Course Outline and Syllabus
CSCI X980, Fall 2018
Topics in Computational Perception and Reasoning in Field Robotics

Junaed Sattar

1 Course Outline

This course looks into challenges in robot perception and reasoning in the field, particularly in unstructured environments, with a focus on human-robot collaboration. Students will learn about the definitional problems and their solutions in field robotics with a human-centric flavor, using machine vision, learning, and human-robot interaction. The emphasis is on algorithms, inference mechanisms and behavior strategies although we will also survey the kinds of mechanical and electronic systems that constitute most field robots today.

2 Instructor

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3 Software Tools

The hands-on aspect of the course shall be based on the Robot Operating System (ROS) middleware. ROS can be found at http://www.ros.org. The Long Term Support version is Kinetic Kane (May 2016), supporting the same lifespan of an Ubuntu LTS release (Ubuntu 16.04 in this case). Lunar Loggerhead would be a more recent and *short-term supported* release. ROS runs natively on Ubuntu Linux, but has known to work on Arch and Mac OS using Homebrew. Alternatively, it is possible to run ROS as a Virtual Machine under Windows, using VirtualBox or other VM software, and the ROS installation page has helpful information and downloads to achieve this (see http://wiki.ros.org/ROS/Installation). The latter option is attractive for testing out a ROS installation without worrying about installing Linux, and also maybe the way to go for Windows users who exhibit a high-degree of Linux aversion, although it is highly recommended to run ROS on a native Ubuntu installation for reasons of simplicity and performance. Please note, no support for Windows installs for ROS or any other software will be provided.

In addition, OpenCV will be the preferred software tool for implementing vision algorithms and it comes bundled with ROS. Many deep learning frameworks are available, though TensorFlow seems to have become the most popular. Students are free to choose any DL framework, but have to be aware that it may not be possible for everyone to have access to significant computational resources.

4 Course Outcome

- Students will be introduced to the fundamental concepts of computational mobile and field robotics and human-robot interaction.
- Students will understand the algorithmic approach towards designing intelligent systems.

- Students will learn about sensory perception algorithms, sensor suites and robot control through sensory feedback. A key focus shall be on visual sensing as an interaction modality.
- Students will learn about deep learning methods applied to field robotics, particularly for perception, gesture recognition, and control.
- Students will have a firm grasp of the algorithms for spatial representation, mapping and localization.
- Through the term project portion, the students will learn about cutting-edge research in areas central to the course.

5 Course Structure

Two lectures per week. Date/time and Location TBA.

6 Course Grading

(Approximate scheme only. Unless otherwise stated, all exams are **closed book**.)

Homework assignments	25
Term project and paper	30
In-class presentation	20
Midterm	25

7 Recommended Text

1. (Recommended: general material) Computational Principles of Mobile Robotics. Gregory Dudek and Michael Jenkin. 2nd ed. Cambridge University Press, 2010.
2. Deep Learning. Ian Goodfellow and Yoshua Bengio and Aaron Courville, 1st Edition. MIT Press, 2016.
3. Selected readings from the research literature, to be distributed in class.
4. Autonomous Robot Vehicles. Cox and Wilfong. Springer-Verlag.
5. (Strongly recommended:localization and mapping) Probabilistic Robotics. S. Thrun, W. Burgard, D. Fox. MIT Press, 2006.
6. (Strongly recommended: Kinematics and Industrial Robotics) Robot Modeling and Control. Mark W. Spong, Seth Hutchinson and M. Vidyasagar. John Wiley and Sons, 2006.

8 References

1. Journals
   (a) International Journal of Robotics Research, MIT Press
   (b) IEEE Transactions on Robotics
   (c) Journal of Field Robotics, John Wiley and Sons
   (d) International Journal of Human-Robot Interaction
2. Software
   (a) ROS: The Robot Operating System; Version K (Kinetic Kane) is the current Long-Term Supported (LTS) Release (2016).
   (b) MATLAB/Octave: Student edition of MATLAB, or GPL'ed Octave are both acceptable platforms.
   (c) Robotics Toolbox for Matlab by Peter I. Corke. Available here.

9 Tentative Topics

1. Robot features, sensors, manipulators. Application areas. State of Robotics research and adoption.
2. Robotic hardware systems.
3. Sensors, sensor data interpretation and sensor fusion.
4. Path planning, Spatial mapping, Configuration spaces, Position estimation.
5. Machine vision
6. Machine learning and Deep Learning in Robotics
7. Human-Robot Interaction basics. Implicit vs Explicit interaction.
8. HRI experimentation design.
9. Intelligent interaction.
10. Multi-agent systems.
11. Applications.
12. Kinematics and inverse kinematics.

10 Term Project and Paper

10.1 Objective

To implement a robotics application based on recently published research. Examples are (this list is by no means complete):

1. a path planner for mobile robots or robot arms.
2. a visual tracker for mobile robots.
3. visual navigation algorithm.
4. a human-robot interaction or dialog scheme.
5. wearable computing towards robust and safe HRI.

10.2 Breakdown

This project consists of five parts:

1. Proposal: 1-2 pages plus reference material.
2. Technical Report: 4 pages maximum plus reference material.
3. Simulation and/or Experiment that demonstrates your work.
4. Presentation, including item 3, scheduled for the last week of classes.
5. Final report, in article format, 6-8 pages, 2 columns, single spaced, 12 point font, including figures and references. Major papers referenced should be attached as an appendix.

10.3 Instructions

1. **Literature Review and Proposal** Students have to find at least one, and preferably several recent (post-2005 vintage) journal research papers regarding a specific, well-defined topic in robotics. They can also use any robotics textbook to assist their work, of course, however the project should be focused on a recently developed (post-2005) technique. Students should read and understand the concepts and methods used in this/these papers. The proposal should describe the type of application the student plan to undertake, the basis (research work) on which his application is based, the tools that will be used to implement the application, and expected results.

2. **Technical Report** After the literature review, a clear plan of how the application will be implemented needs to be reported. The student should have worked out all the equations that are required, and should understand all the variables and values that need to be calculated and used in simulations. The student may have even started implementation at this point. The technical report should lay out clearly how the simulation or experiment will be implemented. It should also give some consideration as to how the results shall be clearly presented to the class and to the instructor.

3. **Simulation and/or Experiment** Students need to present their results in a visual manner such that other students can observe and evaluate them. This can be done using simulations in MATLAB(using the movie capture facility) and/or graphs, charts, or (in the case of physical experiments) video, or straightforward screen-casting.

4. **Presentation** Students should be prepared to give a brief (maximum 15 minute) demonstration/description of their simulation to the class. They will explain briefly the technique their simulation will demonstrate, and give one or two examples. A notebook computer and projector will be available for making presentations. Students wishing to use this equipment should email their presentation to the instructor A MINIMUM OF 24 HOURS BEFORE the presentation.

5. **Report** The final report will present the work done in article format with the typical sections (abstract, introduction, methodology, implementation, results, discussion/conclusions, references, etc.). A guideline on how to format articles can be found here.

10.4 Important Note

It is completely unacceptable to copy text or figures from any published work without indicating that this is copied material (referencing the work), and submit it as one's own work. This is plagiarism and will be dealt with under the UoM rules for violating the student code of conduct. The work in student reports should, therefore, *not* be repetitions of the contents of any published papers. Instead it should include a commentary, discussing the effectiveness of the method presented (as the student views it) and any problems discovered in trying to implement it. Students *should* attach the main papers they used to the report as an appendix. (Not included in the page count.)