Foundation of Applied Machine Learning

Course: PHYS 243

Bahram Mobasher
Physics and Astronomy Department

Syllabus

Week 1: Background and Introduction, Historical Development of machine learning, Applications of Machine Learning, What we learn in this course, Python and R Programming- installation on Window or Mac platforms

Week 2: Basic linear algebra, Review of statistics and probability theory, Matrix formulation and calculation of least squares, Multivariate Calculus, Partial Derivative Gradients, Gradient Descent

Week 3: Multivariate statistics, Joint distributions, Mean vectors, variance-covariance matrices, Conditional distributions, marginal distributions, Multivariate normal distributions and their basic properties, probability theory

Week 4: Classifications, k nearest neighbors, logistic regressions, Naïve Bayes

Week 5: Case studies for different disciplines and applications of classification

Week 6: Regressions, linear, multiple and polynomial regressions; ridge regression; overfitting; regularization

Week 7: Case studies and applications of regressions

Week 8: Advanced topics in ML; cross-validation; Receiver Operating Characteristic (ROC) curves; P-R curves; PCR methods; Stochastic gradient decent

Week 9: Deep learning, neural nets, artificial neural Networks, Convolutional Neural Networks; Multi-layer Network; Back propagation; Deep Neural Network

Weel 10: Case studies and review

Definitions

Machine Learning (ML) can be defined as computational methods using experience to improve performance or to make accurate predictions.

Here experience means the past information available to the learner. This takes form of electronic data collected and made available for analysis. The quality and size of the data are crucial for the success of the predictions.

ML lies at the intersection between statistics and computer science. It is applied on many disciplines from history and literature to physics, engineering and biology.

Further Definitions

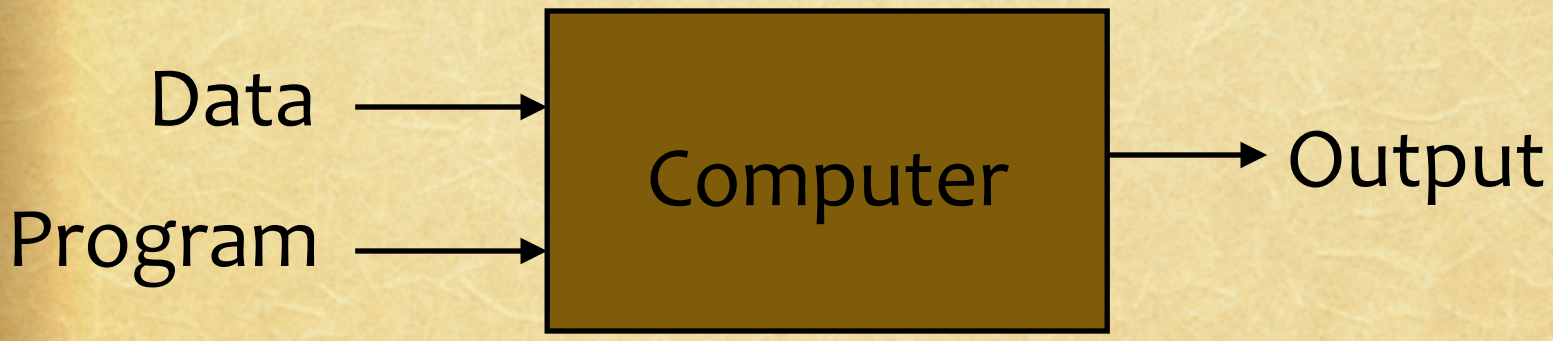
ML consists of designing efficient and accurate prediction algorithms. It involves the algorithms used to extract useful information from data. ML looks for patterns in the data and turns data into information.

ML is a set of methods that can automatically detect patterns in data then perform decision making or predict future developments.

