Introduction to Machine Learning

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This course is intended as an introduction to machine learning with a focus on its applications in economics and business. We will start with the fundamentals of machine learning and build from linear models to modern deep learning techniques.

The course will consist of 20 hours of lectures with occasional exercises and programming assignments. Students are expected to have a basic understanding of calculus, probability/statistics, and linear algebra.

You can find an overview of the course content below. (See the end of this document for a detailed syllabus.)

1. Machine learning fundamentals
    - Overfitting and underfitting
    - Bias variance tradeoff
    - Curse of dimensionality
    - Cross validation
    - No free lunch theorem
2. Supervised learning - Linear models
    - Linear regression
    - Regularization
    - Logistic Regression
3. Supervised learning - Tree based models
    - Decision trees
    - Random forests
4. Unsupervised learning
    - Principal components analysis
    - Clustering
    - Rule extraction/Basket analysis
5. Deep learning
    - Neural networks
    - Backpropagation algorithm
6. Putting it all together: Poverty prediction from satellite images
    - Transfer learning
    - Convolutional neural networks

Resources

Books

- James, Witten, Hastie, and Tibshirani. *An Introduction to Statistical Learning with Applications in R.*
    - Available free online: http://www-bcf.usc.edu/~gareth/ISL/
- Hastie, Tibshirani, and Friedman. *The Elements of Statistical Learning.*

    - Available free online: https://web.stanford.edu/~hastie/ElemStatLearn/
- Bishop C. *Pattern Recognition and Machine Learning.*
    - https://www.springer.com/gp/book/9780387310732
- Goodfellow, Bengio, Courville. Deep Learning.
    - Available free online: https://www.deeplearningbook.org/

Other

- Data Science: Machine Learning course by Harvard University on edx.
    - https://www.edx.org/course/data-science-machine-learning
- Prediction: Machine Learning and Statistics course at MIT Sloan School of Management.
    - https://ocw.mit.edu/courses/sloan-school-of-management/15-097-prediction-machine-learning-and-statistics-spring-2012/syllabus/
- STAT 422/722: Predictive Analytics course at the Wharton School.
    - https://github.com/kapelner/Wharton_Stat_422_722

Syllabus

1. Machine learning fundamentals I
    - AI vs. ML vs. Data Science vs. Business Analytics
    - Sample applications
    - Overview of the course
2. Machine learning fundamentals II
    - A motivating problem: Polynomial curve fitting
        - Overfitting and underfitting
        - Bias variance tradeoff
3. Machine learning fundamentals III
    - Another motivating problem: Nearest neighbor classification
        - Curse of dimensionality
        - Parametric vs. nonparametric methods
    - No free lunch theorem
4. Supervised learning - Linear models I
    - Supervised / Unsupervised / Reinforcement learning
    - Regression vs. Classification
    - Linear regression
5. Supervised learning - Linear models II
    - Regularization
        - l1 and l2 penalties
    - Cross validation
6. Supervised learning - Linear models III
    - Classification
    - Logistic Regression
    - A sample application

7. Supervised learning - Linear models IV
    - Solving logistic regression through gradient descent
    - Two perspectives on ML: probabilistic vs. function approximation (optimization) perspectives
    - Logistic regression: The probabilistic perspective
8. Supervised learning - Tree based models I
    - Decision trees
    - Regression trees
9. Supervised learning - Tree based models II
    - Classification trees
    - CART algorithm
10. Supervised learning - Tree based models III
    - Bagging
    - Random forests
    - Boosting
11. Unsupervised learning I
    - Dimensionality reduction
    - Principal components analysis
12. Unsupervised learning II
    - Clustering
    - K-means algorithm
    - The probabilistic perspective
        - Mixture of Gaussians
        - Soft K-means
13. Unsupervised learning III
    - Rule extraction/Basket analysis
    - Apriori algorithm
    - A sample application
14. Deep learning I
    - Neural networks
    - Fundamentals
    - A brief history
15. Deep learning II
    - Backpropagation algorithm
16. Deep learning III
    - Stochastic gradient descent
        - Improving gradient descent
            - Momentum
            - ADAM
    - Regularization
17. Deep learning IV
    - Types of neural networks
    - Convolutional neural networks
    - Modern deep learning frameworks

18. Application: Poverty prediction from satellite images
    - Putting it all together
        - Transfer learning
        - Convolutional networks
        - Mixture of Gaussians
        - Regularized least squares regression
19. Review
    - Wrap up and review
    - Free time for questions etc.