A Survey of Various Types of Learning Algorithms In Mechatronics

Pranav Purohit[1], H.P.S.Kang[2]
[1]Dept of Instrumentation
[2]Associate Professor, UCIM
[1, 2] Panjab University Chandigarh India

Abstract- *The increased scope of mechatronic systems and their complexity mean that they are designed to cover not only the technical aspects of their core disciplines, but also the organizational, training and management aspects. Machine learning is becoming increasingly important for mechatronic systems and will become an everyday part of every student's life. Machine learning is, unfortunately, seldomly implemented in a substantial way in the curriculum but offered as an optional course. This review offers a comprehensive review of mechatronics studies using machine teaching technology. The fusion of mechanics and electronics in the design of intelligent machines is known as Mechatronics. This paper discusses the most commonly used machine learning techniques for expert estimation in the field of mechatronics, such as clustering, neural networks, decision trees, classification, genetic algorithms, and reinforcement learning. There is also a table comparison of these ML techniques based on parameters and algorithms.*

Keywords- Mechatronics, Machine Learning, Clustering, Classification, Neural Networks.

I. INTRODUCTION

Mechatronics is an inevitable stage in the evolution of modern engineering design.Mechatronics became a major necessity in the latter part of the twentieth century when computers and microcomputers, embedded computers and the associated information and software technologies were developed. The term mechatronics is made up of the words "mecha" from mechanism and "tronics" from electronics.The term "Mechatronics" was coined in Japan in the 1970s. Mechatronics is also known as the replacement of mechanics with electronics or the enhancement of mechanics with electronics. Mechatronics systems encompass a broad range of interdisciplinary electrical and mechanical systems, such as heating, ventilation, and air conditioning systems in building automation systems, which are responsible for providing occupants with a comfortable and productive environment [1].The study of mechatronic systems can be classified into the following specializations. Figure 1 [2] depicts the key elements of mechatronics.

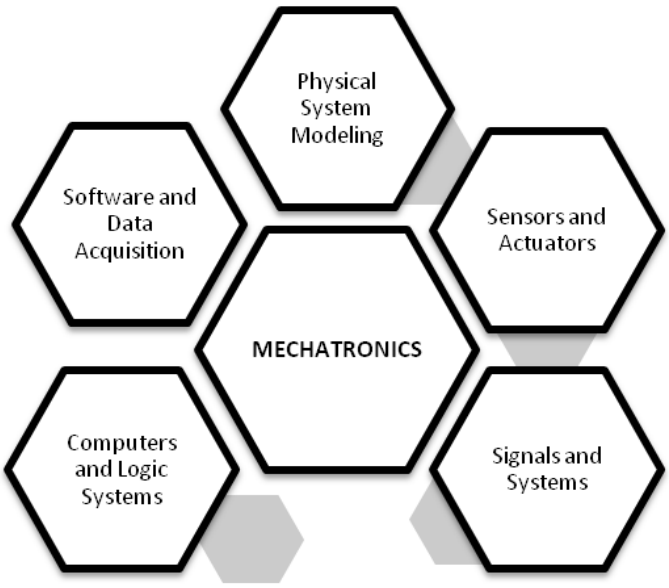

Figure 1. Key Elements of Mechatronics

A mechatronic system collects signals from the environment, processes these signals in order to generate a message and transforms them from force to motion and action to other forms of energy.

1.1 Applications of Mechatronics

Mechatronics is a broad term for the integration of mechanical, telecommunications, and computer engineering, which frequently employs microcontrollers. Engineers in mechatronics may program robots, design telecommunications systems, or create nanotechnology. Robots, digitally controlled combustion engines, machine tools with self-adaptive tools, contact-free magnetic bearings, automatic guided vehicles, and so on are some basic examples of mechatronics systems. The following are some of the most promising mechatronics application areas [3].

- *Production line automation*: A manufacturing environment is designed as a chain process, with each stage leading to the next. During the process, most such systems use belts to move products and materials. Mechatronics allows for the automation of the process by

incorporating devices such as barcode readers, imaging and sound processors along the way. A packaged product, for example, can have its manufacture and expiry dates stamped in and recorded while on the belt.