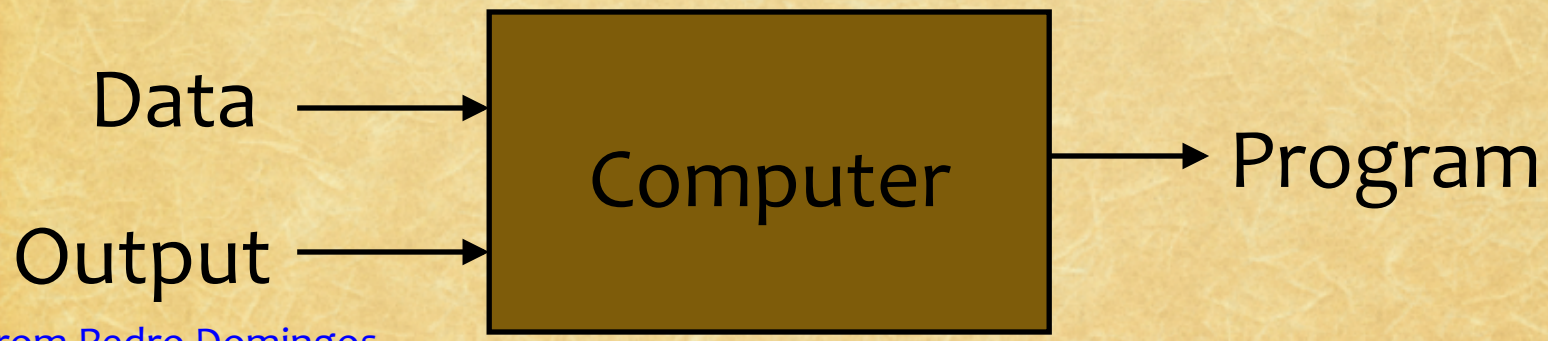
Machine learning is a branch of artificial intelligence that allows computer systems to learn directly from examples, data, and experience. Through enabling computers to perform specific tasks intelligently, machine learning systems can carry out complex processes by learning from data, rather than following pre-programmed rules.

Royal Society Report on Machine Learning

Traditional Programming



Machine Learning



Slide from Pedro Domingos

Recent years have seen exciting advances in machine learning, which have raised its capabilities across a suite of applications. Increasing data availability has allowed machine learning systems to be trained on a large pool of examples, while increasing computer processing power has supported the analytical capabilities of these systems.

Machine Learning: A History

This all started in 1959 when Arthur Samuel first defined ML as "a field of study that gives computers the ability to learn without being explicitly programmed".

Tom Mitchell provided an analytic definition: "A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E".

As a scientific field ML grew out of Artificial Intelligence (AI). Some researchers were interested in having machines learn from the data. This was termed "neural networks". These were mainly perceptron that were found to be generalized linear models of statistics. Between 1980s and 1990s ML based on statistics was out of favor with the researchers invented back propagation.

ML flourished during 1990s by changing its goals from AI to problems of practical nature. It started to use methods from statistics and probability theory. It benefited from availability of digitized data.

ML vs. Data Mining:

ML and data mining often use the same methods. They can be distinguished as follows:

ML focuses on prediction based on known properties learned from training data. Data mining focuses on discovery of unknown properties in the data. Data mining uses many ML techniques but for a different goal. ML uses data mining methods as unsupervised learning or as a step to improve

ML and Algorithm Properties

In ML one needs the notion of sample complexity to evaluate the sample size required for the algorithm to learn a family of concepts.

The success of a learning algorithm depends on the data used. Therefore, ML is inherently related to data analysis and statistics. Broadly speaking, learning techniques are data-d combining fundamental concepts in computer science with ideas from statistics, probability and optimization. r

Applications of ML

ML techniques have been successfully used in a diverse range of disciplines Including:

- Text or document classification
- Language processing (e.g. morphological analysis, statistical parsing)
- Optical character recognition
- Computational; biology (e.g. protein function or structure prediction, computer vision)
- Fraud detection and network intrusion.
- Medical diagnosis
- Search engines, information extraction systems
- Quantitative Finance