Role and Performance of Different Traditional Classification and Nature-Inspired Computing Techniques in Major Research Areas

Samriti Sharma¹*, Gurvinder Singh¹, Dhanpreet Singh²

¹ Department of Computer Science, GNDU Amritsar.
² Centre for IT solution, GNDU Amritsar.

Abstract

In the last few years, different machine learning techniques such as supervised, unsupervised, and reinforcement learning have been effectively employed to solve distinct real-life multidisciplinary problems. These techniques have been effectively applied to accurately predict the problems related to stock values, disease diagnosis, sentiment analysis, text processing, gene classification, crop prediction, and weather forecasting. The objective of this manuscript is to present the systematic review on the use of these techniques in five major domains i.e. agriculture, finance, healthcare, education and engineering. A standard review methodology has been adapted to include and exclude the related literature. The performance of different supervised and nature-inspired computing techniques have been accessed on the basis of different performance metrics. The publication trend on the use of machine learning techniques in these five research areas has been also explored. Finally, the gaps in the study have been identified that will assist prospective researchers who want to pursue their research in these areas.

Keywords: Machine Learning, Agriculture, Engineering, Education, Stock Forecasting, Disease Diagnosis.

1. Introduction

Machine Learning(ML) is one of the major multidisciplinary research areas. As per Stanford University, Machine Learning is defined as a science that makes computer to perform some intelligent activities based upon existing data and without being explicitly programmed[1]. Machine Learning has been used in a wide sphere of life. There are three main categories of machine learning called supervised learning, unsupervised learning and reinforcement learning[2]. These techniques have been effectively used to solve a wide variety of classification, clustering and prediction problems. In supervised learning, the inputs are labeled and these labels are the desired outputs. These techniques assist in the data classification process. Disease diagnosis, stock prediction, sentiment analysis are some of the major application areas for supervised learning techniques. Traditionally, different techniques like naïve Bayes, decision tree, random forest and support vector machine have been dominantly used to solve different data classification problems. On the contrary, an unsupervised learning technique also known as clustering techniques deals with unlabeled data. No extra information is provided for grouping the data that's why these are called unsupervised techniques. Reinforcement learning is concerned with the behavior of software agents. There are some functions associated with these agents and they perform their operations in the specified environment to achieve the reward[3].

In the last few years, exponential growth in the use of machine learning techniques has been observed. Different machine learning techniques have been
employed to solve variety of problems related to engineering[4], finance[5], medical science[6][7], weather forecasting[8], education[9], transportation[10], robotics[11] and agriculture[12]. Figure 1 represents major applications of these techniques.

Figure 1: Applications of Machine Learning

The intention of this research work is to present a systematic review of the role and performance of different machine learning techniques in five major research areas viz. agriculture, finance, healthcare, education, and engineering. Moreover, the publication trend of supervised and nature-inspired computing techniques used in these five research areas have been explored to determine the rate of publication of these two techniques in solving the real-life problems of these five major domains. After exploring different indexing databases, it has been found that several review articles have been written on the use of machine learning in different applications. Some of the major objectives of this study are:

- To briefly introduce the machine learning techniques.
- To accentuate the least and the most explored research domains by machine learning techniques.
- To present and analyze the role of machine learning in five major research areas (agriculture, finance, healthcare, education, and engineering).
- To explore the general publication trend of machine learning techniques.
- To find and present the rate of publication of nature-inspired computing techniques in agriculture, finance, healthcare, education, and engineering.

Section 2 represents related works. Review methodology is presented in Section 3. The role and performance of machine learning techniques in five different areas are given in Section 4. Section 5 depicts the publication trend of related articles. Finally, the concluding remarks are presented in Section 6.

2. Related Works

In the last few decades, several review articles on the machine learning techniques and their applications have been published. Some of the studies are briefly introduced below:

