2023 3rd Asian Conference on Innovation in Technology (ASIANCON)
Pune, India. Aug 25-27, 2023

Mental Health Disorder Detection using Machine Learning and Deep Learning Tehniques

Prathamesh Yadav
Computer Engineering (MTech)
Ramrao Adik Institute of Technology
(DY Patil deemed to be University)
Nerul, Navi Mumbai India - 400706
pratham.1.esh@gmail.com

Shilpa Shinde
Computer Engineering
Ramrao Adik Institute of Technology
(DY Patil deemed to be University)
Nerul, Navi Mumbai India - 400706
shilpa.shinde@rait.ac.in

Rajashree Shedge
Computer Engineering
Ramrao Adik Institute of Technology
(DY Patil deemed to be University)
Nerul, Navi Mumbai India - 400706
rajashree.shedge@rait.ac.in

***Abstract*— In the year 2023 mental illness has become a topic that just can't be ignored. According to "Our World In Data" more than 792 million people suffer from some type of mental illness, that means over 10.7% of the global population suffer from mental illness. Data Science is the most popular technology in the world today, and it's not going away anytime soon. There are many organizations that use data science technologies to solve the mental health problem. There are prediction models built with the help of machine learning and deep learning algorithms. The fact is many developers and medical professionals don't understand the difference between machine learning mental health models and deep learning mental health models. There are different technologies used to solve different metal health problems. This project not only tries to address and solve some of the mental health issues with the help of Machine Learning and Deep Learning techniques but also differentiate between the models built with the help of Machine Learning and Deep Learning Techniques. In this project 4 machine learning models have been used to solve the mental health problem of whether the individual gets the medical attention he/she needs. The techniques used are Logistic Regression, K-Neighbors Classifier, Decision Tree Classifier and Bagging, On the deep learning side of we things a CNN model is built that determines whether the individual is depressed or not depressed.**

Keywords*— *KNN, Logistic Regression, Decision Tree, Boosting Algorithm, CNN.

I. INTRODUCTION

Though mental health had been a topic of concern in the past, it reached an alarming level during the pandemic when everyone was couped up in their homes. Mental health is especially a subject of concern in many Asian countries like India, China, Japan and South Korea. Mental illness is not given much attention in majority of the countries, even though most nation's governments do have a program for mental health awareness. An individual's mental health is important because it can affect every aspect of his/her life such as relationships, professional life as well as the physical health. The aim of this paper is not just to implement the Machine Learning and Deep Learning models and find a solution to a problem, but also to make people more aware on the topic of mental illness.

Data Science is currently the most popular technology and is showing no signs of going away anytime soon. According to the research there has been use of Machine Learning and Deep learning technologies in order to find solutions to the mental health problem. Though people are aware of the ML and DL technologies, they don't or are confused regarding the difference between ML and DL. The fact is Machine Learning and Deep Learning are both part of Artificial Intelligence. The difference is ML is AI that can adapt automatically with very little human intervention. DL is the subset of Machine Learning which uses Neural Networks to mimic the human brain. In this paper 4 ML models have been used, they are Logistic Regression, K Neighbors Classifier, Decision Tree Classifier and Bagging which will find the answer to whether the individual has sought for any treatment for a mental health issue. On the Deep Learning side a CNN model is implemented to see whether the individual is depressed or not. The datasets have been taken from Kaggle.

The organization of the paper goes as follows: Section II describes the Related Work i.e. gives a brief summary of many of the technologies similar to the scope of this topic. Section III is the proposed system which will discuss the methodology of the machine learning and deep learning models in detail. Section IV defines the problem statement and in Section V the results, analysis and findings will be displayed.

II. RELATED WORK

In [1], the authors Iwan, Nadia and Tessy have built a self corpus of diagnosis of mental illness(self - declared) on Twitter. Their study consists of computational linguistic process. The rate of depression is modelled through emotions and linguistic features.

In [2], the authors Rahul and Saurav use different machine

learning models which are SVM, KNN, Regression, Decision Tree and Random Forest to find the best precision and recall on the Mental Health Dataset. The aim is to find what are the factors most contributing to the degrading mental health of employees in technical and non-technical companies.

In [3], the authors have proposed a combination of Machine Learning and Internet of Things(IoT), with a suggestion of a smart watch. The authors have used 31fields of the dataset to determine the mental state of mind of the subject. The Machine Learning models used to find the mental health score are Logistic Regression, Support Vector Machine, Decision Tree, KNN and Naive Bayes.

