EGR 8311 Machine Learning For Engineers

Term:	Spring 2018
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Course Description

Objectives:

This course provides a broad introduction to techniques of machine learning (ML). Machine learning is a set of nature-inspired computational approaches to address complex real-world problems. Related concepts include Artificial Intelligence (AI) and computational intelligence (CI). These methods are especially well suited to solve very complex problems not easily solved by traditional methods that require accurate physics-based models. Although these methods have been used in a wide variety of applications, the emphasis in our course will be on application of these methods to engineering. The course will start with an introduction to the fundamental problems of machine learning. We will cover supervised as well as unsupervised learning approaches. Supervised learning machines consist of neural networks, decision tree and support vector machines. Unsupervised learning machines which will be covered in this course are principal and independent component analysis and self organizing maps. In addition, evolutionary computation methods and their application in optimization problems will be discussed. The course will discuss recent applications of ML to areas such as robotic control, data mining, autonomous navigation, and machinery and biomedical diagnostics.

Prerequisites:

The students are expected to have an adequate background in basic mathematics including differential equations and matrix theory. In addition, the assignments will require computer programming skills. Co-registering for ME 7000 would fulfil the requirements; if you cannot take that course, please seek the permission of the instructor with a complete description of your background in these areas.

Attendance Policy:

Attendance is required at all examinations which will be announced in advance. Make-up tests for excused absences from examinations must be arranged before the scheduled

examination time. It is strongly recommended that the students attend / review all the class sessions promptly. It is imperative that the students participate actively in the class sessions by asking and answering questions.

Grading:

Homework will be assigned every week and should be submitted promptly for grading and subsequent discussion. Solutions will be discussed in class. An individual term project will be required of each student. The project topic may be either selected by the student, with approval, or be specified by the instructor. It is initiated at the mid-term date and is due in the last class week. Each student is required to make an oral presentation on the term project in addition to submitting a written report.

The semester grade is based on the following relative weights (may change based on our discussions in class):

Homework	25%
Midterm	25%
Projects	50%

Grades:

F $<$ 65% C- $<$ 70% $<$ C $<$ 75% $<$ C+ $<$ 80%$<$ B- $<$ 82% $<$ B $<$ 85% $<$ B+ $<$ 87% $<$ A- $<$ 90% $<$ A

Text & References:

There is no required text. Some references are listed below.

1. Christopher M. Bishop, 2006, "Pattern Recognition and Machine Learning," Information Science and Statistics, Springer Verlag, ISBN 978-0387310732.
2. Christopher M. Bishop, 1996, "Neural Networks for Pattern Recognition," ISBN 978-0198538646.
3. Trevor Hastie, Robert Tibshirani, and Jerome Friedman, "The Elements of Statistical Learning: Data Mining, Inference, and Prediction," Second Edition, Springer Series in Statistics, ISBN 978-0387848570.
4. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein, 2009, "Introduction to Algorithms," Third Edition, ISBN 978-0262033848.
5. Stuart Russell and Peter Norvig, "Artificial Intelligence: A Modern Approach," 3rd Edition, ISBN 978-0136042594.

6. Simon Haykin, 2008, "Neural Networks and Learning Machines," Pearson Prentice-Hall, ISBN 978-0131471399.

7. Sergios Theodoridis and Konstantinos Koutroumbas, 2008, "Pattern Recognition," ISBN 978-1597492720.

Supplementary reading material:

Technical papers as appropriate will be placed online and will be required reading for the course.

Computer Software:

All students are required to learn to use MATLAB, an interactive scientific software which can be used for numerical analysis, matrix computation, and graphics.

Other Issues

Academic Integrity All assignments must be in accordance with the Villanova Code of Academic Conduct. Violations of the code of Academic Integrity and will be dealt with appropriately by the office of the Vice President for Academic Affairs. Responsibility for maintaining the code of academic integrity does not rest solely with the faculty. It is the responsibility of students to report violations to the code of academic integrity to the instructor.

It is the fervent hope of this instructor that the students come to this class motivated to learn the material. A final grade is only a partial reward; the real reward should be the understanding and intellectual stimulation I hope to instil in each of you. Hence, any cheating would be self-defeating. I am not responsible for policing and do not want to be diverted from my essential mission of teaching. However, if I discover any cheating I am required by university policy to report all instances to the VPAA; and the penalties are pretty severe. At that point, it will be out of my hands; please don't put me in that position.

Please see the last two pages for the Engineer's Code of Ethics.

Disabilities It is the policy of Villanova University to make reasonable academic accommodations for qualified individuals with disabilities. If you are a person with a disability (non-physical) please register with the Learning Support Office by contacting Learning.support.services@villanova.edu or 610-519-5176 as soon as possible. Registration is needed in order to receive accommodations. More information can be found at http://www1.villanova.edu/villanova/learningsupport.html.

The Office of Disability Services collaborates with students, faculty, staff, and community members to create diverse learning environments that are usable, equitable, inclusive and sustainable. The ODS provides Villanova University students with physical disabilities the necessary support to successfully complete their education and participate in activities available to all students. If you have a diagnosed disability and plan to utilize academic accommodations, please contact Gregory Hannah, advisor to students with disabilities at 610-519-3209 or visit the office on the second floor of the Connelly Center. More information can be found at http://www1.villanova.edu/villanova/studentlife/disabilityservices.html.

Syllabus:

Note that this list is tentative and can change based on class make-up and what we decide as a group.