Kim et al.[13] have reviewed ten different machine learning based manuscripts. However, they haven’t specified any inclusion/exclusion criteria for their study. No significant findings and suitable future directions have been mentioned. Liakos et al.[12] have studied more than a hundred manuscripts related to the use of ML techniques in agriculture. It is an extensive study including the brief introduction of various classifiers and an explicitly stated review methodology. Subhadra Mishra et al.[14] have presented a review paper on the applications of machine learning techniques in crop production. No significant findings and future directions for the prospective researchers have been highlighted. Fan Cai et al.[15] have surveyed distinct clustering techniques for the analysis of financial data. Lin et al.[5] have reviewed different related articles to determine the data mining techniques which are periodically used in distinct business applications. Future directions are explicitly mentioned. Vivek Rajput et al.[16] have reviewed only eighteen articles related to stock market prediction using data mining and sentiment analysis. No significant details are generated in the study. Wei-Yang Lin et al.[17] have performed an extensive review on the various machine learning techniques for bankruptcy prediction and credit scoring. Significant findings are provided by the authors for the practitioners which are interested to pursue their research in the related field. Ashish Sharma et al.[18] have discussed only regression techniques for stock market prediction. No significant future suggestions are mentioned. Kaur and Sharma[19] have presented an extensive analysis of data mining and soft computing techniques for mining diabetic patients. A systematic approach was used while selecting and filtering the article for their review. The authors concluded that in the last decade, a significant rise in the use of data mining and soft computing techniques for early diagnosis of diabetes has been found. Additionally, there is still a need for smart and intelligent diabetes diagnostic framework. Kaur and Sharma suggested combining machine learning and soft computing techniques with the Internet of Things, ontology and information theory for more precise diabetic classification results. Shubham Bind[20] et al. have presented a survey of different machine learning approaches used for Parkinson disease. Authors have also presented a systematic summary of use of machine learning techniques in diagnosing Parkinson disease by different researchers in the literature. But authors have not presented systematic review methodology adopted by
them during their study. In 2018 Kaur et al.[21] have proposed big data and machine learning based diagnostic system model. There are four layers of the model. ML layer is responsible for disease diagnosis. Data security layers assist in providing security to the data. Different security techniques like activity monitoring, granular access control, PAM, OTP etc. have been used. Data storage layer provides the facility to store different types of data. Data source layer provide different source for data analysis. Divya Tomar et al.[7] have explored the various applications of data mining approaches in healthcare domain. Authors have explained different classification and clustering techniques along with their merits and de-merits and brief summary of machine learning techniques used in healthcare applications and the future directions for the other researchers are also presented. Shweta H.Jambukia et al.[22] have presented a detailed review on the classification of ECG(Electrocardiogram) signals. Authors have also discussed the various ECG databases, pre-processing techniques and issues involved in ECG classification. They have observed that neural networks give better results for ECG classification. Meherwar Fatima et al.[2] have presented a contingent analysis of different machine learning techniques for diagnosing five different diseases viz. Diabetes, heart disease, dengue, hepatitis and liver disease. They also highlighted the merits and de-merits of machine learning techniques used in diagnosing these diseases. Sharma et al. [6] have critically examined the role and performance of different data mining techniques used in different lifestyle based human disorders. Authors extensively surveyed more than eighty manuscripts. Authors concluded that a lot of mining work has been carried out for diabetes and cardio problems. However, as a little attention has been paid to develop a predictive model for the diseases viz. ophthalmology, dentistry, and digestive disorders. Therefore, there is a need to explore or mine these areas.

3. Review Methodology

In this study, a systematic review methodology has been adopted. Different articles related to machine learning and their use in agriculture, finance, healthcare, education, and engineering has been explored by executing different queries on Google Scholar. The study covers more than a hundreded articles. The articles embodied in this study have been extracted from peculiar indexing journals such as, IEEE, Elsevier, Springer, Plos|one etc The results found by executing the queries have been scrutinized and filtered based upon title and abstract. Additionally, the final decision regarding inclusion/exclusion has been made based upon the complete contents of the manuscripts. While exploring articles some of the restrictions were applied:
- The language was restricted to English only.
- Only conference and journal articles were considered.
- Patents and other secondary sources have been ignored

4. Review Results

This section will highlight the role of supervised and nature-inspired computing(NIC) techniques in agriculture, finance, healthcare, education, engineering etc.

4.1. Supervised Learning and Nature Inspired Computing Techniques

Supervised learning techniques are important machine learning techniques that assist in data classification. Inspite of classification supervised learning techniques are also employed in programming or prediction problems. Stock forecasting, crop prediction, disease diagnosis, gene classification are some of the important applications of these techniques. Number of techniques such as Naive Bayes, Decision Tree, SVM, CART(Classification and Regression Tree) and regression have been designed and deployed for the same[1].

Nature Inspired Computing (NIC)Techniques are stochastic techniques which have been inspired from individual or swarm behaviour of various human beings, animals, birds and other natural phenomenon like wind, water as well as universe. There are several NIC techniques. Some of most admired are GA(Genetic algorithm), ABC(Artificial Bee Colony), ALO(Ant Lion Optimization), FFA(Firefly Algorithm), GWO(Grey Wolf Optimization), Whale Optimization, Harmony Search and PSO(Particle Swarm Optimization). Inspite of long list and variation, these techniques have been significantly used to solve different computer science problems such as query optimization[23][24][25], image processing[26][27][28], network security[29][30], TSP (Travelling Salesman Problem)[31][32], task allocation[33] etc.

