Survey Paper: Comparative Study of Machine Learning Techniques and its Recent Applications

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***Abstract*— The main objective of human evolution has always been to look for ways to mold the nature to satisfy our needs. A key milestone in this regard is the invention of a machine – called the computer that can complete a task given to it in fraction of time taken by an average human. While that sounds great, the only drawback is that the decision must still be taken by a man who is bound by limitations of the human body. The run to reap the complete benefits has given rise to what is called the Artificial Intelligence. Machine learning is a part of AI, which deals with imparting knowledge to the computer through various related examples. Throughout the years, various machine learning algorithms have been developed each with their own merits and demerits. This paper is a consolidated effort to bring together different ML algorithms like linear regression, KNN (k- nearest neighbours) etc. This research paper discusses the most recent developments in these areas of study and tries to define the best applications for each of those based on previous researches.**

***Keywords:* Applications of Machine Learning Algorithms, KNN, Linear Regression, Deep Learning, SVM, RF, Activation functions**

I. INTRODUCTION

Artificial Intelligence, or AI in short, is the branch of computer science that deals with building machines that are able to make decisions to solve small problems that may arise in the course of completing a much larger task. An important and trending branch of AI is Machine Learning which specifically deals with improving the capability of the system through experience and by the use of data, called the training data. Training data, as the name suggests is a large dataset of examples that helps the system draw certain conclusions based on which it can make decisions.

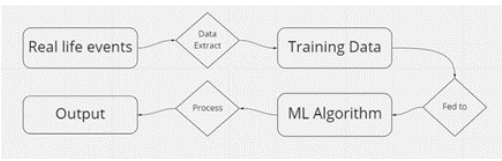

Figure 1: Basic Machine Learning Architecture

Machine Learning is categorized as follows, namely –

- Supervised Learning
- Unsupervised Learning
- Reinforcement Learning
- Deep Learning

These differ in the type of input provided and consecutively in the way data is processed.

A. *Supervised Learning*

The main aim of supervised learning is to understand a relationship between a set of inputs and a set of outputs. As long as the relationship holds true, the algorithm will be able to make output predictions for new input data. For example, the inputs could be profit of a company in the financial year and outputs be the net change in the stock price of the company. For this example, new inputs of profit of a company can be fed and the system will output a prediction for the net change in stock price.

There are 2 main sub divisions to Supervised Learning are

- **Classification:** It uses similar data points of the input data to group them into different classes. These approaches find the best way to make the separate the data points and assign them certain class.
- **Regression:** The major difference between classification and regression approaches is the output. While classification approach classifies and outputs the class, regression outputs a number.

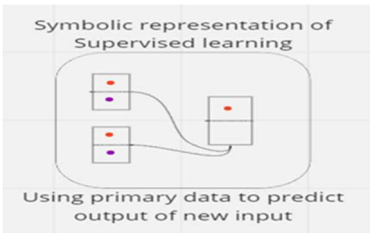

Figure 2: Supervised learning symbolic representation

B. *Unsupervised Learning*

Unlike supervised learning, unsupervised learning accepts un-labelled data and tries to identify similarities in the

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dataset. Based on the features obtained, it then groups the data.

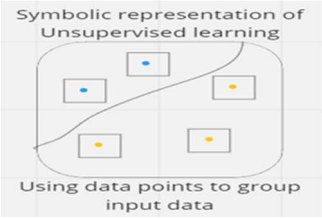

Figure 3: Unsupervised Learning symbolic representation

C. *Reinforcement Learning*

This model is about the algorithm finding the best way to achieve the reward (the desired output state) from the given input state. The training part is different from supervised learning because the algorithm is learning from its own experience rather than from a given set of inputs that have the relationship attached to them. In the absence of a training dataset, the algorithm is bound to learn from its experience.

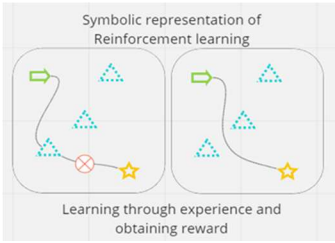

Figure 4: Reinforcement Learning symbolic representation

D. *Deep Learning*

Deep learning is part of machine learning. Input layer, hidden layer and output layer structure is followed in deep learning.

