Stress Detection for Visually Impaired People using EEG Signals based on Extracted features from Time-Frequency Domain

by

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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Abstract

Stress refers to body's physical, emotional and psychological reaction to any environmental change needing adjustment with major impact on human psychology. Stress is specially difficult to manage for visually impaired people (VIP) as they can become easily stressed in unknown situations. Electroencephalogram (EEG) signals can be used to detect stress as it basically represents the ongoing electrical signal changes in human brain. Literature shows that the stress detection techniques are mostly based on either time or frequency domain analysis. However, using either time or frequency domain analysis may not be sufficient to provide appropriate outcome for stress detection. Hence, in this paper a method is proposed using *empirical mode decomposition* (EMD) and *short-term Fourier transform* (STFT) are used to extract features considering spatio-temporal information from EEG signals. In the EMD, the signal is first decomposed into intrinsic mode functions (IMFs) representing a finite number of signals while maintaining the time domain and STFT is used to convert time domain to time-frequency domain. Support vector machine (SVM) is applied to classify the stress of VIP in unfamiliar indoor environments. The performance of the proposed method is compared with a state-of-the-art technique for stress detection. The experimental results demonstrate the superiority of the proposed technique over the existing technique

Keywords: EMD, IMF; Stress; STFT; Beta band

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Chapter 1

Introduction

1.1 Thoughts behind the Prediction Model

There are many people around the world, who have any kind of physical disability due to which they cant able to move around independently or freely. One of those disable people are visually impaired people. They are born as fully or partially blind, also there are many people who suffer from this fully or partially blindness due to any accident or disease caused. For them, any kind of communication or movement is really difficult. In recent times, there are many kinds of OM instructors and other communication machines available which helps them for movement or communication. Still there is so much more scope to make it more accurate and to make it easier for them as no perfect sort of instructor is there. In this field, there is much research going on to provide a better result.

Moreover, Biomedical is one of the promising fields in recent times. In this field it has the combination of both medicine and technology.There are many sort of problem solving procedures and combinations of designs which basically help many kinds of diagnosis, health care system, monitoring, therapy etc. The advancement in this area not only will help many people to live a secure life but also may save many people's lives with its prognosis aspect. Whereas many other field only focus on the comfort lifestyle or advancement in technicality which is also needed in our society no doubt for the evolution in recent times. But if science and engineering can save someone's life or can make anyone's life easier who basically struggles with their situation or diseases, I think that would be a blessing not only for those people but also towards the whole society.

Hence, in this research, we wanted to implement something that will provide not only provide a better result but also the outcome may also be helpful for the people and society. We tried to detect the stress for fully or partially visually impaired people in some particular area. So, that from this result, it can provide a helpful aspect to those, who wants construct and implement instructor accordingly for the visually impaired people considering which places are more stressful.

1.2 Aims and Objectives

As we have already mentioned, mobility in any unfamiliar environment is very much stressful for visually impaired people. It can affect their mental, emotional and psychological minds which may lead them into depression and many other mental health problem. Hence, our aim is to help and to reduce the problem for the VIP's as much as possible. Though there are many kind of instructors available, but none are accurate enough to give them full guidance. As every place has different barriers, dynamics and challenges to pass through, specially for the people who cant see. It is really essential to get proper guidance for them and also recognize those special places where they need extra care or guidance to pass through as those places are more stressful for them considering the other places.

The main objective of this implementation is to build a system which will provide better results in terms of accuracy, specificity and sensitivity compared to the existing ones and detect the stress more precisely and doesn't give wrong or false signals. Our system will basically detect the stress of the visually impaired people in some particular indoor places. There are many study and research going on this field to provide a more accurate result. As, the unfamiliar sites are not only unpredictable but also difficult to detect among them which are more stressful for them to go through.

Hence, we want to build a system that will give better result to detect the stress. As proper stress detection for visually impaired people is really important. More accurate result will not only empathy a better result , but also help for further research and implementation in this field. It will help to build various kind of constructor or indicator to help the visually impaired people to pass through that stressful places more easily and appropriate way. Which will minimize the stress ultimately and it will be also good considering the safety issue of the VIP. As they will be able to get proper help from the instructors , if the correct stress full places can be configured.

1.3 Visually Impaired People- VIP

Visually Impaired people are those people, who are basically fully and partially blind by born, by any accident or by any kind of disease. The main causes of visual impairment and blindness are uncorrected refractive errors and cataracts. Also, the other leading causes of vision impairment are:

- age-related macular degeneration
- glaucoma
- diabetic retinopathy
- corneal opacity
- trachoma

Globally, almost 1 billion people have a near or distance vision impairment. For VIP, any kind of communication is really difficult considering the fact the they cant fully or partially see anything. Whereas any communication is really difficult for them, hence any kind of movement like passing a street, moving my stairs or elevator, passing through narrow space, going through a crowded place where there are already many people, crossing a street etc are much more difficult. Though with the passage of time and experience, VIP's get the idea of their regular surroundings which basically make them habitual of their situation and decrease their difficulties little bit as they get used with the situation eventually. Also, sometimes they have to be dependent on other persons due to their impairment.

Whenever they pass some new stress full places like moving in a crowded place or passing through the elevator or stairs, it again become challenging for them since the place is out of their comfort zone like their home. It can create a huge impact in their brain and mind. Again, if they are dependent on other people for their movement and mobility, it will effect their psychological health and can increase anxiety, social isolation and they can also fall into depression. With the availability of a number of navigation and access technologies has dismissed many barriers for VIP as now they are able to move by themselves with the help of those. It also upgrade their confidence along with their social and personal relations. Though there are many technologies available now to offer help, but still its accuracy is not up to the marks, specially when it comes to unfamiliar places. Hence, whatever be the reason of their visual impairment and regardless what kind of technology they use, in this research we want to implement something, that will help the VIPs indirectly in reducing their stress while passing through the stressful areas.

1.4 Stress Detection Method

Passing over many different indoor environments can be very stressful and undoubtedly challenging when it is concerned for visually impaired people (VIP). On the other hand, stress contemplates human body's response or reaction that requires any kind of adjustment or while facing any kind of unfavorable situation. Commonly, mobility for a VIP itself is a stressful task especially even more while navigating in unfamiliar sites. Visualization for humans is the main interrogation for communication along with touch, sense and hearing. These four are most common and important sensor of human body for doing any kind communication. There are several training approaches now-a-days to facilitate independent functioning for low VIP [18]. Detecting the entrance and exit points, avoiding the obstacles, understand the light variation, estimate the ground level diversity, acknowledgement of street crossing are some major challenge for effortless and inter-missive communication [25].

