Prediction of Mental Health Problems Using Machine Learning Techniques

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- ***Abstract***

Early detection of mental health issues allows specialists to treat them more effectively and it improves patient's quality of life. Mental health is about one's psychological, emotional, and social well-being. It affects the way how one thinks, feels, and acts. Mental health is very important at every stage of life, from childhood and adolescence through adulthood. This study identified five machine learning techniques and assessed their accuracy in identifying mental health issues using several accuracy criteria. The five machine learning techniques are Logistic Regression, K-NN Classifier, Decision Tree Classifier, Random Forest, and Stacking. We have compared these techniques and implemented them and obtained the most accurate one in Random Forest technique based with an accuracy of prediction 81.22%.

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1. Introduction

A person's mental well-being is his or her mental condition, as well as an overview of his or her general environment. Brain chemistry abnormalities are the cause of mental illness. An individual's mental health serves as a barometer for properly addressing his or her diseases. To predict any health-related irregularities, it is critical to keep track of diverse groups' mental health profiles. To avoid serious illness, it is necessary to identify the mental health of different categories at different times. In the next few years, healthcare providers will be required to consider a patient's mental health profile to deliver better medication and aid in a speedier recovery.

Machine learning is a technique that aims to construct systems that can improve through experience by using advanced statistical and probabilistic techniques. It is believed to be a significantly useful tool to help predict mental health. It allows many researchers to acquire important information from the data, provide personalised experiences, and develop automated intelligent systems. Supervised machine learning is widely used in research studies especially in predicting illness in the medical field. In supervised learning, the terms, attributes, and values should be reflected in all data instances. More precisely, supervised learning is a classification technique using structured training data. Meanwhile, unsupervised learning does not need supervision to predict. The main goal of unsupervised learning is handling data without supervision. It is very limited for the researchers to apply unsupervised learning methods in the clinical field.

The primary goal of this analysis is to systematically analyse and summarise the machine learning methods utilised to foresee and recognize psychological issues in the initial phase. It would also focus on the difficulties and restrictions of applying machine learning techniques in this field. In

addition to that, possible openings and spaces in this area for future study will be talked about. Therefore, this analysis will add to the current state of the art in the form of a systematic literature review relating to machine learning techniques applied in anticipating mental health problems. This analysis hence contributes a critical summary and potential research directions that could help researchers gain knowledge about the techniques and uses of big data in the mental health areas.

But, this process is quite challenging because these problem's symptoms have a very complex and heterogeneous nature which makes it difficult to find the actual causes in a precise manner. In previous years, machine learning (ML) algo's have shown good results in predicting and finding mental health problems.

The ambitious goal of harnessing the power of machine learning algorithms to gain insights into mental health is crafting precise and dependable predictive systems that can pinpoint those susceptible to mental illness or foretell the emergence of such afflictions. These models aim to achieve early detection by analysing diverse data sources, including clinical records, behavioural patterns, social media activity, and sensor data. By detecting early signs and symptoms of mental health disorders, machine learning algorithms enable timely interventions, personalised treatment plans, and risk assessments. Although AI predictive models can forecast treatment outcomes, streamline resource distribution, and provide population-level insights for public health policies, they must be used cautiously since they can reflect and even amplify the biases and unfairness in historical data. By harnessing machine learning to advance early detection, tailor treatments, and optimally distribute resources, we aspire to better mental health and lessen the individual and societal toll of psychiatric illness.

Method	Accuracy
Logistic regression	79.63
KNeighborsClassifier	79.89
DecisionTree Classifier	80.69
Random Forests	81.22

Fig.1. Accuracy of all Classifier

2. Methodology

A lot of predictions have been done in the field of health prediction by using various techniques like machine learning and different hybrid techniques. These techniques have helped humans to identify and predict the mental health status of an individual and to know if he/she needs to consult a mental health specialist or not. Some of the most common technologies which are used for predictions include KNN, Logistic regression Random forest based classifier and Decision tree.

KNN is a non-parametric algorithm that belongs to the instance-based learning category. It classifies new data points based on the majority vote of their k nearest neighbours.

