Machine Learning (CS 582): Brief Overview

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1. What is Machine Learning (Ml)?

Machine learning (ML) provides computers the ability to learn without being explicitly programmed. Machine learning focuses on the development of computer programs that can teach themselves to grow, reconfigure and change when exposed to new data.

Traditional Programming*:* Data and program is run on the computer to produce the output.

Machine Learning*:* Data and desired output (from ML if unsupervised learning is used) is run on the computer to create a program. This program can be used in traditional programming.

2. Why Machine Learning?

Computers and Internet have changed our lives and society in a significant way. Programming is the key of this process. Thus, improving "how to program" computers is an exciting growing area of Computer Science.

Programming involves writing the procedure as well as manipulating the data. Accordingly, improving "how to program" means improving both of these aspects. And "automation" is a very important element of this process. **ML addresses this automation part.** In today's data dominated world, automation emphasizes more on the data side. [Note that writing a program by a programmer is a sort of automation. Looking from this particular aspect, ML means "automating the process of automation"].

We have many good algorithms for problems where data do not change the algorithm or procedure (of course, data change the result) – for example, finding minimum, maximum, or average of a set of numbers. However, for many applications data need to change the procedure itself or some parameters of it, or derive (learn) the relationship between inputs and outputs (i.e. discover the hidden dynamics of the system) – for example in Modeling or Regression, Classification and Clustering. How do we write algorithms that can result highly accurate Spam filter, identify a fraud transaction, recognize a picture, produce accurate speech recognition / handwriting recognition, or machine translation system? These are all good examples of applications where data need to change the algorithm itself directly or via some parameters or hidden dynamics of the system needs to be derived i.e. algorithms needs to be automatically created (e.g. learning algorithms to drive a car i.e. auto-driving of vehicles). This means that we need to have a mechanism that can extract the meaning of the data and accordingly make appropriate changes or create new programs to ensure good results. Traditional algorithms either cannot address such problems (especially at large scale) or can address some of them but not with acceptable accuracy (e.g. a Rule based approach will have combinatorial explosion and rule management will be a nightmare; a statistical approach may not have a good generalization capability). The key reason is the fact that the nature of the data has strong influence on the algorithm to yield accurate results, and human experience

is not adequate to model such large complex data. ML algorithms can successfully address this issue and automate the process yielding reasonably accurate results for many applications.

3. How Machine Learning Works?

ML basically tries to learn the meaning of the data by looking into some key properties of the data.

ML algorithms are designed to use such properties of a *large training data set* to complete the learning process. Good learning is ensured by minimizing a good objective function (e.g. minimizing error between actual output and desired results in case of supervised learning – see next paragraph) using an iterative approach. After training is completed, an ML system can predict good results when some *new unseen data are presented*, typically for good modeling, classification or clustering. Since good learning is the key, appropriate data need to be used to maximize the learning, result and the performance.

There are various types of ML algorithms which can be broadly classified as "supervised", "unsupervised", "reinforcement" and "evolutionary". Some mostly popular algorithms are Probabilistic Learning, Neural Networks, Support Vector Machines, Genetic Algorithms, Vector Quantization and Hidden Markov Model.

[See Course Description for details]

4. Relationship of ML to Big Data & Data Science

With the rapid growth of data, we are already getting two exa bytes of new data per day (exa byte is 210^18 bytes, the so *called Big Data*), and hence the need for **ML has become essential** as human cannot extract meaning of such a huge data. Besides, the nature of the data has also become very complex (e.g. we have multi-media data with numbers, texts, audios, images..). Thus, the process of understanding the data has become a new field, so called Data Science (even though Data Science and Big Data are not same, these terms are used interchangeably quite often). ML is the key for Data Science and Big Data to extract the meaning of the data & the associated world, and use the meaning to do further processing.

5. Major Applications

ML driven applications have become in the fore front. It includes Software Engineering, Internet, Healthcare, Financing, Engineering, Automotive Industry, Physics, Biology, Bioinformatics, Meteorology, Economics, Education and many more.

Search Engine companies are using ML to predict what word(s) you will type next in the search field, and also to improve the search results. Financing industry is using it for fraud detection, approving or not approving a loan or credit card application, predicting stock price. Automotive companies are using it for driverless cars, increasing fuel efficiency, antiskid braking, and diagnostic systems. Oil companies are using it in their oil exploration process, the size of the oil reserve and the like. Governments are using it in various ways - identification of important trends and subtle yet complex patterns generate the most relevant and high impact information. This information detects and prevents fraudulent transactions, provide efficient, effective public services and help public officials to make informed decisions. Analysis of data helps in detecting illegal activities such as money laundering, criminal activities, trade of counterfeit items or spread of terrorism. Businesses use ML to gather fresh business insights, especially via BI (Business

Analytics) and taking appropriate actions – improving business process, improving customer support, making more accurate prediction for sales and the like.

6. How ML Relates to Your Future?

No matter which industry and which company you join, you will be working as a Computer Scientist. This means that you will look into some existing or new problems, develop / refine architectures and algorithms for such problems, implement these using some programming languages and test your algorithms and codes. You may also get involved with the software engineering – improving the process (e.g. Automating the process of mapping the requirement specification to design model. Existing methods use a complex manual process that use the knowledge from the requirement specification/modeling and the design, and try to find a good match between them) or tools. You may also do some software related management (usually after spending some time). You may or may not use ML for the initial problems you will deal with – depending on which company you join and what project you will work on.

However, joining a company is the first step. The next step is how do you grow. It depends on various things including your vision, leadership, performance, company's need and the like. **Many companies are already involved with ML.** In the near future many more companies will be involved with ML, Big Data, Natural Language Processing and Artificial Intelligence (AI). So, **you can use your ML and Big Data angle to lead and grow faster.**

ML is well related to other courses you are taking - like WAP, WAA, EA, S/W Engg., and Algorithms. Many Web applications are already using complex Big Data and ML (e.g. Facebook, Amazon, Google, Microsoft). How does **Amazon predict** which of their products will be sold more, or how can **Amazon lower the prices** of a set of items to increase their net profit for those products? Or what type of social interactions are **more prominent on Facebook** and **how Facebook can put** associated ad to such population group to increase their ad revenue from such group? Or how **Priceline dynamically changes** ticket prices to maximize its profits? Or **how a company can understand customer's comments** and improve its Customer Support function? All these applications would need ML, Big Data and Natural Language Processing algorithms. And for this an **Intelligent Agent** is needed which needs to be programmed with existing / refined architectures, design patterns, frameworks and programming languages, e.g. MVC, Spring / RoR, Java / Ruby. For ML, you will probably be using Python and R. You will also use various ML tools and frameworks.

Thus, with ML, Data Science and Big Data, you can more efficiently use your other knowledge from all other key courses to make you more attractive to a broader range of industries / companies; increase your chance to get jobs faster; get more salary; expedite your career growth; enable yourself to become an entrepreneur & innovator, and help start your own companies in future as ML, Big Data, AI & Natural Language Processing are hot areas; and expedite your growth in the industry and life while contributing to the world helping development, prosperity and peace.