II. BACKGROUND

Earlier, we discuss types of Machine learning Algorithm [1]

1. ***Supervised Learning***: It is task driven and has well defined goals. Target variable is available.
2. ***Unsupervised Learning***: It is data driven and outcome is based only on input. Target variable or dependent variable is not available or known.
3. ***Reinforcement learning***: It is based on heuristic method, dynamic programming approach, Learns from mistakes (Playing Games). Initial state and Goal state are defined.
4. ***Deep Learning (DL)***: DL is based on ANN principle and inspired by neurobiology concept. DL models are efficient and widely used for classification and prediction task.

A. *Types of Supervised Learning*

a. ***Regression***: It is based on Continuous target variable, Methods used for classification task is listed as Linear Regression, Decision Tree Regression, Random Forest, KNN Model, Support Vector Machines.

b. ***Classification***: It is based on categorical target variable. Methods used under classification task is listed as Logistic Regression, Naïve Bayes, Stochastic Gradient Descent, KNN, SVM, Decision tree, Random Forest.

i. Linear Regression

Linear Regression is one of the most commonly used statistical technique. It is applied on a data set to determine the correlations between the considered variables, and to predict results on the basis of the relation. The model is expressed as

$$Y = a + b_1X_1 + b_2X_2 + \cdots \qquad (1)$$

where Y is the dependent variable, a is the intercept, b is the slope and X is the independent variable.

This model is easy to implement and is space efficient, however it is only applicable if there exists a linear solution. This model also assumes that the variance is input errors (residuals) is fairly constant and that the inputs are mutually independent.

ii. Logistic Regression

Logistic regression is a supervised algorithm used for classification problems. Even though its name suggests otherwise, it is not a regression model. The simplest logistic regression deals with binary classes, however, it can be extended to multiple classes [3]. It can also be described as transformation of linear regression with the help of a logistic function. Sigmoid function is used most commonly.

$$z = a + b_1X_1 + b_2X_2 + \quad \ldots (2)$$

$$Y(X) = g(z) \quad \ldots (3)$$

$$g(z) = \frac{1}{1+e^{-z}} \quad \ldots (4)$$

It is an easy, simple and fast classification method. The loss function is always convex. This can only be applied on linear classification problems.

iii. K-Nearest Neighbours

K-nearest neighbours is a non-parametric method used for classification and regression. It essentially depends on the assumption that is the basis of all predictions: that observations with similar circumstances will have similar results. The data is arranged in n-dimensional space based on some feature. When new data is provided to the algorithm, it assigns a class to new data determined by the classes of its k nearest neighbours.

In KNN classification, plurality is checked on the k nearest data points whereas in KNN regression, mean of the data points is considered. It is a lazy learning model and is simple to implement. It has fewer hyper parameters to be tuned. Although the computation cost is high during runtime because of the large sample size.

iv. SVM

Support Vector Machine is another supervised ML technique that is capable of solving both regression and classification problems. It can support both linear and non-linear problems

[5]. In SVM, there are two marginal line parallel to hyper plane, one passes through nearest positive points and other passes through nearest –ve points. The main aim of this supervised method is to maximize the marginal distance .It separates data in multidimensional space using kernel functions.

SVM uses kernel tricks to solve even complex problem. SVM Kernel convert 2D (low dimension data) into 3D or higher dimension. It is also able to always achieve global minima by using a convex optimization function. It has longer training times for larger data sets. Also the hyper parameters and kernel needs to carefully tuned to get accurate results.

v. Decision Tree

Decision tree is a tree based algorithm and it can be used to determine regression and classification problems. It is in form of an inverted tree where the data is split based on different conditions. Decision trees classify the examples by sorting them down the tree from the root to some leaf node, with the leaf node providing the classification to the example. Each node in the tree acts as a test case for some attribute, and each edge descending from that node corresponds to one of the possible answers to the test case. This process is recursive in nature and is repeated for every subtree rooted at the new nodes.

Decision Tree does not require preprocessed data and is able to efficiently handle collinearity. It also does not make any assumptions on the data distribution. A drawback is that the tree may grow to be very complex while handling complicated datasets. It also might lose valuable information while dealing with continuous variables.

vi. Random Forest

Random Forest is an evolved form of decision trees. It is a "bagging-type" collection (ensemble) model where multiple decision trees are combined and the average/majority decision of the trees is considered the final result of the Random Forest model.

Random Forest is an accurate and robust model and is able to handle over fitting better than other models. It also supports implicit feature selection and derives feature importance. However, it does become computationally complex and slower as the forest size increases. It's not well descriptive model over the prediction.