4.2. Role of Machine Learning in Agriculture

Machine learning has become a vital approach in the field of agriculture satisfying a number of objectives. These techniques have drastically changed the traditional way of performing agricultural activities. In last few years, it has been observed that a variety of supervised and NIC techniques have been used in predicting the wheat yield, weed detection, boosting crop yield, soil management, crop disease detection etc. ML techniques are also playing a vital role in yield prediction which is considered as the most important objective of agricultural planning. ML approach has been also used in modeling the river suspended sediment which is an important concern in managing the water resources[34]. Moreover, the ML techniques are extensively used in analyzing the agricultural data diagnosing crop diseases. In recent years, ML approaches have been employed for estimating...
the fruit ripeness. Nashwa El-Bendary et al.[35] have proposed a system for evaluating the tomato ripeness and the hybridization of SVM and LDA (Linear Discriminant Analysis) is used to classify distinct stages of ripeness for tomatoes. They found that results produced using this hybrid approach are more useful than other classification techniques. Ulrich Weiss et al.[36] have employed 3D LIDAR Sensor and supervised machine learning techniques for classifying plant species. Authors have used six plant species in their study and observed that SVM, Neural networks and Logistic regression are the best methods for classifying the plant species. Avat Shekofaa et al.[37] have worked on different screening, clustering, and decision tree models and concluded that CART is the best method for predicting maize grain yield. Farzaneh Sajedi-Hosseini et al.[38] stated that machine learning techniques have been also applied fruitfully in risk and hazards prediction in environmental sciences. Authors have used Boosted Regression Trees (BRT), Multivariate discriminant analysis (MDA), and Support Vector Machine (SVM) and Ensemble Modeling for assessing the probability of occurrence of pollution in groundwater and concluded that ensemble modeling gives better results than others. Authors suggested that the quality of groundwater can be improved by making the minimal use of nitrogenous fertilizers during irrigation. X.E.Pantazi et al.[39] have used three Self Organizing Map models viz. Counter-propagation Artificial Neural Network (CPANN), Supervised Kohonen Network (SKN) and XY-fusion network (XYF) for predicting wheat yield in a 22 ha field in Bedfordshire, UK and concluded that SKN model outperforms others with an accuracy of 91.3%. A. Belayneh et al.[40] have employed the hybrid approach of Machine learning techniques such as ANN and SVR (Support Vector Regression) with wavelet analysis and ensemble techniques viz. Bootstrap and boosting techniques for the drought prediction and concluded that wavelet ensemble models perform better than the non-ensemble techniques.

4.3. Role of Machine Learning in Finance

Finance is another important research area for machine learning experts and data scientists. Stock and risk analysis are two major subareas of finance. In the business world, the stock market greatly affects the economic advancement of a country. A country’s economic growth is directly proportional to the performance of the stock market. Stock markets generate ample amount of data so different machine learning methods are used for finding the hidden patterns from the data and predicting the stock prices, future trends which helps the investors to make investments in stock market. In spite of stock and risk analysis, loan approval, bankruptcy are other important research areas. Business enterprise is full of risks viz. market risk, credit risk and operation risk etc. so banks have to implement different policies to handle these risks. Machine learning techniques seem to be very useful for risk management[41]. Several research articles have been published in these areas using different machine learning techniques. Some of the major research works are pointed out below:

In 2012, Chopde et al.[42] used different data mining techniques for credit risk analysis. Different classifiers were used and based upon the predictive rate, the author concluded that the results obtained using decision tree outperformed other classifiers. Lee MC et al.[43] have used SVM (Support Vector Machine) and BPN (Back Propagation Neural Network) for analyzing the financial distress. They found that SVM is more useful than BPN in analyzing financial distress. Byanjankar A et al.[44] have used ANNs (Artificial Neural Networks) which helps the lenders in selecting better loan applications and making the predictions about credit risk.

T. Vafeiadis et al.[45] have applied five major classification techniques of machine learning viz. BPN (Back Propagation Network), SVM, DT (Decision Tree), NB (Naïve Bayes) and LR (Logistic Regression) for making the churn prediction of customers of a telecommunication company. Authors compared the classification methods with their boosted versions and concluded that SVM-POLY (Polynomial Kernel) gives better results in terms of accuracy and F-measure. Junichiro Mori et al.[46] have employed SVM for identifying relationships between new customers and suppliers in a business firm and reciprocal relationships among them. Authors stated that SVM shows the significant performance in predicting customer-supplier relationships by providing better F-measure and reciprocity values.

