An Improved Bagging Ensemble in Predicting Mental Disorder Using Hybridized Random Forest - Artificial Neural Network Model

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Machine Learning majorly provides the process of collecting, identifying, pre-processing, training, validating and visualization of data. This study identifies the problem of late detection of mental disorders in IT employees. There are many cases of mental disorders that are not apparent, notable or diagnosed until they become critical. This affects the productivity of the employees not only in the information technology (IT) industry. The objective of the study is to develop a Hybrid Random Forest (RF) and Artificial Neural Network (ANN) model to predict mental health disorders among employees in the IT industry. The experiment applied a hybrid Random Forest and Artificial Neural Network (RF-ANN) model in predicting the chances of IT employees developing mental disorders. To measure the performance of the model, RF and ANN algorithms were separately developed, their results were recorded and compared with the results of the hybrid model. In the hybrid model using "Bagging Ensemble," the prediction of an IT employee developing a Mental Disorder shows the weighted average performance of 84.5% for precision, recall, and accuracy and precision is 82.5% using the hybridized RF and ANN models on "Bagging Ensemble". This result obtained from the hybrid model correctly shows a significant improvement in its performance over individual performances of the RF model and ANN models. There was a marginal improvement in the performance of the hybrid model when compared with the result of the parameter-tuned RF. This suggests that by applying the RF-ANN model an improved dataset could be investigated and compared with the results obtained in this study.

Povzetek: Članek se ukvarja z napovedovanjem mentalnih težav s pomočjo metod globokih nevronskih mrež, naključnih gozdov in vrečastega ansambla.

1 Introduction

Mental health is defined as a person's psychological, social, and emotional state when they are functioning at an acceptable level of behavioural and emotional adjustment. Mental health can be viewed as a measure of an individual's ability to handle stress and make decisions in all aspects of their life, as it has a significant impact on how such an individual act, thinks and feels. Mental health is an important factor at any stage of life, whether it is adulthood or childhood [1]. According to the World Health Organization, depression is the leading cause of Mental Health Disorders worldwide, affecting individuals as well as communities. It is estimated that more than 350 million people worldwide suffer from depression as of 2020 [2, 3]. Mental health issues have a significant impact on workplace productivity, not only for the individual but also for the organization as a whole. Unfortunately, people generally find it difficult to discuss mental health issues in public, and society does not raise enough awareness. The current evolution of Machine Learning (ML) solutions has resulted in automated models that can predict, classify, and diagnose some of the issues associated with mental health disorders.

The alarming trend of rising mental health problems, combined with the global inability to find effective solutions, was impeding both individual and societal prosperity. There were numerous and significant barriers to accessing mental health care, ranging from socioeconomic inequalities to personal stigmas. This provides an opportunity for technology, particularly artificial intelligence (AI)-based technology, to help alleviate the situation and provide numerous unique benefits. Kolenik & Gams, (2021) [4] provided a brief overview of persuasive technology (PT) for mental health, as well as general, technical, and critical thoughts on implementation and impact in terms of potential benefits and risks. While potential benefits identified in the research include; cost, availability and stigma. Group exclusion and research bias were identified as the PT risk. We believe that such technology can supplement existing mental health care solutions by reducing access inequalities as well as those caused by a lack of it.

In recent years, ML techniques have been adopted in numerous medical researches, especially in biomedicine and neuroscience to gain further insight into mental health disorders [5]. Machine learning, being an area of artificial intelligence involves the process of computers learning from data through the use of heuristic algorithms [6, 7]. ML is divided into two types: supervised ML and unsupervised ML. Supervised ML models are typically used to assign a set of attributes to a target class, which implies classification and regression. Unsupervised ML models are used to describe the relationship or characteristics of a set of attribute data. Unsupervised ML primarily necessitates the processes of feature selection, clustering, and association rule mining [8]. Studies show that employees in IT industries are at high risk of developing mental disorders due to increased stress and pressure to meet targets and deadlines. In many cases, these disorders are not obvious, known or diagnosed until they become life-threatening.

