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DETECTION OF MENTAL STRESS USING BIOSIGNALS THROUGH MACHINE LEARNING- A BRIEF SURVEY

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ABSTRACT

This paper explores the classification of various existing biosignals used for stress detection and evaluates their effectiveness. Out of all the biosignals reviewed, ECG was chosen as the best biosignals . Further review was conducted to determine the most suitable machine learning model for the chosen ECG signal. Results have shown that KNN gives the best accuracy of 96.41% followed by SVM with a considerably high accuracy of 90.10%. The best ML models were then evaluated on other biosignals for comparison of effectiveness on different data signals. The findings of this study offer useful insights into the selection of optimal biosignals and machine learning algorithms for detecting stress, which can contribute to development of personalized stress management technologies and improving mental health.

Keywords: Stress, Emotion Detection, biosignals,Wearables**.**

INTRODUCTION

Mental health is a critical aspect of overall well-being and ranks in the top 5 chronic health conditions, yet it remains an uncomfortable and often stigmatized topic in many societies. Emotions can significantly impact our daily lives and not only reflect a person's mental state, but they also present a strong connection with people's physical health. Stress is a part of our daily lives because of many reasons like a sedentary lifestyle, work-life balance, cutthroat competition of the modern world, illness or injury and all such factors having a detrimental effect on one's mental and physical health. A number of health issues, including heart disease, high blood pressure, diabetes, obesity, and depression, can be caused by persistent stress. The ability to focus, make choices, and perform well at work can all be affected by stress. There are several types of stress that individuals can experience. Some of these types include acute stress, chronic stress, traumatic stress and physiological stress. Many people might be unaware of their stress until it has started to negatively affect their overall well-being. Because of this, stress detection is crucial. Early stress detection allows people to manage their stress and avoid it becoming chronic or contributing to other health issues. Traditionally, self- report surveys were used to gauge stress levels (Aristizabal 2021), however, they were subjective and prone to biases. Advances in technology have made it possible to detect stress through the analysis of biosignals like heart rate variability, skin conductance, ECG, and EEG signals. These signals give accurate, non-invasive assessments of stress that can be used to track people in real-time and offer insightful information on the physiological mechanisms underlying stress. In recent years, the use of these biosignals has garnered interest with various studies exploring their possible uses in fields of mental health assessment and performance enhancement using various ML models(Giannakakis 2019, Ancillon 2022, Panicker 2019). This review paper investigates the following aspects of stress detection

• Various data signals that can be used for stress detection are classified and then the best data signal amongst them is identified.
• Different biosignals along with their wearable device type and classification algorithms is listed
• Further the various ML models that are techniques and algorithms used to analyze these signals are explored and the best is determined on the basis of the most accurate results.
• The chosen ML model's accuracy is then compared for different data signals thus giving a complete analysis.

WEARABLES

Wearables have gained increasing popularity in recent years as a means of monitoring and managing health and wellbeing. With the advent of biosensor technology, wearables can now measure physiological signals like heart rate, skin conductance, and body temperature, which are indicative of stress(Da Silva 2014). Machine learning algorithms can classify the stress levels in these signals and provide the user with tailored feedback(Smirthy 2023). The use of wearables to detect stress has the potential to provide quick, accurate measurements of stress in the present, resulting in better stress management and enhanced overall health. There are different types of biosignals that are currently detected using different wearable devices. Some of the primary biosignals are ECG & EEG and other miscellaneous signals such as GSR, PPG, EMG, HRV etc.

A.Electrocardiogram (ECG)

This is a measure of the electrical activity of the heart, which can be used to assess heart function and diagnose heart conditions. During stress, the sympathetic nervous system is stimulated, which can alter the ECG waveform, heart rate, and heart rate variability. Thus ECG analysis can be used to obtain a more comprehensive understanding of an individual's stress response(Bin Heyat 2022).One of the measures of stress in ECG analysis is heart rate variability (HRV) and its decrease may be an indication of stress(Rajendra Acharya 2006)

B.Electroencephalogram (EEG)

This measures the electrical activity of the brain and is used to diagnose and study conditions such as epilepsy, sleep disorders, and brain injuries. EEG signals are characterized by their frequency, amplitude, and morphology. The shape or pattern of the signal is referred to as its morphology, and it can represent various mental states or activities. EEG signals are commonly analyzed using signal processing techniques such as filtering, feature extraction, and classification (Saini 2022). Stress may alter the brain's activity pattern which can be detected through EEG waveforms. The alpha wave is a frequently utilized stress indicator in EEG analysis and are connected to feelings of relaxation. Stress causes a decrease in alpha wave activity and this decline may indicate stress. Beta waves, which are linked to alertness and concentration, and gamma waves, which are linked to cognitive processing, are two more EEG measurements that may be helpful for stress identification (Kraiwattanapirom 2022).

C.Miscellaneous Signals

Miscellaneous signals include signals such as Galvanic skin response (GSR), which helps in measuring electrical conductivity of the skin and is often used in lie detection tests or to measure emotional arousal (Kurniawan 2013).An increase in sweat gland activity is caused during periods of stress. Thus the increase of GSR is indicative of high stress levels. PPG(photoplethysmogram) is used for measurement of heart rate, blood pressure, and other cardiovascular parameters. A PPG signal's waveform typically consists of a sequence of peaks and valleys that represent various stages of the cardiac cycle(Joseph 2014).Stress causes the sympathetic nervous system to become active, which can alter blood flow and, as a result changes the PPG waveform by decreasing its amplitude, increasing its heart rate and changing the timing of certain PPG features. Henceforth changes in PPG may be a sign of stress. Electromyogram (EMG) which measures the electrical activity of muscles and is used to diagnose and study neuromuscular disorders such as muscular dystrophy and ALS(Ahsan 2009).

D. Activity monitoring using different wearables

Activity monitoring using wearables has become increasingly popular in recent years, as it allows individuals to track their physical activity and fitness levels. Fitness trackers, smartwatches, and smart clothing are just a few examples of wearables that can be used to monitor activity.

Fitness trackers and smartwatches are devices that are designed to track physical activity and fitness-related metrics such as steps taken, distance traveled, calories burned, heart rate and body temperature.

Activity monitoring using wearable sensors is important for individuals who want to track their fitness progress, set goals, and stay motivated. It can also be useful for healthcare professionals who want to monitor patients' physical activity levels and identify any potential health issues.

ECG signals are used in wearable devices such as ECG patches and Chest strap monitors which help in measuring heart rate and rhythm accurately. EEG signals can also be used for accurate measurement of stress, however their only drawback is that they are bulky headsets which cannot be worn at all times while doing day to day activities especially resting hours and thus cannot be commonly used as a practical wearable device. Thus ECG has an advantage over EEG signals when it comes to wearables for stress detection. PPG signals can be detected by smartwatches and are used to detect skin moisture and other skin conditions. Thus PPG can also offer a low cost alternative as wearable for detecting .

There are various biosignals that are detected by various wearable devices. After detecting the biosignals they are passed through numerous machine learning algorithms , giving different outcomes.

Hence, we concluded Table 1 having different biosignals along with their wearable device type and classification algorithms.

Table 1: Different data signals with devices and classification algorithms

Data Signal	Device	Classification
GSR(2011)(de Santos Sierra 2011)	Wearable	Fuzzy Decision Algorithm
GSR(2012)(Villarejo 2012)	Wearable	WEKA learning machine
GSR (2016) (Cantara 2016)	Wearable	Adaptive Neuro-Fuzzy Inference System (ANFIS)
ECG(2011) (Karthikeyan 2011)	A small and lightweight sensor named RF-ECG(Medic al device)	KNN
ECG(2014) (Ferdinando 2014)	Existing DB(Medical device)	SVM
ECG(2019) (Giannakakis 2019)	Wearable	mRMR, SVM
ECG (2019)(He 2019)	Wearable	CNN(SGDM)
ECG(2022)(Ishaque 2022)	Wearable	Random Forest
EEG(2014,2016,2019)(Jegan 2022, Ashwin 2022, Mizrahi 2022)	Emotiv Epoc Neuro-headset(Medical device)	SVM
EEG(2017)(Suryawanshi 2023)	Medical device	Logistic Regression, SVM, Naive Bayes
EEG(2020)(Majid 2022)	EMOTIV Insight headset (Medical device)	SVM
PPG(Gomes 2022)	Wearable	SVM

From Table 1 we can conclude that changes in HRV measured by ECG signals can be used as a reliable indicator of stress. The timing and duration of each heartbeat, the amplitude and morphology of the waveforms, and the variability of the gaps between successive heartbeats are just a few of the details that ECG signals can reveal about the electrical activity of the heart. It is possible to find patterns and trends related to stress by examining these parameters. Hence, ECG signals are the best data signals to detect stress.

MACHINE LEARNING MODELS

Machine learning involves developing models and data and make predictions.ML algorithms can be broadly categorized into supervised, unsupervised, and reinforcement learning. Supervised learning is training a model on a labeled dataset with known expected outputs. The model then develops the ability to forecast events based on the supplied data. In unsupervised learning, a model is trained on an unlabeled dataset where the desired outcome is unknown. The model then picks up on the structure and trends in the data. In reinforcement learning, a model is trained to make decisions in an environment where it will receive feedback in the form of rewards or penalties based on its behavior.

Machine learning has made it feasible to capture the patterns in biological signals and generate predictions with higher accuracy. After data pre-processing and collecting, the processed data is analyzed by a machine learning classifier to understand the physiological characteristics of the users and detect their mental states under various circumstances(Smirthy 2023). The following classification algorithms are discussed -

● **KNN** - It stands for K nearest neighbor and is a classification algorithm used in machine algorithms. It is a specific kind of supervised learning method that is applied to both classification and regression issues. In KNN-based stress detection, a biosignal is taken as input and compared with the k nearest neighbors in the training set. The biosignal is then classified based on the majority class of the k neighbors(Rahman 2015).

● **SVM** - Support Vector Machine is a classification algorithm used in stress detection using biosignals(Gaikwad 2017).The goal of SVM-based stress detection is to identify the hyperplane in a high-dimensional space that best divides the various classes of data. The algorithm might, for instance, look for the hyperplane that best distinguishes the biosignal data linked to high stress from the data linked to low stress. The hyperplane is chosen such that the margin between the hyperplane and the nearest data points from each class is maximized(Ghaderi 2015).

● **CNN** - Convolutional Neural Network is a type of artificial neural network used primarily in image and video recognition tasks. While detecting stress using CNN, the algorithm looks for patterns in the frequency domain or time-frequency domain. The CNN is made up of several layers of convolutional and pooling processes, followed by one or more fully connected layers. These layers are trained using labeled data in order to determine the stress level of the input biosignal data.(Gil-Martin 2022)

● **LSTM** - Long short term memory is a type of recurrent neural network architecture. Each vector in the input sequence of the LSTM network denotes a particular time step in the biosignal data. Then, either as a continuous value or as a binary classification, the LSTM network can learn to map these input vectors to corresponding stress levels.(Awais 2020)

A. Accuracy of various ML models on ECG signal to predict stress

As concluded from Table 1 there are various biosignals from which stress can be detected. Out of these, ECG stands out to be the most widely used signal in wearables that can be used in day to day life while doing the daily chores.

After choosing a biosignal it is important to process the signal with the help of different algorithms to measure stress.

Table 2 consists of the accuracy of various machine learning algorithms on ECG signals to predict stress.

Table 2: Accuracy of various Machine learning models on ECG signal to predict stress

ML Models	Accuracy
KNN(Gedam 2021)	96.41%
SVM(Gedam 2021)	90.10%
CNN(Kang 2021)	88.35%
LSTM(Kang 2021)	86.25%
FCM(Kang 2021)	82.7%

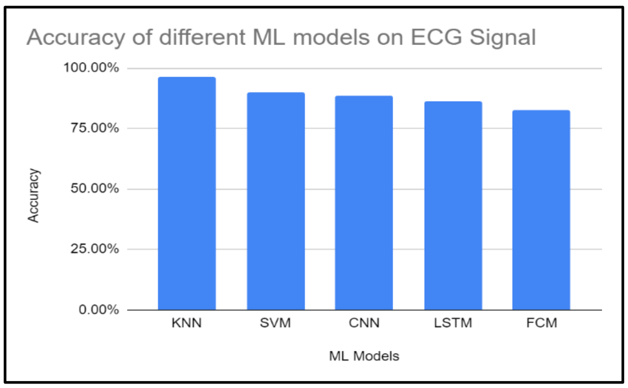


Fig 1: Graphical representation of accuracy of various ML models on ECG signal to predict stress

From Figure 1 we can see that there are various machine learning models that perform well with ECG signal in stress prediction but KNN outperforms all of them by giving an accuracy of 96.41%. KNN is followed by SVM having an accuracy of merely 6% less than KNN. CNN and LSTM giving almost the same accuracy and FCM having the least accuracy of 82.7% only.

Both KNN and SVM outperforms other ML algorithms. The choice between these two algorithms then depends on the goal of our analysis. KNN is advantageous when data has clear boundaries between classes and feature space is small. However SVM is advantageous when data has non linear boundaries and feature space is high dimensional.

Thus we conclude that both KNN and SVM are best ML algorithms for ECG signal and the choice of which one is better depends solely on the characteristics of the dataset.(Grčar 2006)

B. Performance of KNN on various biosignals during stress prediction

As concluded from section 3.1. ,KNN is determined as one of the best ML algorithms for widely used ECG signals. KNN can be applied to various data signals including time series data, image data and text data. For time series data like ECG and EEG, KNN can be applied to feature vectors that have been retrieved from raw data using fourier transform. For Image and text data, KNN is useful as it can handle high dimensional feature spaces.(Hazer-Rau 2020)

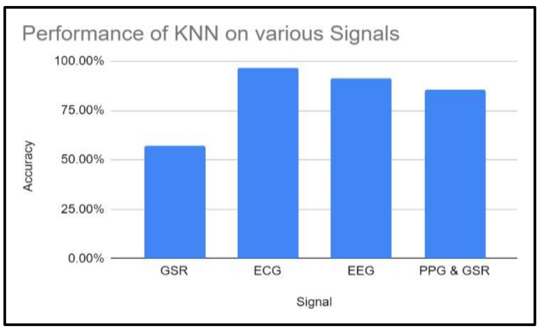
Thus, in Table 3 evaluating the performance of KNN for various data signals using appropriate metrics and techniques.

Table 3: Accuracy of KNN on various biosignals

Signal	Accuracy
GSR(Koné 2018)	57.24%
ECG(Gedam 2021)	96.41%
EEG(Rahman 2015)	91.26%
PPG & GSR(Gedam 2021)	85.30%

Fig 2: Graphical representation of accuracy of KNN algorithm on different biosignals

From Figure 2 it can be analyzed that KNN performs best with ECG signal with 96.41%, EEG being the second giving an accuracy of 91.26%. PPG & GSR combined performed tolerably well with KNN, whereas GSR performed the worst with an accuracy of 57.24% only.



C. Performance of SVM on various biosignals during stress prediction

As concluded from Section 3.1.,SVM is also one of the best ML algorithms with high accuracy for wearable signals like EEG and ECG. SVM is a useful ML model as it can be trained to classify data into two categories based on input features and it can also handle high-dimensional and non-linear data(Kurniawan 2013).The input features for stress detection can be physiological and behavioral data like heart rate, breathing rate, skin conductance, and other such comparable measurements, that are indicative of stress. Thus these characteristics of SVM make it suited for handling the complex and varied nature of stress reactions.

Table 4: Accuracy of SVM on various biosignals

Signal	Accuracy
GSR(Udovičić 2017)	77.13%
ECG(Gedam 2021)	90.10%
EEG(Gupta 2020)	96.36%
PPG(HRV)(Giannakakis 2019)	85%

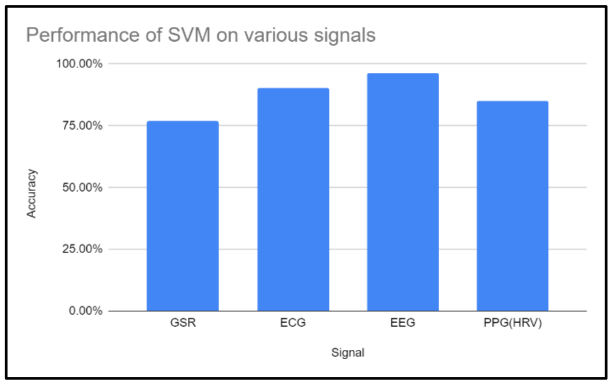


Fig 3: Graphical representation of accuracy of SVM algorithm on different biosignals

From Figure 3 we can determine that SVM gives the best performance with EEG signals with an accuracy of 96.36%. This is followed by an ECG signal having an accuracy of 90.10% which is also considerably high. It can be further concluded that SVM gives tolerable accuracy of 85% with PPG(HRV) signal, however it performs the worst for GSR signal with the least accuracy of 77.13%.

CONCLUSION

Stress is a response triggered by various situations encountered in daily life. It involves both psychological and physiological aspects. One or more stressors can cause stress, and sensors can identify the resulting change in physiological responses. ECG signals are biosignals which can be detected easily using various wearable devices unlike other signals which demand advanced medical equipment or bulky wearables to detect stress. ECG signal was tested on various algorithms after which it was concluded that KNN gave the highest accuracy of 96.41% followed by SVM with an accuracy of 90.10%. Hence, ECG signals with KNN or SVM can be used to detect stress.

Since ECG signal is detected by low cost wearable sensors it is only useful for detecting stress at very initial stages after which if an individual's stress level goes par a threshold value then a medical device must be used for more accurate stress detection.

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