Depression Detection Using ECG: Machine Learning

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Abstract: The major mental disorders affecting the society. The research utilizes electrocardiogram (ECG) signals together with advanced Support Vector Machine, Random Forest, Convolutional Neural Network and Long Short Term Memory based machine learning models to objectively predict depression using heart rate variation, age, and other ECG derived features. With its promise of an early and precise detection of depressive patterns, this method can well revolutionize mental health diagnostics with a noninvasive and cost effective detection which can be brought into real time diagnosis and telemedicine. The major preprocessing steps like noise filtering and normalization to improve the data quality and to automatically extract the features as comparison to manual feature engineering are important which the key to this approach are. Additionally, the system could be enhanced by the integration of other physiological signals, e.g. the EEG and the skin conductance, which would allow the system to cope with ECG signal variability and to require high quality data sets for the system to find robust and reliable implementations in real world applications.

1 INTRODUCTION

Depression is a common mental health disorder characterized by a significant impact on one's mood, thought and physical well-being which can therefore lead to major social and occupational impairment. Traditionally, depression by us diagnose checking the self-reported symptoms and by psychiatrists based on a structured clinical interview. However, detecting these early and accurately can be subjective, time consuming and biased with the person's experience and they can be difficult approaches. As the need for detecting depression, objectively, automatically and by using data becomes even greater, for those who may not seek professional help out of social stigma or because of a lack of access to mental health care.

Recent biomedical signal processing advances and machine learning methods, such detection of depression has been enabled with physiological data and Electrocardiogram (ECG) signals can be seen as a possible biomarker in that process. Heart function is closely connected to the autonomic nervous system that, in turn, is strongly influenced by emotional states: research indeed revealed that depression dramatically modifies HRV and any other ECG derived parameter. By studying these
variations in various aspects, machine learning models are capable of classifying people as depressed or not depressed, thus providing a reliable alternative to such screening tests, which can otherwise be both subjective and unreliable.

In this study, we develop a machine learning based system for depression detection making use of ECG signals. In the proposed work, ECG data is collected, meaningful features are extracted, and classification algorithms such as SVM, Random Forest, CNN and LSTM networks are applied. The high performance of these models is based on the use of time domain, frequency domain and non-linear features of ECG signals to identify depressive pattern. In addition, deep learning techniques will be able to extract features and features automatically reducing the dependency on manual processing and therefore classify better. This system can be implemented to improve the early detection and to continuously monitor depression in the clinical and home environments in real time. IoT Enabled wearable ECG devices can allow the integration in healthcare

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to allow remote monitoring and Telemedicine Applications, paving the way for scalable solution of cost effective mental healthcare. This research seeks to fill the gap between the psychiatric assessments as is traditionally done and the modern tech ready mental health diagnostics through exploitation of machine learning and physiological signal analysis to detect depression and improve accessibility, efficiency, and reliability in diagnosis.

2 RESEARCH METHODOLOGY

2.1 Research Area

The methodology for depression detection using ECG signals and machine learning follows a structured approach, beginning with data collection and pre-processing, followed by feature extraction, model training, evaluation, and implementation. The steps involved in the research methodology are as follows:

Data Collection: The ECG signal data is passed from the publicly available datasets and clinical trials of both depressed and non-depressed people. Wearable ECG devices or clinical grade ECG monitors record the data (or other corresponding physiological indicators relevant to depression) to obtain heart rate variability (HRV).

Preprocessing of ECG Signals: However, the observed raw ECG signals are majorly corrupted by noise and artifacts caused by muscle movements, respiration, and external electrical noise. Data quality improvement is done through the application of preprocessing techniques like bandpass filtering, denoising and normalization in order to increase the feature extraction.

Feature Extraction: Depression related variations are captured from ECG signals in the form of various time domain, frequency domain and non-linear features. Heart Rate Variability (HRV), RR intervals, Power Spectral Density (PSD), as well as Poincaré plot features are key features. The machine learning models are used with these extracted features as input.

Machine Learning Model Training: Initial classification is done by using Supervised learning algorithm like Support Vector Machines (SVM), random forest, logistic regression, etc. Moreover, use of deep learning models (specifically Convolutional Neural Networks (CNN), and Long Short Term Memory (LSTM) networks) for automatic feature extraction and higher accuracy is made. To ensure that the model generalizes properly, the dataset are split into training and testing sets.

Model Evaluation and Performance Metrics: Accuracy, precision, recall, F1 score and Area Under the Receiver Operating Characteristic Curve (AUC-ROC) are used to evaluate the trained models. We apply cross-validation techniques so as to reduce overfitting and improve the generalization.

Implementation and Deployment: The model is thus implemented in an application or embedded in IoT enabled ECG device for real-time depression monitoring once validated. It is possible to integrate the system with healthcare platforms for remote diagnosis, and also provide continuous mental health tracking.

2.2 Research Area

ECG signals utilizing machine learning can be used to detect depression under multiple research domains: biomedical engineering, artificial intelligence, mental health informatics, and wearable technology. This research is heavily dependent on biomedical engineering for the reason that it requires pathophysiological signal analysis to find the biomarkers associated with depression.

The ECG signals have the capacity to offer insights into mental health conditions through the heart rate and the autonomic nervous systems activity. Biomedical signal processing techniques can be used to extract patterns that will distinguish depressed individuals from healthy ones, making ECG a great tool for mental health assessment.

This research is greatly supported by the artificial intelligence (AI) and machine learning field, as it allows us to detect depression using AI based data driven model. The removal of subjectivity in traditional clinical approaches to kidney function has been replaced by objective, accurate, scalable and highly accurate AI driven systems. Depression is classified using Machine learning techniques, such as Support Vector Machines (SVM), Random Forest, Logistic Regression using ECG derived features. In addition, the Convolutional Neural Networks (CNN) and Long Short Termed Memory (LSTM) models are deep learning models that enhance the classification performance through automatic extraction of the complex patterns in the ECG signals and diminishing the requirement of the manual feature extraction.

Another major research area that merges technology and psychology as well as psychiatry to improve diagnostic and monitoring in mental health is mental health informatics. To reach such a high level of detection and tracking for depression early and continually, digital health solutions have been developed and used physiological signals, mobile applications and cloud systems. This research is part of creating a non-invasive, real time ECG based monitoring system to incorporate in mental health informatics that can assist healthcare professionals for relieving depression more effectively. It improves diagnostic precision and provides a means of monitoring the course of depression throughout the time course of treatment.

Moreover, wearable technology and Internet of Things (IoT) also increase the usage of this research by its potential for monitoring depression in real time in life as usual. With ECG sensors integrated into wearable devices (like smartwatches, fitness band, etc.), they can continuously be worn without the need of clinical visits. Typically, these are IoT enabled devices, which transmit ECG data to cloud based platforms that can have AI models analyzing the signal that can in turn generate the insights related to mental health. By developing this addiction, they can change the way depression is detected and found to be accessible, less stigma, and be treated on time.

3 LITERATURE SYSTEM

The authors says that the work attempts to detect depression using ECG signals through Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks, as the study of deep learning. This presents how it uses both of those temporal and spatial ECG data features to distinguish between depressed and non-depressed individuals. The results report high classification accuracy, which serves to demonstrate that deep learning has a large potential toward automating mental health diagnostics. Overall, this cycle of communication with the sensor can empower healthcare professionals to go beyond the score put forth by the questionnaires.

- The authors discuss the statistical and frequency domain features, the classifiers like Support Vector Machines (SVM) and Random Forest were utilized to identify depression with the help of heart rate variability (HRV) analysis. Through their study, they observe a large correlation between lower HRV and depression, therefore proving that HRV is an effective marker to use when conducting mental health assessments.
- The authors of the study introduces the use of a hybrid feature extraction method involving the time domain, frequency domain, and non-linear feature of ECG signals as the robust indicators for stress and depression. Later on, logistic regression and neural networks are applied for classification with this approach. According to their results ECG is shown to be a viable and cost effective noninvasive tool for mental health screening with possible wider clinical field application.
- The authors describe to improve depression detection accuracy and since both ECG and EEG signals contain information related to anxiety and depression, I develop a hybrid deep learning model that combines ECG and EEG. This model is using CNN and BiLSTM network to analyze both spatial and temporal features. The research shows that combining these physiological signals significantly improves upon using ECG or EEG separately.
- The authors describe an IoT framework for real time mental health monitoring with ECG signal based sensors and cloud analytics to assess the depression risks. To develop the remote healthcare interventions through a deep learning model, the model processes ECG patterns in order to detect potential depressive episodes.

These studies collectively highlight the effectiveness of ECG signal analysis for depression detection, showcasing various machine learning and deep learning approaches for classification and monitoring.

4 EXISTING SYSTEM

Most of the present systems for depression detection are based on psychological assessments, self-reported questionnaires, and clinical interview with the mental health professional. Depression symptoms are usually evaluated by using the commonly used standard diagnostic tools like The Patient Health Questionnaire (PHQ-9), Hamilton Depression Rating Scale (HAM-D) and Beck Depression Inventory (BDI). However these methods are subjective since they rely on the person's self-perception and willingness to report honestly his or her mental state. Consequently, it can result in misdiagnosis or underreporting, especially in people who are reluctant to have recourse to treatment because of the stigma or unfamiliarity they feel being stuck at home most of the time.

A few of the systems already in place include the use of neuroimaging techniques like functional Magnetic Resonance Imaging (fMRI) and Electroencephalography (EEG) in order to more objective depression diagnosis. However, these methods are expensive, time-consuming, and not suitable for frequent access in the case of routine mental health monitoring. Moreover, they are fairly complex and require specialised equipment to be widely used in real world scenarios.

An alternative method consists of wearable devices and smartphone applications that monitor behavioral patterns such as those during sleep, exercise, and also heart rate. Artificial intelligence in these systems is applied to spot deviations from daily routines which could suggest depressive symptoms. However, these methods are usually indirect and thus limit their utility in providing precise physiological evidence for depression and can in fact mislead to false positives or inadequate sensitivity for clinical diagnosis.

The existing depression detection systems do not have required accuracy, objectivity as well as tracking in real time. However, there is a need for a more reliable, noninvasive, and cost effective method, thus increasing the interest to use physiological signals such as ECG to detect depression due to its functionality as a direct and measurable biomarker of the autonomic nervous system.

5 PROPOSED SYSTEM

The objective of the proposed system is to develop an automated, non-invasive and objective, a depression detection framework based on the Electrocardiogram (ECG) signals and machine learning based techniques. Such system departs from conventional methods based on traditional self-reported psychological assessments or expensive neuroimaging methods and takes advantage of the ECG based physiological markers for measuring depression with high accuracy. The system determines patterns of autonomic nervous system dysfunction, a key indicator of depressive disorders by analyzing ECG derived feature such as Heart Rate Variability (HRV).

A wearable ECG sensor is used to obtain real time heart signal data that the system integrates. The preprocessing of this data is done to remove the noise and extract the time domain, frequency domain and the nonlinear HRV parameters. Support Vector Machines (SVM), Random Forest and Deep Learning models, such as Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM), are applied to classify a person as depressed or Non-depressed given their ECG patterns.

5.1 System Architecture and Results

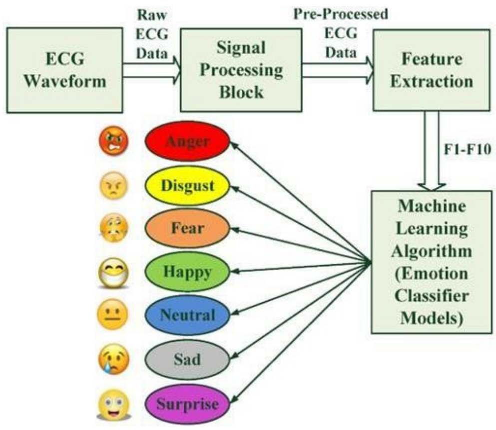

Figure 1: System Architecture.

The system as shown in figure 1 is aimed to work with an IoT based cloud platform to enhance the accessibility and usability by providing the remote monitoring and real time analysis. The machine learning model processes and returns the instant depression risk assessments on the cloud server using the ECG data being securely transmitted to it. If abnormal ECG pattern indicating depression is detected then the system can alert the healthcare providers or person for early intervention and continuous mental health monitoring. The proposed system is overall an objective, cost effective and scalable solution for depression detection. For the application, machine learning is employed to utilize ECG signals, thereby replacing any level of subjectivity in mental health diagnosis by improving diagnostic accuracy, as well as enabling real time monitoring whether for clinical or personal applications.

Figure 2 shows the Total Normal & Depression Detection Records and Figure 3 shows the Run Existing SVM output. Figure 4 shows the Run Propose CNN Output. Figure 5 shows the Comparison Graph of SVM and CNN.

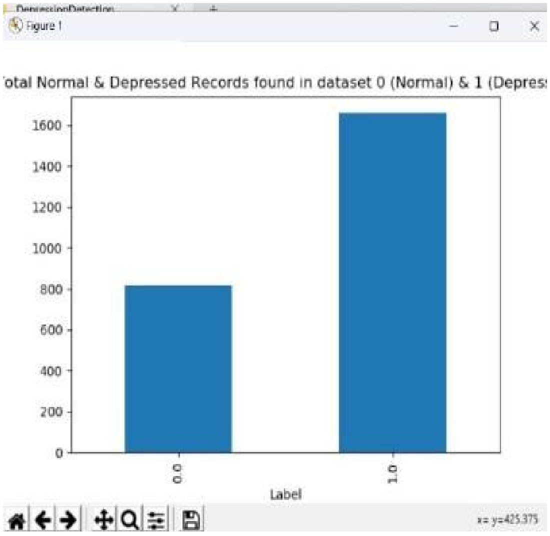

Figure 2: Total Normal & Depression Detection Records.

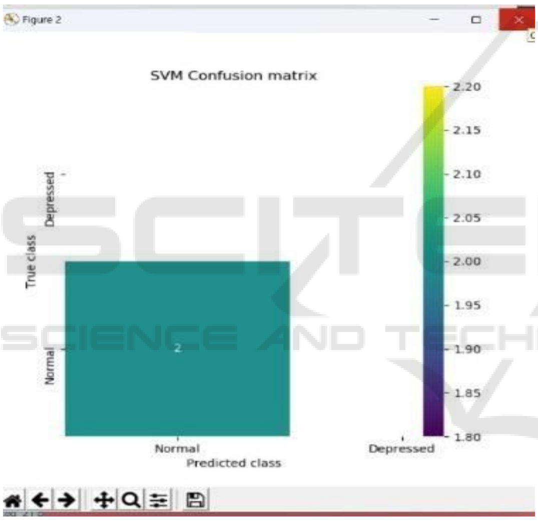

Figure 3: Run Existing SVM Output.

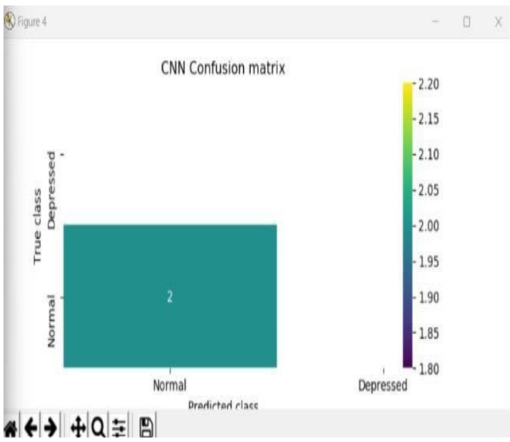

Figure 4: Run Propose CNN Output.

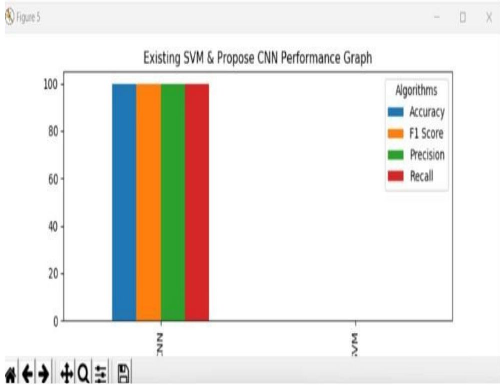

Figure 5: Comparison Graph of Svm and Cnn.

6 CONCLUSIONS

The implementation of detection of depression from ECG signals using machine learning offers an innovative method to replace conventional depression diagnosis methods by providing an objective, non-invasive real time depression assessment. Depression detection as it is done traditionally, relies heavily on self-reported questionnaires or clinical interviews both of these aspects of depression detection can be subjective and can result in misdiagnosis. However, ECG based detection takes advantage of the physiological biomarkers including heart rate variability (HRV) as measurable indicators of mental health status. This system is improved by machine learning models that help to distinguish the complex patterns of ECG signal to detect depression in earlier and more reliable way.

The system as proposed will integrate ECG feature extraction with advance classification algorithms that will give high precision in discriminating the depressed and the nondepressed people. The system allows the analysis of these ECG signals by utilizing techniques, for instance, Support Vector Machines (SVM), Random Forest, and Deep Learning models such as CNNs and LSTMs that help improve the accuracy and efficiency of the analysis process. In addition, the system can be used as a wearable or IoT-based device for continuous monitoring leading to early intervention and reducing the amount of load on traditional healthcare facilities and transferable to realistic applications compared to other existing systems that typically need expensive neuroimaging techniques or indirect behavioral assessments. It allows remote monitoring so that people in danger of depression are not forgotten and get to receive health intervention when required.

Furthermore, cloud based analytics brings in more accessibility to the healthcare providers, as their involvement in the mental health assessments is decreased leveraging more data driven solutions. Overall, we have made advances towards using a machine learning driven ECG analysis for depression detection. It then closes the gap between subjective assessment and objective biomarkers to enable such reliable, affordable, and preventive mental health care solutions. Future work may consist in integrating multimodal data sources, e.g., EEG and behavioral data, to assist in the detection of mental health conditions and provide an overall basis for mental health assessment.

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