MEC 634 - Advanced Topics in Kinematics and Dynamics of Machines: Machine Learning for Design, Control, and Prediction

Instructors: Nilanjan Chakraborty

Contact Information

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Lecture Hours

Time: Tuesday and Thursday, 2 : 30 PM - 3 : 50 PM.
Location: MELVILLE LBR, N4006.

Office Hours

Location: Heavy Engineering 212
Time: Tuesday and Thursday, 12 : 15 PM - 2 : 15 PM.
Alternate Times: Please send me an email to make an appointment.

Course Description

The goal of this course is to learn the basics of modern machine learning techniques and explore their use to (a) build an AI system for synthesis of machines/mechanisms (b) solve estimation and control problems for autonomous mechanical systems operating under uncertainty and (c) combine simulation data with experimental data to predict mechanical system performance. This course will be a hands on project-based course. The course will cover basic theory and techniques from machine learning with a view towards the applications stated above. Topics that we plan to cover include neural networks, convolution networks, deep neural networks, recurrent neural networks, reinforcement learning, deep reinforcement learning, support vector machines, and Gaussian processes. Students are expected to work with the instructor to formulate and solve problems related to their research interest using learning techniques. This course is intended for graduate students with interests in Design, Robotics, and Artificial Intelligence. Prerequisites include basics of probability theory, linear algebra, and calculus. The course will be programming heavy, so the ability to program competently in Python/C++/MATLAB is a must.

Books

There is no required books for this course. I will be providing notes. The following books are recommended references:

- Yaser S. Abu-Mostafa, Malik Magdon-Ismail, and Hsuan-Tien Lin, "Learning from Data: A short course", AMLBook.com.

- Ian Goodfellow and Yoshua Bengio and Aaron Courville, "Deep Learning", MIT Press, 2016. Available online at http://www.deeplearningbook.org/.
- Richard S. Sutton and Andrew G. Barto, "Reinforcement Learning: An Introduction", 2nd Edition, MIT Press.

Assignments, Exams, and Projects

- **Homeworks**: There will be 6 homeworks. You will have about $1-2$ weeks to complete a homework. Homeworks will be due in class. The homeworks will include Matlab coding. You are allowed to discuss with your colleagues but you have to submit your individual work. Any discussion or help that you have taken from your colleagues or other sources should be acknowledged. In other words, you should write the name of the persons you have worked with and also state explicitly the kind of help you have received.
- **Paper Critique**: There will also be one paper review report that you have to submit. You have to select one paper from a list of papers that I will provide (or you can choose your own paper based on your final project) and you have to write a critical review of the paper. You will get one week for the paper review.
- **Midterm Exam**: There will be one take home midterm exam. The exam will be open book, open notes. You will have approximately 7 days to complete your exam. You are not allowed to consult with your colleagues for the exam.
- **Final Project and Presentation**: There will be one final project that will be done in groups of at most 2 students. You have to do one presentation and two reports for the final project. The first report will be a project proposal where you will describe the problem you want to solve and what are your plans for solving the problem. The final report and presentation will be a comprehensive description of your work. The reports are to be written using Latex. I will provide the supporting style files.
- **Final Exam**: There will be one take home final exam. The exam will be open book, open notes. You will have approximately 3 days to complete your exam. You are not allowed to consult with your colleagues for the exam.

Grading Breakdown and Policy

Your overall grade will be based on your performance in all the class work mentioned above. The weight distribution on grades for the different components are given below.

- 6 Homeworks and 1 Paper Critique (25%).
- 1 Take Home Midterm Exam (25%).
- 1 Take Home Final Exam (25%).
- Final Project and Project Presentation (25%).

The GRADING SCALE will be an accumulation of your course work, as follows (there will probably be no curves): A (100-90), A- (89-85), B+ (84-80), B (79-75), B- (74-70), C+ (69-65), C (60-64), F (59 or below).

Late Assignment Policy: Assignments are due in class unless otherwise stated or you have made prior arrangements with me. You are allowed at most two late days for each homework or paper critique. If you submit your homework late you will be penalized 20% of the points. Assignments will not be accepted after

the late days expire. No late submission is allowed for the mid-term exam or the final project report.

Collaboration Policy: You are allowed and encouraged to collaborate with your fellow students on home works. However, you are required to turn in your own work and you should not copy the work of another person. Any collaboration or help should always be acknowledged explicitly. **No collaboration is allowed** on the take home exams. Please also see the Academic Integrity Statement below.

Assignment and Exam Schedule (Tentative)

Name	Date Available	Due Date
Assignment 1	**9\6\2018**	**9\13\2018**
Assignment 2	**9\13\2018**	**9\20\2018**
Assignment 3	**9\20\2018**	**10\04\2018**
Take Home Exam	**10\04\2018**	**10\11\2018**
Assignment 4	**10\18\2018**	**10\25\2018**
Assignment 5	**10\25\2018**	**11\08\2018**
Paper Critique	**11\08\2018**	**11\15\2018**
Assignment 6	**11\15\2018**	**11\27\2018**
Final Project Presentation	NA	**12\04\2018**
Final Project Report	NA	**12\04\2018**
Take Home Exam	**12\05\2018**	**12\07\2018**

Course Learning Objectives

Upon completion of this course students will be able to

- Understand basic concepts like training, validation, and testing.
- Use different variations of Neural Networks (NNs) as appropriate for a given application scenario.
- Understand and apply synthetic data generation for learning.
- Use Neural Networks for approximating time-series data.
- Understand basics of online decision making.
- Model a problem as a Reinforcement learning (RL) problem and apply different algorithms for solving it.
- Apply Policy Search methods to large scale RL problems.
- Implement Learning Algorithms and use modern tools for quickly implementing learning algorithms.
- Apply support vector machines (SVMs) and understand the strengths and weaknesses of SVMs vis-a-vis NNs.
- Use Gaussian processes for combining simulation data with (costly) experimental data for prediction.

Lecture Topics (Tentative)

1. Week 1: Introduction to Machine learning; Refresher on Probability Theory.
2. Week 2: Perceptrons, Perceptron Learning, and Introduction to Neural Networks
3. Week 3: Backpropagation, Stochastic Gradient Descent, Recurrent Neural Networks (RNN).
4. Week 4: Convolution Neural Networks, Deep Networks.
5. Week 5: LSTM and Variations of RNN .
6. Week 6: Generative Adversarial Networks.
7. Week 7, 8: Markov Decision Processes and Reinforcement Learning.
8. Week 9: Value-function based Methods, Temporal Difference Learning.
9. Week 10: Policy Search.
10. Week 11: Deep Reinforcement Learning.
11. Week 12: Support Vector Machines.
12. Week 13, 14: Gaussian Processes.
13. Week 15: Wrap-up and Class Project Presentations.

Disability Support Services

Americans with Disabilities Act: If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Disability Support Services, ECC(Educational Communications Center) Building, Room 128, (631)632-6748. They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential. `http://studentaffairs.stonybrook.edu/dss/index.shtml`.

Academic Integrity Statement

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at `http://www.stonybrook.edu/uaa/academicjudiciary/`

Critical Incident Management

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Judicial Affairs any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures.