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A Comprehensive Review on Anxiety, Stress and Depression Models Based on Machine Learning Algorithms

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Abstract: Anxiety, stress, and depression are the different stages of a person's mental illness that negatively impact their health, emotions, and social interactions. In the present time, 450 million people are suffering from mental illness, according to the World Health Organization (WHO). Thus, determining the mental illness in the earlier phase helps people achieve better health. However, determining the mental illness stage through medical procedures is time-consuming, costly, and requires monitoring patients for a long time. To overcome this issue, in the present time, machine learning algorithms are deployed to detect mental illness in the earlier phase by analysing the behaviour of the patients. Therefore, in this paper, we have done a comprehensive review of anxiety, stress, and depression models designed using machine learning algorithms. Initially, different stages of mental illness are explained and how they are differentiated from each other. Further, we have studied and analysed the machine learning algorithms and their various types. Next, we have explained the different stages used to build the anxiety, stress, and depression models using machine learning algorithms. After that, we have done a critical analysis of the existing models based on their aim, machine learning algorithm, input and output parameters, database, performance metrics, and tool used. Based on the critical analysis, we have given a detailed description of the tool, database, and performance metrics. Finally, we have identified some open research challenges and recommendations to enhance the existing models.

Keywords: *Anxiety, Depression, Machine Learning, Mental Health, Mental illness, Prediction, Psychological illness, Stress*

1. Introduction

Psychological illnesses such as stress, anxiety, and depression (SAD) may have significant negative consequences on mental stability, disrupting everyday life and, in extreme circumstances, leading to trauma [1]. Many chemicals are released by the body when it is under the effect of stress, sadness, or anxiety, and this is reflected in the person's nonverbal behavior. Stress, anxiety, and depression are studied because they have common symptoms and distinct phases that may be understood via in-depth investigation. The first, transient phase of the illness is anxiety. It is possible that this is brought on by pedantic problems in the typical day [2]. It is widely accepted that stress is the second phase of mental illness, with psychological problems being mitigated by the persistent influence of worry [3]. At its third and worst stage, depression is a mental health illness that may have a devastating impact on a person's emotional and physical well-being [4]. Anxiety and depression are physical manifestations of the mental distress caused by excessive stress. The term "stress" refers to a broad category that includes everything that has the potential to make a person feel overwhelmed. Things like working out more than usual, taking on too much at once, breathing deeply, staying up late, not getting enough sleep, etc., all count as stressors.

In the present time, millions of people of facing this psychological illness according to the WHO. Thus, the challenging task is how to determine this illness in the initial phase so peoples are not faced last stage of psychological illness that is depression. To overcome this issue, medical process followed by psychologists in which time spend with patients and its behavior is observed. However, this process is time-consuming and expensive. Thus, in the current scenario, machine learning based models are designed. These models take the input data (patients audio and video signal, bio-signals such as EEG, ECG, skin temperature and conductance, blood pressure) from the IoT devices (typically sensors) or questionnaires form is received from patient [1]. In the machine learning based models, input data plays an important role and due to psychological illness variations in the input data signal is easily recognized over normal signal. Thus, the main contribution of this paper is to study and analysed the various machine learning algorithms are deployed for predict the anxiety, stress, and depression. To achieve this goal, we have done a comprehensive review of the existing models are designed using the machine learning algorithms. The keywords are taken under consideration for exploring the database are mental illness, anxiety, stress, depression, psychological illness, suicide. Further, relevant research papers are studied and analysed from the standard database such as IEEE, Elsevier, and Springer. The review strategy of this paper is as follows.

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- Initially, we have studied the different stages of mental illness and how these are differentiated from each other.
- In the second step, a detailed overview of machine learning and their types are given to understand the machine learning algorithms. In the literature, machine learning algorithms are classified into four types, such as, supervised, unsupervised, semi-supervised, and reinforcement.
- In the third step, we have explained the different stages are used in the anxiety, stress, and depression model for predict/detect using the machine learning algorithm.
- In the fourth step, we have done the critical analysis of the existing models. The models are analysed based on the aim, input and output parameters, machine learning algorithm used, database, tool, and performance metrics are used.
- In the fifth step, different tools (such as R, WEKA, SPSS, and MATLAB), standard database, and performance metrics (confusion matrix, accuracy, recall, sensitivity, specificity, precision, F-score) are used to evaluate the machine learning algorithms are defined.
- In the sixth step, we have defined the open research challenges based on the critical analysis. Besides that, we have also defined the recommendation to overcome these challenges to enhance the existing models.

