EEG – Based Stress Detection Using Machine Learning

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Abstract

According to WHO (World Health Organization), Stress is a serious problem among mankind. It affects both the physical and mental health of an individual. Various traditional techniques are available for stress detection. The research in the field of stress detection has developed many techniques for human brain monitoring which helps in the study of human behavior. In this research, a novel approach to detect the stress based on EEG signals using Convolutional Neural Network (CNN) system is proposed. A Machine Learning (ML) Framework is proposed involving electroencephalogram (EEG) signal analysis of stressed participants. The proposed ML framework involves EEG Dataset collection, Data Munging (i.e. cleaning of data and making it useful for further processing), and Training and Testing. The EEG dataset was collected from the UCI Machine Learning Repository. The proposed method can help in developing a computer-aided diagnostic (CAD) tool in the future for stress detection.

Keywords: *EEG, Machine Learning Framework, Convolutional Neural Network, Data Munging.*

1. Introduction

One feels stressed many-a-times. Some individuals might cope up with stress very effectively or pass through many nerve-wracking events a lot quicker than many others. There are different kinds of stress – all that carry physical and psychological state risks. A stressor may be a one time or a short term incidence or may occur often which keeps on happening over a prolonged period.

With the speedy pace of life, more and more individuals are feeling stressed. Following a worldwide survey reported by *Newbusiness* in 2010, half the population has experienced a considerable rise in stress over the last two years. Although stress itself is non-clinical and common in our life, excessive and chronic stress is often rather harmful to people's physical and psychological health state. According to already existing research works, long-term stress often brings many diseases, e.g., clinical depressions, insomnia, etc.

Moreover, as said according to the Chinese Center for Disease Control and Prevention, suicide has become the highest reason for death among youth, and excessive stress is taken into account to be a significant cause of suicide. All these reveal that the speedy increase of stress has become a good challenge to human health and life quality [2].

Stress detection is an ongoing research topic among both psychologists and engineers. Stress is experienced in every person almost every single day which is automatically related to the interconnection between the environment and the person itself. Various technologies are developed on human stress detection using wearable sensors and biosignal processing [5]. Stress is commonly recognized as a state in which an individual is expected to perform too much under sheer pressure and in which he/she can only marginally contend with the demands. These demands can be psychological or social. It is known that psychosocial stress exists in daily life, which has resulted in a poor quality of life by affecting people's emotional behavior, job performance, mental and physical health [1].

Stress generally contributes to a sustained feeling of low-energy and depression. Stress causes inefficiency during routine work which makes it a social cause [3]. Psychosocial stress is a leading cause of several psychophysiological disorders. For example, it increases the likelihood of depression, stroke, heart attack, and cardiac arrest, etc. A Machine Learning (ML) Framework is proposed involving electroencephalogram (EEG) signal analysis of stressed participants. The proposed ML framework involved EEG dataset collection, data munging, training and testing of data and validation. The proposed method could prove helping hand in developing a computer-aided diagnostic (CAD) tool for stress detection.

2. Methodology

The proposed system is represented in the schematic format in figure 1:

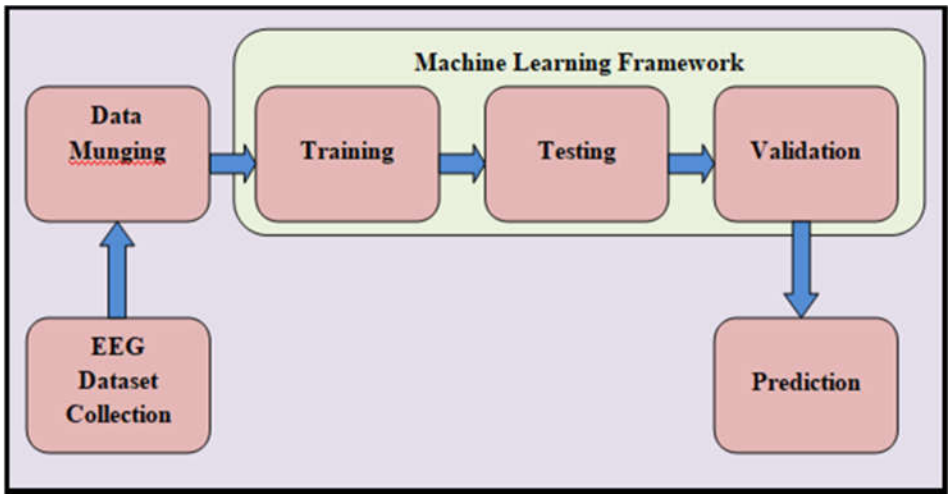


Figure 1. Schematic Representation of Proposed Work

The main aim of this work is:

- Collection of EEG Dataset for further processing.
- Data munging, the general procedure for transforming data from an erroneous or unusable form, into the usable form.
- Performing actual training and testing (by splitting data into 80:20 ratio) where we retrieve actual accuracy for Machine Learning model

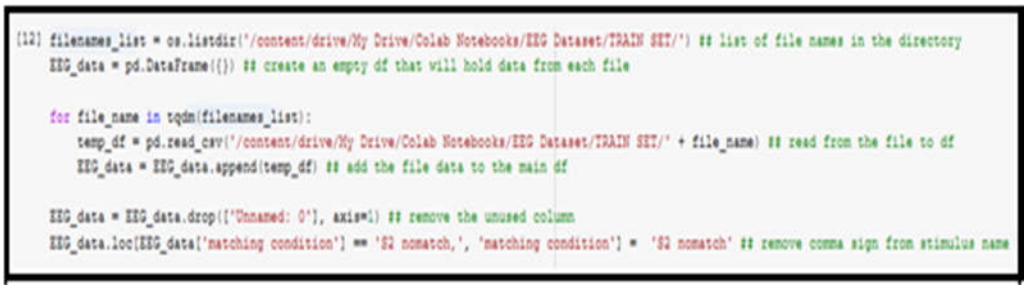
2.1 EEG Dataset Collection

Electroencephalogram (EEG) that is the electrical activity of the brain is collected from the 122 subjects completing 120 trials where different stimuli were shown. The 64 electrodes were placed on the subject's scalps to measure the electrical activity of the brain. The response values were sampled at 256 Hz for 1 second. Each subject was exposed to either a single stimulus (S1) or two stimuli (S1 and S2). The stimuli were pictures of objects chosen from the 1980 Snodgrass and Vanderwart picture set. The two stimuli shown were presented in either a matched condition where S1 was identical to S2 or in a non-matched condition where S1 differed from S2. The obtained dataset was already pre-processed dataset [6].

2.2 Data Munging

It is a process of transforming and mapping a "raw" data into another format to making it more appropriate and valuable for a variety of downstream purposes such as analytics. It is a concept and a methodology for taking data from an unusable and erroneous form to the new levels of structure and quality required by modern analytics process. Data Munging is the term coined for cleaning up a messy data set. It is usually used together with another term 'data science' which is data analysis. So, in general, all the operations that one does on the raw data to make it "clean" enough to input to an analytical algorithm is data munging.

The dataset used was a labeled dataset. Here, all the unused columns (i.e. columns having no entries or columns with zero values or columns with invalid values) are removed. All the invalid characters like commas are removed. As shown in the figure below:



```
[12] filenames_list = os.listdir('/content/drive/My Drive/Colab Notebooks/EEG Dataset/TRAIN SET/') ## list of file names in the directory
     EEG_data = pd.DataFrame({}) ## create an empty df that will hold data from each file

     for file_name in tqdm(filenames_list):
         temp_df = pd.read_csv('/content/drive/My Drive/Colab Notebooks/EEG Dataset/TRAIN SET/' + file_name) ## read from the file to df
         EEG_data = EEG_data.append(temp_df) ## add the file data to the main df

     EEG_data = EEG_data.drop(['Unnamed: 0'], axis=1) ## remove the unused column
     EEG_data.loc[EEG_data['matching condition'] == 'S2 nomatch,', 'matching condition'] =  'S2 nomatch' ## remove comma sign from stimulus name
```

Figure 2. Data Munging Process

2.3 Training and Testing

The actual task of training and testing is done using Convolutional Neural Network (CNN). The task of feature extraction and classification has been performed by the CNN itself. It includes TensorFlow as a software development tool to implement the algorithm for building a CNN model. Here the data is split into 80:20 ratio i.e. 80% data is used for training purposes and the remaining 20% data is used for the testing purpose. Here, the actual accuracy of the Machine Learning Model is retrieved and validated.

The CNN model build consist of one input layer (64), four dense hidden layers (128, 256, 256, 128), and one output layer (1) giving output in 0 and 1 (not-stressed and stressed). The activation function used for hidden layers was the ReLU (Rectified Linear Unit) activation function. The ReLU function is half rectified (from bottom) function. Function f(z) is zero when z is less than zero and is equal to z when z is above or equal to zero.

$$f(z) = 0; \text{ for } z<0$$

$$f(z) = z; \text{ for } z>0 \text{ or } z=0$$

The activation function used for the output layer was the Sigmoid activation function. The Sigmoid Function has an S-shape curve. The sigmoid function is used because it exists between 0 and 1.

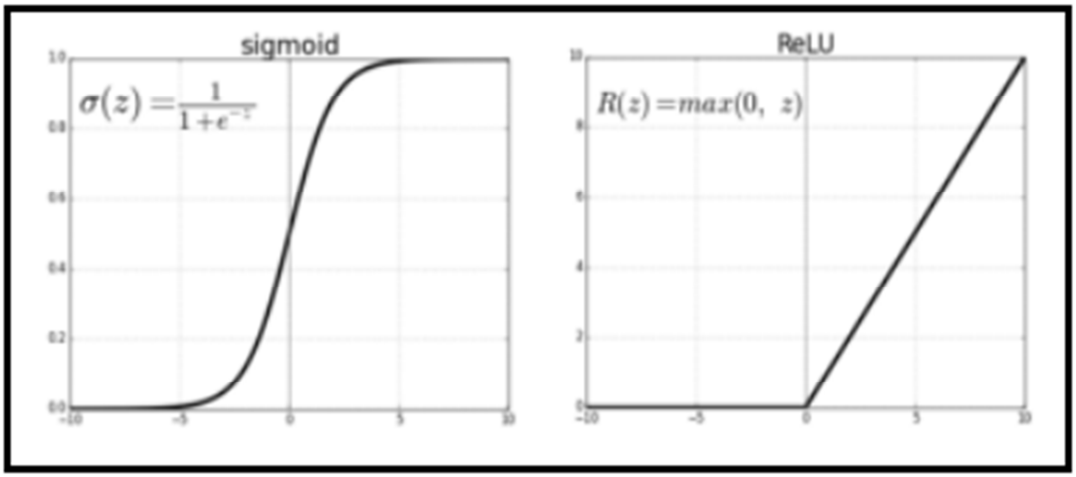


Figure 3. ReLU Activation Function and Sigmoid Activation Function [7]

The constructed CNN model layers are as shown in figure 4:

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_5 (Dense)              (None, 128)               8320
_________________________________________________________________
dense_6 (Dense)              (None, 256)               33024
_________________________________________________________________
dense_7 (Dense)              (None, 256)               65792
_________________________________________________________________
dense_8 (Dense)              (None, 128)               32896
_________________________________________________________________
dense_9 (Dense)              (None, 1)                 129
=================================================================
Total params: 140,161
Trainable params: 140,161
Non-trainable params: 0
```

Figure 4. Build CNN Model

3. Software Used

The software used for constructing the code is Python 3. The Python code is written in Google Colaboratory since it allows one to write and execute code in any browser, with

- a zero-configuration requirement of one's system
- free access to Google Hardware
- easy sharing of code

The Computational Framework for building the CNN Model is TensorFlow. It has given the Machine Learning world numerous capabilities from scalability to building production-ready models. TensorFlow provides a variety of different tool kits that allows writing code at the preferred level of abstraction.

The library called scikit-learn is also used which provides various features like classification, regression, etc. The libraries like Numpy (Numerical Python) for mathematical array operations, Pandas for data statistics and analytics, Seaborn and Matplotlib for data visualizations in form of graphs are used.

4. Results

The CNN model is trained over 60 epochs to get the training accuracy and validation accuracy. The maximum model accuracy obtained was 97% - 99% and the maximum validation accuracy obtained was 84% - 86%. The maximum model loss obtained was 3% - 4% and the maximum validation loss obtained was 14% - 15%.

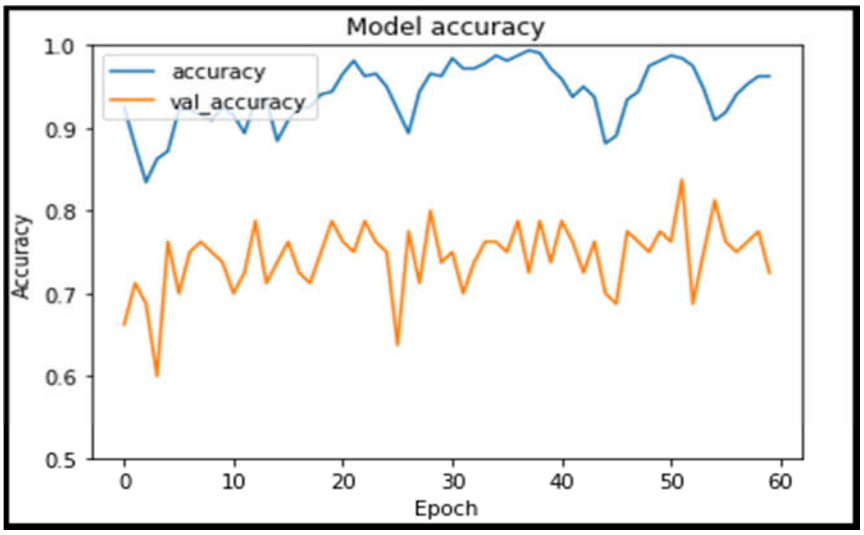


Figure 5. A Plot of Training Accuracy and Validation Accuracy over Training Epochs

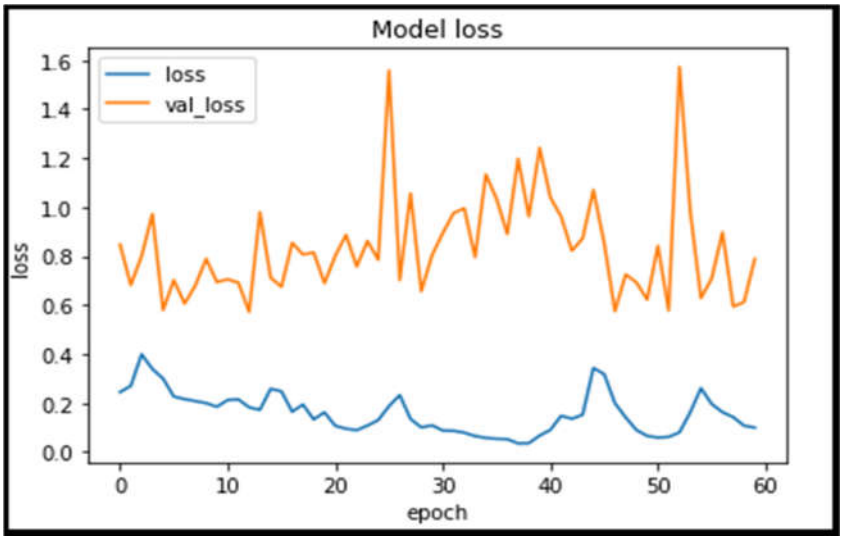


Figure 5. A Plot of Training Loss and Validation Loss over Training Epochs

5. Conclusion

The Machine Learning Framework, building the Convolutional Neural Network model was obtained using the EEG dataset for stress detection. The accuracy of the model obtained was 97%-99%. The CNN model used helped to provide maximum accuracy. Nowadays, human beings are suffering from severe stress problems, so this can prove a helping hand to build a Computer Aided Diagnostic (CAD) tool for stress detection. This research in the field of stress detection can be merged with researches on music therapies to obtain artistic performances that not only provide psychological treatment effects but also improve the ability of the person to focus [4].

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7. References

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