- *Measuring products*: A manufacturing process is only successful if the end products are the correct shapes, sizes, weight, and quality. Installing intelligent sensors, testing, and calibration systems at the appropriate points can help to ensure this. All of this falls under the purview of mechatronics.
- *Control systems*: Measures must be put in place in any effective manufacturing line to ensure that the installation operates at peak efficiency. As a result, dealing with factors such as pressure and temperature becomes a top priority. This is very easy to accomplish with sensors and response mechanisms that monitor and maintain the desired operating conditions. For example, when the temperature rises to a certain level, a sensor can activate the cooling system.
- *Real life application:* Mechatronics is widely used in daily life. It iss found in things like washing machines and dishwashers. It is also used in measuring devices such as sensor testing and calibration devices. Furthermore, its applications in automatic air conditioning systems, automatic door systems, and security systems enhance both the quality of life and the security of secure facilities.
- *Healthcare:* Using a robot to perform surgery has numerous advantages, including the fact that it is less invasive, resulting in faster recovery and a lower risk of infection. Since the FDA approved the da Vinci Surgical System in 2000, robotic surgery has been available. A camera is mounted on one arm of the robot, and surgical equipment is mounted on the other.

1.2 Advantages and Disadvantages of Mechatronics

Table 1 lists the various benefits and drawbacks [4] of mechatronics.

Table 1. Advantagesand Disadvantages of Mechatronics

S. No.	Advantages	Disadvantages
1.	Products are reasonably priced and of high quality.	High initial cost.
2.	High degree of flexibility.	High cost of maintenance.
3.	Proper maintenance and timely diagnosis of the fault are expected to result in a longer life.	To operate, highly trained personnel are required.
4.	It allows for remote control as well as centralized monitoring and control.	A multidisciplinary engineering background is required for design and implementation.
5.	It is ideal for applications requiring high dimensional accuracy.	It has a high level of complexity in identifying and correcting system problems.

This review paper is divided into the following sections: Section 1 provides a high-level overview of mechatronics and its applications, as well as their benefits and drawbacks. The second section goes over the various types of learning algorithms and their significance. Section 3 depicts the literature review. In addition, this section compares ML algorithms in mechatronics. Section 4 is concerned with the conclusion of the paper.

II. LEARNING ALGORITHMS

The study and development of algorithms which can learn from data is explored in machine learning [5, 6]. In this context, learning entails the ability to recognize complex patterns and make informed decisions based on previously seen data.The key challenge of machine learning, in order to produce a useful decision on new and previously unexpected events, is how to generate knowledge derived from the small number of previous experiences.In order to address this problem, machine learning develops an algorithm based on sound statistical and computational principles to discover knowledge of specific data and expertise.

Figure 1 shows a typical process of machine learning. This process consists of five steps in which the first step involves the collection of data, i.e. the collection of the data to be analyzed.The second and third phases are concerned with monitoring the system's behaviour and extracting relevant features. When these phases are completed, we can use the features gathered in the learning and classification procedure. Finally, the classifier is evaluated in the final phase.

Figure 1. A Typical Machine Learning Process

The basis of data mining and the most commonly used way of data processing is machine learning.A major advantage of machine learning algorithms is to filter large amounts of information into overlooked patterns.ML tasks are usually categorized according to the type of study (unsupervised), models of learning (classification, regression, clustering, and reduction in size), or the learning pattern that are used to implement a task selected. A comparison of these techniques is presented in table 3.

2.1 Supervised Learning

Supervised learning [7, 8] is an approach defined by the use of labelled datasets in the machine learning approach.These datasets are intended to train or “supervise” algorithms in accurately classifying data or predicting

outcomes.The model's accuracy can be measured with labelled inputs and outputs. Classification and regression are the two types of problems that can be solved using supervised learning.

Table 2. Categorization of Learning Techniques

Machine Learning Techniques					
Supervised		**Unsupervised**		**Semi-supervised**	**Reinforcement Learning**
Classification-based	•Decision trees •Bayesian networks •Neural networks •Evolutionary algorithms •Genetic algorithm	Clustering-based	• k-means • Gaussian Mixture Model • Mean shift clustering • Expectation–Maximization (EM) •		
		Dimensionality Reduction			
		Association Rule-Mining	• Apriori algorithm		

2.1.1Classification-based Learning algorithms

Classification [9] is one of the most studied tasks for machine learning. The classification theory is based on the expected attribute for predicting the target attribute class defined by the user. The main problems in genomics are genome classification and sequence annotation. In biological sequence mining, commonly used algorithms include fuzzy sets, neural networks, genetic algorithms, and rough sets. There are also a number of general classification models, such as naive Bayesian networks, decision trees, neural networks, and laws of learning using evolutionary algorithms.