The existing studies in different fields have implemented various machine techniques to predict mental disorders. However, there is a need to address the issue of late detection of mental disorders in IT employees. Developing automated models that can predict, diagnose and classify mental health disorders is now possible with the help of computer-aided systems [9]. By using these developed models, they help in saving manpower, time and other resources, while also removing the possibilities of human bias. A large amount of data is readily available thanks to the advancement in the usage, power and capacity of the latest computer technologies. This has resulted in an increase in the ability to collect, store and manipulate data. Subsequently, knowledge can be extracted from the data by bringing out patterns and relationships through the development of a methodology. Such methodology can be developed from a database of existing tools and methods available for the discovery of knowledge and data mining [10, 11, 12].

A hybrid model of neural network (NN) with a random forest (RF) structure can produce a result with improved generalization ability and accuracy. The ability of this hybrid architecture to reduce the back-propagation algorithm to a more powerful and generalized decision tree structure makes it more effective than random forests. In addition, this model is more efficient to train as the number of training examples usually requires only a small constant factor [12, 13]. Therefore, this study aims to develop a model that can predict the chances of IT employees developing mental disorders using a hybrid of the two best performing models in previous studies consisting of RF and ANN. The developed hybrid model was evaluated using standard metrics in this study area such as precision, recall, and F1-score. The organization of this paper is as follows: the introduction is in section one, review of the literature is contained in section two. Section three is the methodology and the result and discussion were highlighted. Finally, the conclusion is contained in section 5.

2 Review of literature

Mental health disorders, also known as mental illnesses, refer to a variety of mental health conditions that affect a person's thinking, mood, and behavior. Anxiety disorders, depression, addictive behaviors, schizophrenia, eating disorders, and other mental disorders are examples. Many people experience various mental health issues from time to time. However, these mental health issues only become a mental disorder when the ongoing signs and symptoms cause frequent stress and impair a person's ability to function effectively. Loss of pleasure or interest, poor concentration, loss of appetite, disturbed sleep, feelings of guilt, and low energy are all symptoms of mental health disorders. These problems have the tendency to become chronic and recurrent, and thus impair a person's ability to take care of their daily responsibilities [14]. According to [15], more than 30% of people suffering from major mental disorders do not seek treatment, while more than 80% of people battling with some form of mental disorder do not seek to be treated at all. Variations of mental illnesses Depression, bipolar disorder, schizophrenia and other psychoses, dementia, and developmental disorders are all examples of mental illnesses.

Machine Learning and Healthcare: Precision medicine is a way in which healthcare professionals can move to more personalized care by adopting ML in finding patterns and reasons about data [16]. With the large volume of data being collected about patients in the healthcare sector, it is near impossible for humans to analyze. With sufficient data and permission to use, there are numerous ways in which ML can be applied in healthcare. In times past, hard-coded software has been developed based on external studies to provide recommendations and alerts for different medical practices. The limitation to this however is the problem with the accuracy of data due to other factors such as location, environment, population, and so on. With ML, data can be refined to a particular environment, for instance, refining data from a hospital and the surrounding environment in a way that the patient's information is anonymized. Examples of ways in ML can help healthcare providers include: the prediction of a possible outbreak of disease, predicting the possibility of hospital readmission for critically ill patients, prediction of cancer risks in patients, and so on [9].

According to the study by Groves et al. (2013) [17], being able to identify patients that are most liable to the risk of hospital readmission helps healthcare providers to offer better support after discharge. The lives of those at risk are improved when the rate of readmission is lowered, and this can be made possible with the intervention of ML. Implementation of artificial intelligence in healthcare organizations as a response to the needs of doctors to aid the patients in their daily decision-making activities is now on the increase. This hopes to improve decision making and reduce errors. In the long run, it reduces cost and improved workflow and the general well-being of people.

Related works:

The Internet of Things (IoT), which refers to the integration of technology into everyday life and the interconnectivity of omnipresent devices, has stymied a dedicated research venture in the field of mental health. Recognizing that mental health issues are on the risen, affecting individuals and society in increasingly complex ways and that existing human resources are insufficient to address the crisis, decision-makers have turned to technology to see what opportunities it may provide. The role of IoT-enabled technology in this new digital mental health landscape can be divided into two complementary processes: assessment and intervention [18].