Shubham Jain et al.[47] used three machine learning techniques viz. LR (Linear Regression), RF (Random Forest) and MLP (Multilayer Perceptron) for analyzing the trend of stock market indices viz. NYTimes and DOW Jones Industrial Average. Authors stated that MLP outperforms the other two techniques in predicting the stock values. Osman Hegazy et al.[48] have proposed a hybrid approach of PSO (Particle Swarm Optimization) and LS-SVM (Least Square Support Vector Machine) for predicting the stock market price. Authors have used thirteen different financial technical indicators in their study and compared the proposed approach (PSO-LS-SVM) with LS-SVM and ANN-BP (Artificial Neural Network-Back Propagation Neural Network) and concluded that proposed hybrid approach outperforms other approaches. Nanxi Wang[49] has used different machine learning techniques viz. SVM, NN with dropout, Autoencoder for bankruptcy prediction. Author has compared these three techniques with the traditional methods viz. GA (Genetic Algorithm), Inductive Learning and Logistic Regression and observed that SVM, NN with dropout and Autoencoder gives better accuracies than the older methods. Mustansar Ali Ghazanfar et al.[50] have employed distinct machine learning techniques for predicting the Karachi Stock Exchange.
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(KSE) and concluded that Ada-Boost, MLP and Bayesian Network give better outcomes than others. Ashish Sharma et al.[18] have surveyed different regression techniques viz. Polynomial regression, RBF(Radial Basis Function) regression, Sigmoid regression and Linear regression and concluded that Linear Regression is considered as a better one in making the predictions than others. Regression analysis is basically used in finding the cause and effect relationships between dependent and independent variables. Yuqing He et al.[51] have calculated the twelve technical indicators for analyzing the stock market trend. Authors have also studied the three different feature selection algorithms viz. Principle Component Analysis (PCA), Genetic Algorithm (GA) and Sequential Forward Selection(SFS) along with their merits and de-merits.

4.4. Role of Machine Learning in Education

Machine Learning(ML) techniques hold a great obligation for education. These techniques have been employed in the prediction of student dropout in higher education.[52]. ML techniques are also applicable in performing the student modeling. Dursun Delen[9] has used SVM decision trees, neural networks, and logistic regression and ensemble methods and observed that ensemble methods perform better than others for predicting the student's retention management. S. Kotsiantis et al.[53] have employed ensemble classifiers for the prediction of student’s performance in distance education which allows the teachers to understand the fact that which students will complete their course of study and which will not. Getting placed in a renowned company is a dream of every student and they work hard to achieve their goal. Every reputed organization has a placement cell for selecting the potential students and improving their skills. ML techniques have been also employed in this domain. Sentkil Kumar Thangave et al.[54] have presented a recommendation system for the student’s placement analysis an achieved an accuracy of 71.66%. Authors have used five different data mining techniques viz. Naïve Bayes, MLP, Reptree, J48, decision tree etc. for predicting the academic performance of students. S. Kotsiantis et al.[53] have proposed different models for the enhancement of student modeling. Jagath Sri Lal Senanayaka et al.[57] have used SVM for the detection and classification of bearing faults at an early stage. Authors stated that bearings are the most important component of machinery used in the industry and in household devices therefore, early detection of faults in bearings is very crucial. Carbon dioxide(CO₂) is known as one of the major Green House Gases. Examining the virtue of CO₂ requires large number of resources as well as time, therefore, Zhen Zhang et al.[58] have used ML techniques viz.back-propagation neural network (BPNN) and general regression neural network (GRNN) for rapid prediction of thermodynamic properties of CO₂ in solution environment, its solubility, viscosity, density in potassium lysinate solution amalgamated solution with monoethanolamine (MEA). Authors concluded that ML techniques provide high speed and meticulous prediction of thermodynamic properties of CO₂ Edward W. Lowe et al.[59] have used three different ML techniques viz. ANN, SVM, and K-NN for the prediction of logP which is a partition coefficient which is a measure of hydrophilicity of a compound and concluded that ML approaches give better prediction than XlogP which is also a well-established method of predicting logP. Ruchika Malhotra et al.[60] have proposed different models for the enhancement of software quality. In their study authors have used six different machine learning techniques viz. Adaboost, Random Forest, MLP, Bagging, Genetic Programming and SVM and one statistical method for determining the faulty classes in the software development. Authors have evaluated nineteen different metrics and concluded that the models based on bagging and random forest methods outperformed all the other models. Adriano L.I. Oliveira et al.[61] have proposed a hybrid approach based on GA and machine learning techniques for estimating the software efforts. In this study authors have used three different machine learning techniques viz.MLP, SVR(Support Vector Regression) and Decision Tree(M5P) and stated that proposed approach gives better results in terms of accuracy.