The remaining paper is classified into six sections. Section 2 explains the machine learning algorithms are deployed for anxiety/depression detection models. Section 3 illustrates the anxiety/depression detection models based on machine learning algorithms. Section 4 shows the critical analysis of these models based on the various metrics. Section 5 defines the tools used for simulate the models. Section 6-7 explains the relevant database and performance metrics. Section 8 defines the open research challenges and recommendations. Finally, conclusion is drawn in Section 9.

2. Machine Learning Algorithms Deployed for Anxiety/Depression Detection

Here, we examine the machine learning methods used for anxiety/depression identification in the existing literature and provide conclusions based on our findings [5].

Machine learning, also known as computational learning or data science, is the study of how computers acquire and apply information. The study of how computers may acquire new skills without being given such instructions is known as "machine learning" [6]. Supervised learning, semi-supervised learning, unsupervised learning, and reinforcement learning are the four main types of machine learning [7].

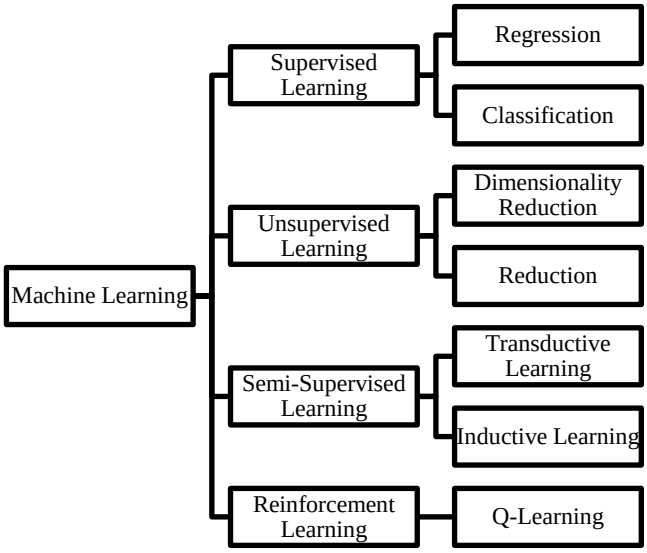

Fig.1. Categories of Machine Learning Algorithms [5]

2.1. Supervised Learning

The goal of supervised learning is to train an algorithm to correctly anticipate a target response when presented with new instances, where the target response may be a numeric value or a text label (e.g., a class or tag) [8]. The labelled output variables of a supervised learning algorithm [7] are the focus of the training dataset. By providing several instances on the same subject for the learner to memorize, guided learning allows the student to infer overarching principles about the issue at hand. Under supervised learning, two classes of algorithms exist. Regression and classification are the two [7].

Both linear and logistic regression are examples of regression algorithms. When trying to represent the connection between a set of "explanatory" variables and a set of "result" variables with numerical values, statisticians often turn to linear regression [8-9]. Despite the fact that the aim of logistic regression is to characterize the connection between a single dependent binary variable and several independent nominal, interval, ordinal, or ratio-level variables [9-10]. Classification algorithms include decision trees, SVMs, Naive Bayes, KNNs, Random Forests, and ANNs [9, 11-12].

Using a series of if-then rules, a decision tree may be used to categorize data [9]. Statistical support vector machines (SVMs) are a kind of classifier that uses a hyperplane to classify data optimally, whereas naive Bayes is based on a statistical learning technique [9]. KNN employs feature similarity to assign a new point value via the application of distance functions like Hamming distance, Euclidean distance, and others [9]. Each tree in a random forest method classifies data, making the system very useful for finding

patterns [9]. The ANN data classification model is based on the structure of a human neuron [9].

2.2. Unsupervised Learning

By evaluating data patterns independently, unsupervised learning enables an algorithm to learn from basic instances without a corresponding response [8]. When there are no "supervisors" or "target variables" in a dataset, the learning is unsupervised. The programme will figure out how to fix this by comparing individual cases and identifying commonalities. The process of unsupervised learning is analogous to labelling different varieties of chilies based on their size, colour, flavour, and spiciness. Similarity scores are used to categorise chili varieties. Clustering and dimensionality reduction are the algorithms used for unsupervised learning [9, 12].

K-means, hierarchical, and fuzzy-c-means are all examples of clustering algorithms [9]. K-means relies on selecting a fixed number of sites at random (K) and then associating the remaining points with their closest centres [9]. Using a top-down or bottom-up approach, hierarchical clustering [9] sorts related items into distinct clusters. The observation is clustered using fuzzy-c-mean [9]. Dimensionality reduction algorithms include singular value decomposition (SVD), principal component analysis (PCA), and independent component analysis (ICA) [9]. PCA is a feature extraction technique for multivariate analyses. The dimensionality reduction technique SVD is based on matrix factorization. ICA decomposes multivariate observations into additive subcomponents [9] and so provides a new foundation for data representation.