- *Decision Tree*

A decision tree is a flowchart-like structure in which each internal node represents a test on a feature (e.g. if a coin flip comes up with heads or tails), each leaf node represents a class label (decision made after computing all features) and the branches represent a mixture of features that lead to those class labels. Decision trees are typically used as a tool to identify a strategy that will most likely achieve an objective, but also as a common tool for machine learning, especially in decision-making. It is one of the predictive methods of modelling used in statistics, data mining and computer education. Decision trees are developed through an algorithm which identifies ways of splitting a collection of data on different conditions. It is one of the most popular and practical methods of supervised education. Decision Trees are a non-parametric supervised method of learning for classification and regression.

- *Neural Networks*

Neural networks are a class of machine learning algorithm used in multimedia layers and non-linear functions to model complex patterns in datasets. A neural network is just a couple of neurons linked together as illustrated in Figure 1. Neural networks have a unique capacity to remove meaning from imprecise or complex data to find patterns and detect trends that are too convoluted for the human brain or computer techniques. Neural networks are used for solving many business problems such as sales forecasting, customer research, data validation, and risk management.

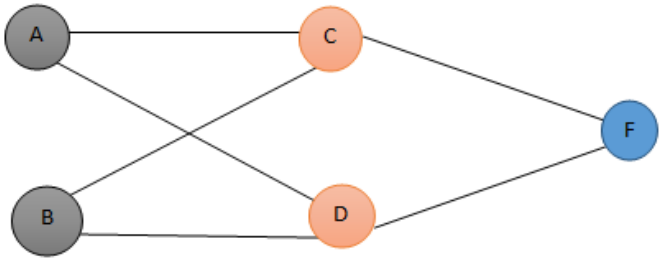

Figure2. Neural Network

- *Bayesian Networks*

A Bayesian network is a probabilistic graphical model which represents a set of variables and their conditional dependencies that uses directed acyclic graph. It is also named as Bayes network, belief network, decision network, or Bayesian model. A Bayesian network is an interpretable, lightweight, scalable representation of a combined distribution of probabilities. It is likely that the Bayesian networks are constructed from a distribution of probabilities and that they also use probability theory for the prediction and detection of anomalies. It can also be used for various tasks, such as prevention, detection of anomalies, diagnose, automated insights, reasoning, prediction of time series, and uncertain decision making. For building models based on data and expert opinions, the Bayesian network can be used and comprises two sections:

- Directed Acyclic Graph
- Table of conditional probabilities
- *Genetic Algorithm*

Genetic Algorithms are algorithms focused on the evolutionary idea of natural selection and genetics. Genetic algorithms are stochastic search algorithms that operate on a population of possible solutions. They are loosely based on population genetics and selection mechanics. In computing terms, a genetic algorithm implements a computing model by using arrays of bits or characters (binary strings) to represent

chromosomes. Each string represents a possible solution. The genetic algorithm then manipulates the most promising chromosomes in search of improved solutions.

2.2Unsupervised Learning

Unsupervised learning [10] analyses and clusters unlabeled data sets with machine learning algorithms. These algorithms uncover hidden patterns in data without requiring human intervention, hence termed as unsupervised. Unsupervised learning models are used to accomplish three main tasks: clustering, association, and dimensionality reduction.

Table 3. Comparison of Machine Learning Techniques

Machine Learning Techniques	Advantages	Disadvantages
Decision Trees	• Handling both continuous and discrete data. • Ability of selecting the most discriminatory features.	• Unstable. • Calculations can get very complex as time goes on.
Clustering	• To discover natural grouping. • To produce hypothesis from data. • To find reliable organization of data.	• Very efficient technique. • Provides end user high level view of what is going in database.
Association Rule Learning	• Finds similar patterns from data and produce rules. • Generates association relationship form data.	• Helps to find sequential patterns. • Uses acquisition, integration and integrity check methods.
GMM	• Flexible • Clusters can be characterized by small number of parameters.	• Need large datasets. • Hard to estimate the number of clusters.
k-Means	• Easy to implement and identify unknown data groups from complex datasets. • Flexible	• No optimal set of clusters. • Lack of consistency.
Genetic Algorithm	• Coding genetic algorithm is easy. • Can find fit solutions in less time.	• Hard for people to come up with good heuristic. • Might not find optimal solution to defined problem in all cases.