Random Forest is an ensemble algorithm that combines multiple decision trees and makes predictions based on the majority vote or averaging of the predictions of individual trees.

Logistic Regression is a parametric algorithm that models the relationship between the independent variables and a binary outcome using a logistic function.

A decision tree is a non-parametric supervised learning algorithm, which is utilised for both classification and regression tasks. It has a hierarchical tree structure, which consists of a root node, branches, internal nodes and leaf nodes.

We've used all three techniques to find out which one best suits in these conditions, the

methods we've used to find the result of all three algorithms and compare them are as below:
The first phase is data cleaning, which is the process of finding incomplete, erroneous, unneeded, or missing data and then modifying, replacing, or eliminating it based on the specific necessity. We found that three columns have the missing data. Not a Number, or NaN, is a special value in Data Frames and Numpy arrays that represents a cell with no value.

The second step is data encoding. When the categorical feature is identified ordinal, we apply this categorical data encoding strategy. In this case, it is important to retain the order. Hence the sequence should be reflected in encoding. Each label will be turned into a value of an integer value during label encoding.

In the third step, we'll look for the covariance matrix. In data science and machine learning, it is one of the most significant matrices. It offers information on feature co-movement (correlation). In Feature scaling, we put the data's independent features into a set range. It handles significantly changing values or units and magnitudes during data pre-processing.

For the fourth step, we split the dataset into a training and testing data set.

The fifth step is feature importance. Feature selection is critical in machine learning since it is a fundamental strategy for directing variable usage to what is most efficient and effective for a certain machine learning system.

The sixth step is applying the model, we have chosen 4 models which are KNN, Decision tree, Logistic regression and random forest classifier.

For the seventh step, we train all the four models from our training data and after training the testing phase occurs. All the models are tested upon testing data and accuracy is calculated based on their performance on testing data.

After that we plot the ROC curve of all the models are plotted and at final step the graph of comparison between all models are plotted.

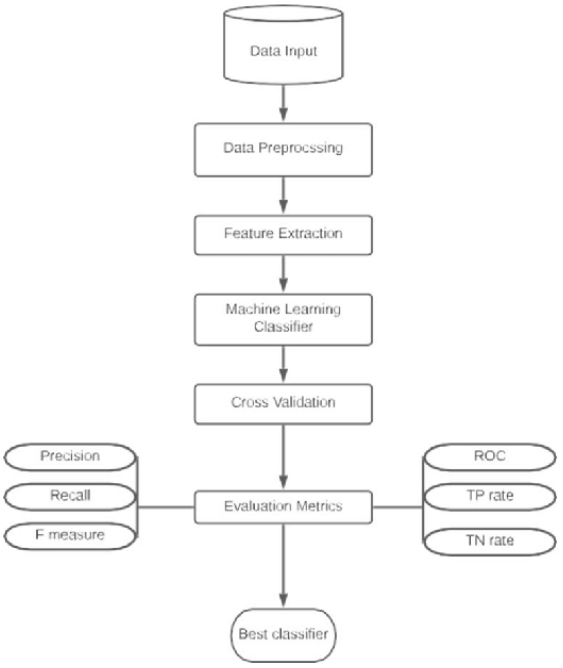


Fig. 2. Flow Chart

3. Mathematical Descriptions

- **K-Nearest Neighbors Algorithm(KNN):**

KNN stands for K-nearest neighbour, it's one of the Supervised learning algorithm mostly used for classification of data on the basis how it's neighbour are classified

formulae used:

Euclidean distance function:

$$dist((x, y), (a, b)) = \sqrt{(x - a)^2 + (y - b)^2}$$

After computing the distance, the input x gets assigned to the class with the largest probability:

