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Machine Learning Techniques for Mobile Devices: A Review

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Abstract
Machine learning in a very broad sense denotes the acquisition of knowledge, skill and understanding by machine from guidance, experience or reflection. Machine learning is the study of computer algorithms, applying these algorithms machines improve automatically with experience. In other words it is the ability of the computer or mobile program to acquire or develop new knowledge or skills from examples for optimizing the performance. It is an emerging technology that helps in the discovery of rules and patterns in datasets. This field has evolved from the field of Artificial Intelligence, which aims to imitate intelligent abilities of humans by machines. The advent of Mobile technology has fostered development of Machine learning. This paper presents a review on machine learning and presents a brief study on different machine learning techniques along with their applications on mobile devices. It also presents an overview of performance related parameters of machine learning techniques useful for mobile devices.

Keywords Mobile phones; CART, Bluetooth, ANN, GSM, k-NN, Mobile computers, Mobile Intelligent System, PDA, Pocket PC, Wireless networks, 3G+.

I. INTRODUCTION

The field of Machine learning has developed from the field of Artificial Intelligence that aims to follow intelligent capabilities of humans by machines. Mitchell [2] accentuates machine learning as a study of algorithms in computer science that perform better with experience. In other words it implies computer programs use their past experience of problem solving tasks to improve their performance. But description does not include the concept of acquisition of knowledge for the stated computer programs. Alpaydin [3] defines Machine learning as "the capability of the computer program to acquire or develop new knowledge or skills from existing or non-existing examples for the sake of optimizing performance criterion". The stream of Machine Learning has shown potential growth since last 50 years. Alpaydin [3] states the two important factors for growth in this field are elimination of tedious human effort and reduction of cost. Machine Learning techniques when applied to different fields as Medical diagnosis, Bioinformatics, Speech and handwriting recognition, Natural Language Processing, Game playing, Efficient search engine design, Mobile SMS classification, Mobile learning , Web document classification, Classifying DNA sequences, , object identification in Computer vision, Robot Locomotion, Stock Market Analysis, detecting credit card fraud in financial institutions have proved to work with large amounts of data and generate results in a matter of seconds. Thus, machine learning algorithms work better in improving the efficiency and accuracy of intelligent decisions making process by intelligent computer programmes. Machine learning techniques have also proved efficient for mobile devices such as Smartcards, Smartphones, Sensors, handheld and automotive computing systems [20]. Mobile Technology has fostered development in recent years with the help of increasing mobile terminals (e.g. mobile phones, Pocket PC, PDA, mobile computers) and mobile networks (wireless networks, Bluetooth, GSM, 3G+ etc.). Machine learning techniques like Naïve Bayesian, C4.5, Decision trees etc are helpful for mobile devices. Some important machine learning applications for mobile devices include Sensor based activity recognition, Mobile text categorization, Malware detection on mobile devices, Language understanding etc. But traditional machine learning approaches have some limitation:

a) A mobile device has limited computational and memory capacity which restricts the application of machine learning algorithms that work with large data set.
b) A mobile learning environment exhibits concept drift, for e.g. the concept being learned changes as the user's mode of operation changes.
c) A user's intolerance of any hindrance that machine learning techniques may introduce in the normal mobile phone operation.
d) Therefore, a study of different machine learning techniques on different parameters is of much importance in order to pave a way for future works in this direction.

II. TYPES OF MACHINE LEARNING

Machine learning can be categorized into major groups as supervised, unsupervised machine learning and reinforcement learning as shown in Fig. 1. These groups represent how the learning method works.

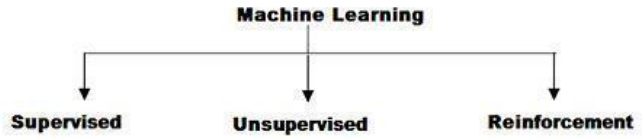

Figure 1. Machine learning types

Supervised learning

It consists of algorithms that reason or learn from externally supplied instances to result in a general hypothesis that makes prediction about future instances [1].