Prediction of mental health problems in children using eight ML techniques, three of which, multilayer perceptron, multiclass classifier, and logical analysis of data (LAD) tree, produced more accurate results with only a slight difference between their performances over the full attribute set and the selected attribute set. The study found that by developing a high-performing model, early diagnosis of mental health problems in children will help healthcare professionals to treat it at an earlier stage and subsequently improve the quality of patients' life. Therefore, there comes an urgent need to treat basic mental health problems that persist among children which may lead to complicated problems, if not treated at an early stage [19]. By introducing a genetic algorithm (GA) in developing a system for intelligent data mining and ML for mental health diagnosis, Azar, et al., (2015) [20] were able to extract keywords from the user's symptoms. The research introduced a new approach that was used for a semiautomated system that helps in the preliminary diagnosis of the psychological disorder patient. This was achieved by matching the description of a patient's mental health status with the mental illnesses. The study constructed a semi-automated system based on an integration of the technology of genetic algorithms, classification data mining and ML. The goal was to help psychological analysts make informed, appropriate and intelligent assessments leading to accurate prognoses by ensuring that they are aware of all possible mental health illnesses that could match the patient's symptoms.

The predictive research for mental health disease was proposed in a prototype that used RF classification to determine the mental state of a person based on attributes such as lifestyle, age, education, gender, vision, occupation, sleep, personal income, mobility, diabetes and hypertension [21]. With the amount of data produced by humans daily and with most of this data stored in a semi-structured way, these researchers believed that by using this ML technique, hidden patterns can be found between the different attributes of data. WEKA and RATTLE were used and the result of 83.33 % and 92.85. % accuracy was reported. With these, the system would be able to predict whether a patient was suffering from mental illness or not. A critical review using SVM to identify imaging biomarkers of neurological and psychiatric disease was conducted by [22]. The study provided an overview of the method and reviewed studies that applied SVM in the investigation of schizophrenia, Alzheimer's disease, Parkinson's disease, bipolar disorder, pre-symptomatic Huntington's disease, major depression, and an autistic spectrum disorder. Standard univariate analysis of neuroimaging data revealed a host of neuroanatomical and functional differences between healthy individuals and patients suffering a wide range of psychiatric and neurological disorders.

The mental health evaluation model based on the fuzzy neural network was carried out by [23] by selecting the important factors such as the input vector, the model was used to evaluate the psychological health of college students in China. The combination of neural networks (NN) and fuzzy mathematics improved the accuracy of the mathematical model compared to other traditional models and made it easy to analyze the overall mental health trend of students. Recurrent and linear models to detect depression early were developed [24]. The goal of the study was to achieve early automatic detection of depression from users' posts on the social media site – Reddit. For prediction, both sequential (RNN) and non-sequential (SVM) models were used. The results showed the superiority of sequential models over nonsequential models. The research did not sufficiently explore the broad range of possible features. Different ML techniques such as KNN, SVM, naïve bayes classifier, decision trees, and logistic regression to identify the state of mental health in a target group. The replies to the designed questionnaire from the target group were first exposed to unsupervised learning techniques. The Mean Opinion Score was used to validate the labels obtained by clustering. The cluster labels were then utilized to create classifiers that could predict an individual's mental health. Population from a wide range of groups such as college students, high school students, and working professionals were considered as target groups.

A survey on the analysis of the mental state of social media users to predict depression was conducted by [25]. The survey was done to detect depression and mental illness through the use of social media are surveyed. They found out that there was a very high rate at which depression and mental illness were being diagnosed in recent times. They observed that some symptoms linked to mental illness were detectable on Facebook, Twitter, and web forums. They suggested that using automatic methods would help in locating inactivity and other mental diseases. Various automated detection methods could help to detect depressed people using social media. Mentally ill users were pointed out through the use of screening surveys, their Twitter analysis based on community distribution, or their membership in online forums, and they were detectable through the patterns in their language and online activities. Additionally, they observed that a number of authors experienced that numerous activities on social networking sites could be linked to low self-confidence, especially in young people and adolescents.

A predictive model for the determination of the risk of depression among university students was also developed by [10]. The study extracted knowledge on the factors causing depression among university students. In the study, a predictive model for depression risk with a view to determining the risk of depression among university students was formulated, simulated and validated.