B. Types of Unsupervised Learning

a. ***Clustering*****:** Group of similar type of data from dataset is put into cluster. Algorithms utilized as clustering task are listed as K-means, Nature inspired Meta heuristic Algorithm such as PSO, WOA, SSA, MFO, SCA, BAT, Firefly, ACO, etc.

b. ***Dimension Reduction*****:** Principal component analysis is utilized to find the best features by dimension reduction concept.

C. Types of Reinforcement Learning

a. ***Positive***: It is defined as an event that occurs because of specific behavior. It increases the strength and the frequency of the behavior and impacts positively on the action taken by the agent.

b. ***Negative***: Negative Reinforcement is defined as strengthening of behavior that occurs because of a negative condition which should have stopped or avoided.

D. Types of Deep Learning

Various types of Deep learning models [17] are Convolution neural network (CNN), Recurrent Neural Network (RNN), Multi-Layer Perceptrons (MLP), Long Short-Term Memory Networks (LSTMs) etc.

a. **Activation function:** It is integral part of neural network. Without activation function (No transformation), neural network is a simple linear regression modal. The derivation of Linear activation function (LAF) is constant and gradient information is not updated means gradient information would be same in back propagation stage. Output of linear function is not confined between range [0,1], hence LAF is inappropriate to generate probability for binomial or multinomial case.

$$f(LAF) = ax + b \; ; \; f'(LAF) = a;$$

CNN utilize non-linear activation function such as sigmoid, tanh, relu, pelu, softmax, various optimizer, loss function such as binary cross entropy, categorical cross entropy for prediction and classification task.

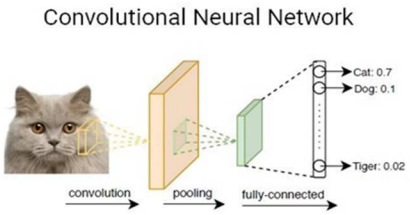

Figure 5: Convolutional Network Architecture

b. ***Recurrent Neural Network (RNN)***: In RNN, sequential output is generated for respective sequential input. It is widely used to solve time series problem where input length is not fixed.

c. ***Multi-Layer Perceptron (MLP)***: MLP is based on feed forward ANN concept which overcomes high computation power required by modern deep learning models.

d. ***Pre trained Deep Learning Models***: Various pre-trained deep learning models such as VGG16, VGG19, Resnet 50, Mobilenet, ResNeXt etc. are utilized in image classification, text classification, cyber security enhancement, medical disease diagnosis etc.

Non Linear Activation Functions are summarized in Table 1 and their nature is shown in Figure (Fig. 6 to Fig. 10)

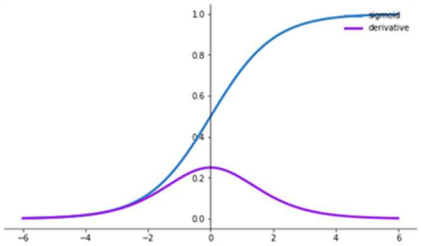

Figure 6: Sigmoid and its gradient/derivation

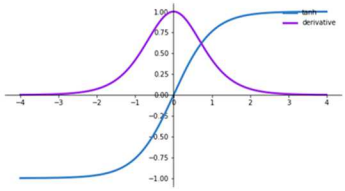

Figure 7: Tanh(x) and its gradient/derivation

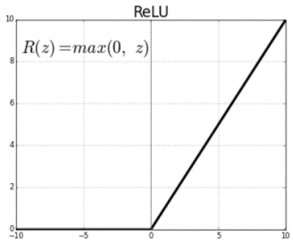

Figure 8: Rectified Linear Unit (RELU) Activation function

Let understand the derivation mechanism of relu AF.

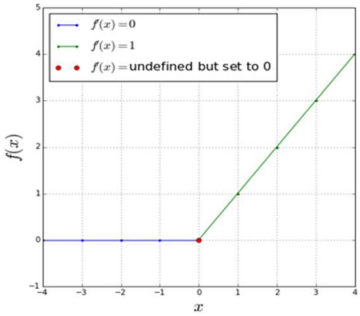

Figure 9: No change in slope/derivation for Relu AF

Here f'(0) does not exist, we can typically define f'(0)=0.In figure , we can see that there is no derivation/slope (no change in Y) for derivation or slope at +ve and –ve points [x=-3, -2,-1, 1 ,2,3]**.**