In [6], the authors have implemented various machine learning techniques for stress prediction. The ML models used are Bagging, Boosting, Decision trees, KNN, Logistic Regression and Random Forest.

2023 3rd Asian Conference on Innovation in Technology (ASIANCON) | 979-8-3503-0228-8/23/$31.00 ©2023 IEEE | DOI: 10.1109/ASIANCON58793.2023.10270707

In [7], the authors have built a model using Open CV and Sentimental Analysis. The model consists of 4 modules, they are Pulse based Depression Detection, Facial Emotion Detection, Questionnaire and Bot Assistant.

In [9], the authors have implemented used various Machine Learning models to find the depression score among the dataset. The models used are K-Nearest Neighbors, Stacking, Boosting, Bagging, Random Forest Classifier, Decision Tree and Multinomial Logistic Regression.

In [10], the authors have used data mining to collect their own data from the available resources and create their own dataset. Then they have used the dataset to predict the mental illness problem by using 3 separate ML models which are Decision Tree, Random Forest and Naive Bayes.

Authors Mengjiao, Kang, Juan and Xudong have built a 3D CNN model to identify the patients who are schizophrenic[12].

In [13], the authors have built a clinical decision support system for mental. The system tells the user how a patient will respond to a certain type of treatment.

Authors Khalid and Mohammed have proposed a frame in their paper [14] which uses a sensor to monitor the physiological signals of the body. These are signals are variation in the heart rate, irregularities in the pattern of breathing and skin conductance. This is a CNN model.

In [16], the authors have implemented a model to detect Online Social Networks. The authors have screened the major articles from 2007 till 2018. The articles were coded in reference to the dataset. After the data extraction process, the data was examined using statistical analysis or the ML techniques.

The idea behind [17] is that people usually share their feelings intentionally or unintentionally on the social media. The authors have proposed a deep learning model to identify the mental state of mind of the social media user based on their posts.

[18] is a CNN model that predicts the mental state of an individual with the help of an electroencephalogram (EGG). EGG is an instrument that measures and record's brain's electrical activities.

In [20], the authors have proposed a framework to build a Multimodal Deep Learning system that will detect symptoms of mental illness and can provide some insight.

According to the research much of the content available is only research material and very limited actual implementation has been done on the topic. The entire point of the application is that the results are highly experimental and subjective, the application or the research may not be accurate 100% of the time because that's not how data science works. The results are approximate but that doesn't mean the models are ineffective. The advancement in data science has slowed down a bit over the years, since there's a lot of new findings to be researched among the current versions.

III. Problem Definition

There are many people who know they have mental illness but would not get any treatment for that. The model discussed in the paper is divided into two parts, which is Machine Learning part and deep learning part (CNN). In ML part 4 ML algorithms have been used which will predict whether the individual is getting the treatment for his/her mental health problem. The DL part consists of a CNN model which predicts whether the individual is depressed or not.

IV. Proposed System

Machine Learning and Deep Learning models are being used on a large scale to predict mental health problems. In this study we will focus on "depression". Though deep learning is still a work in progress, there are many machine learning models that are being used to predict depression, bipolar disorder etc. Machine Learning models can perform only one specified task unlike the deep learning which is used to create a highly efficient model which performs multiple task. The solution design is displayed below which basically comprises of two major modules which consist of various components.

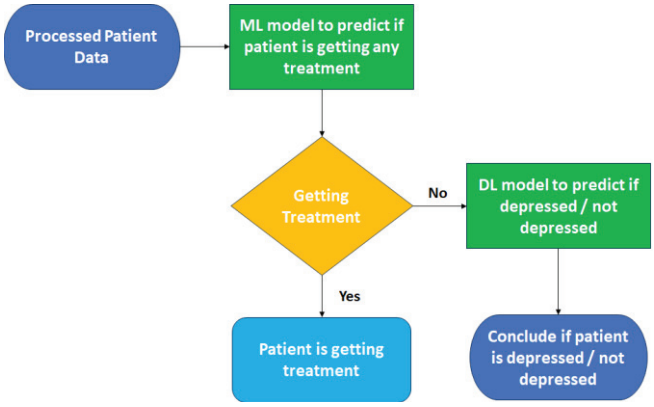

Fig. 1. Solution Design

A. Machine Learning Module

The machine learning module is divided into smaller modules which can be seen in the diagram below. The machine learning module is very important as it is the basis of finding whether the individual is getting any help for his/her mental health problem in the first place.