The result of the study identified variables that have strong relevance to developing depression among university students. The simulation results showed that the model without feature selection gave a total of 465 correct classifications out of 507 records with an accuracy of 91.7% while feature selection, gave a total of 475 correct classifications with an accuracy 93.7 %. It has been established that the are research gaps in the area of using ML techniques to provide solutions to some of the issues relating to mental disorders among the IT employee, hence, this study was informed. Table 1 shows the summary of the related works, the goals and their respective contributions

S/N	Ref	Goals	Contribution
1	[18]	Identify approaches in digital mental health	Distinguished technology for mental health diagnosis into two complementary processes: assessment and intervention
2	[21]	RF (ML) classifier was used alongside predictive models to determine mental health diseases.	WEKA and RATTLE were used as predictive models, 83.33 % and 92.85 accuracies were reported.
3	[20]	To introduce GA in developing intelligent data mining and ML system for mental health diagnosis, was able to extract keywords from the user's symptoms.	Matched the description of a patient's mental health status with the mental illnesses. The research introduced a new approach that was used for a semiautomated system that helps in the preliminary diagnosis of the psychological disorder patient.
4	[19]	Prediction of mental health in children	Multilayer perceptron, Multiclass classifier, and LAD tree outperformed other ML models used.
5	[22]	To identify imaging biomarkers of neurological and psychiatric disease using SVM was conducted	Method and reviewed studies that applied SVM in the investigation of schizophrenia, Alzheimer's disease, Parkinson's disease, bipolar disorder, pre-symptomatic Huntington's disease, major depression, and an autistic spectrum disorder were reported.
6	[23]	To evaluate mental health based on the fuzzy neural network	The combination of NNs and fuzzy mathematics improved the accuracy of the mathematical model compared to the existing method.
7	[24]	To achieve early automatic detection of depression from users' posts on the social media site RNN and SVM	The approach achieved early automatic detection of depression and ensured superiority of sequential models over nonsequential models
8	[25]	to conduct a survey on detecting depression and mental illness by the use of social media information.	They found out that there was a very high rate at which depression and mental illness were being diagnosed in recent times. They observed that some symptoms linked to mental illness were detectable on Facebook, Twitter, and web forums.
9	[10]	To depression risk with a view to determining the risk of depression among university students using predictive models	93.7% accuracy was achieved on the ML model used

Table 1: Summary of related works

3 Methodology

The developed model consists of the phases namely: the dataset pre features extraction (training and testing), and the evaluation results. During the preprocessing phase, values of missing data were replaced and even distribution of data was ensured with features scaling. Features of the pre-processed data were split into two with 67% of the data set aside for training and the remaining 33% set aside for testing. Using the bagging ensemble method, the training set was passed through hybridized RF and Artificial Neualgorithms, using RF as the base. The performance of the result was then evaluated using the standard evaluation metric namely: precision, recall, f1-score and accuracy. Figure 1 shows the developed methodology framework in this research, the framework showing the stages followed to achieve the results. The selection gave a total of 475 correct classifications.

3.1 Data collection and implementation

The input data for this model is the dataset provided by OSMI Ltd. The dataset is derived from a survey aimed at measuring the attitudes of people towards mental health in IT workplace and examining the rate of mental disorders set contains 63 variables or columns and 1,433 responses/ observations. The performances of the models

built were evaluated on the basis of their precision, recall, and F1-score. To further understand and measure the performance of the hybrid model, a different set of algorithms was implemented. These models include: RF with default parameters, RF with tuned parameters and the developed model consists of three different phases namely: the dataset pre-processing, features extraction (training and testing), and the processing phase, values of missing data were replaced, even distribution of data was ensured with features processed data were split into two with 67% of the data set aside for training and the remaining 33% set aside for testing. Using the bagging ensemble method, the training set was passed through hybridized RF and ANN.

4 Results and discussions

The performances of these models were observed and compared with the hybrid model. The results obtained from the trained models are discussed below:

Random forest technique*:* The result obtained from the model as shown in Table 2, though the model performance was poor in the classification of IT employee with the status of mental health disorder with 44%, 44%, and 45% precision, f1 accuracy, recall respectively. The default-parameterized RF model performed at a weighted average of 48% precision, 49% F1-score and 50% recall respectively. This poor performance called for the need to tune the parameter in order to obtain improved performance. This outcome attests to the study of [22].