2.3. Semi-Supervised Learning

The next kind of learning method is called semi-supervised learning (SSL). This learning strategy relies on a combination of classified and unclassified data [7]. Half of the training is supervised, and half is done on its own. Researchers designed SSL to address the shortcomings of both supervised and unsupervised learning. When comparing SLL's accuracy to that of supervised and unsupervised learning, the combination of unlabelled data patterns with labelled data patterns proves to be superior [13]. Semi-supervised learning may be broken down into inductive and transductive sub-types [9]. Predicting correct labels for previously unlabeled data is the main goal of transductive learning [9]. While Inductive semi-supervised generates both labels and classifiers for previously unlabelled data.

2.4. Reinforcement Learning

Finally, reinforcement learning is a kind of learning that uses information gleaned from interactions with the environment to determine what behaviors would provide the greatest reward or pose the least danger. It is possible to teach reinforcement learning through incorrect or incorrect examples of observation. It makes mistakes and uses them to inform its model-building efforts. An example of a game that might benefit from reinforcement learning is one in which the player must navigate a maze while trying to avoid an opponent [14]. This software feeds back the outcome of an action to the algorithm, which thereby learns to avoid potentially harmful behaviors [14]. Each agent engages in environmental interaction and generates a state-action-reward sequence via the use of the Q-learning algorithm [14], which is a model-free reinforcement learning approach.

3. Anxiety/Depression Detection Models Based on Machine Learning Algorithms

This explains the basic flowchart of the anxiety/depression detection model based on the machine learning algorithm, as shown in Figure 2 [1]. In this model, initially, anxiety/stress/depression database is read. The database contains numerous attributes which is basically demographic and clinical information of the participants. Next, pre-processing of the database is done to inappropriate data, to fill missing values, and select the appropriate features for the machine learning algorithm. Next, the database is split into different ratio for training and testing purposes. In the literature, 70:30, 80:20, 75:25 ratios are used. The first value of the ratio defines how much data from the database is used for training purposes whereas second value defines how much data is used for testing purposes. Further, machine learning algorithm is applied which basically process the database attributes and gives the prediction in the output. Finally, performance analysis of the machine learning model is done to validate its performance. In the literature, various scales values of anxiety/stress/depression, confusion matrix (accuracy, precision, sensitivity, specificity, F-score, AUC), and various statistical tests are measured in the performance analysis.

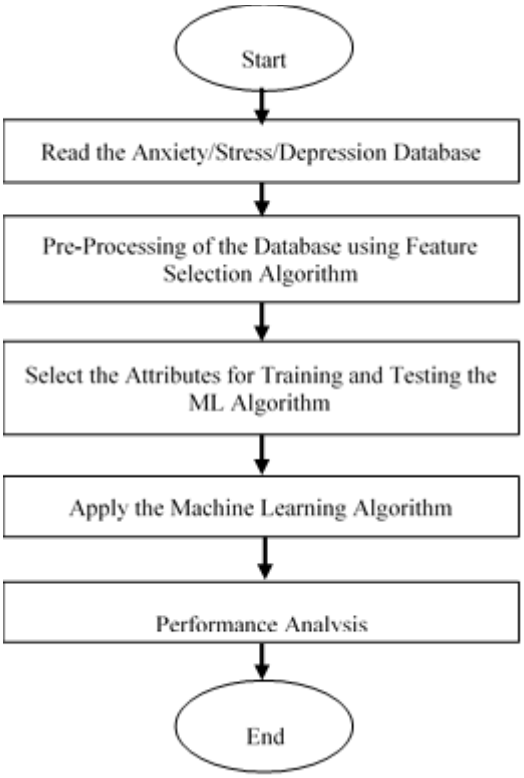

Fig. 2. Flowchart of the Anxiety/Depression Detection Models based on ML Algorithm

4. Critical Analysis of the Anxiety/Depression Detection Models

In this section, we have done the critical analysis of the anxiety/depression detection model based on various parameters.