2.2.1Clustering-based ML algorithms

The machine learning clustering [11] algorithm will group sequences with some same characteristics together and explore the effective knowledge of unknown sequences in known functions and structures. Therefore, for bioinformatics research it is very important to cluster biological sequences. The difference is that clustering does not enforce a given category. Each cluster has its own features. The aim of cluster analysis is to divide the information into one category with common characteristics, then use other methods for analysing the data. The clustering algorithm has become in recent years a common research path in the field of machine learning with the growth of artificial intelligence. Domestic and foreign scholars have carried out deeper research on clustering algorithms to increase the processing ability of large-scale data. Several excellent algorithms were developed for clustering. The characteristics of and algorithm are different, the algorithm in all cases cannot be implemented. Understanding each algorithm's advantages and drawbacks may help us better leverage and investigate.

- *k-means*

K-means clustering is one of the simplest and most common non-supervised machine learning algorithms. A cluster refers to the set of data points which are aggregated together due to such similarities. The 'means' in the K-means refers to the average of the data; that is, the finding of the centroid. The K-means algorithm determines the k number of centers, then attributes each data point to the closest group while keeping the centers as small as possible.

- *Mean Shift Algorithm*

Mean Shift is an algorithm for hierarchical clustering. In comparison to supervised machine learning algorithms, clustering attempts to group data without first training on labelled data. Mean-shift builds on the principle of kernel density estimation by sorting KDE. The first step in executing the mean shift clustering algorithms is to view your data in a mathematical manner, which means that you represent your data as points such as the one set below. This algorithm needs no previous knowledge of the number and the form of the clusters.

- *Gaussian Mixture Model (GMM)*

Gaussian mixture models are a probabilistic model for the representation in the general population of normally distributed subpopulations. Gaussian is a distribution type, and is a common and mathematically convenient distribution type. Mixture models do not usually need to know which subpopulation has a dataset to which the model can spontaneously learn subpopulations. It is an invariably used paradigm for unsupervised, generative learning or clustering. The benefit of the mixture models is that they do not need the subpopulation to which the data point belongs. This enables the model to learn subpopulations automatically.

- *Expectation–Maximization (EM)*

The expectation-maximization algorithm is an approach for performing maximum likelihood estimation in the presence of latent variables. It is a way to find maximum-likelihood estimates for model parameters when your data is incomplete, has missing data points, or has unobserved (hidden) latent variables. It is an iterative way to approximate the maximum likelihood function with latent variables.

2.2.2 Association Rule-Mining Algorithm

As one of the most important branches of data mining, the association rule for mining can identify associations and frequent patterns of a set of items in the database. In business data analysis, the association rule mining

has played an important role and has also succeeded in many other fields such as virtual basket analysis and medical data analysis.

- *Apriori Algorithm*

Apriori algorithm is a standard association-based mining algorithm that has applications for sequence pattern mining and protein structure prediction. It looks for a variety of frequent sets of datasets. It builds on the relationships between the itemsets. R. Agrawal and Srikant provided this algorithm in 1994.

2.2.3 Dimensionality Reduction

Dimensionality reduction is a learning technique that is used when the number of features/dimensions in a given dataset is excessively large.It reduces the number of data inputs to a manageable number while maintaining data integrity.This technique is often used in data pre-processing, for example when auto encoders remove noise from visual data to enhance the quality of the image.

2.3 Semi-supervised Learning

Semi-supervised [12] learning is a machine learning approach that combines a small amount of labelled data with a large amount of unlabeled data during training, providing the advantages of both supervised and unsupervised learning.It employs a small amount of labelled data and a large amount of unlabeled data, allowing it to reap the benefits of both unsupervised and supervised learning while avoiding the difficulties associated with locating a large amount of labelled data.A text document classifier is a common application of semi-supervised learning.

2.4 Reinforcement Learning

Reinforcement learning [13] is the process of teaching machine learning models to make a series of decisions.It is used by various software and machines to determine the best possible behaviour or path to take in a given situation.Reinforcement learning differs from supervised learning in that the training data contains the answer key, allowing the model to be trained with the correct answer, whereas in reinforcement learning, there is no answer and the reinforcement agent decides what to do to complete the given task.It is bound to learn from its experience in the absence of a training dataset.