$$P(y = j|X = x) = \frac{1}{k}\sum_{i \epsilon A} I(y^i = j)$$

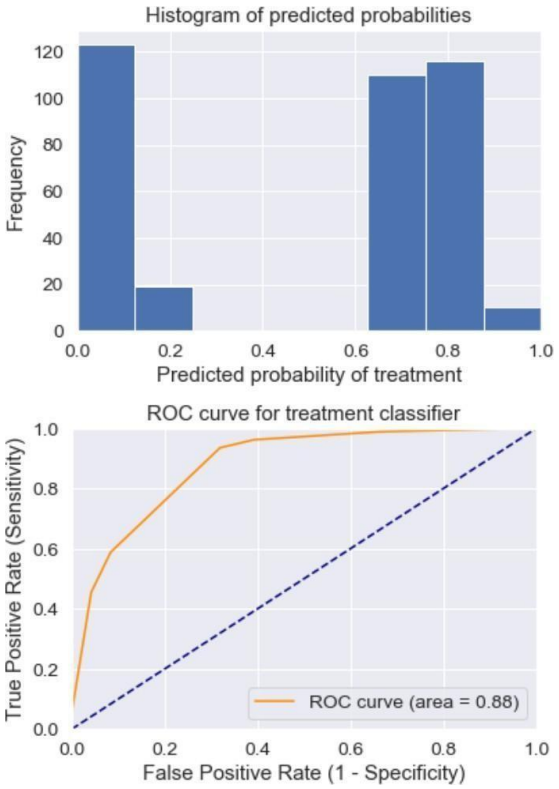


Fig. 3. Frequency and ROC curve for KNN

- **Decision Tree :**

It is a supervised learning technique that can be used for both classification and Regression problems, but mostly it is preferred for solving classification problems. It is a tree-structured classifier, where internal nodes represent the features of a dataset, branches represent the decision rules and each leaf node represents the outcome.

Formulae used:

Information gain *is the opposite of entropy that measures the decrease in entropy.* Information gain computes the difference between entropy before split and average entropy after split of the dataset based on given attribute values.

$$Info(D) = -\sum_{i=1}^{m} p_i \log(p_i)$$

Gain ratio handles the issue of bias by normalising the information gain using Split Info.The gain ratio can be defined as

$$GainRatio(A) = \frac{Gain(A)}{SplitInfo_A(D)}$$

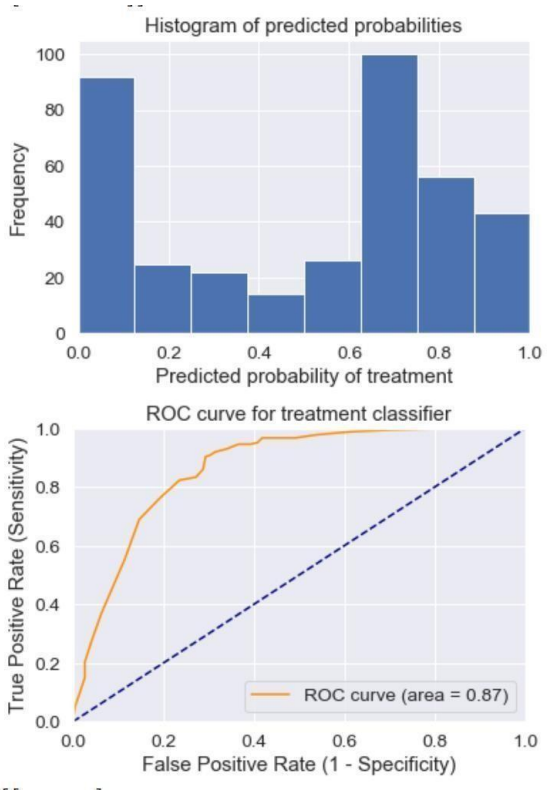


Fig. 4. Frequency and ROC curve for Decision Tree

- **Logistic regression :**

We could start by assuming p(x) be the linear function. However, the problem is that p is the probability that should vary from 0 to 1 whereas p(x) is an unbounded linear equation. To address this problem, let us assume log p(x) be a linear function of x and further, to bound it between a range of (0,1), we will use logit transformation. Therefore, we will consider log p(x)/(1-p(x)). Next, we will make this function to be linear:

$$\log \frac{p(x)}{1-p(x)} = \alpha_0 + \alpha . x$$

After solving for p(x):

$$p(x) = \frac{e^{\alpha_0+\alpha}}{e^{\alpha_0+\alpha}+1}$$

To make the logistic regression a linear classifier, we could choose a certain threshold, For e.g :- 0.5. Now, the misclassification rate can be minimised if we predict y=1 when p >= 0.5 and y=0 when p < 0.5. Here, 1 and 0 are the classes.