Table 1 Critical Analysis of the Anxiety/Depression Models

Ref.	Year	Aim	Machine Learning Algorithm	Input Parameters	Output Parameters	Dataset	Tool Used	Performance Metrics
Nordin et al.[15]	2023	Suicide Risk Prediction	Random Forest, Gradient Boosting, and Shapley Additive Explanation	Demographic and Clinical Information	Axis I Diagnosis (Anxiety),Beck Depression Inventory (Severity of Depression), Scale for Suicidal Ideation (SSI) (suicidal ideation)	Data Collection from Psychiatrist (Sample Size:75, Total Variables: 18)	NF	Accuracy, Precision, Specificity, Sensitivity, area under precision recall curve

Priya et al. [16]	2019	Anxiety, Depression, and Stress Prediction	Decision Tree, Random Forest Tree, Naïve Bayes, Support Vector Machine and KNN.	Clinical Information	Anxiety, Depression, and Stress	Depression, Anxiety and Stress Scale Questionaries (DASS-21) (Sample Size: 348), Total Variable: 21, Dataset Ratio for Training and Testing: 70:30	R-Tool	Mental Illness, Accuracy, Precision, error rate, recall, specificity, and F1-Score
Kumar et al. [17]	2020	Anxiety, Depression, and Stress Prediction	Naïve Bayes (NB), Bayes network (BN), k-star, local nearest neighbor (LNN), multilayer perceptron (MLP), radial basis function network (RBFN), random forest (RF) and J48.	Clinical Information	Severity Level of Anxiety, Depression, and Stress	DASS-42 (https://openpsychometrics.org/_rawdata/) (Sample Size: 39776, Total Variables: 42, Dataset Ratio for Training and Testing: 75:25)	WEKA Data Mining Tool	Mental Illness, Accuracy, Precision, error rate, recall, kappa, ROC, and F1-Score
Bhatnagar et al. [18]	2023	Anxiety	Naïve Bayes, Decision Tree, Random Forest, Support Vector Machine	Anxiety Related Questionnaires	Anxiety Classification	General Anxiety Disorder (GAD)-7, DASS-21, (Sample Size: 127, variable: 40)	IBM SPSS, Jupyter Notebook, and Python Libraries	Cronbach's Alpha Test, Accuracy
Jain et al. [19]	2019	Depression and Suicidal Ideation Detection	Logistic Regression, Decision Tree, XGBoost Algorithm	Demographic and Clinical Information	Depression Stage	Parents Health Questionaries (PHQ-9), PRAW Dataset of Twitter from Kaggle Database, (Sample Size:619, Variable size: 18, Dataset Ratio: 80:20)	ND	Accuracy, Precision, Recall, and F-Score

Simjanoski et al. [20]	2020	Depression and Anxiety	Elastic Net, Random Forest, and Gradient Tree Boosting	Demographic, Covid-19 Experience, Lifestyle, and Clinical Information	Screening of Depression and Anxiety	Short Multidimensional (Sample Size: 22562, Variable Size: 101) Inventory Lifestyle Evaluation (SMILE) scale	SPSS 21, R Software, Caret Library	T-test, Chi-Square Test, Accuracy, Sensitivity, Specificity
Chiong et al. [21]	2021	Depression	Single and Ensemble Classifier	Text Information	Depression	Twitter Dataset and Non-Twitter Dataset(Facebook, Reddit, and Electronic Diary) (Sample Size:348723)	Natural Language Toolkit and Peter Norvig's code	Accuracy, Precision, Recall, and F-Score
Sarsam et al.[22]	2022	Suicide Detection	Latent Dirichlet Allocation (LDA) algorithm, Hierarchical Clustering Algorithm	Text Information	Suicide Classification	Twitter Dataset (Sample size: 54385)	WEKA Tool	Accuracy, Kappa Statistic, and RMSE
Richter et al. [23]	2020	Cognitive Bias among Anxiety and Depression	Random Forest	Demographic and Clinical Information	Differentiate between Anxiety and Depression	DASS-21(Sample Size: 125, Dataset Ratio:80:20)	MATLAB	Confusion Matrix
Nemesure et al. [24]	2021	Depression and Anxiety	Xgboost, SVM, RF, KNN, NN, and Baysian Hyperparameter Optimization	Electronic Health Record	Major depressive disorder (MDD) and generalized anxiety disorder (GAD)	Dayad Dataset (Sample Size:4184, Variables:59, Dataset Ratio:70:30)	ND	Area under the receiver operating characteristic curve (AUC)

5. Tool Used

This section gives an overview of the tools are deployed for simulate the machine learning models are designed for anxiety/ stress/depression.

- R Tool: This software was invented by “Ross Ihaka and Robert Gentleman” in New Zealand [25]. It is used for statistical analysis, reporting, and graphics representation. R is based on an interpreted language that enables for modular programming with functions, branching, and looping. For optimal performance, R can be used with programs written in C, C++, .Net, Python, or Fortran. R is open source software distributed without any charge under the GNU general public license, with pre-built binaries available for a wide range of platforms.