There are having significant amount of research about the approaches and mechanism for VIP for easy access considering both neuro-cognitive factor and communication [11]. It is emotionally and mentally challenging for VIP to pass through an indoor area which is not so familiar and they might feel unsafe and not so confident despite having a rough representation of that area. Though there are many appliances and devices available to assist them, still there is not much information

about the management of their cognitive load and psychological stress during their way finding process [17]. Electroencephalogram (EEG) prevails as one of the ways of identifying physiological stress and detecting central and peripheral modalities. EEG is a graphical representation that records on-going electrical activity measuring the electrical voltage fluctuation of brain through different electrodes located at various locations of brains [14]. Thus, it obtains the ability to determine the information and state of the brain through those electrodes.

A lot of research has been carried out using either frequency domain [46], [52] or time domain [31], [37], [45] to detect stress using EEG signals. EEG signals are non-stationary in nature, therefore the existing methods [31], [37], [45], [46], [52] are not suitable for stress detection. However, literature shows that time-frequency analysis of EEG signals is suitable for feature extraction [19].

Therefore, in this dissertation we propose a method using time-frequency domain to extract features that help us to detect stress in VIP. Our experimental results which we have found in this dissertation (maximum accuracy 95.77% and average accuracy 92.14%) also support that claim. in this dissertation *empirical mode decomposition* (EMD) is considered to decompose non-stationary EEG signals into series of intrinsic mode functions (IMFs) [38] without shifting the domain (i.e., time domain). Then *short-term Fourier transform* (STFT) is applied to extract feature in time-frequency domain and *support vector machine* (SVM) is used to detect stress for VIP in the unfamiliar indoor environments.

The aim of this dissertation to detect the stress for visually impaired people with better accuracy for more perfect prediction using the EEG signal in some particular indoor environments. This dissertation thus focuses on the following major aims-

- To detect the stress from the EEG signal which will provide more precise result compare to other relative study.
- To achieve the implementation on time frequency domain and spatio-temporal information.
- To develop a stress detection model approach having innovative features which will contribute better outcome in terms of accuracy, specificity and sensitivity.

To achieve the above mentioned aim, this dissertation has made the following contribution-

- To identify and get more clear knowledge of various range of EEG signal and time frequency domain, I have worked for the research - Predicting seizure onset based on time-frequency analysis of EEG signals and the work has been accepted in Elsever journal of Chaos, Solitons and Fractals: the interdisciplinary journal of Nonlinear Science, and Nonequilibrium and Complex Phenomena (Tamanna, Rahman, Sultana, Haque & Parvez)
- Detecting the stress for visually impaired people using EEG signal on time frequency domain feature, this work has been accepted and presented in International Conference on Machine Learning and Cybernetics (ICMLC-2020/Publisher-IEEE) (Sultana, Rahman & Parvez)

The dissertation is organized as follows-

In chapter 2, a brief description has been given of the other relative study and research work similar to our research, so that we can have a more clear view and understanding regarding the scenario of this research.

In chapter 3, background explanation has been given of each of the components which have been used to in this research. Like there is basically detailed description of the major modules of our study like- EEG signal, EEG band, EMD Classifier etc.

In Chapter 4, first of all, there is the information of the data set that have been used along with a brief description of the VIP's who had gone through the study and their situation. Moreover, a complete explanation of the proposed model along with procedure of the technique have been demonstrated.

In chapter 5, the result analysis has been presented along with the *receiver operating characteristics* (ROC) curve and a table which show the comparison with another relative study in terms of accuracy, sensitivity and specificity.

In chapter 6, lastly the conclusion of the overall research work has been presented along with future scope of the corresponding study.

Chapter 2

Literature Review

In this chapter, we will basically have brief description of the relevant studies of the corresponding work. There are so many research going on to detect the stress of visually impaired people, as this is very important aspect considering the problematic situation of the VIPS. Different types of researches have focused on different modules, pattern or root cause, but the ultimate goal is to find out the stress in various physical, environmental and mental condition.

In the paper [47] , crudden identifies the stress caused by movement and navigation in public transportation. They have done their experiment upon visually impaired people and in unknown and unfamiliar public transport areas they measured their stress during navigation and movement. Hence, they found higher stress levels for some particular places like- steering for unfamiliar bus routes, walking in unknown places and moving around urban areas. They observed that there are many other aspect which also control the stress like age, years of vision loss as in the years of experience, dog guide use and also other physical limitation. Older-age people and who has self-reported physical limitations had higher amount of stress while , those who use the public transportation more frequently has low level stress also those who use dog guide had lower stress level. Participants also instructed not to engage in such kind of activities like entertainment, visiting friends and family so that stress level can be measured perfectly.

In the paper [52], they have detected the stress for visually impaired people in indoor and outdoor environments and have used some medium like EEG, EDA, BVP(Blood volume pulse). In their result they have been able to detect the stress for VIP successfully for those specific areas. But still there is much more scope, since no results are 100% accurate. Also different types of study have used different aspect and modules for their research. Hence, there is a lot of variation also.

In the paper [55], Keryakos tried to detect the stress of visually impaired people with the help of cane which in used by the visually impaired people. As in more stressful they use their cane more than any normal place. They have used three kind of sensor- GSR sensor, EMG myoware sensor HR pulse sensor in order to build the cane. They have used electrodermal activity, muscle contraction and heart rate to identify and detect the more stressful places. In future, they indent to build cane, which can help accordingly to the more stressful places which they have identified by their study.
Participants had to travel through automated doors, take the elevator, cross a packed

open space, down a big spiral staircase, and manage various obstacles in the indoor environment they had built up for the VIPs' navigation. The walking time range is between 4-8 minutes and average has been considered as 5 minutes. Also, the distance that they have covered is around 200 meters.The authors wanted to know where blind persons experience more stress indoors and what environmental elements are responsible for their indoor mobility. They used EEG, MotivEpoc+ equipment, EDA signals, and blood volume pulse (BVP) by Empatica E4 equipment to identify stress in their implementation.