Table 2: Result of the random forest model

	Precision	**F1-Score**	**Recall**	**Support**
0	0.23	0.19	0.17	103
1	0.53	0.53	0.53	183
2	0.56	0.60	0.65	157
Macro average	0.44	0.44	0.45	473
Weighted average	0.48	0.49	0.50	473
Accuracy	-	0.50	-	473

Artificial neural networks (ANN) techniques: The result of ANN model is as shown in Table 3 poorly incorrectly classifying “Employees not sure of their mental health status”. Overall, the model performed at a weighted average of 72% precision, 69% F1 score and 71% recall.

Table 3: Result of the ANN Model

	Precision	**F1-Score**	**Recall**	**Support**
0	0.52	0.36	0.28	103
1	0.90	0.79	0.70	183
2	0.65	0.77	0.95	187
Macro average	0.69	0.64	0.64	473
Weighted average	0.72	0.69	0.71	473
Accuracy	-	0.71	-	473

RF-ANN technique: RF and ANN algorithms were hybridized for the Bagging ensemble issue. The hybrid model was trained on the training set and its performance was evaluated on the testing set. The result of the hybridized model in table 4 showed a significant improvement in the performance of the hybrid model over the performances of the RF model with default parameters and ANN model and a slight improvement over the per parameter-tuned RF ANN model’s weighted average performance was improved by the hybrid model from (72%, 69% and 71%,) to (74%, 72% and 74%) precision, F1-score and recall respectively. The results are similar to the finding in [23-24].

Table 4: Result of the hybrid model

	Precision	**F1-Score**	**Recall**	**Support**
0	0.64	0.48	0.38	103
1	0.84	0.79	0.74	183
2	0.69	0.94	0.94	187
Macro average	0.73	0.69	0.68	473
Weighted average	0.74	0.72	0.74	473
Accuracy	-	0.74	-	473

Back-propagation is the stage in which the weights are adjusted based on the loss in an attempt to find an optimal weight. Training an ANN is a process that entails determining the optimal weight that will minimize loss. In doing so, "categorical cross-entropy loss" was used to find the loss and "adam" optimization was used to find the optimal solution, with "accuracy" as a metric for performance evaluation. As shown, the model was trained with 45 epochs and a batch size of 10. Figures 2 and 3 Depict the training process, with decreasing loss and increasing accuracy as training progresses.

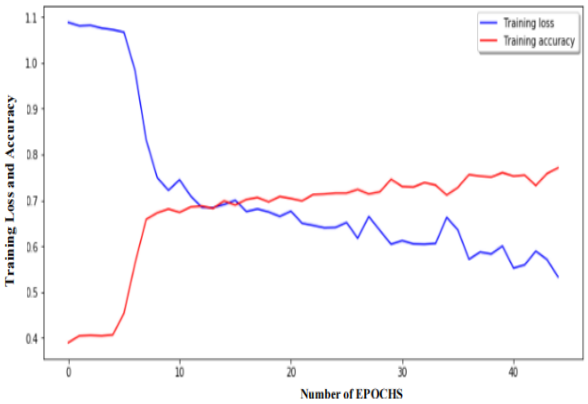

Figure 2: The Training loss and the Training Accuracy Against Number of Epochs

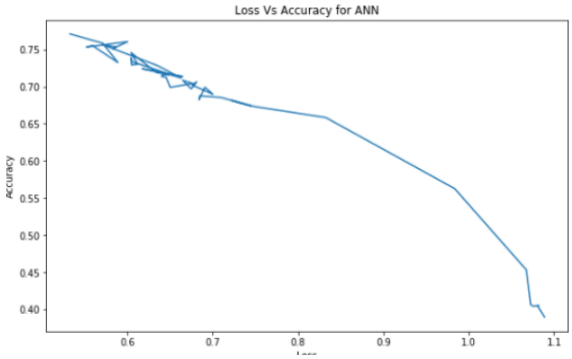

Figure 3: Training Accuracy versus Training Loss Showing Inverse Relationship

Findings: From all the results obtained, Table 5 reveals that the hybrid RF and ANN using "Bagging Ensemble" gave the best performance with the weighted average performance of 84.5% for precision, recall, and accuracy and precision is 82.5%. It can also be observed that the model is able to correctly predict IT employees suffering from Mental Health Disorders with 97% recall. Additional insight has gotten from the results in this experiment reveals that there was only a marginal improvement in the performance of the hybridized model when compared with the result of the parameter-tuned RF. This shows that RF is one of the best classifiers in the predictive algorithm which is consistent with the work of [21] and [25-28].