III. LITERATURE SURVEY

Machine learning allows for data-driven predictions to be made in order to extract knowledge and relationships from experiences and data sets. It employs some mathematical fields, primarily regression, optimization, and statistics, for this purpose [14]. This section discusses and analyses previous research in the field of mechatronics that employed machine learning algorithms.

In order to verify the validity of the algorithm, the three datasets on the UCI public dataset are experimented undermatlab2016a by Huang *et al.* [15].The authors proposed DCTkNN, a kNN algorithm based on class contribution and feature weighting. To begin, traditional kNN is used to calculate the accuracy of the original dataset and of the data lack of each dimension feature in turn. Then, by comparing two accuracies, the feature is weighted and the weighted distance is calculated, yielding the k-nearest neighbors. Finally, the final labels of the samples are obtained by using class contribution, which combines the number of k-nearest neighbors and their mean distance.

Linli*et al.* [16] compare the performance of the traditional K-means algorithm and the K-means algorithm based on double attributes of objects in MATLAB. All experiments were carried out on a PC running Windows XP, a Pentium IV 1.8GHz CPU, and 1GB of SDRAM memory.Iris Plants data set (iris) and Seeds data set (seeds) were the two data sets used to test the K-means algorithm based on double attributes of objects (seed). The two data sets were obtained from the UCI Irvine Machine Learning repository.This algorithm not only improves the accuracy of the classical k-means algorithm, but it also compensates for the flaws of the classical k-means clustering algorithm caused by a different choice of initial cluster centers instability, and an improved algorithm of cluster centers closer to the actual cluster centers.
In order to identify vibration factors in the master education process, Ghorbani and Polushin[17] have applied non-parametric statistical method, single decision tree. The lathe machine model 16K20VF1 (Russia) with a maximum power of 5.5 kW and a maximum spindle speed of 1600 rpm was used to inform the experiment. The Taguchi method is used to design experiments in this work.

Ya*et al.* [18] used an improved Apriori algorithm based on matrix multiplication to investigate the interaction of children's anti-infective drugs, antipyretic-analgesic and anti-inflammatory drugs, and drugs for the digestive system, in order to investigate the rule of the combination of three types of drugs and to provide theoretical guidance and reference for children's clinical rational drug use.

Shuwen and Jiyi [19] proposed an improved Apriori algorithm based on the transaction and item set matrices. The size of the scanned data is reduced by compressing the matrix and then bit-wise operations are performed on compressed matrix line vectors depending on the preceding nature of frequent data items. For frequent item sets, the item set count and prefix index list are used.

To overcome tracking difficulties in the case of sudden changes, Wang *et al.* [20] proposed a Mean Shift tracking algorithm based on improved target location prediction. To optimize the initial search centre of the traditional Mean Shift tracking algorithm and the tracking problem caused by fixed bandwidth, motion estimation and scale estimation algorithms are used to predict the target position.In order to validate the improved algorithm's effectiveness, this paper compares it to the traditional Mean Shift algorithm in terms of tracking effect and tracking performance.Using VS2010 and Opencv2.4.9 software, the Windows10 system performs two segments of vehicle video sequences and tracks them in various interference contexts.The experimental results show that, when the target moves quickly, scale change and occlusion occur, the mean shifted tracking algorithm based on prediction of the target position still can track the moving target accurately in real time.

Zhao *et al.* [21] proposed a novel motion state estimation method based on the ECMM, which results in an accurate trajectory prediction. The category in ECMM is treated as a latent variable in this method, and the likelihood of motion state is formulated as a Gaussian Mixture Model (GMM) of the differences between trajectory predictions and observations. The effectiveness and accuracy of the proposed method are validated through offline and online evaluations of a collected dataset.

Shen *et al.* [22] propose a clustering-based Gaussian mixture model learning method for the engine knock threshold. A statistical analysis is performed to investigate the stochastic property of the logarithm of knock intensity, and it is discovered that the Gaussian mixture model is better suited for fitting the probability distribution of the logarithm of knock intensity.The proposed method has the potential to be used in real-world applications to reduce time and labor costs associated with knock threshold calibration. However, the technical issue of the EM algorithm's convergence rate should be improved to make the method more reliable in industrial applications.