4.5. Role of Machine Learning in Engineering

In the last few years, it has been noticed that machine learning is providing viable alternatives to the traditional methods of solving the engineering problems in different domains such as software engineering, civil engineering, chemical engineering, mechanical engineering, computer engineering etc. Jagath Sri Lal Senanayaka et al.[57] have used SVM for the detection and classification of bearing faults at an early stage. Authors stated that bearings are the most important component of machinery used in the industry and in household devices therefore, early detection of faults in bearings is very crucial. Carbon dioxide(CO₂) is known as one of the major Green House Gases. Examining the virtue of CO₂ requires large number of resources as well as time, therefore, Zhen Zhang et al.[58] have used ML techniques viz.back-propagation neural network (BPNN) and general regression neural network (GRNN) for rapid prediction of thermodynamic properties of CO₂ in solution environment, its solubility, viscosity, density in potassium lysinate solution amalgamated solution with monoethanolamine (MEA). Authors concluded that ML techniques provide high speed and meticulous prediction of thermodynamic properties of CO₂ Edward W. Lowe et al.[59] have used three different ML techniques viz. ANN, SVM, and K-NN for the prediction of logP which is a partition coefficient which is a measure of hydrophilicity of a compound and concluded that ML approaches give better prediction than XlogP which is also a well-established method of predicting logP. Ruchika Malhotra et al.[60] have proposed different models for the enhancement of software quality. In their study authors have used six different machine learning techniques viz. Adaboost, Random Forest, MLP, Bagging, Genetic Programming and SVM and one statistical method for determining the faulty classes in the software development. Authors have evaluated nineteen different metrics and concluded that the models based on bagging and random forest methods outperformed all the other models. Adriano L.I. Oliveira et al.[61] have proposed a hybrid approach based on GA and machine learning techniques for estimating the software efforts. In this study authors have used three different machine learning techniques viz.MLP, SVR(Support Vector Regression) and Decision Tree(M5P) and stated that proposed approach gives better results in terms of accuracy.

4.6 Role of Machine Learning in Healthcare

Nowadays, a large number of people are suffering from different human disorders such as diabetes, cancer, cardio, neuro digestive, and psychological disorders. A huge amount of data related to medical diagnosis is available, so it is required to classify the whole data to make predictions about the diseases and
their treatments. Machine learning techniques can be used in diagnosing different diseases viz. breast cancer, heart problems, skin problems, Alzheimer's disease, diabetes etc. [62].

Several authors have employed differently supervised and NIC(Nature Inspired Computing) techniques for early diagnosis of these human disorders. Some of the studies are briefly presented below:

Tariqoppula V.S. Sriram et al.[63] have employed different machine learning techniques viz. Naive Bayes, Logistic Regression, KStar, ADTree, I48, SVM, Random Forest etc. for diagnosing Parkinson disease. They have compared the machine learning techniques used in their study and concluded that Random Forest outperforms others in terms of accuracy. Deepa Gupta et al.[64] have applied machine learning techniques for diagnosing the eleven different chronic diseases viz. Diabetes, Cancer, Chronic heart failure, Ischemic heart disease, Chronic kidney disease, Alzheimer, Obsessive pulmonary disorder, Osteoporosis, Depression, Arthritis and Stroke and generated the diagnostic codes. They have employed Adaboost and Information Gain on the CMS(Centre for Medicare Services) dataset and concluded that AdaBoost outperforms. Mehrbaksh Nilashi et al.[65] have proposed a knowledge-based system for diagnosing the real world datasets by using different prediction techniques, noise removal, and clustering techniques. Authors observed that a hybrid approach of fuzzy rule-based techniques, clustering techniques and PCA(Principal Component Analysis) give better results in terms of disease prediction accuracy. Shashikant Ghumbre et al.[66] have performed the diagnosis of heart disease using SVM and Radial Basis Function(RBF) network. Authors have conducted a statistical analysis of patients datasets in terms of accuracy, sensitivity, and specificity and observed that SVM gives better results than RBF in terms of the parameters used. Javad Sahimi Sartakhti et al.[67] have proposed a hybrid approach of SVM and Simulated Annealing(SA) for diagnosing hepatitis disease. The proposed approach is compared with other classification techniques mentioned in the literature in terms of accuracy, recall, and F-measure and it is concluded that the proposed method outperforms the other methods.