Table 5: Result Comparison of the 3 Models

Performance metrics	**Recall (%)**	**Prediction accuracy (%)**	**F1 Score (%)**	**Precision**
ANN	81.5	81.5	82.5	82.5
RF	60.5	60.5	58.5	58.5
Developed model (RF-ANN)	**84.5**	**84.5**	**82.5**	**84.5**

A comparison of the existing work with our study is presented in Table 6, showing the comparison of the goals in the existing works with our goals viz-a-viz the respective contributions

5 Conclusion

The study described various approaches to predicting mental disorders. It focused on the development of a hybrid predictive model for determining the risk level of mental disorders among employees in IT industry. Most of the existing models focused on predicting mental disorders using a single ML technique. This study identified the variables measured in IT employees which are relevant to the prediction of mental disorders in the dataset collected. The results obtained showed that developing a hybridized RF-ANN model had the best overall performance, hence, our developed model. The study described various approaches to predicting mental disorders. It focused on the development of a hybridized predictive model for determining the risk level of mental disorders among employees in IT industry. Most of the existing models focused on predicting mental disorders using a single ML technique. However, there is also the need to address the issue of late detection of mental disorders in IT employees. This study identified the variables measured in IT employees which are relevant to the prediction of mental disorders in the dataset collected.

In conclusion, the best performing model to predict mental disorders in employees of IT industry has been identified, the work has been able to develop a predictive model based on the most relevant factors causing mental disorders. From all the results obtained the hybrid RF and ANN using "Bagging Ensemble" gave the best performance in predicting IT employees suffering from Mental Health Disorders with a weighted average performance of 84.5% for precision, recall, and accuracy and precision is 82.5%. meaning there was a marginal improvement in the performance of the hybrid model when compared with the result of the parameter-tuned RF. This suggests that by applying the RF-ANN model an improved dataset could be investigated and compared with the results obtained in this study. In addition, insights gotten from the results in this study reveal that there was only a marginal improvement in the performance of the hybrid model when compared with the result of the parameter-tuned RF. The study is not only contributing to the computing field but also to healthcare delivery.

Recommendations

The following recommendations are made based on the findings of this study: This model can be adopted as an assistant tool by mental health professionals to help them in making an early and more consistent diagnosis of mental disorders. The model can be integrated into an existing employees' Health Information System (HIS) which has clinical data about the employees. It is recommended that variables monitored in IT employees be reviewed on a regular basis in order to increase the amount of information relevant to developing an improved mental health disorder prediction model. In the future, the hybridized algorithm could be used to predict mental disorders in a variety of fields. Similarly, using RF with parameter tuning on a better dataset could be investigated and compared to the findings of this study.

Table 6: Comparison of the existing work with our study

S/N	Ref	Goals	Contribution
1	[18]	Identify approaches in digital mental health	Distinguished technology for mental health diagnosis into two complementary processes: assessment and intervention
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4	[19]	Prediction of mental health in children	Multilayer perceptron, Multiclass classifier, and LAD tree outperformed other ML models used.
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8	[25]	to conduct a survey on detecting depression and mental illness by the use of social media information.	They found out that there was a very high rate at which depression and mental illness were being diagnosed in recent times. They observed that some symptoms linked to mental illness were detectable on Facebook, Twitter, and web forums.
9	[10]	To depression risk with a view to determining the risk of depression among university students using predictive models	93.7% accuracy was achieved on the ML model used. Only accuracy was measured
10	**Our study**	**to develop a hybrid model to predict mental health disorders among employees in an IT industry**	**An effective hybrid technique was developed that is capable of predicting the mental health of IT industry employees, the model was also evaluated singly before hybridizing and after hybridization, the hybridized model shows improved performance than the single ones**

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