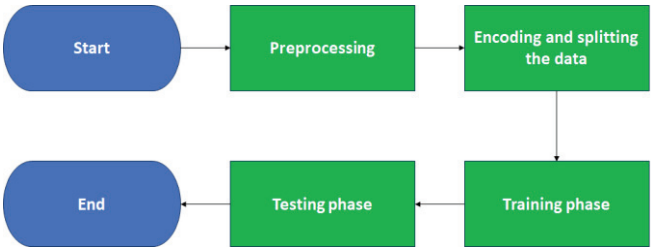

Fig. 2. Machine Learning Module Workflow

1) Pre-processing

Pre-processing is the very first stage of the ML module. This is where the data is collected, imported and cleaned. The dataset used in the project does indeed contain the information we require but is not in the exact format that we need it in. Data pre-processing is essentially a processing stage where the data is processed. Failing to do data preprocessing will / can affect the model in the future.

a) Import the data

Before importing the data, the data needed to be collected or a perfect dataset for the problem had to be discovered. Kaggle is a popular online platform that hosts a vast collection of datasets contributed by individuals, organizations, and research institutions. It provides a centralized repository where data enthusiasts and researchers can discover, access, and share datasets. Kaggle offers a wide range of datasets spanning diverse domains, including finance, healthcare, social sciences, and more.

To find the dataset on Kaggle, I utilized the search functionality provided by the platform. By specifying relevant keywords, filters / categories, I able to narrow down my search and find datasets that matched my specific requirements. Once I identified a suitable dataset, it accessed for download, exploration, and analysis. Kaggle provides features for previewing dataset descriptions, examining sample data, and understanding the data structure before downloading it. By leveraging Kaggle's vast dataset collection, I able to save time and effort in data collection, as well as benefit from the expertise and contributions of the Kaggle community. This allowed me to focus on the analysis and insights generation, accelerating my research. The data is imported with the help of the library pandas.

b) Clean the data

Though we found the correct dataset, the data was not in the correct format and can't be used directly. The dataset had a lot of missing values as well as some values that were not in the right format which were not suitable for further operations. Out of all the attributes in the dataset only 15 were used for prediction. So, a new file was created to store all the changes because the original file could have gotten a bit messy. The cleaned dataset was ready for use and further operations would be performed on the cleaned dataset.

2) Encoding and splitting the data

Encoding and splitting the dataset are crucial steps in machine learning (ML) to prepare the data for training and evaluation. There is a lot of categorical data in the dataset. The machine does not understand any categorical variables because the machine only understands numbers, therefore encoding is done on the dataset. Encoding involves transforming categorical variables into a numerical representation that ML algorithms can understand. Categorical variables, such as gender or product categories, are typically represented as strings or labels. However, ML models often require numerical inputs. OneHotEncoding is done on the dataset. Scaling is done on the numerical data because of the inconsistency in the dataset. After the dataset is ready, it is split into training set and test set. The split is 60-40. The split is done in accordance to the vast research and as seen in the examples in the literature survey.

3) Training phase

The training phase is the most crucial part of the module, since if there would've been any problems in the training phase the entire model would be rendered useless. During this phase, the model is exposed to labelled examples, and it adjusts its internal parameters based on the patterns and relationships it discovers in the data. The training phase included the following steps:

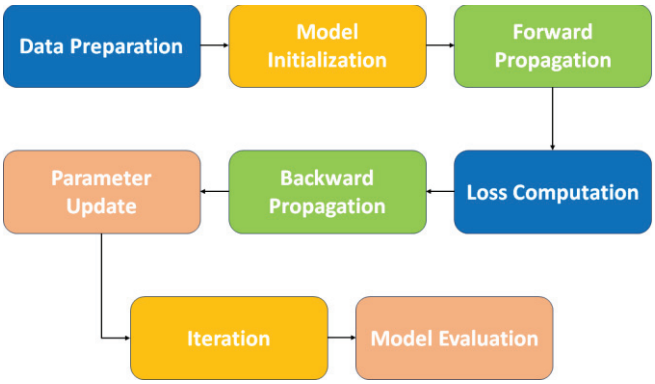

Fig. 3. Training Phase Workflow

a) Data Preparation

The training data is preprocessed, which may include encoding categorical variables, normalizing numerical features, handling missing values, or performing feature engineering.