- Introduction to machine learning
- Introduction to probability and statistics; Bayes Theorem
- Overview of matrix theory and optimization algorithms
- The least mean square algorithm and logistic regression
- MAP Estimation and Regularization
- Neural networks
  - Rosenblatt's Perceptron
  - Multilayer perceptron
  - The Back-Propagation algorithm
- Kernel methods and Radial basis functions
- Support vector machines
- Overview of nonlinear system theory
  - Fixed points and stability
  - Lyapunov theorem
  - Strange attractors
- Hopfield Network & Neurodynamics
- Data mining and decision trees
- Adaboost and similar combined classifiers
- Estimation theory for dynamical systems

  - Bayesian Filters
  - Kalman Filters
  - Extended Kalman Filters
  - Unscented Kalman Filters
  - Particle Filters
- Hidden Markov Models
- Applications to fault diagnostics
- Evolutionary computation
  - Genetic algorithm
  - Simulated annealing
  - Particle swarm optimization
- Combining with physics-based approaches

National Society of Professional Engineers®

Code of Ethics for Engineers

Preamble

Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct.

I. Fundamental Canons

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

II. Rules of Practice

1. Engineers shall hold paramount the safety, health, and welfare of the public.
   a. If engineers' judgment is overruled under circumstances that endanger life or property, they shall notify their employer or client and such other authority as may be appropriate.
   b. Engineers shall approve only those engineering documents that are in conformity with applicable standards.
   c. Engineers shall not reveal facts, data, or information without the prior consent of the client or employer except as authorized or required by law or this Code.
   d. Engineers shall not permit the use of their name or associate in business ventures with any person or firm that they believe is engaged in fraudulent or dishonest enterprise.
   e. Engineers shall not aid or abet the unlawful practice of engineering by a person or firm.
   f. Engineers having knowledge of any alleged violation of this Code shall report thereon to appropriate professional bodies and, when relevant, also to public authorities, and cooperate with the proper authorities in furnishing such information or assistance as may be required.
2. Engineers shall perform services only in the areas of their competence.
   a. Engineers shall undertake assignments only when qualified by education or experience in the specific technical fields involved.
   b. Engineers shall not affix their signatures to any plans or documents dealing with subject matter in which they lack competence, nor to any plan or document not prepared under their direction and control.
   c. Engineers may accept assignments and assume responsibility for coordination of an entire project and sign and seal the engineering documents for the entire project, provided that each technical segment is signed and sealed only by the qualified engineers who prepared the segment.
3. Engineers shall issue public statements only in an objective and truthful manner.
   a. Engineers shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, or testimony, which should bear the date indicating when it was current.
   b. Engineers may express publicly technical opinions that are founded upon knowledge of the facts and competence in the subject matter.
   c. Engineers shall issue no statements, criticisms, or arguments on technical matters that are inspired or paid for by interested parties, unless they have prefaced their comments by explicitly identifying the interested parties on whose behalf they are speaking, and by revealing the existence of any interest the engineers may have in the matters.
4. Engineers shall act for each employer or client as faithful agents or trustees.
   a. Engineers shall disclose all known or potential conflicts of interest that could influence or appear to influence their judgment or the quality of their services.
   b. Engineers shall not accept compensation, financial or otherwise, from more than one party for services on the same project, or for services pertaining to the same project, unless the circumstances are fully disclosed and agreed to by all interested parties.
   c. Engineers shall not solicit or accept financial or other valuable consideration, directly or indirectly, from outside agents in connection with the work for which they are responsible.
   d. Engineers in public service as members, advisors, or employees of a governmental or quasi-governmental body or department shall not participate in decisions with respect to services solicited or provided by them or their organizations in private or public engineering practice.
   e. Engineers shall not solicit or accept a contract from a governmental body on which a principal or officer of their organization serves as a member.
5. Engineers shall avoid deceptive acts.
   a. Engineers shall not falsify their qualifications or permit misrepresentation of their or their associates' qualifications. They shall not misrepresent or exaggerate their responsibility in or for the subject matter of prior assignments. Brochures or other presentations incident to the solicitation of employment shall not misrepresent pertinent facts concerning employers, employees, associates, joint venturers, or past accomplishments.
   b. Engineers shall not offer, give, solicit, or receive, either directly or indirectly, any contribution to influence the award of a contract by public authority, or which may be reasonably construed by the public as having the effect or intent of influencing the awarding of a contract. They shall not offer any gift or other valuable consideration in order to secure work. They shall not pay a commission, percentage, or brokerage fee in order to secure work, except to a bona fide employee or bona fide established commercial or marketing agencies retained by them.

III. Professional Obligations

1. Engineers shall be guided in all their relations by the highest standards of honesty and integrity.
   a. Engineers shall acknowledge their errors and shall not distort or alter the facts.
   b. Engineers shall advise their clients or employers when they believe a project will not be successful.
   c. Engineers shall not accept outside employment to the detriment of their regular work or interest. Before accepting any outside engineering employment, they will notify their employers.
   d. Engineers shall not attempt to attract an engineer from another employer by false or misleading pretenses.
   e. Engineers shall not promote their own interest at the expense of the dignity and integrity of the profession.
2. Engineers shall at all times strive to serve the public interest.
   a. Engineers are encouraged to participate in civic affairs; career guidance for youths; and work for the advancement of the safety, health, and well-being of their community.
   b. Engineers shall not complete, sign, or seal plans and/or specifications that are not in conformity with applicable engineering standards. If the client or employer insists on such unprofessional conduct, they shall notify the proper authorities and withdraw from further service on the project.
   c. Engineers are encouraged to extend public knowledge and appreciation of engineering and its achievements.
   d. Engineers are encouraged to adhere to the principles of sustainable development[1] in order to protect the environment for future generations.