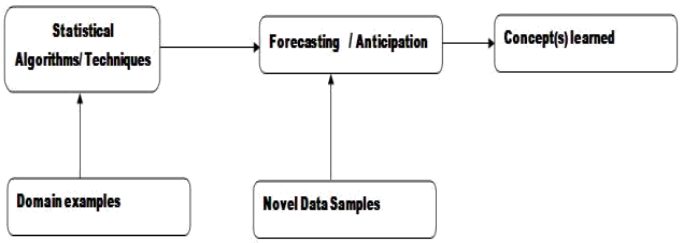

Figure 2. Supervised Machine Learning

This type of learning works with examples. In other words machine is supplied with some training examples to learn the given function. Hence machine learns the given function and it is capable to work for extrapolated examples as well. In this type of learning machine develops the capability to forecast or learn new concept or given hypothesis on the basis of examples that are provided. There exists an outcome or output variable to guide the process of learning. There are many supervised learning algorithms as decision trees, K-Nearest Neighbor (KNN), Support Vector Machines (SVM) and Random Forests [4].

Unsupervised learning

In Supervised learning there is an outcome or output variable to guide the learning process whereas unsupervised learning works with models without predefined classes or examples [5].

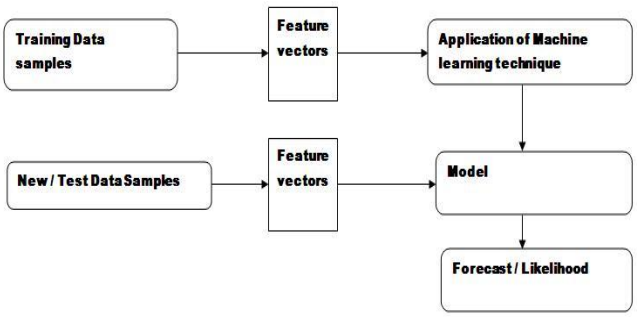

Figure 3. Unsupervised Machine Learning

In this category there is no supervisor available and learning depends upon the guidance obtained heuristically by the system testing different data samples or environment. This type of learning makes use of training samples as well as testing samples with their feature vectors to make prediction.

Reinforcement learning

The machine communicates with its surroundings by producing certain actions in reinforcement learning. These actions result in affecting the state of the environment, which ultimately result in the machine receiving some scalar rewards (or punishments).In other words the agent/machine receives some evaluation of actions such as a scalar reward or punishment from its surroundings.

Figure 4. Reinforcement Learning

In this category the goal of machine is to learn to act in such a way that maximizes the future rewards it receives (or minimizes the punishments) over its lifetime. This learning is related to decision theory (in statistics and management science) and control theory (in engineering).

III. MACHINE LEARNING ALGORITHMS

There are various machine learning algorithms depending upon the domain of their application [1]. The following Machine learning algorithms are considered to give readers a basic understanding of machine learning algorithms.

A. Decision Tree

A decision tree is a classifier that works with recursive partition of the instance space. It is used to represent a supervised learning approach. It is a simple graphical model where non-terminal nodes represent tests on one or more attributes and terminal nodes give decision outcomes. This tree consists of one root, branches, internal nodes and leaves. Each node corresponds with a certain feature or characteristic or feature and the branches correspond with a range of values or decision outcomes. A decision tree works with local regions that are identified in a series of recursive splits in a smaller number of steps that implements divide and conquer paradigm. It is used in classification and regression related tasks [3]. A decision tree works with input data and uses decision rules for future predictions. Decision trees work with rules that are well understood by humans and used in knowledge system such as database. The strengths of using decision tree learning include

a) It works with understandable rules.
b) It performs classification without much of tedious computation.

c) It works well with categorical variables.
d) It provides clear classification and traces fields important for prediction or classification.

The limitations of using decision tree learning are

a. This learning tool is not suitable for prediction of continuous attribute.
b. It does not perform well with multiple classes and small data.
c. Training decision tree is computationally expensive.

B. k-Nearest Neighbor (k-NN)

This is also known as k-NN or Instance Based learning which a type of supervised learning algorithm. k-NN works by simply storing in memory current training dataset, when a new query is fired, a set of related instances that show resemblance or neighbors are retrieved from memory. These instances are further used for classification of new instance [2]. k-NN considers more than one neighbor at a time while classifying hence it is known as K-Nearest Neighbor. This nearest neighbor is determined in terms of Euclidean distance which measures the dissimilarities between examples represented as vector inputs and some related measures.