5. Summary of Review Results

Table1 depicts the accuracies of different machine learning techniques used in particular applications. It is found that, in general twelve different supervised learning techniques such as SVM, Naive Bayes, Decision Tree/C4.5, Logistic Regression, MLP, Neural Networks, ANN, CART, AdaBoost, AutoEncoders, SKN(Supervised Kohonen Networks), Ensemble Modeling have employed to solve different problems of agriculture, finance, healthcare, education and engineering. The rate of prediction is different using different supervised learning techniques. All these details are highlighted in Table1.

Table2 summarized the results of the use of eleven different nature-inspired computing techniques viz. Genetic Algorithm, Grey Wolf Optimization, Crow Search Algorithm, Ant Lion Optimization, Firefly algorithm, Ant Colony Optimization, Whale Optimization, Artificial Bee Colony, Cuckoo Search, Multiverse Optimization(MVO) and Hybrid approach in five major research domains such as agriculture, finance, healthcare, education and engineering. It is observed that as compared to supervised learning techniques better predictive results have been achieved using different NIC techniques.

5.1. Publication Trend

Figure 2 depicts the general publication trend of last ten years of applications of machine learning in the five major research areas viz. agriculture, finance, healthcare, education, and engineering within a period of 2010 up 2019. It has been observed from the table that a large number of articles have been published in the field of engineering using machine learning techniques during this period.
## Table 1: Summary of Supervised Learning (Traditional) Techniques

| Author, Year | SVM | Naïve Bayes | Decision Tree/ C4.5/ID3/Iterative Dichotomy | Logistic Regression | MLP | Neural Networks | ANN | CART | Ada Boost | Autoencoders | SKN | Ensemble Modeling | Application | Accuracy |
|--------------|-----|-------------|--------------------------------------------|--------------------|-----|----------------|-----|------|-----------|--------------|-----|-------------------|-------------|----------|
| Farzaneh Sajedi-Hosseini (2018)[38] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Risk Assessment of nitrate groundwater contamination | Above 80% Grass | Risk Assessment of nitrate groundwater contamination | Above 80% Grass |
| Shubham Jain et al., (2018)[47] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Stock Analysis | Not mentioned |
| Jagath Sri Lal Senanayaka et al., (2017)[57] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Bearing Fault Classification | 96% |
| Mustansar Ali Ghazanfar, et al., (2017)[50] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Prediction of Stock Exchange Index | Not mentioned |
| Nanxi Wang (2017)[49] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Bankruptcy Prediction | Not mentioned |
| Sentkil Kumar Thangavel et al., (2017)[54] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Logistic regression+Decision tree+Naïve Bayes+Metabagging classifier+Classification via Regression | Student Placement Analyzer | 84.42% |
| Lovenoor Aulck et al., (2016)[52] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Student Dropout | 66.59% |
| X.E. Pantazi et al., (2016)[39] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Wheat yield | 91% |
| T. Vafeiadis et al., (2015)[45] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Customer Churn | 97% |
| T. K. Das (2015)[68] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Customer Classification | 95% |
| Jigar Patel et al., (2014)[69] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Stock Analysis | 90.19% |
| Nashwa El-Bendary (2014)[35] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | SVM+PCA+LDA (Linear discriminant analysis) | Tomato ripeness | 90.2% |
| Avat Shekoofa et al., (2014)[37] | ✔️  | ✔️          |                                            |                    |     |                |     |      |           |              |     |                   | Maize Grain yield | Not mentioned |
| Authors                          | Techniques                                      | Classification of datasets | Application Area                        |
|---------------------------------|-------------------------------------------------|-----------------------------|----------------------------------------|
| Seema Sharma et al.,(2013)[70]  | PCA+Genetic Algorithm+SFS(sequential forward feature selection) | 75.06%                      | Classification of datasets             |
| Yuqinq He et al.,(2013)[51]     | PCA+Genetic Algorithm+SFS(sequential forward feature selection) | Stock Market Analysis       | Stock Market Analysis                  |
| Tarioppula V.S. Sriram et al.,(2013)[63] | Random Forest+KStar+AD(Alternating Decision)Tree+J48+LMT(Logistic Model Tree) | 90.26%                      | Parkinson Disease Prediction           |
| Junichiro Mori et al.,(2012)[46] | PCA+Genetic Algorithm+SFS(sequential forward feature selection) | Business partners and building reciprocal relationships | Not mentioned                         |
| Saurabh Pal(2012)[71]           | Random Forest+Adaboost+Bagging+MLP+SVM+GA+Logistic Regression | Dropout Rates of Engineering Students | Dropout Rates of Engineering Students |
| Ruchika Malhotra(2012)[60]      | Random Forest+Adaboost+Bagging+MLP+SVM+GA+Logistic Regression | Fault Prediction            | Fault Prediction                       |
| Yakup Kara et al.,(2011)[72]    | Stock Analysis                                  |                             | Stock Analysis                         |
| Gianluigi Guido et al.,(2011)[73]| Direct Marketing Campaigns                      |                             | Direct Marketing Campaigns             |
| Ulrich Weiss et al.,(2010)[36]  | Students retention management                   |                             | Students retention management          |
| Dursun Delen et al.,(2010)[9]   | bagging,boosting,information fusion             |                             | Students retention management          |
| S. Kotsiantis et al.,(2010)[53] | Naive Bayes+1-NN(Least Neighbour)+WINNOW         |                             | Students' performance in distance education |

