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Research Article

Analytical Study of Systematic Predictive Model of Integral Machine Learning and Data Visualization Technologies for Modern Healthcare

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ABSTRACT

In this evolving world, machine learning and data visualization technologies are furnishing many domains worldwide including healthcare. Integrating these advance modern technologies are undoubtedly enhancing the accuracy and efficiency of predictivity analytics in modern healthcare marvelously. However, there still remains some limitations that need to be resolve for maximizing the potential of these technologies in modern healthcare. Objective of our review paper is to perform a analytical study by reviewing some recent studies regarding the utility of machine learning and data visualization in the field of healthcare and tries to address the possible research gaps that could assist researchers for carrying out further research in this area. This study also discusses the possible future trends that could probably bridge this existing research gap and can robust the use of machine learning algorithms and data visualization tools in predictivity and could create an user-friendly, scalable and trustable technological environment for individuals in healthcare sector.

Keywords: Machine Learning; Data Visualization; Predictive Analytics; Healthcare

1. Introduction

In this modern era, various advance technologies has been introduced to this world. By leveraging these modern technologies a major transformation has been observed in various domains. Many sectors had got an upper hand by using predictive analytics as an ultraconvenient source. Predictive analytics also profited modern healthcare sector by improving it in many areas such as- patient outcomes, resource allocation, scaling down the operational inefficiency, etc. Predictive analytics utilises historic data to predict the upcoming results and facilitating healthcare sector to improve resource allocation [1]. Nowdays, predictive analytics is enhanced by the utilization of various machine learning algorithms and data visualization tools.

Figure 1: Some use of predictive analytics in modern healthcare

Machine learning (ML), a subgroup of AI had improved the efficiency of predictive analytics by applying its various algorithms. Machine learning as the name suggest machine itself has the potential to acquire knowledge from the data. Number of ways a machine can learn are: - supervised, unsupervised, semi supervised and reinforcement learning each consisting many procedures [2] [Figure(2)]. Machine Learning algorithms aid in analysing the huge and complex data and generate meaningful insights, discovers hidden patterns in the data that helps in better decision making which improves the quality of patient care [3]. Recent study [4] had discussed the performance of different machine learning algorithms across multiple healthcare predictive task such as:- patient risk assessment, fraud detection, disease diagnosis, early disease detection. Machine learning not only used in analysing the complex data sets but also plays a vital role in the data security concern, as healthcare industries are generating the huge amount of data everyday such as – clinical records, operational data, genome data, medical images [5]. Machine Learning can be more understandable by the integration of data visualization techniques. Here the major part is played by data visualization in increasing trust in ML models by applying various tools [6].

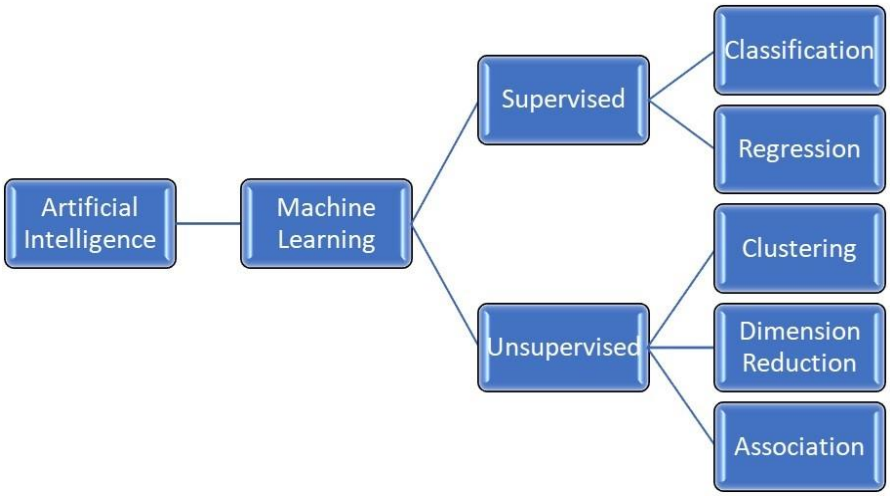

Figure 2: Various types of ML algorithms

Visualization, another powerful tool for exploratory data analysis [7]. Data visualization is a technology which visualize the information from the complex datasets into a pictorial form (charts, graphs, diagrams, maps, etc) that makes the complex data easily accessible for the stakeholders. The relevant information that is not mentioned anywhere in the document is often assimilated by data visualization [8]. Implicating visualization techniques have several advantages in healthcare, improving overall patient care, identify disease trend and pattern recognition,

presenting data among various individuals (especially non-medical), enhancing decision making in critical situation, errors and fraud detection [9].

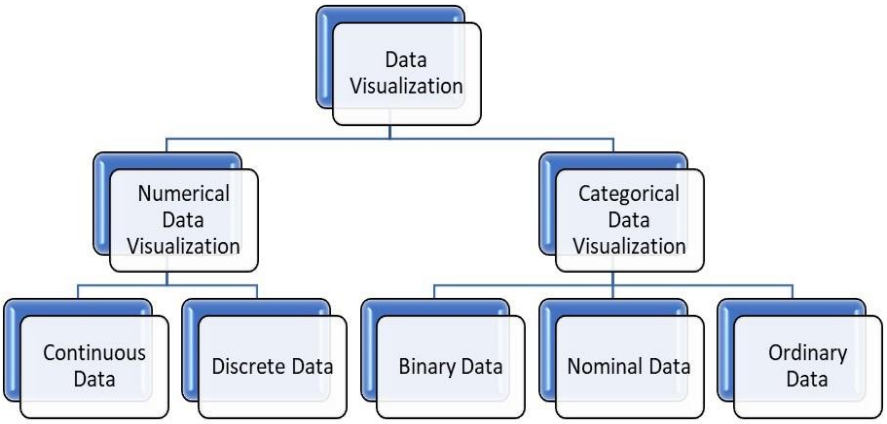

Figure 3: Data Visualization with its categories

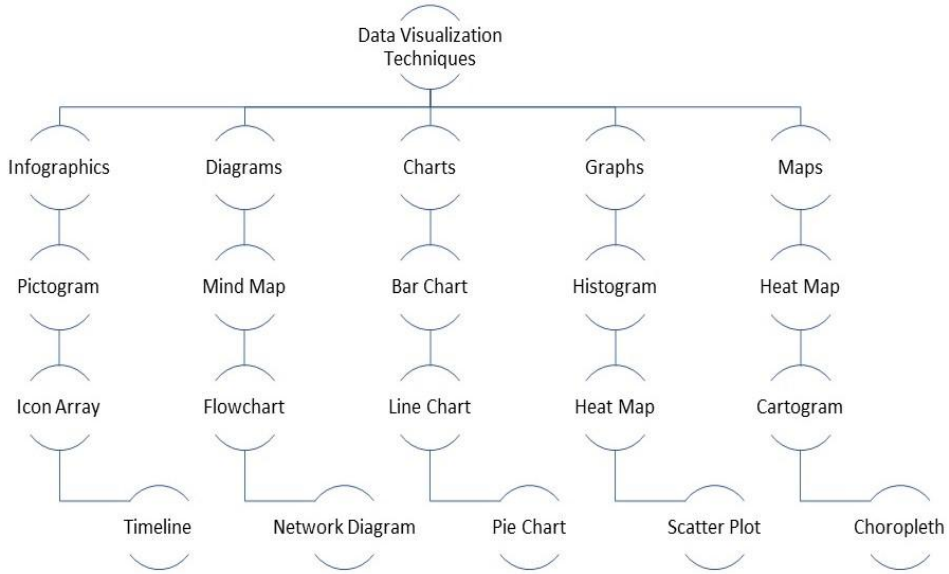

Figure 4: Various Data Visualization Techniques

2. Commonly used ML algorithms

2.1. Decision Tree(DT)

Decision Tree(DT), a kind of supervised ML algorithm which uses both classification as well as regression. It has a flowchart like composition which is used for decision making and prediction. Decision tree consists of a root node which represent the complete dataset, internal nodes which denotes decision or tests on attributes, rules or result of a decision is described by branches and leaf nodes which denotes the final result of the algorithm.

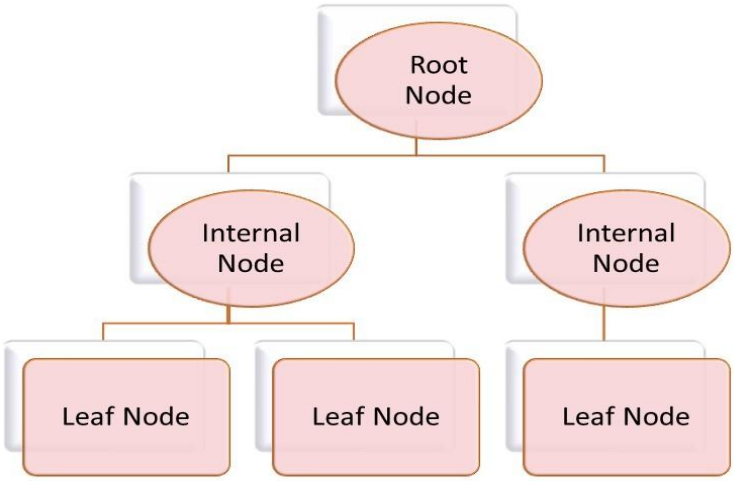

Figure 5: DT with its root node, internal node and leaf node.

2.2. Support Vector Machine(SVM)

Support Vector Machine(SVM), the effective type of supervised ML algorithm among all ML algorithms for pattern recognition which uses both regression and classification. Hyperplane, a decision boundary is created that separates n-dimensional interplanetary into dissimilar categories. Because of this hyperplane one could place the new data points easily in accurate decision in the prospective future time. Support Vector Machine selects extreme points which is known as support vectors that helps in creating the hyperplane.

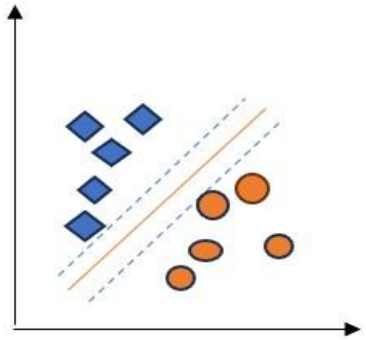

Figure 6: Support Vector Machine with red line indicating hyperplane

2.3. Naïve Bayes

Naïve Bayes, a bayes theorem based widely used supervised ML algorithm which uses classification. It is a probabilistic classifier and an efficient algorithm for large datasets. According to naïve bayes theorem,

$$P(X|Y_1, Y_2 \_\_ Y_n) = \frac{P(Y_1|X) \times P(Y_2|X) \times \_ \times P(Y_n|X)}{P(Y_1) \times P(Y_2) \times \_ P(Y_n)} \times P(X)$$

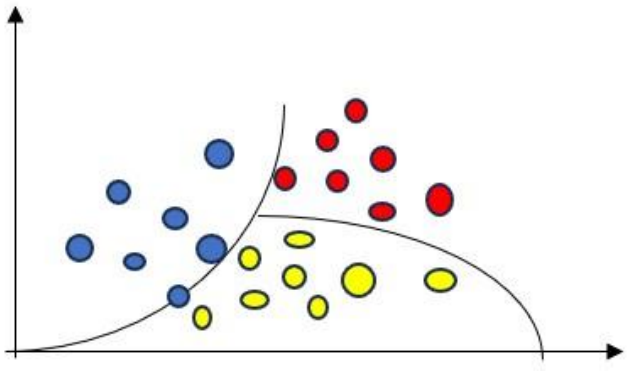

Figure 7: Naïve Bayes with distribution of different classes

2.4. K-Nearest Neighbours(KNN)

K-Nearest Neighbour(KNN) is a simple and frequent used ML algorithm that is identified as supervised which uses both classification as well as regression. KNN uses distance metric to find k nearest neighbours from the given data point.

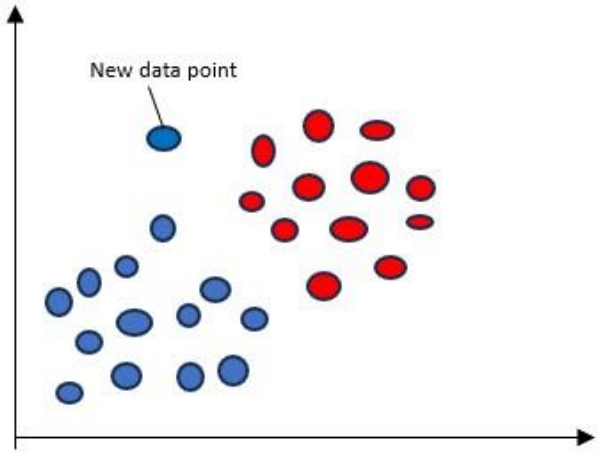

Figure 8: Demonstration of K-Nearest Neighbour having two categories

2.5. Logistic Regression(LR)

Logistic Regression(LR) which is used for predicting discrete class labels dissimilar to linear regression that has the utility for predicting continuous quantities [10]. It is a kind of ML algorithm which is identified as supervised that uses only classification. In logistic regression algorithm logistic function also known as sigmoid function is used that produces binary outcomes between 0 and 1 by taking an independent variable as input.

$$\Upsilon = \frac{1}{1 + e^{-(a_0 + a_1 x)}}$$

2.6. Random Forest

Random Forest, another kind of ML algorithm which is identified as supervised that uses both classification as well as regression. Random forest is the updated version of decision tree which correct the overfitting habit of decision tree. A random forest model contains several decision trees for having better performance than a single decision tree because of the separate training on random samples from the training dataset [11].

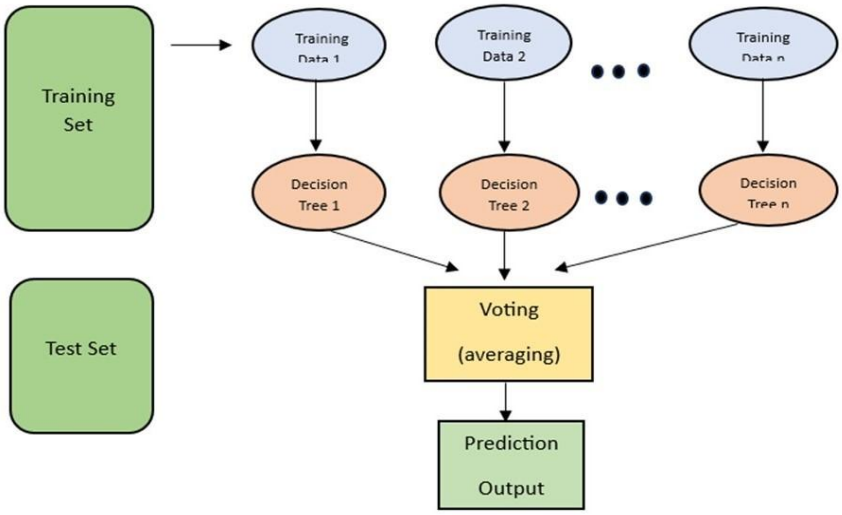

Figure 9: Demonstration of Random Forest Algorithm

Table 1. Summarised review of machine learning algorithm

Algorithm Name	Learning Type	Used for	Applications in Healthcare
Decision Tree	Supervised	Classification, Regression	• Diagnosis and prediction • Treatment Optimization • Medical Imaging • Electronic Health Care (EHR) Management • Cost Prediction in Healthcare
Support Vector Machine	Supervised	Classification, Regression	• Diagnosis and prediction • Medical Imaging • Genomic Data Analysis • Drug Discovery
Naïve Bayes	Supervised	Probabilistic Classification	• Diagnosis and prediction • Medical text Classification • Genomic Data Analysis • Risk Assessment
K-Nearest Neighbour	Supervised	Classification, Regression	• Diagnosis and prediction • Medical Image Analysis • Patient Risk Stratification • Personalized Treatment Recommendations
Logistic Regression	Supervised	Classification	• Diagnosis • Predicting Patient Outcomes • Risk Assessment • Healthcare Policy and Planning
Random Forest	Supervised	Classification, Regression	• Diagnosis • Patient Risk Stratification • Drug Discovery and Development • Medical Image Analysis

3. Related work

In this section, we reviewed the latest studies in related area of ML and data visualization in predictive analytics in modern healthcare.

Table 2

Authors	Year	Aim of the study	Result of the study
Muhammet Faith AK [12]	2020	Impact of data visualization and ML for the diagnosis of breast cancer.	Applying different types of machine learning algorithms on dataset and achieving the highest accuracy (98.1%) with logistic regression model among all models.
Victor Chang et al. [13]	2022	Developing a python-based model by utilizing ML algorithms for prediction of heart diseases.	This paper developed a model with random forest classifier algorithm achieved the significant accuracy approximately 83%.
Gregor Stiglic et al. [14]	2020	Provides a comprehensive overview of interpretability in machine learning in healthcare.	Dividing interpretability into two categories: local and global interpretability and concluded the critical role of machine learning in healthcare.
Sashikala Mishra et al. [15]	2022	Improving classification accuracy in healthcare system by proposing a bit fusion algorithm.	Uses five diversified base classifiers (Naïve Bayes, KNN, SVM and DT) and the results shows 3-5% improvement in accuracy over traditional fusion methods.
Katelynn E. Boerner et al. [16]	2022	Implicating data visualization to track and monitor the symptoms of chronic pain among youth.	Concluded the importance of data visualization platform with Ecological Momentary Assessment (EMA) increasing the management of chronic pain among youth.
Parameshwar Reddy Kothamali et al. [17]	2024	Evaluating the influence of AI and ML on diagnostic accuracy and personalized treatment within telemedicine.	Concluded a satisfactory result of using AI-driven telemedicine in healthcare system.
Kamlesh Kumar et al. [18]	2023	A survey of integration of AI and ML in healthcare.	Artificial intelligence and machine learning models can be useful in healthcare by enhancing the standard and effectiveness of the service.
Jian Ping Li et al. [19]	2020	Forming a system that is based on ML mechanism for diagnosis of heart disease.	Good accuracy (92.37%) has achieved from the suggested system (FCMIM – SVM) feasible with support vector machine as compared to previously suggested methods.
Nasmin Jiwani et al. [20]	2021	Creating a AI – based framework using ANN for detecting real time cardio arrest.	Proposed method has achieved 85% accuracy and validation accuracy of 83%.
Brahmaji Godi et al. [21]	2020	Suggested an advanced automation system for healthcare that uses IOT	Proposed system E-healthcare Monitoring (EHMS) given the accurate result by passing the collected data through support vector machine. This

		technology with machine learning techniques.	system can aid in monitoring and decision making for proper diagnosis.
Vijeta Sharma et al. [22]	2020	Building a model that can be use for predicting heart disease using different ML algorithms.	Random Forest Algorithm gives the highest accuracy (99%) in less time comparing with other machine learning algorithms.
Nan Liu et al. [23}	2020	Building a ML based predictive model that can evaluate the 30 – days readmissions risk.	Proposed model sparse Bayesian extreme learning machine (SBELM) has achieved better performance on comparing with traditional LACE index.
Jeremy Petch et al. [24]	2021	Reviewing a comprehensive understanding in cardiology leveraging machine learning techniques and also addressing the concern for its black box nature.	Study conclude that development of machine learning models is increasing the clarity in cardiology and also addressing the limitation in current models. This study also proposes a rule of thumb for the usage of black box models.
Francisco Jose Garcia Penalvo et al. [25]	2022	A platform is presented that is user-friendly in healthcare. This platform can guide the user who do not have programming or theoretical knowledge in machine learning.	A graphical platform called KoopaML is designed for building machine learning pipelines for healthcare workers. This platform help user in definition and execution of machine learning pipelines, and can also aid in interpretating and visualizing the machine learning outcomes, verification of data and handling heuristics management.
Saiful Khan et al. [26]	2022	A data visualization service (RAMPVIS) has designed and developed for responding in urgent need assisting epidemiologist in visualizing the data during COVID-19 pandemic.	A successful design of RAMPVIS, a data visualization service has been developed which can be valuable for visualizing data in COVID-19 pandemic and can be used in future during an emergency response.
Matthew J. McAuliffe et al. [27]	2001	Developing an user-friendly application that can easily analyse the medical data for researcher and clinicans.	A significant progression has achieved for proposed tool, Medical Image Processing Analysis and Visualization (MIPAV) and addresses the future work to meet the immense need for healthcare data.
Mahendra Botlagunta et al. [28]	2023	Aim of this paper is forming a system for diagnosing breast cancer.	Study concluded that for early diagnosis of breast cancer metastasis, we can make use of blood profile data a non - invasive machine learning method. Decision tree algorithm displays 83% accuracy as compare to other machine learning algorithms.
Rahul Shetty et al. [29]	2024	Enhancing the retrieving efficiency from electronic medical record (EMR) especially for the care of diabetic patients.	Suggested framework i4C (Insights for Care) dashboard have experienced greater time efficiency as compared to traditional EMR information retrieval method.

Md. Monirul Islam et al. [30]	2024	Study provides the early detection of mental health by reviewing various machine learning models, algorithms and applications.	Study provides an overview of the recent work regarding the field that will be helpful for new researcher and also addresses the implication for future research
Jun Kit Chaw et al. [31]	2023	Developing a system by utilising ML algorithms that can predict the shock developing risk in dengue patient.	Uses different ML algorithms: ANN, Decision Tree, SVM and Logistic Regression for shock prediction among dengue patients. Out of these algorithms Support Vector Machine outperformed other methods.
Mohammad Mihrab Chowdhury et al. [32]	2023	Aim of this paper is to predict the risk of diabetes among persons through machine learning algorithms and data augmentation techniques.	Implicating various machine learning and data augmentation techniques can enhance predictivity of patients at risk of diabetes.
Kosar Ghaddaripouri et al. [33]	2024	A systematic review for prediction and diagnosis of meningitis by using machine learning algorithms.	By reviewing the studies, author conclude the ML algorithms were effective for diagnosing and predicting meningitis and can aid in the decision making process for healthcare providers.
Asli Z. Dag et al. [34]	2023	Aim of this paper is forming a system which utilises machine learning that can enhance the prediction of lung cancer for factors relating to survival rates of years: one, ten and five .	Extreme Gradient Boosting (XGB) gives the highest accuracy for one and ten year survival prediction while for the five year survival prediction Logistic Regression gives the better score.
Rakibul Islam et al. [35]	2024	Developing a system for enhancing the predictivity of liver disease by integrating various ML algorithms with the Tree – Structured Parzen Estimator (TPE).	Model that was proposed in this research has got highest accuracy (95.8%) employing ETC (Extra Tree Classifier) with TPE.
Jiyoun Song et al. [36]	2021	Forming a model that can predict the risk of wound infection associated with hospitalization or emergency department visiting home healthcare (HCC).	By the usage of different ML algorithms such as: ANN, Logistic Regression and Random Forest forms a model which concluded that Logistic Regression was most effective model comparing with other models.

4. Research Gap

Although many studies mentioned in above section had highlighted sustainable amount of work in the field of predictive analytics in healthcare by integrating machine learning and data visualization, there still remains a feasible gap that need to be pursuit. The existing review notifies these gaps such as:- using limited machine learning algorithms, which could seeks the opportunity for future research by exploring more machine learning algorithms on larger datasets to improve the accuracy in predictivity.

Data privacy and safety is also among the most concern gap in the above mentioned literature review. As patient's privacy is the first priority that should not be negotiated. This gap opens the doors for the further research that can robust safety and privacy of modern healthcare data. This review also seeks the limited integration of machine learning technique with data visualization tools. As healthcare industries generate huge and different types

of data everyday which increases the complexity in the data and machine learning could be complicated among the non - programmers so, implicating data visualization tools with machine learning algorithms makes the data analysis and decision making more effective and accurate.

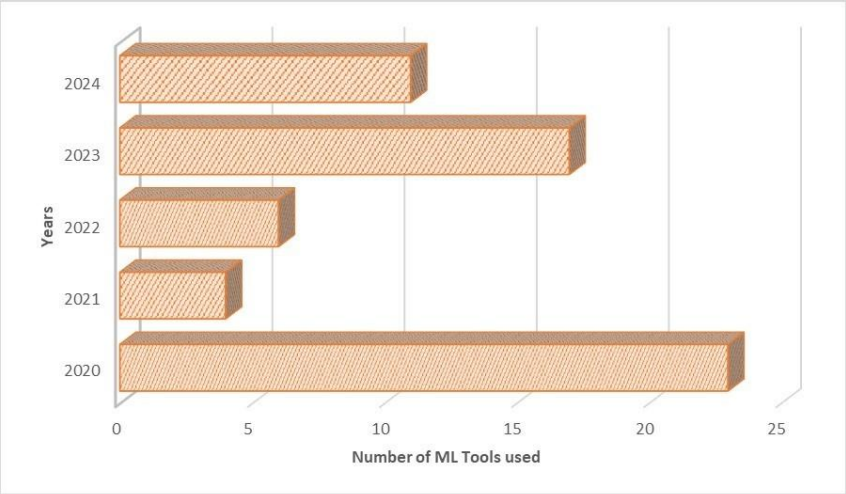

Figure 10. Demonstrating the use of Machine Learning (ML) Tools from the above review in following years.

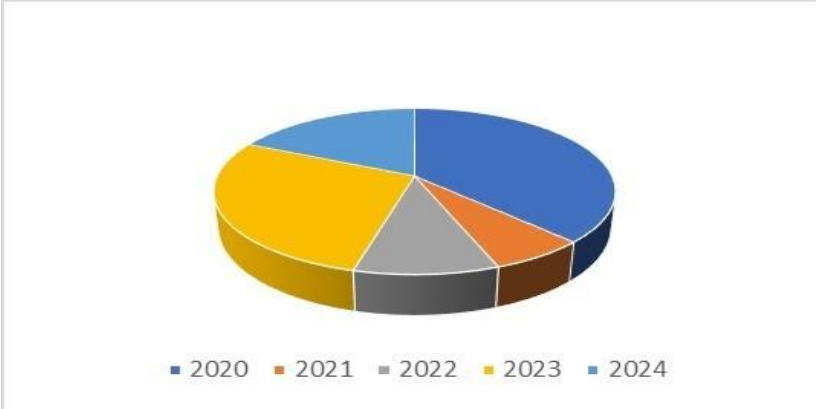

Figure 11. Percentage of Machine Learning Tools in the following years.

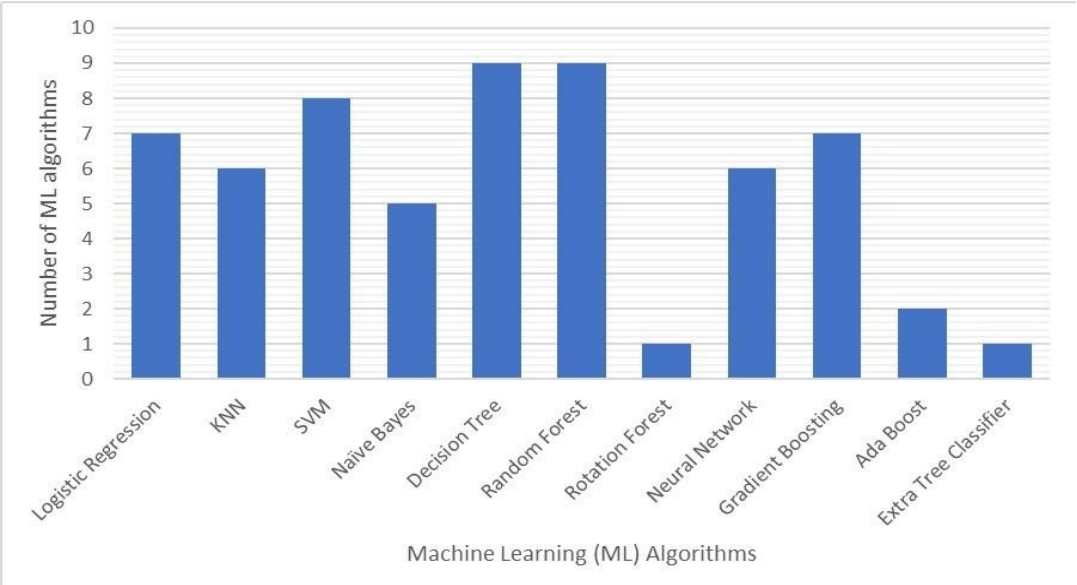

Figure 12. Different types of machine learning algorithms used from the review studies.

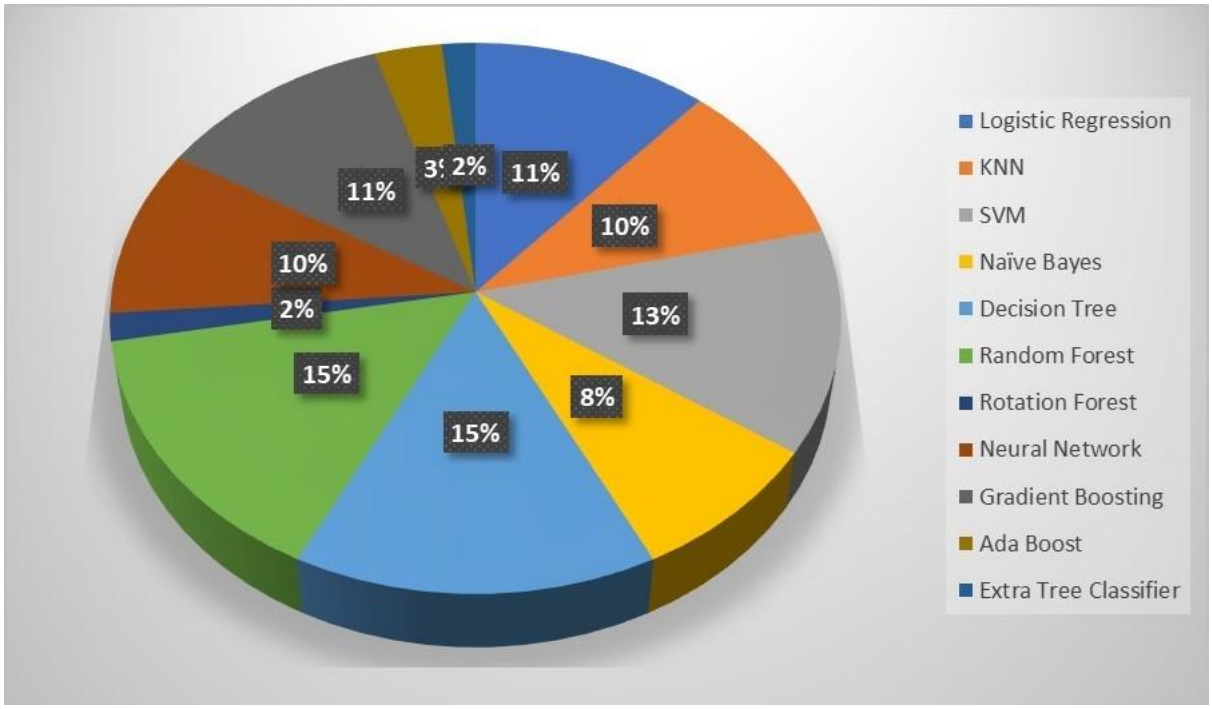

Figure 13. Percentage of usage of the various machine learning algorithm.

5. Future Work

As addressed the notable research gaps in the previous section that could lead researcher for further research related to the field of leveraging machine learning and data visualization in predictivity in healthcare. By bridging these gaps the efficiency of predictivity in healthcare can be boosted immensely. Since healthcare industries generates the huge amount of data everyday, to maintain the data security some existing techniques can enhance the security and privacy in big data related healthcare industry [37]. Cloud based system can be benefited for healthcare sector by reducing cost, providing scalability, more secured patient's information [38]. Some recent studies also highlighted the use of Federated Learning (FL) [39], Blockchain and Distributed Ladger for security and privacy purpose in healthcare data [40].

There is a need of further research for the development of more advance visualization tools that can leverage clinicians in understanding complex machine learning models so that they could easily bring out meaningful insights from the data. Some recent studies suggested that the efficiency and accuracy in data visualization can be enhanced by appending Artificial Intelligence (AI) and Generative AI techniques [41 , 42].

6. Conclusion

This review analyses some recent studies on utilising the different ML algorithms and data visualization in predictivity in modern healthcare and demonstrated that, though in this modern era machine learning and data visualization are the key pillars in healthcare sectors which have various advantages in predictivity in healthcare, there still remains some limitations (like use of limited machine learning algorithms on small datasets, data security and privacy, etc) that are raised in this paper and discussed the future possible research that could overcome these limitations. By overwhelming these limitations we can enhance the predictivity in healthcare by leveraging machine learning and data visualizations techniques.

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