C. Case Based Reasoning

Case based reasoning is a popular technique by which we solve new problems by making use of the solutions for the problems solved earlier. This technique takes the instances of solutions from the problems solved earlier and tries to solve step by step new problems by using these cases. Each solution available is termed as a case [8]. A new case is defined by the initial description of the problem. A case is picked up from a set of past cases and this case is then combined with the new case through reuse strategy resulting into the solved case. This solved case becomes a sample solution to the defined problem. When this solution is known, it is implemented practically to the real world problems and therefore it is tested. This testing process is termed as revision of the problem. The process of retaining starts after testing process. In retain process important experience is retained for reusing it in future and case base is enhanced by a newly learned case or by updating of some existing cases.

D. Artificial Neural Network (ANN)

ANN is based on Biological nervous system. Artificial Neural Networks models consists of nonlinear computational components or processing units that work in parallel and are arranged in patterns resembling biological Neural Networks [7]. These Computational components or nodes are connected via links that have weights. A set of data (input-output pairs) is used for training the Neural Network. After the network has been trained it can be given any input data (should be from the input space that is to be approximated) and results in an output, which would corresponds to the expected output from the approximated mapping [8].Single-layer ANN or Perceptrons work with algorithms like Gaussian maximum-likelihood classifiers. A multi layer ANN is used for better decision making in a variety of problems like disease diagnosis, to test oracle, project effort and cost estimation, text identification and hand writing recognition problems etc.

E. Classification and Regression Trees (CART)

It is a well known technique because it requires less input data for further analysis. This is the greatest advantage of this technique as compared to other learning techniques which require extensive input, detailed examination of intermediate results and explanation of results are required [8]. CART makes use of classification and regression trees for estimating categorical predictor variables (classification) and continuous dependent variables (regression). This technique is useful in solving either regression type problems or classification type problems. CART analysis is basically designs a tree, which is different from other conventional data analysis methods. It is a process of designing a tree and finally selecting an optimal tree that fits the required information.

F. Support Vector Machine (SVM)

It is a machine learning technique proposed by Vladimir Vapnik and colleagues at AT&T Bell laboratories in 1992. It is the state of art in machine learning techniques. Support Vector Machines work on decision planes or hyper planes that define decision boundaries. A decision plane is a plane that separates a set of objects having different class memberships. SVM uses a set of supervised learning methods. SVMs perform wonderful in bioinformatics in DNA sequencing and modeling protein structure. SVM learning is used for data analysis and patterns identification that are useful for classification and regression analysis. SVMs make use of a (nonlinear) mapping function (Φ) that transforms input data space to data in feature space in such a way as to make a problem linearly separable. SVMs are used tremendously as they stand on a good theoretical base and are also applicable in real world applications. There are two categories of software that provide SVM training algorithms. The first category is specialized software whose prime objective is to have an SVM solver. LIBSVM [6] and SVM^{light} [6] are two popular software of SVM for this category. The other category of software is machine-learning libraries that provide a variety of classification methods and other facilities such as methods for feature selection, preprocessing etc.

G. Rule Induction

It is widely used machine learning technique and easy as rules are simple to frame and interpret than a regression paradigm or a trained Artificial

Neural Network. It works on condition-action rules, decision trees or same kind of knowledge structures. In this technique the performance portion orders the instances underneath the branches of a decision tree or finds the first rule whose conditions match the instance, making use of an all-or-none match process [8]. This technique makes use of greedy search method. Propositional learning and Relational learning [8] are two ways of rule induction-.

H. Genetic Algorithms and Genetic Programming

These are a type of evolutionary computing models that are used for problem solving and work on the principle of biological evolution like natural selection. Genetic algorithms have concepts of genes, chromosomes and population. These models are based on the Darwin theory "the survival of the fittest" relying on the fitness function where the best solutions are selected from a set of individuals. The individuals that are found fit have good chance of their selection. Once selection process concludes, new individuals have to be formed. The process of crossover or mutation forms the new individuals. In crossover process, a combination of the genetic makeup of the two solution candidates results in creation of new individuals. In mutation process, some randomly chosen portions of genetic information are varied to obtain a new individual. This process of generation of individuals does not complete till one of the conditions such as minimum criteria is fulfilled or the desired level of fitness is achieved or a specific number of generations are attained or any of the combinations above is reached [9].

