**Machine Learning**

**Semester: August**

**Credits: 3**

**Objective:** The course introduces students from a variety of science and engineering backgrounds to the fundamentals of machine learning and prepares them to perform R&D involving machine learning techniques and applications. Students learn to design, implement, and evaluate intelligent systems incorporating models learned from data.

**Learning Outcomes**: Students, on successful completion of the course, will be able to

1. Formulate a practical data analysis and prediction problem as a machine learning problem.
2. Plan for data acquisition considering the characteristics of the data set required for a particular machine learning problem.
3. Train and test supervised regression and classification models, unsupervised learning and density estimation models, and reinforcement learning models.
4. Integrate a trained machine learning model into an online software system.

**Prerequisites:** None

**Course Outline**:

1. Introduction to Machine Learning
2. Supervised Learning
   1. Linear regression, logistic regression, and generalized linear models
   2. Generative probabilistic models
   3. Convex optimization and quadratic programming
   4. Support vector machines
   5. Decision trees and ensemble models
   6. Non-parametric methods
3. Neural Networks
   1. Perceptrons and inspiration from neuroscience
   2. Multilayer neural networks and backpropagation
   3. Optimization techniques, best practices, loss curve analysis
4. Learning Theory
   1. Bias-variance tradeoff
   2. Regularization, model selection, and feature selection
   3. Generalization bounds and VC dimension
5. Unsupervised Learning
   1. Clustering: k-means, Gaussian mixture models
   2. Principal components analysis
   3. Independent components analysis
   4. Autoencoders
6. Reinforcement Learning
   1. Markov decision processes and the Bellman equations
   2. Value iteration, policy iteration
   3. Q-learning

**Laboratory Session(s):**

1. Linear regression models
2. Logistic regression
3. Support vector classification
4. Decision trees
5. Single-layer and multi-layer neural networks
6. Multi-layer back-propagation, regularization, hyperparameter search
7. Model selection, feature selection
8. Clustering with k-means and GMMs
9. Principal components analysis and autoencoders
10. Value iteration and policy iteration
11. Q-learning
12. Deploying a machine learning model

**Learning Resources:**

Textbooks: No designated textbook, but class notes and handouts will be provided.

Reference Books:

Mitchell, T. (1997), *Machine Learning*, McGraw-Hill.

Bishop, C. (2006), *Pattern Recognition and Machine Learning*, Springer.

Goodfellow, I., Bengio, Y., and Courville, A. (2016), *Deep Learning*, MIT Press.

Hastie, T., Tibshirani, R., and Friedman, J. (2016), *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*, 2nd edition, Springer.

Sutton, R.S. and Barto, A.G. (2018), *Reinforcement Learning: An Introduction*, 2nd edition, MIT Press.

Journals and Magazines:

*IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)*

*Journal of Machine Learning Research (JMLR)*. Microtome

*Pattern Recognition*. Elsevier

*Neural Networks*. Elsevier

*IEEE Transactions on Knowledge and Data Engineering*

Others:

Proceedings of the *Advances in Neural Information Processing Systems (NeurIPS)* conference. Neural Information Systems Foundation, Inc.

Proceedings of the *International Conference on Machine Learning (ICML)*. International Machine Learning Society.

Lecture notes, posted online.

**Teaching and Learning Methods**:

1. **Use of online resources outside of class:** Students will be periodically assigned online video lectures prior to the face-to-face lecture.
2. **Lectures**
3. **In-class tutorials**: Tutorials on important data analysis and modeling tools will be given in class periodically.
4. **Laboratory sessions**: Students will be required to perform a series of exercises in data analysis and submit a lab report.
5. **Homework**: Several homework exercises requiring students to apply the knowledge acquired from lecture and discussion will be assigned and graded.
6. **Project**: Students will propose and execute a plan for a significant machine learning project in groups of 1-3. Students should formulate their data analysis problems independently under the guidance of the instructor, deploy a prototype, and make a formal present the results.

**Time Distribution and Study Load**:

* In-class lecture/discussion: 30 hours.
* Laboratory sessions: 30 hours.
* Tutorials: 30 hours.
* Self study: 65 hours.
* Homework: 35 hours.
* Project work: 35 hours.

**Evaluation Scheme:**

1. Term project: 25%
2. Homework and laboratory reports: 25%
3. Midterm examination: 20%
4. Final examination: 30%

A grade of “A” indicates excellent and insightful understanding of the key concepts and ability to implement sophisticated systems; “B” indicates a good understanding of the key concepts and ability to implement basic techniques; “C” indicates barely acceptable understanding and implementation ability; and “D” indicates poor understanding and implementation ability.