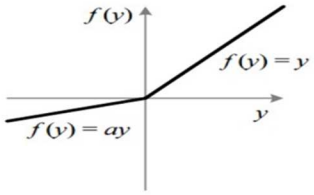

Figure 10: Leaky Relu AF

TABLE I. NON LINEAR ACTIVATION FUNCTIONS

Non Linear Activation Function	Description	Drawback
1.Sigmoid: Refer Fig 6. Range of S(z) ε(0,1) $S(z) = \frac{1}{1+e^{-z}}$ Derivative of Sigmoid S'(z) is S(z)(1-S(z)) S' (z) =0 when S (z) =0 or 1. Range of S'(z) ε (0,0.25) Single node in output layer predicts the class 1 or 0.	1. It is well suited for Binary Classification. 2. It gives probability value between 0 and 1. 3. Function output is not zero centered hence weight updation efficiency is reduced.	1. Slower computation due to exponential operation. 2. Suffers from vanishing (kill) gradient problem due to function is not zero centered.
2.Tanh(x): Refer Fig. 7 $f(x) = \frac{1-e^{-2x}}{1+e^{-2x}}$ Or f(x) = 2*Sigmoid(2x)-1 Range of f(x) is (-1,1) Derivation of f(x) f'(x) = 1- f(x)^2 Range of f'(x) is (0,1)	1. Function output is zero centered. 2. Used in hidden layer. 3. Better than Sigmoid	1. Suffers from vanishing (kill) gradient problem
3.Relu: Refer Fig. 8 ,Fig. 9 $f(x) = \max(0, x)$ $f(x) = \begin{cases} x & x > 0 \\ 0 & x < 0 \end{cases}$ $f'(x) = \begin{cases} 1 & x > 0 \\ 0 & x < 0 \end{cases}$	1. If input is +ve, there is no gradient saturation Problem. 2. Used in hidden layer. 3. Better than Sigmoid.	1. Derivation at point 0 is undefined. 2. For –ve input number, Gradient/derivation will be zero .Non updating weights leads to dead relu/neuron problem and vanishing gradient problem.
3a. Leaky Relu: Refer Fig 10. $f(x) = \max(0.01x, x)$ $f(x) = \begin{cases} x & x > 0 \\ 0.01x & x \leq 0 \end{cases}$ $f'(x) = \begin{cases} 1 & x > 0 \\ 0.01 & x \leq 0 \end{cases}$	1. It is zero centered. 2. Attempt to resolve/fix dying relu/neuron problem. 3. It has small gradient at α=0.01 (constant)	1. Suffers from vanishing gradient problem due to small gradient(α=0.01 (constat)
3b. Parametric relu: $f(x) = \max(\alpha x, x)$ $f(x) = \begin{cases} x & x > 0 \\ \alpha x & x \leq 0 \end{cases}$	1. When α=0, act as Relu AF When α=0.01,act as leaky relu.	1. Same as discussed in relu and leaky relu

$f'(x) = \begin{cases} 1 & x > 0 \\ \alpha & x \leq 0 \end{cases}$		
4. Softmax: $Softmax(z)_i = \frac{e^{z_i}}{\sum_{k=1}^{j} e^{z_j}}$ z represents the values from neurons of the output layer	1. It is well suited for multiclass classification Problem 2. Exponential introduces non linearity	1. When the number of classes are two, it acts as sigmoid AF. 2. Computation expensive because probability of all classes are computed.

- ***Softmax AF*:** It converts a vector of numbers into vector of probabilities i.e. scales numbers into probability output. It returns maximum value at particular index. The sum of all possible classes/outcome must be 1.

  [3.2 1.3 0.2 0.8] → [0.775 0.116 0.039 0.070]

  Numbers → Softmax AF → Probability

  Sum of probability [0.775 0.116 0.039 0.070]=1

$$oftmax(3.2) = \frac{e^{3.2}}{e^{3.2} + e^{1.3} + e^{0.2} + e^{0.8}}$$

$$= 0.775$$

In multiclass classification, one node for each class in output layer is available. Categorical data is converted into numerical data by either integer encoding [0, 1, 2, 3] (Ordinal/services) or one hot encoding.

III. APPLICATIONS

1. Applications of Supervised Learning

a. Applications of Supervised Learning in Regression

b. Weather forecasting, Market forecasting, Stock price prediction, House price prediction, Population growth prediction, the temperature for a given day etc

c. Applications of Supervised Learning in Classification, Image classification , Sentiment Analysis, Fraud /Non Fraud Transaction, Spam /Non Spam mails Covid /Non-Covid disease, Benign/ Malignant tumor, Medical disease prediction and classification etc.