**Table 2: Summary of Nature-Inspired Computing Techniques**
| Author, Year | GA | GWO | CSA | ALO | FFA | ACO | Whale Optimization | ABC | Cuckoo Search | Multiverse Optimization | Hybrid Approach | Application | Accuracy |
|--------------|----|-----|-----|-----|-----|-----|-------------------|-----|--------------|------------------------|-----------------|-------------|---------|
| N. Emam et al.,(2019)[74] |    |     |     |     |     |     |                   |     |             |                        | Affinity Propagation+FFA+SVM | Breast Cancer | 98.60%   |
| G. Ignisha Rajathi(2019)[75] |    |     |     |     |     |     |                   |     |             |                        | Whale Optimization with Simulated Annealing + Ensemble Classifier | Liver Disease | 98%      |
| M. Prabukumar et al.,(2019)[76] |    |     |     |     |     |     |                   |     |             |                        | Cuckoo Search Algorithm +SVM | Lung Cancer   | 98.51%   |
| PrernaSharma et al.,(2018)[77] | ✓  |     |     |     |     |     |                   |     |             |                        |                             | Parkinson’s disease | 94.83%   |
| Ilyas Benmessahel et al.,(2018)[78] |    |     |     |     |     |     |                   |     |             |                        | MVO+ANN                  | Intrusion Detection System | 99.61%   |
| Ramit Sawhney et al.,(2018)[79] |    |     |     |     |     |     |                   |     |             |                        | Binary FFA+ Random Forest(RF) | Cancer       | 97.69%   |
| Prerna Sharma et al. (2018)[80] |    |     |     |     |     |     |                   |     |             |                        | Improved GWO+ ANN          | Protein Structure       | 91%      |
| HuiWang et al.,(2018)[81] | ✓  |     |     |     |     |     |                   |     |             |                        |                             | Demand estimation of water resources | 97.91%   |
| R.S. Chithra et al.,(2018)[82] | ✓  |     |     |     |     |     |                   |     |             |                        |                             | Tuberculosis            | 96.15%   |
| Deepak Gupta et al.,(2018)[83] | ✓  |     |     |     |     |     |                   |     |             |                        |                             | Parkinson's disease       | 100%     |
| Gehad Ismail Sayed et al.,(2017)[84] | ✓  |     |     |     |     |     |                   |     |             |                        |                             | Feature Selection        | 100%     |
| Zeinab Arabasadi et al.,(2017)[85] | ✓  |     |     |     |     |     |                   |     |             |                        | GA +Neural Networks        | Heart disease           | 93.85%   |
| Abdalla Mostafa et al.,(2016)[86] | ✓  |     |     |     |     |     |                   |     |             |                        |                             | MRI Liver                | 94.49%   |
| Hoda Zamani et al.,(2016)[87] | ✓  |     |     |     |     |     |                   |     |             |                        |                             | Diseases Diagnosis        | 97.86%   |
| Name                          | Methodologies                                      | Domain                        | Accuracy |
|-------------------------------|----------------------------------------------------|-------------------------------|----------|
| Gadekallu Thippa Reddy et al. | FF+ Neural Network (NN)                            | Diabetes Diagnosis            | 79%      |
| Abdalla Mostafa et al.        | CT liver image segmentation                        |                               | 93.73%   |
| Esraa Elhariri et al.         | GWO+SVM                                            | EMG signals                   | 90%      |
| Chih-Feng Chao et al.         | Ultrasonic Supraspinatus                           |                               | 93.75%   |
| E. H. Mostafa Ganji et al.    | Fuzzy Classification system + ACO                  | Diabetes diagnosis            | 84.24%   |
| Chae Hoon Kwon et al.         | ACO+SVM                                            | Weed Identification           | 94%      |
| Anbarasi et al.               | GA+Naive Bayes+Decision Tree                       | Heart Disease                 | 99.2%    |
Table 3: Role of NIC Techniques

| Algorithms/Domains                  | Agriculture | Finance | Healthcare | Education | Engineering |
|-------------------------------------|-------------|---------|------------|-----------|-------------|
| Genetic Algorithm (GA)              | 17,000      | 16,800  | 16,200     | 31,400    | 298,000     |
| Grey Wolf Optimization (GWO)        | 93          | 80      | 52         | 255       | 1500        |
| Crow Search Algorithm (CSA)         | 30          | 19      | 29         | 62        | 396         |
| Ant Lion Optimization (ALO)         | 21          | 16      | 19         | 65        | 395         |
| Fire Fly Algorithm (ALO)            | 785         | 848     | 505        | 2720      | 13,700      |
| Ant Colony Optimization (ACO)       | 4080        | 4250    | 2890       | 15,400    | 41,100      |
| Whale Optimization                  | 61          | 70      | 63         | 203       | 1140        |
| Artificial Bee Colony (ABC)         | 1560        | 1700    | 1080       | 7040      | 18,100      |
| Monkey Search                       | 25          | 23      | 12         | 72        | 301         |
| Cuckoo Search                       | 726         | 714     | 634        | 2850      | 13,400      |
| Multiverse Optimization (MVO)       | 0           | 1       | 0          | 3         | 19          |

Table 3 depicts the publication trend of different nature-inspired algorithms in five research areas viz. agriculture, finance, healthcare, education, engineering. It has been observed that ample amount of work has been published in these domains using Genetic Algorithms (GA), Ant Colony Optimization (ACO) and Artificial Bee Colony (ABC) algorithm and a relatively lesser number of articles have been published using other algorithms. Additionally, little attention has been paid to use of multiverse optimization in five major domains (agriculture, finance, healthcare, education, engineering).

Table 4 : Details of Publications

| Author Name                          | Citation | Journal                      | Country    |
|--------------------------------------|----------|------------------------------|------------|
| Andrea Mannini, And Angelo Maria Sabatini (2010)[99] | 538      | Sensors                      | Italy      |
| Christos A. Frantzidis et al. (2010)[100] | 131      | IEEE Xplore                  | Greece     |
| Youn-Jung Son, et al. (2010)[101]    | 55       | KoreaMed Synapse              | Korea      |
| Asha Rajkumar et al. (2010)[102]     | 136      | Global Journal of Computer Science and Technology | India |
| Ulrich Weiss et al. (2010)[36]       | 34       | Ninth International Conference on Machine Learning and Applications | Germany |
| Edward W. Lowe et al. (2011)[59]     | 5        | IEEE Xplore                  | USA        |
| Ketaki Chopde et al. (2012)[42]      | 1        | International Journal of Engineering and Advanced Technology | India |
| Wei-Yang Lin, et al. (2012)[17]      | 120      | IEEE Transactions on Systems  | Taiwan     |
|                                     | 255      | International Journal of Bio-Science | India |

Table 4 depicts the contribution of different authors, universities and the journals in publishing the different articles related to the role and performance of machine learning in five different research domains viz. agriculture, finance, healthcare, education, and engineering.
The articles published in the five domains are further examined and the details are mentioned in the Table4. It has been observed from the table that a number of researchers have done their research in these domains and the contribution of the researchers and their universities are highlighted in the table. On the average the rate of citations is in two digits. However, some special cases of three digits are also present.

### 6. Conclusion

This paper presents the systematic review of role and performance of machine learning techniques in five major research areas viz. healthcare, education, finance, agriculture, and engineering. Some of the major applications areas of ML techniques are highlighted. The research works of some of the key authors related to the use of ML techniques particularly in agriculture, finance, education, engineering, and healthcare has been examined and presented in this study. Furthermore, to examine the rate of publication, the publication trend of the related articles has been analyzed. From the last ten year of publication trend, it is observed that a significant amount of research work has been carried out for exploring the role and performance of different ML techniques in engineering. However, agriculture, finance, and healthcare still need more attention. Additionally, as far as nature inspired computing (NIC) techniques are concerned, more attention is required for multiverse optimization techniques. Moreover, the latest and emerging NIC techniques should also be employed in these areas and their performance need to be examined.
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