b) Model Initialization

The ML model is initialized (in this case a functions has been declared that initializes all the algorithms e.g. logistic regression, KNN etc.) with random or predefined initial parameter values.

c) Forward Propogation

The training data is fed into the model, and the model performs forward propagation, calculating the predicted outputs based on the current parameter values.

d) Loss Computation

The difference between the predicted outputs and the actual labels in the training data is calculated using the chosen loss function.

e) Backward Propogation

The model uses backward propagation, also known as backpropagation, to calculate the gradients of the loss function with respect to the model parameters. These gradients indicate how the parameters should be updated to reduce the loss.

f) Parameter Update

The model parameters are updated based on the gradients using an optimization algorithm, such as gradient descent. The learning rate, which controls the size of the parameter updates, is an important hyperparameter to consider.

g) Iteration

Steps 3 to 6 are repeated iteratively for a specified number of epochs or until the convergence criteria are met. Each iteration helps the model refine its parameter values and improve its performance.

h) Model Evaluation

Throughout the training phase, the model's performance is monitored on a validation set or using cross-validation techniques. This evaluation provides insights into the model's generalization ability and helps in making decisions about hyperparameter tuning or early stopping. The training phase continued until the model had learned the patterns and achieved satisfactory performance on the training data.

4) Testing Phase

The model is tested on unseen data i.e. the 40% split that happened earlier. This data contains examples that were not part of the training or validation data. The testing set is labeled, meaning it has ground truth values or target labels for comparison with the model's predictions. The following are the objectives of the testing phase:

a) Performance Evaluation

The ML model's performance is measured using appropriate evaluation metrics, depending on the specific task.

b) Generalization Assessment

The testing phase helps assess the model's generalization ability, which refers to its performance on unseen data. It indicates how well the model has learned the underlying patterns and can apply them to unseen instances.

c) Overfitting Detection

Testing phase assists in identifying overfitting, which occurs when a model performs exceptionally well on the training data but fails to generalize to new data. If the model exhibits a large performance drop on the testing set compared to the training set, it indicates overfitting, suggesting that the model has memorized the training data rather than learned meaningful patterns.

d) Hyperparameter Tuning

Different combinations of hyperparameters are tested on the testing set to find the optimal configuration that maximizes the model's performance. However, it's important to use a separate validation set for hyperparameter tuning to avoid overfitting the testing set.

e) Model Comparison

Since multiple ML models or algorithms were trained, the testing phase allows for a fair comparison of their performance. By evaluating different models on the same testing set, we can determine which model performs better and is more suitable for the given task.

B. Deep Learning Module

In the deep learning section of the project a Convolutional Neural Network (CNN) has been used which predicts whether the individual is depressed or not depressed. The dataset used in the process contains timestamps of the individuals for a certain period of time along with their activity score. The combination of timestamp and activity score tells whether the individual is depressed or not. The following diagram depicts the Deep Learning module workflow:

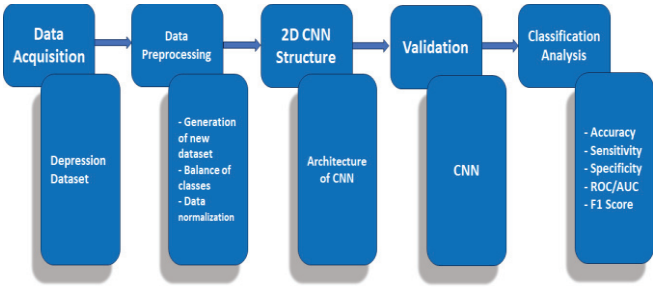

Fig. 4. Deep Learning Module Workflow

1) Data Description

The dataset used for the development of this research is the depression dataset available on Kaggle. This dataset is publicly available. It contains timestamp, date and activity score of each subject. The data on the dataset contains real data that has been collected overtime.