In the book chapter [58], the authors have discussed about the people who are visually impaired and have a lot of difficulty communicating in their daily lives. Their major goal was to collect stress data from five bands. Moreover, use several techniques of machine learning to see which one provided the best results for detecting stress using multi-class classification. The authors discovered stress in five previously unknown indoor locations for visually impaired people. According to experimental data, the Random Forest (RF) classifier has the most appropriate and efficient classification accuracy for various scenarios. The performance of their suggested technique is assessed using precision, recall, and F1 score.

In a study [59] prepared by the Indian Research Institute, Students investigate the difficulties that visually impaired people have when using public transportation buses. A survey of 16 visually challenged people was done to determine the difficulties they confront when boarding buses. The findings revealed that 14 participants always needed assistance, 11 participants requested assistance but did not receive it, 9 participants were misled, 5 participants were assaulted, 14 participants had trouble finding doors, and 10 people were confused between various buses. These findings show that every visually challenged or blind person misses three to four buses every day, wasting important time in getting to their final destination. Along with that they definitely had stress, anxiety about boarding on a public bus which may cause harm to their psychological health.

In the paper [60], they have analysis some situation for visually impaired people and their mental condition in their day to day life. How the VIPs cope up with those condition and what is their thought process of regarding this was the main objective of the paper. How they should be self aware regarding disability, self interrogation, facing with all the abuse and remarks, dealing with environment around, disowning and abandonment from friends and family and self regulation are few points for their consideration.

In the study [26], they have analysed and stress level and how VIP who were in their adolescence period cope up with the situation and basically what is their strategies. As we all know adolescence is a very sensitive period of anyone's life regardless of the gender male or female. In this phase basically everyone has the recognition of their own self in various aspect. Everyone has their own dream for life and future goal they want to achieve. So, along with self identification process, they have to fight with another fact they are fully or partially blind which will be hinder in their path. Hence, the main purpose of their study was to get to know the stress level and coping up with the stress strategy in this study. After the experiment they have got the results like - The overall level of stress felt by adolescent with vision impairment revealed that 42 (52.5%) of respondents were under moderate stress, 36 (45%) were

under minimal stress, and 2 (2.5%) were under extreme stress.

In the paper [20], they have discussed about retinitis pigmentosa (RP) patients who gradually face a slowly progressive loss of vision which has no treatment found as of now. Stress occurs if the difficulties or the sufferings of the disease become a burden and it become really difficult for the patients to manage and cope up with that situation [2]. In this study, the authors, basically detected the strategies about how VIP's (via RP), cope up with their situation. In most of the cases according to their data and sample they found, The long-term, slow-progressive nature of RP vision loss allows people to find effective strategies to deal with and lessen negative thoughts and feelings as they arise, rather than trying to avoid them entirely. [10].

The stress prediction in the paper [47] is not that much well facilitated as their main focus was on the reason of the stress like the age or public transport rather than the accuracy. The stress detection in the paper [52] is pretty much good in all aspect, however still there is much scope left. In the study [55], they had established their implementation on the logic that in the stress full places VIP's will use their cane more, which might be correct in general cases but not necessarily every time, it could be someone habitual fact or some other thing bothering them to do that. In the book chapter [58], they basically on compare between some classifier and which provide the better result. The study conducted in [59], their main focus detect ting the stress mainly while getting on a bus or their bus journey. In [60] the authors mainly detect the mental condition or stress in in some places or condition of their day to day life. Moreover, the paper [26] has really good observation and result but they only focused on adolescence not the people of all ages. Last of all, in [20], the authors have also provided a very good result but again they only concentrate on the patients who have become blind from retinitis pigmentosa (RP). Hence it does not provide the coverage of the wide variety of VIP's who have lost their vision fully or partially due to others reasons or may b by birth.

With all prospect keeping in mind, we have intended to implement a system to figure out the stress for visually impaired people in some particular indoor areas. We have tried cover the people of all ages (there was no restriction, voluntarily who had the eager to participate), also we have no restrain on the reason or cause of their blindness. Lastly we have also compared our result to another most relative study out of all of these to prove the betterment of our result. In chapter 3, we have the background study of all the important modules of our study.

Chapter 3

Background Study

There is a strong link between an individual's physical condition and his or her emotional state. Stress, according to the World Health Organization, is a significant problem of our time that affects people's physical , emotional and mental health. In today's world, stress has become a prominent cause of many diseases [53]. Stress is a widely used phrase, however defining it is difficult because it is subjective and tough to explain the phenomenon. According to, Merriam Webster Stress is a physical, physiological, or emotional component that creates physical, psychological or mental pressure and may have a role in the development of disease. The definition of Stress can be described informally as the body's reaction to any unusual or dangerous environment. The brain triggers the pressure response arise from the brain to other sensory information such as the eye, ear, skin and nose. While the body detects any warning or threat, actual or imagined, the body's protective mechanisms launch a quick, self activating process known as the "fight-or-flight" arouse to defend him/herself from that situation.

Stress reaction, also known as physiological stress, is an individual's physiological response to a stressful situation. Moreover, another type of stress known as perceived stress is a sort of stress that comes as a result of an individual's mental appraisal and perception of stressful conditions . Perceived stress or individuals' perceptions of stress can be quantified using self-reports collected on a regular basis. In other words, it is how a person perceives stress from his or her own perspective. Theoretically, experts anticipate that there is a coordination between these two stress level . Moreover, Perception is a irrational concept that varies from man to man. When faced with various scenarios, the nervous system reacts in similar manner it would do in a life-or-death crisis. If the activation occurs frequently and the person becomes too much worried, the body will be stressed the majority of the time, which can lead to serious health concerns.

When it comes to visually impaired people who are partially or completely blind, stress is much more crucial. Traditional stress detection technologies are accessible in a variety of forms. Many approaches for monitoring the human brain have been developed as a result of research in the field of stress detection that may be utilized to analyze human behavior.