2. Applications of Unsupervised Learning

a. In Clustering Optimal threshold values for multilevel image segmentation, Recommender System, Targeted Marketing, Customer Segmentation , etc.

b. In Dimension reduction Big data visualization, Meaningful compression, Feature elicitation, Structure discovery, Text mining, Image recognition, Image enhancement.

3. Applications of Reinforcement Learning

a. Real time decision, Game AI, Robot navigation, optimized marketing, Driverless Cars etc

TABLE II. RECENT APPLICATION OF VARIOUS MACHINE LEARNING ALGORITHMS

Machine Learning / Deep Learning Algorithms	Reference / Year	Proposed Technique by Authors	Data Type	Result / Accuracy
KNN	Lishan Wang[2] (2019)	Letter Recognition	Letter dataset of UCI machine repository	82%
	Gupta, Sheifali et,al.[3] (2016)	Classification of Astrocytoma in MR Images by KNN	BRATS Database	93%
SVM	Babacar Gaye, Dezheng Zhang et.al.[4](2021)	Improvement of svm kernel by statistical learning and optimization theory in the context of big data platform	Iris flower dataset	98%
	Wenhao Xie, Yanhong She et. al.[5] (2021)	Improved SVM Algorithm for Balanced Binary Decision Tree	Five dataset: Segmentation,Statlog,Iris, Breast tissue, Page blocks	98.5 %, 95.2%, 97%, 72.4%, 93.5%
Random Forest	Chen, RC. Dewi, C., uang, SW. *et al.[6] (2020)*	Feature selection for data classification using RF,SVM,KNN,LDA	Three popular dataset : Bank Marketing, Car Evaluation Database, Human Activity Recognition Using Smartphones	98.57 % by RF
	Schonlau M, Zou RY [7](2020)	Prediction of Credit card defaulter by RF	https://www.kaggle.com/ uciml/default-of- credit-card-clients-dataset	Out of bag or minimum error 18.24%
	Xiang Gao, Cheng Zhang et.al.[8](2019)	weighted quadratic random forest algorithm	Employees dataset of a branch of a communications company in China	92.80%
Deep learning models	Muhammad Arif et.al.[9](2022)	Brain tumor detection and classification using Berkeley wavelet transform and cnn	22 normal MRI Brain image ,44 abnormal MRI Brain image. http://med.harvard.edu/ AANLIB/	98.5 %
	Dilbag Singh, Manjit Kaur et al.[10](2021)	MADE based convolution neural network to detect COVID-19-Infected Patients	127 covid-19 chest xray ,500 normal chest xray , 500 pneumonia chest xray	94.65±2.1% for (70 % training ,30% testing ratio)
	Manjit Kaur, Dilbag Singh et. al.[11](2021)	Met heuristic-based Deep COVID-19 Screening Model	1926 covid-19, 1926 normal,1926 pneumonia Chest Xray images	99.5% training accuracy
	Ioannis D et. al.[12] (2020)	Utilize transfer learning in cnn to diagnose covid disease	224 covid-19 images,714 viral and bacterial pneumonia and 504 normal chest Xray images	96.78%

	Sethy, Prabira & Santi, Kumari et.al.[13] (2020)	Detect covid disease by deep features(Resnet50) and svm	25 covid-19 images,25 normal chest Xray images	95.38%
	Plamen Angelov et al[14](2020)	Covid-19 detection with deep learning	1252 covid chest CT scan and 1229 normal chest CT scan images	97.31%
	Stamate D, Smith R, TsygancovR et.al[15] (2020)	Prediction of Dementia and Mild Cognitive Impairment using deep learning approaches	(ADNI) Alzheimer's Disease Neuroimaging Initiative data repository	88% by MLP2

IV. CONCLUSION

Artificial Intelligence is a vast field of study and is grown at a greater pace than ever before. Through this paper we have made an attempt to consolidate the major milestones in Machine Learning approaches. It wouldn't be an exaggeration to say that these approaches lead our way in making newer technologies like autonomous cars a reality.

In this paper, we have introduced the basics of Machine Learning and the sub categories associated with it. We also discussed the differentiating factors among the Machine Learning approaches that are currently in use and defined their best use cases. Lastly, we also highlighted the latest research findings with respect to Machine Learning approaches in the field of Artificial Intelligence.

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