- WEKA: Weka can pre-process huge data, run machine learning algorithms, and compare outcomes [26]. This software simplifies machine learning and huge data processing.
- SPSS: This software invented by IBM in 1968. It is used for statistical analysis and used in the number of applications such as management, healthcare, education, and data miners [27]. Further, it analyses descriptive statistics, numeral outcome forecasts, and groupings. This program manages data via data processing, charting, and direct marketing.
- MATLAB: MATLAB is basically stands for matrix laboratory and it is a 4th generation programming language [28]. It supports various programming, visualization, numerical computation, interface with other programming language. In the present time, MATLAB has huge number of library and functions which supports artificial intelligence and machine learning algorithms.

6. Database

This section gives a detailed overview of database are deployed for design anxiety/stress/depression models using machine learning algorithms.

- Kaggle Depression on Twitter Database: This database contains sentimental data. It contains total six fields, such as “target”, “Ids”, “date”, “flag”, “user”, “text” of 1.6 million tweets [29].
- Reddit Self-reported Depression Diagnosis (RSDD) Dataset: The RSDD dataset includes Reddit posts from 9,000 diagnosed individuals and 107,000 matched control users [30].

7. Performance Metrics

This section explains the performance metrics are measured by various researchers to evaluate the machine learning models are designed for anxiety/ stress/depression [31].

- Confusion Matrix: In machine learning, the effectiveness of a classification task is evaluated using a measurement known as the confusion matrix. This confusion matrix may provide results with two or more distinct categories. There are four possible permutations of observed and forecasted data for a two-class problem. The notations are true positive (TP), false positive (FP), false negative (FN), and true negative (TN).

Predicted Values \ Actual Values	Positive (1)	Negative (0)
Positive (1)	TP	FP
Negative (0)	FN	TN

Fig. 3 Confusion Matrix [31]

- Accuracy: Among the most often used measures of performance is accuracy, which indicates how many of our forecasts are true. If a model has a high accuracy score, it is superior to others.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

- Precision: The true accuracy of a forecast is shown by its degree of precision. All the correct predictions made by the model may be identified using this metric. It's a useful tool for checking whether or not we're obtaining reliable outcomes. It is the proportion of correct positives to all positives.

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

- Recall: The results of recall indicate that the projected values were accurate. It is the proportion of correct classifications to those that were either incorrect or missed. It is a measure of the model's accuracy and is used to count the number of correct predictions the model had made.

$$Recall = \frac{TP}{TP + FN} \quad (3)$$

- F-Score: The F-score balances off the importance of being accurate and being recalled. Simply said, it is a metric that takes into account both precision and recall. Balanced F-score is another name for this metric. Only when both the accuracy and recall numbers are high will there be a high value assigned to the F1-Score.

$$F - score = \frac{2*(\text{Recall} * \text{Precision})}{(\text{Recall} + \text{Precision})} \quad (4)$$

- Sensitivity: Sensitivity, also known as True positive Rate (TPR), is the percentage of worried persons who experience a good outcome. It accurately pinpoints those who are under stress. It is determined by using TP and FN.

$$Sensitivity = \frac{TP}{TP + FN} \quad (5)$$

8. Open Research Challenges and Recommendations

Based on the critical analysis, open research challenges and recommendations are defined in this section to enhance the existing anxiety/stress/depression model based on the machine learning algorithms.

- In the literature, number of authors, applied the machine learning models individually and comparing their performance. However, each algorithm has some pros and cons, as shown in Table 1. Therefore, in the future, the hybridization of the machine learning algorithm overcome these limitations. The hybridization of the machine learning algorithm can be done using bagging, boosting, and stacking methods.
- The neural network contains three layers, input, hidden, and output layer. The hidden layer connects the input and output layers and each node of the layers are associated with some weight values. Thus, determination of the optimal weight values enhances the neural network performance. The metaheuristic algorithm can be used for determine the optimal weight values of the neural network because these algorithms based on the objective function determines the optimal solution.
- In the dataset ratio, same dataset is used for training and testing purposes. Thus, researchers are achieved high accuracy but in the real-scenario for check the robustness of the model, random data should be trained. Thus, how to generate random data from the available dataset. In order to check the robustness of the model, data augmentation is performed in the testing phase.

9. Conclusion

In this paper, we have reviewed the machine learning algorithms deployed for design anxiety/stress/depression model. Initially, this paper is given a comprehensive difference between anxiety, stress, and depression. After that, an overview of machine learning and its types are given. Next, various steps are explained that used for design machine learning based model. Further, we have done the critical analysis based on the machine learning algorithm, input and output parameter, tool, performance metrics, and dataset used. Based on the critical analysis, database, tool, and performance metrics are explained.

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