if the results are technically correct.
- You meaningfully comment and organize your code, it is easy to see your reasoning process, and you type your answers: add 3 points, even if the results are not completely correct.

If you were not able to fully complete a part of the assignment, please state so clearly in the report, including a sentence about the reason why.

Video

The video should be around 1 to 3 minutes long. It should contain the following elements:

1) A short introduction of yourself (even if this is not your first video for this class). You need to appear on camera.

2) A presentation showing that you completed all the questions of the activity, demonstrating that your implementation works correctly.

3) Comments on what was hard and what you learned from the activity.

If you were not able to get some part of the assignment working, please state so clearly in your discussion. You will get a pre-fixed amount of points for each part; for part *2)*, the maximum score might vary depending on the number of "demos" requested in the assignment.

Late homework policy

For the entire semester, you will have *two* late-homework credits. You can use one credit to submit your work up to 24 hours later than the normal deadline without penalty (no question asked); just include the statement *"I am using a late-homework credit for this assignment"* at the top of your report. You can also use the two credits together to get a 48 hours extension, but then you would have to submit all your successive assignment on time. If you do not use a credit or run out, the credit you will receive will halve after the deadline, and after each successive 24 hours period (that is, 50% after the deadline, 25% after 24 hours, 12.5% after 48 hours, etc.) If you feel that you are falling behind on multiple assignments, please come to see me to discuss.

Mini-hackatons

I will be the only judge regarding whether you passed the challenge or not.

Academic conduct policy

You are responsible for following BU's academic conduct policy (http://www.bu.edu/.../academic-conduct-code/). In a nutshell, do no cheat at exams, and do not share your work on assignments unless explicitly allowed. In a nutshell:

- Any behavior by which a student misrepresents her or his academic proficiency constitutes misconduct.
- I am obligated to report any case of misconduct to the department, which will the be followed up with hearings from a specialized committee, and, in case of established wrongdoing, notes on your transcript or expulsion.
- Misconduct has often direct or indirect repercussions to peers other than the perpetrator.
- Facilitating misconduct (e.g., allowing another student to submit your work as their own) is as serious an offense as if you were committing it yourself.

Collaboration policy

In this class you may use any textbooks or web sources when completing your homework, and/or one human collaborator (from class) per homework, subject to the following strictly enforced conditions:

- You must clearly acknowledge all your sources (including your collaborators) on the top of your homework report (as a side effect, I might suggest the same resources to future students to enhance their learning experience).
- Collaboration with humans must be restricted to the "whiteboard level": you can discuss approaches and solutions with your peers, but you must write code, reports and

analytical derivations by yourself. Naturally, this does not apply with members in your group for group assignments; however, it does apply across members of different groups.

- You must be able to fully explain your answers upon demand.
- You may not use any human resource outside of class (including web-based help services, outside tutors, students from past years, etc.)
- Plagiarism (use of someone else's material without acknowledgment) is considered misconduct.
- Regarding coding assignments, I have tools on Gradescope that allow me to find similarities between different submissions, and also with submissions from previous years. As such, if you illegally reuse code, you will be likely to be caught.

If you have any doubt on these policies, ask the instructor before the fact, otherwise you might have to face the college disciplinary committee.

These guidelines have been adapted from those provided by the Mechanical Engineering department. While the general BU-mandated policies always applies, you should ask the corresponding instructors for additional policies adopted in other courses (especially regarding collaboration).

Policy on your work

By default, the work you submit (code, reports, derivations) will be used only and specifically for grading. I might occasionally ask your permission to distribute your work to other students in the class, possibly with some modification.