EEG signals

Electroencephalography (EEG) is becoming a more significant tool for diagnosing and treating mental and neurological diseases and anomalies. EEG records reveal information about the brain's electrical activity. EEG signal characteristics and patterns show brain health. EEG data is used to identify neurological conditions such as epilepsy, brain tumors, head injuries, sleep disorders, and dementia, as well as to determine the degree of anesthetic during surgery. It's one of the most crucial things you can do. Autism, attention deficit hyperactivity disorder, learning impairments, speech delays, and other comparable conditions can all be treated with it. [32].
The responsibility of EEG is to determinate the electrical activity of the brain. The brain is made up of billions of neurons, each of which helps and promotes the other half of neural activity. These neurons are connected to a dense network by synapses that act as gates for inhibitory or excitatory activity. An electroencephalogram, or EEG, is the most effective method for recording electrical activity generated by the brain on the scalp surface [51].
These devices with high temporal resolution may measure brain impulses in milliseconds, resulting in a vast volume of data. The electrodes are encased in an elastic cap like a swim cap, allowing all participants to collect data from the same scalp location from all the participants.
When it comes to identifying electroencephalogram signals, feature extraction is really important. Various studies have focused on EEG signal processing because it has the ability to establish an objective technique to capture brain events. It's been employed in medical diagnostics and rehabilitative engineering, and it's very much used in brain-computer and machine learning interface research [33].
EEG analysis has been done in a variety of ways. Several sophisticated functions have recently been hypothesized as a result of research into the brain's intrinsic non-linearity. Variation in the EEG signal, such as peak-to-peak amplitude between seizure and non-seizure intervals, distance to energy ratio, or postictal state and baseline period entropy are examples of EEG signal changes.[48]. Parameters, on the contrary, are often not suitable for generalization because they are created or selected according to individual case-specific procedures.

EMD & IMF

Iterative Filtering (IF) and Empirical Mode Decomposition (EMD) are popularly known to represent a signal as a superposition of smaller, systematic peripheral acknowledged as Intrinsic Mode Functions (IMFs). They are more applicable for the analysis of non stationary, moving and non linear data than traditional approaches. [54].

Huang's (Huang, 1998) EMD approach adaptively dissolves a signal into 'intrinsic mode functions (IMF),' which may subsequently be transformed to analytic signal using HT [29].From the corresponding dissolves, HT can be used to acquire the TD delineation and transitory frequency using the intrinsic modes. The fundamental approach of dissolving a signal into a sum of functions that first of all, having the equal number of zero crossings and extrema and lastly are symmetric concerning to the local mean. The first and foremost estate is comparable to the necessity for a stationary Gaussian process to have a narrow band. The next phase novitiates a

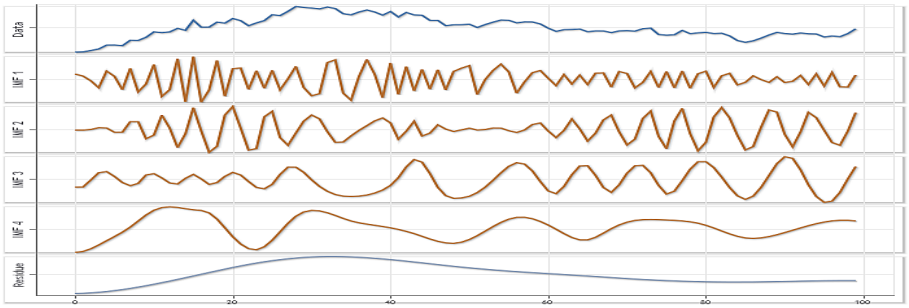


Figure 3.1: EMD Signal on different IMF's

global obligation into a local one, and it is important to make sure that the transitory oscillation doesn't contain admissible fluctuation because asymmetric wave forms can make this type of changes. These functions and activities of the process are called intrinsic mode functions (IMF).

IMFs, which are important because they contribute to the exposing of fault signatures, usually have several distinct properties. The IMF's selection criteria are based on these factors. The first trait is that they are usually more powerful, which is backed by the EMD process's goal. The EMD clips out the inner frequency modes from a signal with ease. [8]. Actually the frequencies that appear as a result of an error should have a higher power than frequencies that do not appear as a outcome of an error. As a result, certain oscillatory modes have a higher power than others. The IMFs' harmonic contents are the second feature. The maximum of the fault errors are often occurred as peak amplitude at many harmonics of a primary oscillation.
EMD (Empirical mode decomposition) is a popular technique to decompose any sort of signal. [24]. EMD is a self sufficient operation that does not need any pre-designed basis functions and strong enough to self modify and extract IMF (intrinsic mode function) components from the original signal, unlike some other signal module such as Wavelet transform , Fourier transform and single spectrum analysis. The features of EMD can be used to operate the unstable and nonlinear signals, surpassing the limitations of earlier techniques. In order to solve the time frequency related problem and data analysis related issues, EMD has been offered a flexible approach. [57]. For data analysis and synthesis, the EMD approach and dissected IMFs can be employed. EMD has been used in a number of research to dissect inferred fluctuation periods and examine various time series. There have been numerous nonlinear and non-stationary research in the hydrological sector in recent years: The model proposed by Lee and Ouarda reproduces Using EMD and nonparametric simulation techniques, nonstationary oscillation (NSO) processes illustrates the fact that IMFs can be infused with the maximum local frequencies by EMD in a iterative approach. [15].Furthermore, many research have been published that use the EMD approach to anticipate and estimate spill data. A modified EMD-based support vector machine for non-stationary streamflow prediction which is very important for these kind of simulation technique has been created and developed by Huang and Meng. [30] [41].

Short term Fourier transform (STFT)

To translate signals from the time domain to a time–frequency representation, STFT (the Short-Time Fourier Transform) is commonly and most widely employed. Though this representation has some important time-frequency resolution issues. [5]. The short time Fourier transform (STFT) is a way of determining a signal's oscillatory content varies over time and may result in a more accurate representation of signals. **xing2015ultra** The fast Fourier Transform (FT), along with its all other signal counterparts, shifts a signal from the time domain to the frequency domain. [40]. It is even more appropriate to examine signals w hich fluctuate with the passage of time in the time-frequency domain, albeit this may introduce some additional redundant information.The manner in which time-frequency representations (TFR) depend on the signal is a fundamental characteristic of TFR. This relationship could be linear, quadratic, or nonlinear in nature. The superposition or linearity principle is satisfied by all linear TFRs, including STFT and wavelets. The STFT is frequently utilized in signal processing, such as image processing, speech, engineering, biology, and medicine. [49]. The STFT adds a temporal dimension to a non-stationary signal by slicing it into numerous frames with apparent stationary parts and employing a window function to decrease extra portion in the spectra. As, this process has a fixed number of window size, it is considered an inconvenience in many ways. Such as- if we take long size window, it will provide good frequency resolution but time resolution will be low. On the contrary, short size window is not good for lower frequency resolution but are suitable for better temporal. The transformation conversion to restore the original signal, and the shift of the discrepancy and the rotation of the quality of the discrepancy are all thoroughly studied. The reassignment approach can be used to make time-frequency and time-scale illustration more readable. This process modifies the depiction by relocating the time-frequency points from the first position where they are calculated to a more appropriate location [43]. this process can also be used to investigate the dynamics of a signal's periodicity, for example time-varying frequency and amplitude.