Hu *et al.* [23] created a neural-network prediction and feedforward compensation strategy for precision multi-axis motion control systems with contouring performance orientation.To capture the dynamical characteristics of contouring error obtained by the Newton extremum seeking method, a deep artificial gated recurrent Unit (GRU) neural network is built.When compared to iterative learning control methods, the proposed NNC feedforward strategy is simple to implement and has excellent contouring control performance without iteration/repetition tasks. The proposed strategy has the potential to be useful in a wide range of industrial mechatronic applications.

Reddy *et al.* [24] presented AMB optimization for compact size. For the minimization of the AMB volume, the nonlinear constrained optimization problem is formulated with three inequality constraints and one equality constraint.AMPGA is preferred over MPGA and SGA for dealing with this nonlinear constrained optimization problem. Adaptation in MPGA is accomplished by adjusting parameters such as crossover probability, mutation probability, and migration rate in response to population diversity. AMPGA results are compared to MPGA and SGA results.The AMPGA's convergence is investigated in terms of a fixed number of generations and the same optimal solutions. AMPGA takes longer to complete a fixed number of generations.

Yang *et al.* [25] investigated the impact of initial clustering center selection on K-means algorithm performance. Better initialization techniques improve the algorithm's performance.In the K-means clustering process, significant improvement was achieved by the local optimum defects and large intracluster variation in the traditional K-means clustering algorithm when calculating the density of a data set using a weighted remote density method.The experimental results show that the algorithm can prevent local optimization, reduce the variance in the internal cluster and further improve the performance of clustering.

Table 4. Comparative Analysis of ML Algorithms in Mechatronics

Year	*Reference*	*Type of ML Algorithm*	*Technique Used*	*Performance Metrics*
2015	[16]	Clustering	k-means	Euclidian distance, Accuracy
2016	[17]	Classification	Decision Tree	Accuracy
2020	[19]	Association Rule	Apriori Algorithm	Boolean Matrix, Association Rules
2019	[20]	Clustering	Mean Shift	Tracking error curve
2017	[21]	Clustering	Expectation Maximization	Computational Time
2020	[22]	Clustering	Guassian Mixture Model	Threshold Value, Density, Frequency
2020	[23]	Classification	Neural Network	Contouring error
2019	[24]	Classification	Genetic Algorithm	Time

IV. SUMMARY

Mechatronics is a multidisciplinary field, that includes parts of mechanical engineering, electronics and computer engi- neering. Mechatronics is a multidisciplinary dossier which includes mechanical and electronic engineering components which essentially lead to robotics. This paper presented a comparative analysis in tabular format of different learning techniques.In addition, advantages and disadvantages of mechatronic and machine learning are also discussed.Expansion in mechatronic systems will be driven in the future by growth in the component sectors.Advances in traditional disciplines fuel the expansion of mechatronic systems through the provision of technology.

REFERENCES

[1] Behravan, A., Abboush, M., &Obermaisser, R., "Deep Learning Application in Mechatronics Systems' Fault Diagnosis, a Case Study of the Demand-Controlled Ventilation and Heating System,"*2019 Advances in Science and Engineering Technology International Conferences (ASET)*, 2019.

[2] Kyura, N. and Oho, H., "Mechatronics—an industrial perspective," *IEEE/ASME Transactions on Mechatronics*, vol. 1, no. 1, pp. 10–15, 1996.

[3] Shetty, D., Manzione, L., & Ali, A., "Survey of Mechatronic Techniques in Modern Machine Design," *Journal of Robotics*, vol. 2012, pp. 1–9, 2012.

[4] Dinsdale, J., "Mechatronics and Asics," *CIRP Annals*, vol. 38, no. 22, pp. 627–634, 1989.

[5] Edgar, T. W., &Manz, D. O., "Machine Learning,"*Research Methods for Cyber Security*, pp. 153–173, 2017.

[6] Bonetto, R., &Latzko, V., "Machine learning,"*Computing in Communication Networks*, 135–167, 2021.

[7] Chourasiya, S., & Jain, S., "A Study Review on Supervised Machine Learning Algorithms," *International Journal of Computer Science and Engineering*, vol. 6, no. 8, pp.16-20, 2019.

[8] Muhammad, L. J., Algehyne, E. A., Usman, S. S., Ahmad, A., Chakraborty, C., & Mohammed, I. A., "Supervised Machine Learning Models for Prediction of COVID-19 Infection using Epidemiology Dataset. *SN Computer Science*, vol. 2, no. 1, 2020.