I . Random Forest

Random forests models are used for classification purpose. Random forests are a combination of tree forecasters such that every tree depends upon the values of an independently sampled random vector where same distribution is used for all trees in the forest. This technique consists of generating a set of trees that vote for the most prevalent class. There are two important characteristics of using Random forests. The first characteristic is that the generalization error converges with the increase in number of trees increases and second characteristic is that this type of learning does not suffer from over fitting [10].

IV. MACHINE LEARNING TECHNIQUES FOR MOBILE DEVICES: A STUDY

Machine learning techniques are useful for mobile devices. XPod Mobile MP3 player was developed by Sandor et al. [11]. XPod automated song selection process as per user interest or liking. This system successfully played contextually music as per user's choice using machine learning techniques. SVMs suited the best for different tasks of mobile music player as to begin with SVMs very less training data. This is an interesting feature from the point of view of user because a mobile user spends very less time in system setting and more time in enjoying the benefits. But designing SVMs on a constrained device is a tedious task. SVMs can be designed easily on an unconstrained device such as a Personal Computer or a laptop and then be transferred to a portable device. In this way a constrained device can evaluate an SVM. Whereas decision trees are classifiers that can be properly converted into a rule set that can be further evaluated. The performance of Decision trees can be improved with boosting strategy. Unsupervised Machine learning techniques are useful in data mining domain [12]. Machine learning techniques are also helpful in network management and surveillance domains [13]. Machine learning techniques like reinforcement learning and instance-based learning perform better in mobile devices. These techniques are also useful for mobile music platform for different categories of music expressions [15]. Soar cognitive architecture is efficient to assist for mobile music interactions. Mobile learning is a novel and useful form of learning as it has all the strengths of e-learning and bridges the gap of time and space in classroom learning [16]. To enhance English learning [16] presented a Personalized Intelligent Mobile Learning System (PIMS). PIMS advised English news articles or readings to the readers as per the reading habits and abilities [16] of reader. PIMS used fuzzy item response theory. PIMS was implemented successfully on Personal Digital Assistant (PDA) to furnish personalized mobile learning for improving the reading ability of readers. PIMS also enriched English vocabulary of learners. The advancement of mobile technologies and efficient access to multimedia resources are important contributions that led to development of mobile learning systems [17]. A mobile learning system using existing web resources was designed that resulted in learning material as per the requirements of user in [17]. Mobile agents are agents that traverse in a network from one host to other for successful completion of different tasks [18]. A mobile agent is an intelligent decision maker concerning its itinerary and updates the decision(s) as per the available information as it traverses from one host to another [18]. Machine learning classification techniques like Naïve Bayesian and ANN are useful for document classification and efficient retrieval [18] for mobile agents. Mobile devices offer a wide range of services above several wireless network access technologies [19]. Mobile devices are prune to threats and machine learning techniques like K-Nearest Neighbor, Bayesian Networks, Random Forests are useful in intrusion detection for mobile devices [19]. Machine learning techniques are efficient for mobile devices in several ways. Mobile learning applications include language translation, game playing, intelligent agents etc. An architecture for designing an Intelligent System on mobile device was discussed by Jawad et al. [21]. This design makes use of sensor networks.

The success of any mobile intelligent system depends upon the performance of learning techniques implemented on mobile devices. The performance criteria of any machine learning algorithm depend upon its Prediction accuracy, Sensitivity and Specificity [14]. The Prediction accuracy is a measure of accuracy of prediction or classification. The sensitivity of an algorithm is a measure of how an algorithm classifies correctly the positive instances [14]. The Specificity is a measure of performance of an algorithm in classifying the negative instances. Performance can be improved by good prediction accuracy and good sensitivity. Hence, the choice of most appropriate algorithm plays a vital role designing mobile learning applications.

V. CONCLUSION

This paper presents a review of machine learning techniques. It emphasizes that each machine learning technique has some strengths and weaknesses. It gives brief study of recent areas of applications of machine learning techniques for mobile devices. It also presents some performance measures for a machine learning algorithms. It is somewhat not an easy task directly to state that one learning technique performs better than the other one. However the performance of a machine learning technique greatly depends on the application domain and the requirement. Recent advances in Mobile technologies are the areas of application of machine-learning techniques.

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