EEG Frequency Band

EEG frequency bands are a set of wave signals and amplitudes that remain constant across time and can be illustrated as a fixed range of wave signals and amplitudes. These bands are parts of an electrode-captured EEG waveform. To clip out the band information from the overall EEG wave signal, experts employ mathematical models such as Fourier transform, Fast Fourier Transforms or short term Fourier transforms. A neuron can electrically oscillate on and off in a rhythmic pattern, and several neurons in a neural ensemble (neurons that work together on a specific brain calculation) can also oscillate in unison. When a extensive number of neurons cycle altogether at the same corresponding frequency, large-scale, macroscopic oscillations emerge, which are significant enough to be detected by an EEG. The larger the macroscopic oscillations recorded, the higher the wave amplitudes. In the figure , The five most frequent EEG bands are listed, along with their frequency ranges. Delta, theta, alpha, beta, and gamma are the Greek letters assigned to these bands by scientists. From the gradual roll of the delta wave to the hyperactivity of the gamma wave, and everything in between, these bands are all quite different.
The EEG power spectrum is thought to be divided into a few frequency ranges. The

designations delta, theta, alpha, beta, and gamma have been assigned to these preset spectral windows, which move from the lower to the upper end of the spectrum [3]. EEG frequency bands can describe a set range of wave frequencies and amplitudes throughout time. Alpha, beta, gamma, theta, delta, and other time frequency bands are used to detect brain oscillation and time frequency cognition. [27].

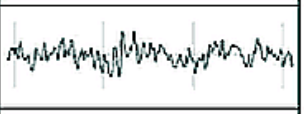
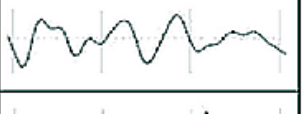
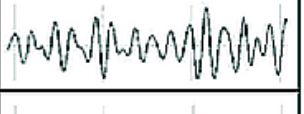
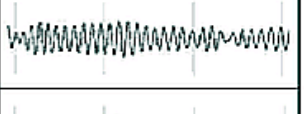
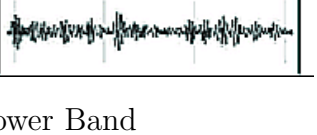
Frequency Band Name	Frequency Bandwidth	State Associated with Bandwidth	Example of Filtered Bandwidth
Raw EEG	0–45 Hz	Awake	
Delta	0.5–3.5 Hz	Deep Sleep	
Theta	4–7.5 Hz	Drowsy	
Alpha	8–12 Hz	Relaxed	
Beta	13–35 Hz	Engaged	

Figure 3.2: EEG Power Band

The type of activity a person engages determines the electrical exertion in the brain. The brain waves of a person fighting or playing games, for example, are considerably different from those of a person relaxing. Brain patterns are categorized into the five bands listed above. There are also information about a person's health and mental condition while remaining in these particular frequency range. Each band has its own meaning and way of reacting to data or action [42]. Such as-

- Delta Waves: The most lowest range brain signals are reported by delta waves.. They're most common in babies, toddlers and they're mostly linked to the deepest levels calm. composed and curative phase. Brain damage, learning difficulties, inability to think, and poor sleep are all common symptoms of Delta. Delta wave generation that is enough boosts and freshen up the overall immune system, making us feel entirely renewed.

- Theta waves: This frequency range is associated with being absent minded or daydreaming and the phases where brain are less active like sleep. When theta waves are dominant, depression, hyperactivity, impulsiveness, and inattentiveness are evident. When they are suppressed high anxiety in human nature, low emotional awareness, and tension, these kind of activities are observed. Theta aids with creativity, emotional connection, intuition, and relaxation when it is at its best. Theta waves have the effect of improving our instinct and creativity while also we feel more comfortable doing this. Restorative sleep is also influenced by theta.

- Alpha waves: The frequency range of alpha waves is between beta and theta. They assist us in de-stressing and promoting sensations of profound relaxation when needed. Daydreaming, difficulty to focus, and being excessively relaxed are all examples of Alpha waves. If they are inhibited, anxiety, elevated stress, and insomnia might result. They lead to a relaxed state when they are at their best.

- Beta waves: Low-amplitude, high-frequency brain waves that are frequent in waking people and considered in beta range. It promote conscious mind and rational reasoning, as well as having a stimulating effect. We can focus when we have the correct amount of beta waves. Anxiety, high alertness, inability to relax, and tension are among symptoms of this wave's prominence.

SVM Classifier

Support Vector Machine (SVM) is one of the most popular, frequently used and supervised machine learning technique to solve classification and regression problems in various kind of problems. Many people prefer the support vector machine because it produces great accuracy while using less computing power [61]. Support Vector Machine is a type of support vector machine. In this classification activity model, there are two categories of machine learning model that employs classification techniques. SVM models has the ability to assort new text after being given sets of labeled training data for each category. They have two key advantages over newer algorithms like neural networks. First one is the better performance and greater speed with a limited number of samples (in the thousands). As a result, the technique is well suited to text classification tasks.[50].

Procedure of SVM Classifier:

Consider the following linear data, which has two characteristics: x and y. We're looking for a classifier that can determine whether a pair of (x,y) coordinates is red or blue. On an aircraft, we plot our already labeled training data.