[9] Reddy, V. K., & Ravi Babu, U., "A Review on Classification Techniques in Machine Learning," *International Journal of Advance Research in Science and Engineering*," vol. 7, no. 3, Mar. 2018.

[10] Usama, M., Qadir, J., Raza, A., Arif, H., Yau, K. A., Elkhatib, Y., … Al-Fuqaha, A., "Unsupervised Machine Learning for Networking: Techniques, Applications and Research Challenges,"*IEEE Access*, 2019.

[11] Min, E., Guo, X., Liu, Q., Zhang, G., Cui, J., & Long, J., "A Survey of Clustering With Deep Learning: From the Perspective of Network Architecture," *IEEE Access*, vol. 6, pp. 39501–39514, 2018.

[12] Van Engelen, J. E., &Hoos, H. H., "A survey on semi-supervised learning,"*Machine Learning*, 2019.

[13] Qiang, W., & Zhongli, Z., "Reinforcement learning model, algorithms and its application,"*2011 International Conference on Mechatronic Science, Electric Engineering and Computer (MEC)*, 2011.

[14] Frochte, J., Lemmen, M., & Schmidt, M., "Seamless Integration of Machine Learning Contents in Mechatronics Curricula,"*2018 19th International Conference on Research and Education in Mechatronics (REM)*, 2018.

[15] Huang, J., Wei, Y., Yi, J., & Liu, M., "An Improved kNN Based on Class Contribution and Feature Weighting. *2018 10th International Conference on Measuring Technology and Mechatronics Automation (ICMTMA)*, 2018.

[16] Linli, T., Yanni, D., &Siyong, C., "A K-Means Clustering Algorithm Based on Double Attributes of Objects,"*2015 Seventh International Conference on Measuring Technology and Mechatronics Automation*, 2015.

[17] Ghorbani, S., &Polushin, N. I., "Using Single Decision Tree to Access the Impact of Cutting Conditions on Vibration," *International Scholarly and Scientific Research & Innovation*, vol. 10, no. 10, pp. 1557-1562, 2016.

[18] Ya, L., Lei, Y., Li, W., Chun, M., &Guiming, Y., "Application Research of Apriori Algorithm Based on Matrix Multiplication in Children's Drug Interaction," *2020 12th International Conference on Measuring Technology and Mechatronics Automation (ICMTMA)*, 2020.

[19] Shuwen, L., &Jiyi, X., "An Improved Apriori Algorithm Based on Matrix,"*2020 12th International Conference on Measuring Technology and Mechatronics Automation (ICMTMA)*, 2020.

[20] Wang, H., Wang, X., Yu, L.,& Zhong, F., "Design of Mean Shift Tracking Algorithm Based on Target Position Prediction,"*2019 IEEE International Conference on Mechatronics and Automation (ICMA)*, 2019.

[21] Zhao, Y.,Xiong, R., & Zhang, Y., "Model Based Motion State Estimation and Trajectory Prediction of Spinning Ball for Ping-Pong Robots using Expectation-Maximization Algorithm,"*Journal of Intelligent & Robotic Systems*, vol. 87, no. 3-4, pp. 407–423, 2017.

[22] Shen, X., Zhang, Y., Sata, K., & Shen, T., "Gaussian Mixture Model Clustering-based Knock Threshold Learning in Automotive Engines,"*IEEE/ASME*

Transactions on Mechatronics,vol. 25, no. 6, pp. 2981 - 2991 Dec. 2020.

[23] Hu, C., Ou, T., Chang, H., Yu, Z., & Zhu, L., "Deep GRU Neural-Network Prediction and Feedforward Compensation for Precision Multi-Axis Motion Control Systems,"*IEEE/ASME Transactions on Mechatronics*, vol. 25, no. 3, pp. 1377-1388, 2020.

[24] Reddy, A. S., Kumar Agarwal, P., & Chand, S., "An adaptive multi-population genetic algorithm for the optimization of active magnetic bearings,"*IOP Conference Series: Materials Science and Engineering*, vol. 691, 012009, 2019.

[25] Yang, W., Long, H., Ma, L., & Sun, H., "Research on Clustering Method Based on Weighted Distance Density and K-Means,"*Procedia Computer Science*, vol. 166, pp. 507–511, 2020.