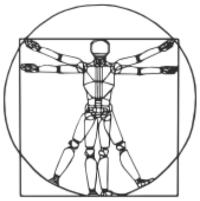

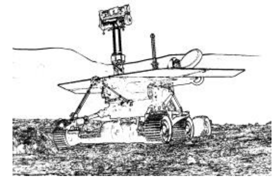

COMP417
Winter 2017
Introduction to Robotics and Intelligent Systems
McGill School of Computer Science

Teaching Staff

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Office Hours:	Office Hours:	Office Hours:
Thursdays	Wednesdays	Tuesdays
10:30-11:30am	3-4pm	1-2pm

Course Description

This course provides an introduction to robotic systems from a computational perspective. A robot is regarded as an intelligent computer that can use sensors and act on the world. We will consider the definitional problems for robots and look at how they are being solved in practice and by the research community. The emphasis is on algorithms, inference mechanisms and behavior strategies, as opposed to electromechanical systems design. The course will broadly cover the following areas:

- Kinematics and Dynamics: how can we model robotic systems using approximate physical models that enable us to make predictions about how they move in response to given commands?

- Feedback Control (and Planning): how can we compute the state-(in)dependent commands that are required to bring a robotic system from its current state to a desired state?

- Mapping: how can we weigh noisy measurements from sensors as well as the robot's known pose to build a map of the environment?

- State Estimation: the state of the robot is not always directly measurable. How can we determine the relative weighs of multiple sensor measurements in order to form an estimate of the state?

- Computer Vision: how to model inputs from an RGB camera. How to triangulate points seen from two cameras. How to estimate the camera's pose (and therefore the robot's) while it is moving in the environment.

- Reinforcement Learning (optional section, pending time and interest): how can we learn the parameters of a state-dependent controller without having a prior physical model of the robot's dynamics?

To answer these questions, we will rely on concepts from linear algebra, optimization, and probabilistic reasoning, which are some of the pillars of modern AI systems. Tutorials will be provided by the teaching assistants and the instructor to help students develop a solid grasp of this important background material. Algorithm implementation will be done mainly in Python and C++/C. If your software engineering background does not include these languages, please talk to the instructor as soon as possible. Students are also going to be introduced to the ROS (Robot Operating System) environment and set of interfaces, as well as to the Gazebo 3D simulation environment, which comprise the state-of-the art tools used by the robotics community today.

Online Communication

- MyCourses (https://mycourses2.mcgill.ca/), COMP417 Forum.
- Email the instructor or the TAs with "COMP417" in the subject line
- Anonymous feedback any time during the semester: https://www.surveymonkey.com/r/5Z3F56P

Official Prerequisites (minimal)

- COMP251 Algorithms and Data Structures
- MATH 223 Linear Algebra
- ECSE 321 or COMP206 Software Engineering

Additional Prerequisites (recommended, good to have, but optional)

- A course on multivariate probability distributions
- Familiarity with Linux
- Familiarity with Python, C++/C

Textbooks

All texts for this course are optional and will only be used for reference.
However, you may find it useful to purchase or borrow the following books:

- Computational Principles of Mobile Robotics, 2^{nd} edition, by Dudek and Jenkin.
- Probabilistic Robotics, by Thrun, Fox, and Burgard
- Planning Algorithms, by Lavalle (available online for free)

Evaluation

4 Assignments: 50% (each is worth 12.5%)
5 Quizzes (in class, dates TBA): 5% (each is worth 1%)
1 Midterm Exam (in class, February 21): 15%
1 Final Exam (3 hours, TBA): 30%

No make-up midterm will be offered. If you are not happy with your midterm grade you can choose to make the weight of the final exam be 45% of your final mark. Assignments are going to include implementation of algorithms presented in class as well as a small (~10-20%) theory component, which is going to examine the depth of understanding of the presented material.

Tentative assignment dates:
A1: Jan 19 – Feb 2
A2: Feb 4 – Feb 19
A3: Feb 23 – Mar 9
A4: Mar 11 – Mar 31

Review sessions will be held before the midterm and before the final exam, outside normal class hours. The room for the review sessions is to be announced.

Tentative Syllabus

Week	Date	Topic	Description
1	Jan 5	Intro	Motivation, logistics, syllabus, rough description of assignments, sense-plan-act paradigm
2	Jan 10	Kinematics & Dynamics	Dynamical systems and control. Examples: Dubins car, differential drive car, unicycle, pendulum, cartpole, quadcopter. Underactuated vs fully-actuated systems. Holonomic vs. non-holonomic systems.
2	Jan 12	Kinematics	Frames of reference. Rotation representations. Homogeneous coordinates and transformations. Rigid body motion.
3	Jan 17	Sensors & Actuators	Observation models from: images, lasers, touch sensors, IMU, depth, GPS, hall-effect, encoders, acoustic sonar, RGBD. Pulse-Width Modulation.
3	Jan 19	Feedback Control	PID controller, tuning, cascading PID, advantages and drawbacks.
4	Jan 24	Feedback Control	Artificial potential fields, implementation issues, navigation functions
4	Jan 26	Feedback Control	Definition of a policy. Linear Quadratic Regulator.

5	Jan 31	Planning	Dijkstra, A*
5	Feb 2	Planning	RRT, PRM, RRT*
6	Feb 7	Planning	Voronoi Graph and Topology, Visibility Graph, Trapezoidal decompositions
6	Feb 9	Mapping	Occupancy grid mapping
7	Feb 14	State Estimation	Least squares, least squares with a Gaussian prior, online least squares
7	Feb 16	State Estimation	Case study: GraphSLAM
8	Feb 21	Midterm	
8	Feb 23	State Estimation	Bayes Rule, Bayes Filter, Kalman Filter
	Feb 28	Reading Week	
	Mar 2	Reading Week	
9	Mar 7	State Estimation	Extended Kalman Filter, Case Study: EKF-SLAM
9	Mar 9	State Estimation	Importance Sampling, Particle Filter
10	Mar 14	State Estimation	Case studies: Markov localization
10	Mar 16	Vision	Perspective projection, pinhole projection model, camera calibration,
11	Mar 21	Vision	Stereo cameras, 3D triangulation of a pair of matched pixels
11	Mar 23	Vision	Case studies: Visual odometry, Visual Monocular SLAM

12	Mar 28	Reinforcement Learning [not exammable]	MDPs, Value function, Q-function, Reward, stochastic and deterministic policies. Bellman operator
12	Mar 31	Reinforcement Learning [not exammable]	Function approximation, Cross-Entropy Method, examples of RL systems in robotics
13	Apr 4	Reinforcement Learning [not exammable]	Least Squares Policy Iteration
13	Apr 6	Research topics	HRI, humanoids, learning from demonstration [mostly videos, no technical content, fun class]

Language policy

In accordance with McGill University's Charter of Students' Rights, students in this course have the right to submit any written work that is to be graded in English or in French.

Academic Integrity

Students are encouraged to discuss assignment solutions with each other, however, everyone must write up their own solution. Submissions that are found to be identical will be penalized. Plagiarism is very easy to spot. It is also not worth it. Do your own work.

McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures (see www.mcgill.ca/integrity for more information).

Final Exam Conflicts

If you are unable to write your final examination due to scheduling conflicts, you must submit a Final Exam Conflict Form with supporting documentation at least one month before the start of the final examination period. Late submissions will not be accepted. For details, see: https://www.mcgill.ca/students/exams/dates/conflicts

Examination schedules are posted at the Centre and on the following page approximately 6-8 weeks before the examination period commences: https://www.mcgill.ca/students/exams/home-page