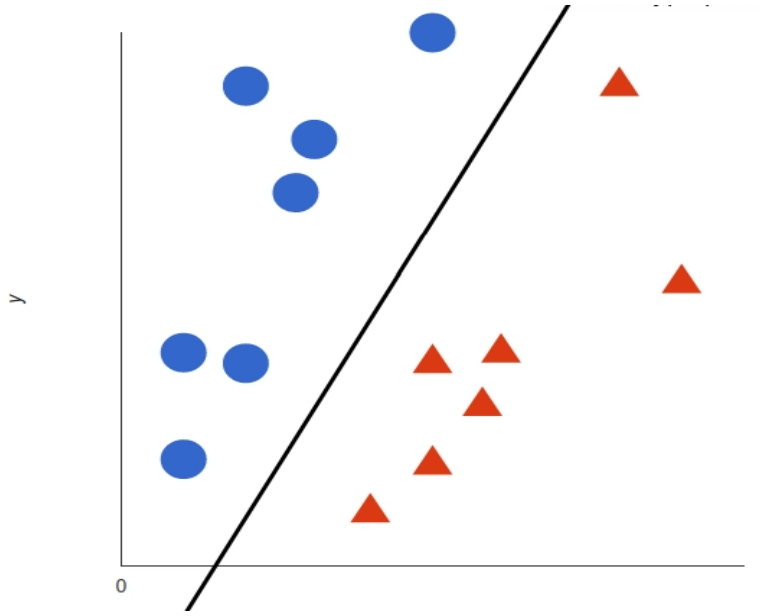


Figure 3.3: Raw Data

The hyper-plane (which in two dimensions is essentially a line) that optimally separates the tags is produced by a support vector machine using these data points. This is the decision boundary; anything on one side of it will be classified as blue, and anything on the other will be classified as red [6].

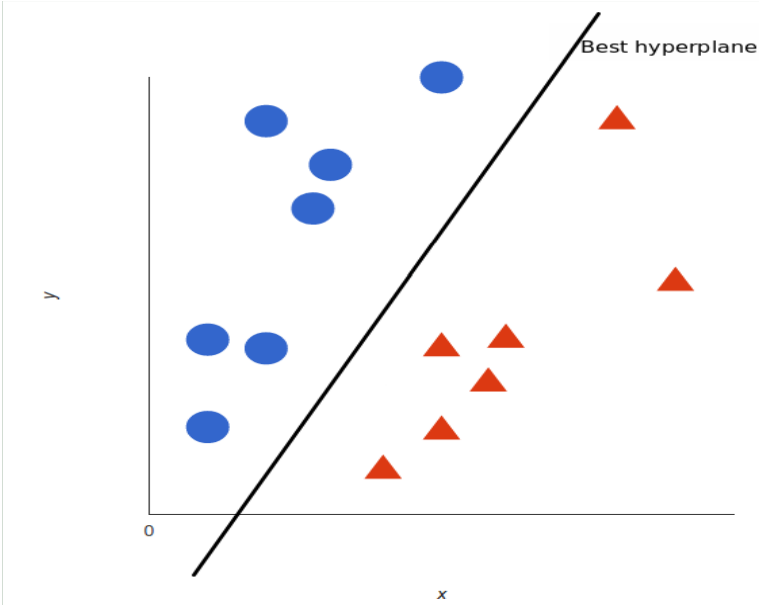


Figure 3.4: Best Hyper-plane

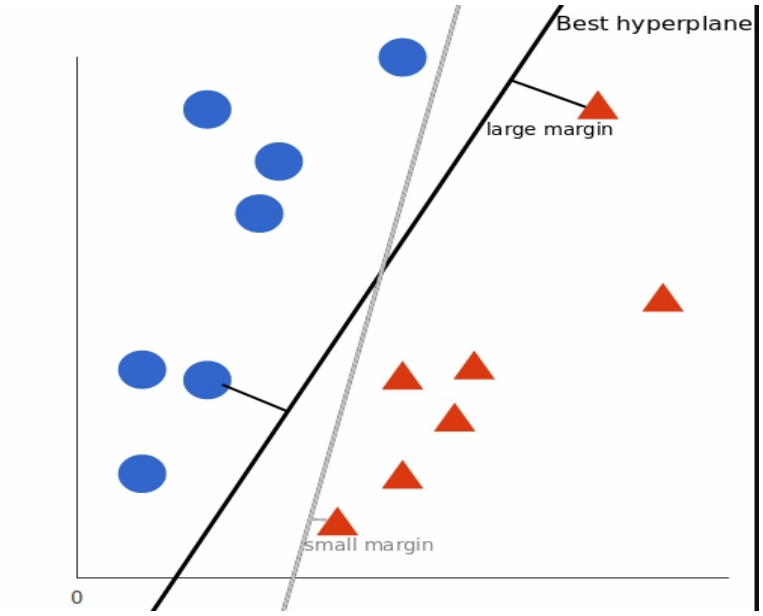


Figure 3.5: Mixed Hyper-plane

In the next chapter which is chapter 4, we have described about model and structure along with other details of our proposed method step by step.

Chapter 4

Methodology

4.1 Proposed Method for stress Detection

For any kind of implementation there are some basic steps after which we need to go through to get the final result. Here also, to analyze and understand the final output, we have followed some phases starting the data collection for our corresponding study. In this chapter, we present the method for stress detection for VIP using EEG signals when they are navigating unfamiliar indoor environments. There are four basic steps of our proposed method as shown below:

- Step 1: Acquiring the EEG signals from the participants
- Step 2: Time-Frequency Based Feature Extraction from EEG signals considering spatio-temporal information
- Step 3: Collecting the power of beta band from the EEG signals and labelling the stress
- Step 4: Classification and stress detection

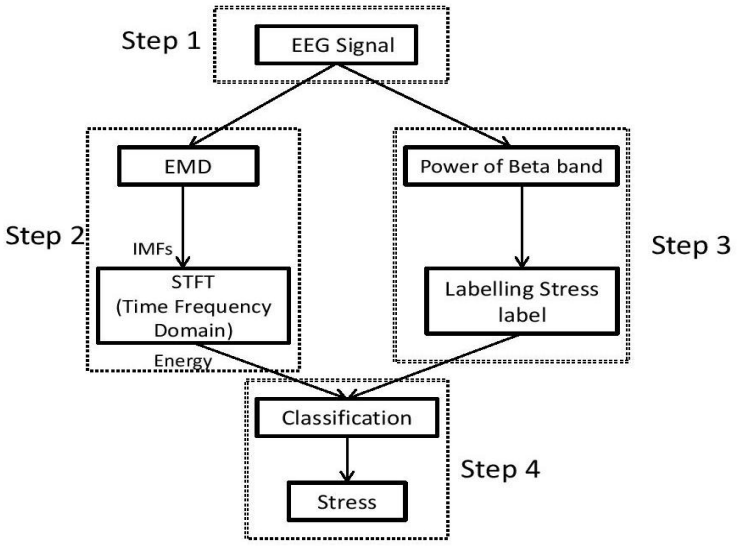


Figure 4.1: The framework of the proposed methodology.

A basic scheme of the proposed approach is presented in Figure 4.1. In Step 1, we have described about the participants and the specific indoor environments we are considering and extracting the EEG signals from those participants. As we will work on those EEG signal for our further proceedings. In Step 2, the process for feature extraction is provided. We also have two sub-steps in step 2 divided in EMD application STFT execution.Along with step 2, simultaneously in Step 3, stress labelling procedure is explained from of EEG signal and beta band. Finally, in Step 4, we have stated how classification procedure was done considering all the available information and data. We now explain all the steps in details.

4.1.1 Acquiring the EEG signals from the participants

In this section, the information about the participants and the environment settings are provided. Moreover, a discussion on EEG signals is also provided.

Participants

For our experiment, we have collected the dataset from [52] which were acquired in the University building of Iceland. The study was approved by National Bioethics Committee of Iceland[52].
According to the data set, ten healthy visually impaired people (VIP) who were associated with with different grade of sight loss participated in this study where six of them were female and rest of them were male. Age range for VIP's was started from 22 years and last approximate age as 53 years. Among all the participants, one participant was fully blind. The other three had visual acuity less than 2%. Vision loss of less than 5% was found in four participants. Lastly, the final two had visual ingenuity between 5% and 10%. Eight of them have become blind in the earlier stage of life like 2-3 years age, the other two became blind later in their life. The VIP's were permitted to walk with their white canes and O&M instructor if they wished so. Participants were encouraged not to take take any kind of caffeine or sugar like cola, chocolates , coffee and cigarettes one hour prior to the study. The VIP's who have performed the study had participated willing by their own wish (volunteering participation), no one forced them to for them and they had full free Independence to give their consent.

Those who had participated had the experience of actively move through various indoor environments on daily basis apart from the place where they live because four of them had been occupied to work full time, while three of them work part-time. Lastly, three of them were used to attend educational institutes. That means all of them are going outside and faces various kind of indoor and outdoor environments regularly. Moreover, all of them always travel alone for their corresponding destination.

Environment

For the indoor environments, most important and also common indoor places have been chosen for their study. Those were some places that we definitely need to go through in our regular life for any kind of movement.

Table 4.1: Description of the Environment

ID	*Description*	*Challenges*
A	Entering through automated doors	Finding the entrance point and also be aware of the other people who are entering along with him/her
B	Using elevator to move from one floor to another	Finding the button to call the elevator, selecting the elevator and careful about the people who are entering or exiting.
C	Walking through a narrow corridor	Careful about the people, noise , doors and windows opening all of a sudden etc.
D	Moving across open space	Careful about the people who are moving, standing and the obstacles in the way like tables, chairs etc which need to avoid.
E	Moving Object	Understand the dimension of any moving object, person and act accordingly.
F	Sound	Careful about the sounds to get alert beforehand.

The description of the different location and challenges for the experiments are given in Table 4.1.Considering the environment or the locations that the participants move around, the experimental setting is comprised of six units of the University of Iceland campus in Reykjavik. Participants passed through the indoor paths thrice in account of training purposes. Though the direction was given only for the first time. They were urged not to move their head and hand unnecessarily and not to use the O&M instructor except any emergency.

EEG signals

The electroencephalogram (EEG) is a dynamic noninvasive and comparatively inexpensive method which is used to analyze the state of the brain [4].It is a standard neuro-imaging tool for the study of neuronal dynamics within the human brain. EEG signals are used in different types of clinical scenarios, which may vary from from monitoring normal alertness or arousal states to more complex clinical situations .[28]. As the EEG approach is noninvasive and painless, that's why it is widely used to investigate how the brain organizes different types of cognitive processes in wide range people. [7]. EEG signals records the electrical functionality from the scalp of the brain using small metal disc and thin wires and send the results to the system for further processing. EEG signal activity is quite small, the unit is measured in microvolts (mV) [35].

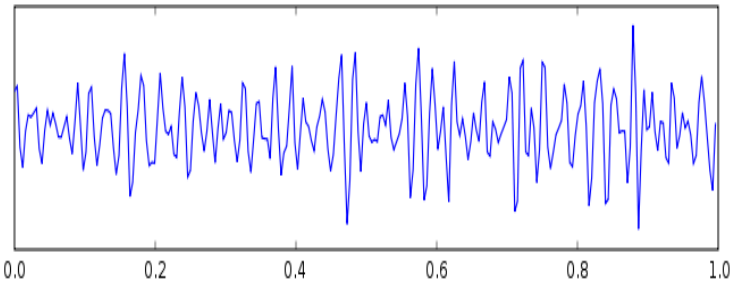


Figure 4.2: EEG Signal

While the VIPs pass the indoor routes, the EEG signals is collected for the analysis

of their brain function and as already mentioned earlier, we detected the stress of the VIPs in those particular indoor settings. We define EEG signals (i.e., x(t)) for the further processing.

4.1.2 Time-Frequency Based Feature Extraction from EEG signals considering spatio-temporal information

Empirical mode decomposition (EMD) is a technique which remain the time domain and split a signal. [13]. The technique is significant for analyzing natural signals as it filters out functions which formulate a full and complete basis for the original signal [12]. EMD is basically depends on the dataset, doesn't have an assumption about the data.

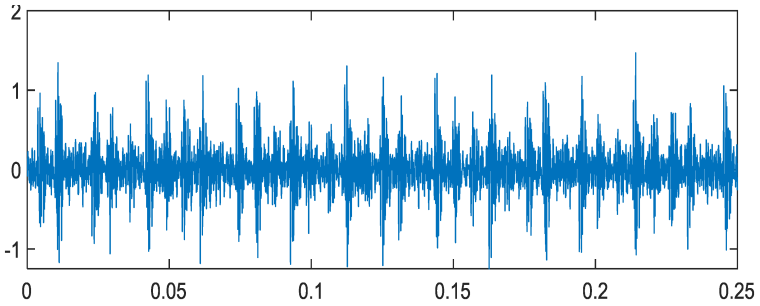


Figure 4.3: EMD Signal

Furthermore, when a noisy signal is reduced into intrinsic vibratory segments known as intrinsic mode functions (IMFs) using a sifting technique [16]. IMF represents a basic and considerably more general oscillatory mode. IMF illustrates a variable amplitude and vibration instead of consistent amplitude and vibration in a simple harmonic functions and signals. The process's primary goal is to utilize of fragmentary signal reformulate, with the necessary IMFs corresponding to the signal's most necessary steps. [22]. Different IMF possess the same frequencies as overlapping components when the EMD is unable to split the signal into unique frequency components.