Since Logistic regression predicts probabilities, we can fit it using likelihood. Therefore, for each training data point x, the predicted class is y. Probability of y is either p if y=1 or 1-p if y=0. Now, the likelihood can be written as:

$$L(\alpha_0, \alpha) = \prod_{i=1}^{n} p(x_i)^{y_i}(1 - p(x_i)^{1-y_i}$$

$$l(\alpha_0, \alpha) = \sum_{i=0}^{n} - log\ 1 + e^{\alpha_0+\alpha} + \sum_{i=0}^{n} y_i(\alpha_0 + \alpha.x_i)$$

The next step is to take a maximum of the above likelihood function because in the case of logistic regression gradient ascent is implemented (opposite of gradient descent).

Now Maximum Likelihood Estimation (MLE)

A method of estimating the parameters of probability distribution by maximising a likelihood function, in order to increase the probability of occurring the observed data. We can find MLE by differentiating the above equation with respect to different parameters and setting it to be zero. For example, the derivative with respect to one of the component of parameter alpha i.e. a_j is given by:

$$\frac{dl}{d\alpha_j} = \sum_{i=0}^{n} (y_i - p(x_i; \alpha_0, \alpha))x_{ij}$$

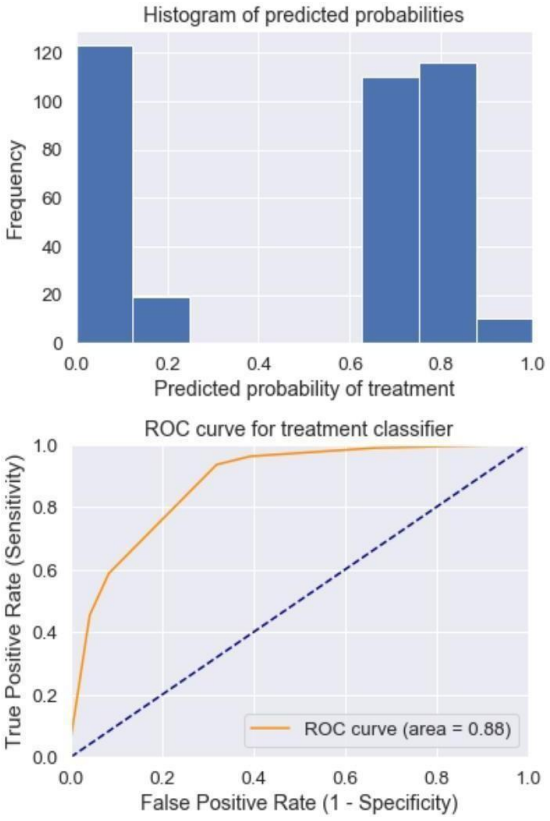


Fig. 5. Frequency and ROC curve for Logistic Regression

- **Random forest :**

It is a machine learning algorithm that uses a group of decision trees to make predictions. Each decision tree in the Random Forest gives its prediction, and the final result is determined by combining the predictions from all the trees. This helps to improve accuracy and make more reliable predictions compared to using a single decision tree. Random Forest can be used for tasks like classifying emails as spam or not spam, predicting the price of a house, or diagnosing a disease based on symptoms.

Formulae used :

The importance for each feature on a decision tree is then calculated as:

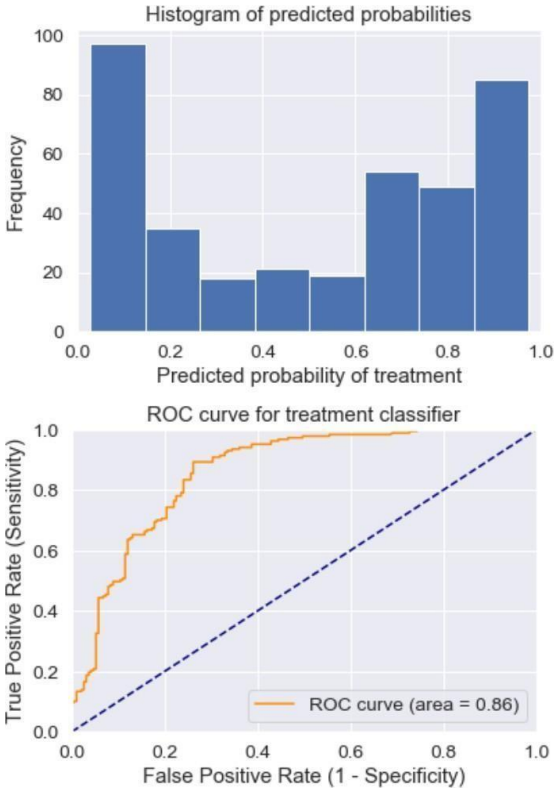
$$fi_i = \frac{\sum_{j:node\ j\ split\ on\ feature\ i} ni_j}{\sum_{k \epsilon all\ nodes} ni_k}$$

These can then be normalised to a value between 0 and 1 by dividing by the sum of all feature importance values:

$$normfi_i = \frac{fi_i}{\sum_{j \in all\ features} fi_j}$$

The final feature importance, at the Random Forest level, is it's average over all the trees. The sum of the feature's importance value on each trees is calculated and divided by the total number of trees:

- RFfi sub(i)= the importance of feature i calculated from all trees in the Random Forest model
- normfi sub(ij)= the normalised feature importance for i in tree j



- T = total number of trees

Fig. 6. Frequency and ROC curve for Random Forest

4. Visual and Tabular Results

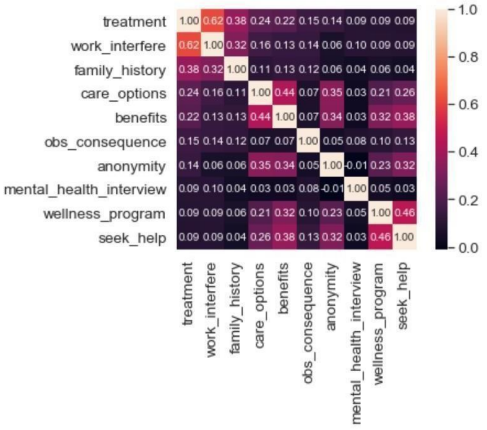


Fig.7 . Correlation Matrix/Heatmap

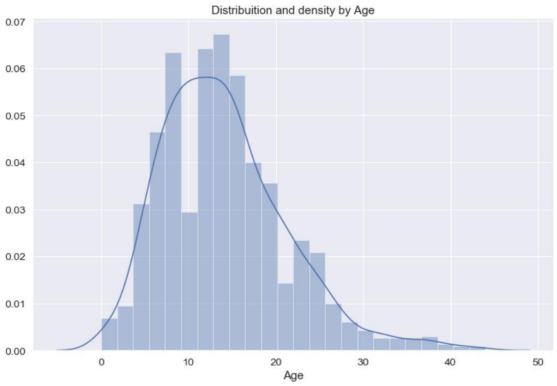


Fig. 8 . Distribution and density by Age

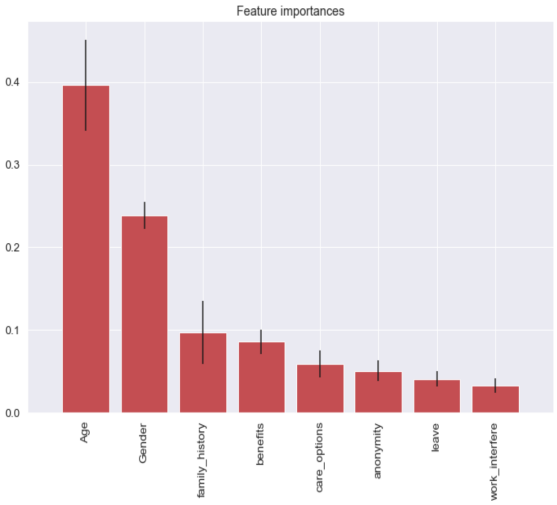


Fig. . 9. Feature importance

5. Evaluating models

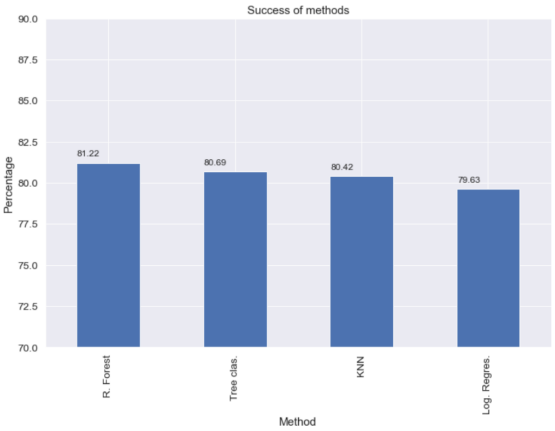


Fig.10.. Accuracy of all models

6. Results:

This study identified four machine learning techniques i.e k nearest neighbour classifier, logistic regression, decision tree and random forest. And we assessed their accuracy in identifying mental health issues. First, we executed the classifiers which included all the 27 attributes which were identified from the text documents and then we executed it by including 8 attributes were selected using the algorithm of feature selection. Figure 4 illustrates the feature importance of the 8 selected features. The Accuracy of a given test set for a classifier is the percentage of test set instances that are classified correctly by using the classifier. The accuracy of any classifier will depend upon how well the classifier will classify the data set which is being tested. We measured that by using the area under the Receiver Operating Curve. In the ROC area, a perfect test will represent an area of 1 and a worthless test will represent an area of 0.5. Figure 5-8 illustrates the graph of four classifiers on ROC Area values. We observed that the classifiers were more accurate in predicting the condition of mental health than other classifiers because the ROC area of all classifiers used is between 0.8 and 0.9.

Now the last plot is about comparing the models. This curve is between the percentage of accuracy of different models vs the models as shown below:

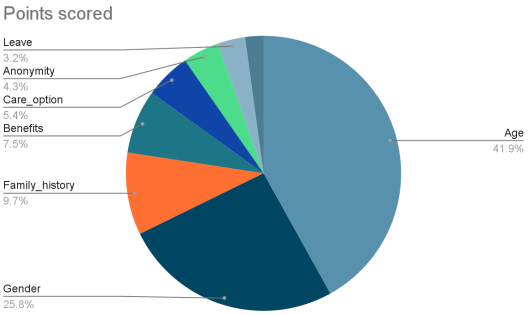


Fig.11.Scaling and fitting

Our results showed that the ML algorithms performed well in predicting mental health conditions based on the extracted features. Among the models, the random forest model outperformed the other models, achieving an accuracy of 81.22 % and decision tree classifier score of 80.69%. The KNN model also performed well, with an accuracy of 80.42% .

7. Discussion:

Our study highlights the potential of ML algorithms in predicting mental health conditions based on various data sources and features. Through their complex analyses and predictive capabilities, these intricate algorithms are poised to facilitate the timely identification and intervention of mental health afflictions, ultimately engendering more favourable prognoses for those beset by such maladies. Although the efficacy of such algorithms relies heavily on both the nature and calibre of the information they are fed. In order for machine learning models deployed in medical settings to be trusted and scaled, their logic and decision processes must be transparent and interpretable to practitioners, given the potential ramifications of their recommendations on patient well-being.

The below chart show the scaling of the important feature of the data set.

Model	Accuracy	Precision	Recall	F1-Score	AUC
Decision Tree Classification	0.80	0.87	0.82	0.84	0.91
Random Forest	0.81	0.85	0.78	0.81	0.88
KNN	0.80	0.84	0.73	0.82	0.87
Logistic Regression	0.79	0.82	0.75	0.78	0.85

Fig.12.Feature of all classifier

8. Conclusion:

In conclusion, our study demonstrated the effectiveness of ML algorithms in predicting mental health conditions using various data sources and features. The models showed high accuracy and performed well in identifying patients with mental health disorders. While these models have shown promise, additional study is still required to determine whether their application can extend equally well to other groups and to develop techniques by which the reasoning of machine learning systems in the medical field can be made more transparent.

9. References

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