2) Data Pre-processing

The data pre-processing stage is divided into 2 steps: the generation of the new dataset, balance of classes and data normalization.

a) Generation of new dataset

First, a significant portion of the data from the original dataset is taken to generate a new dataset. This new dataset contains enough observations to be used in the Convolutional Neural network.

b) Balance of sections

There is an uncertainty between the depressed instances and non-depressed instances. The number of depressed instances is higher than the non-depressed instances class balancing is applied using a sampling technique called Adaptative Synthetic sampling. This technique uses a weighted distribution for different minority class examples, according to their level of difficulty in learning. This is done where more synthetic data is generated for minority class examples that are easier to learn.

c) Data Normalization

Data normalization is a crucial preprocessing step in deep learning that aims to standardize the input data to a common scale and distribution. Data normalization is required for scaling since most of the data is not scaled in the dataset.

3) CNN Architecture

A CNN structure has been adapted for this research. The CNN model used in the research consists of an input layer, then two convolutional layers, then one max-pooling layer, then one convolutional layer, and finally a max-pooling layer. Finally, a dense layer. The convolutional layer operates in a very different way compared to the other neural network layers. This layer does not contain connection weights and a weighted sum. Instead, it contains filters. The max-pooling layer uses the maximum value in the filter with a specified size and then conducts subsampling. The filters mentioned in the model are the ones that perform pattern recognition.

4) Classification Analysis

For the classification stage, a CNN model is used to detect depressive episodes based on the new dataset that is generated. This is how we can see if there is any difference between the results of the two. In the new dataset, the "depressed" and" non depressed" subjects are separated by each one getting a separate folder, this is done for better observation. CNN improves the accuracy of human emotion recognition.

5) Validation

Validation is the final stage of the deep learning module. For validation there are two main parameters that are looked at, "prediction" and" confidence". It's important to note that the confidence in CNNs is not absolute and can vary depending on factors such as the quality and quantity of training data, model architecture choices, hyperparameter

tuning, and potential biases in the data. Additionally, the level of confidence can be subjective and may vary depending on the specific context and requirements of the task at hand.

V. Result and Analysis

At 79.8% accuracy score, the logistic regression can be considered the best model for the Machine Learning side. At 79.8% accuracy score, the logistic regression can be considered the best model for the problem statement i.e. to check which people sought treatment for their mental illness. Bagging is the runner-up with 78% accuracy, whereas KNN and decision tree classifier have accuracy of 76.9% and 72.8% respectively. The CNN model that works on the activity sensor data gives a very high accuracy with a very high confidence rate as displayed in the test results below:

TABLE I. Comparative Analysis of Results of ML Techniques

Technique	Accuracy	Precision	Advantages	Disadvantages
Logistic Regression	79.8%	83%	Easier to implement, interpret and efficient in training.	May lead to overfitting if observations are lesser than features
K-Neighbors Classifier	76.9%	79%	Easy implementation and no training period.	Not preferred for large dataset, as well as sensitive to noise and missing data.
Decision Tree Classifier	72.8%	76%	Easy to understand.	Suffers from overfitting problem.
Bagging	78%	81%	Weak learners can combine their efforts to perform like a single strong learner	Suffers from underfitting problems.

On the deep learning side the first prediction which is condition3 is given as “nondepressed” with a confidence of 93%. The second prediction is condition11 which is predicted as “depressed” with a confidence of 96%.

According to the analysis of the results, in the ML part of the project logistic regression gives the best accuracy at 79.8%. Bagging comes at second place with 78% accuracy followed by KNN and decision tree which give 76.9% and 72.8% respectively. On the deep learning side the CNN model gives an accuracy of 93% for the given input parameter.

VI. Conclusion and Future Scope

At 79.8% accuracy score, the logistic regression can be considered the best model for the Machine Learning side. At 79.8% accuracy score, the logistic regression can be considered the best model for the problem statement i.e. to check which people sought treatment for their mental illness. Bagging is the runner-up with 78% accuracy, whereas KNN and decision tree classifier have accuracy of 76.9% and 72.8% respectively. The CNN model that works on the activity sensor data gives a very high accuracy with a very high confidence rate as displayed in the test results above.

Mental health is a sickness, and millions of people around the world are still either unaware or won't do anything about it. The aim of this study is not just to find the solution to the mental health problem but also to bring awareness on this serious topic. Also, for the future scope there are many innovations and functionality additions that can be done. The concept of the CNN model in the study can be incorporated into a smart watch. Medical professionals can use this model to check the mental state of mind of their patients. Feature selection can be improved by the guidance of an actual psychiatrist The main goal is to find a better solution to the mental illness problem and spread awareness about mental health. The improved features can help any organization to provide mental health care for the employees/students.

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