The major aspect of EMD method is to evaluate non-stationary signals like EEG signals and recognize the intrinsic mode by the characteristic of time scale of data. As already mentioned, EMD decomposes the EEG signals into set of frequency component known as IMF and it is obtained from higher frequency element to lower frequency element. Local characteristic of the function estimate the number of IMF from a particular signal. Because of this feature, it is tough to determine the original characteristic of the function from each IMF. After calculating the IMFs, we consider the first IMF for further processing as features from the first IMF provides the better classification result because it shows the most sharp change in the signal from the beginning to ending. [34].

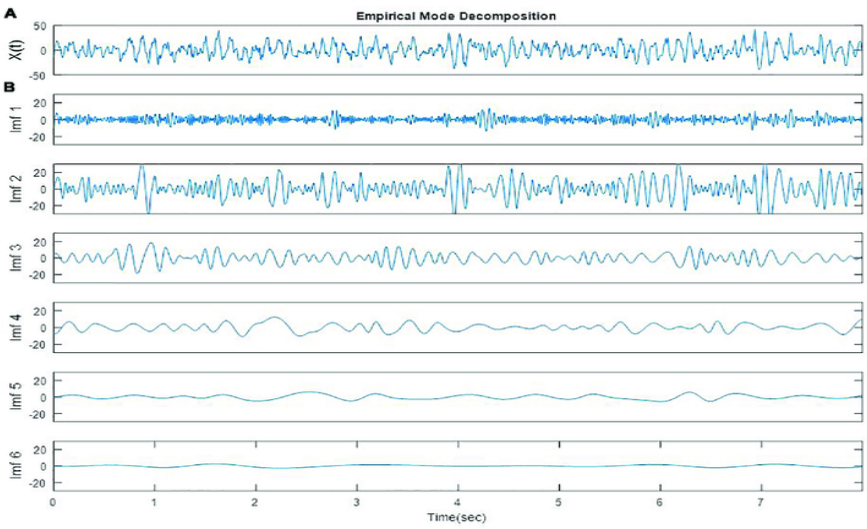


Figure 4.4: IMF after applying EMD

In Figure 4.4, the first signal implies the status of EEG signal after applying EMD upon it. And the signals B and below shows the IMFs from the first one to the next few. As mentioned earlier, for further proceedings, we have chosen the first IMF, as it will give better analysis result.

$$B = A(x(t)) \tag{4.1}$$

In equation 1, A is a function of EMD technique for EEG signals and B denotes IMFs of the corresponding EEG signals. Signal of IMF are considered from the relative changes between the span of time of per second or epochs because we are detecting stress considering per second annotation.

Afterwards, we apply STFT to convert the signals from time series domain to time-frequency domain. STFT is a dynamic and dominant tool of processing the audio signal in time frequency domain distribution [56].

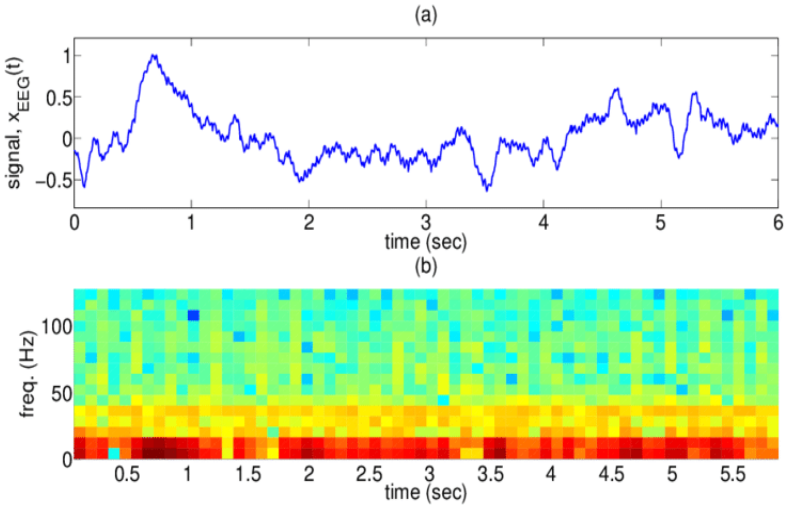


Figure 4.5: Signal transformation after applying STFT

In Figure 4.5 (a), we can observe the EEG signal (basically the state of after applying EMD and getting the 1st IMF) where we can see the signal occupies only the time domain. whereas , after applying the STFT in Figure 4.5 (b), we can see the signal representing both the domain , time in X-asix and frequency in Y-axis.

It is used to generate representations that capture both the local time and frequency content in the signal. STFT gives a sub-optimal trade off between time and frequency constancy since the frequency constancy of the STFT is the same for all locations in the spectrum [1].

$$\eta = \Lambda(B) \tag{4.2}$$

In equation 2, Λ is the STFT technique which we are applying on our first decomposed IMF α and η is the transformation in time-frequency domain. After that, we have derived the energy for the further processing.

$$\lambda = \Omega(\eta) \tag{4.3}$$

In equation 3, λ is the energy feature and Ω represents the equation of the energy upon the IMF of the time-frequency domain η. We have extracted feature for each second (sampling rate 128Hz) with each channel where the number of channels are 14. Therefore, each feature contains spatio-temporal information.

4.1.3 Power of Beta Band and Stress Label

In this implementation, we use beta band information to determine stress label. Mostly, the power of beta band decreases during any movement or execution of human body and disintegrate after the termination of an action. In this study, we will consider beta waves (13-30 HZ) to detect the EEG signals since Beta waves are correlated with physical, emotional and mental stress [36]. Also, beta band examines the fact that, the brain responds the same way for any observation or movement even if it is not associated by muscular activity. Additionally, signals and rhythms reflect the collective behavior of large groups of synchronous neurons that may be somewhat different from local brain operations [21]. As a result, beta band assembles the signals that occur during a stressful situation.

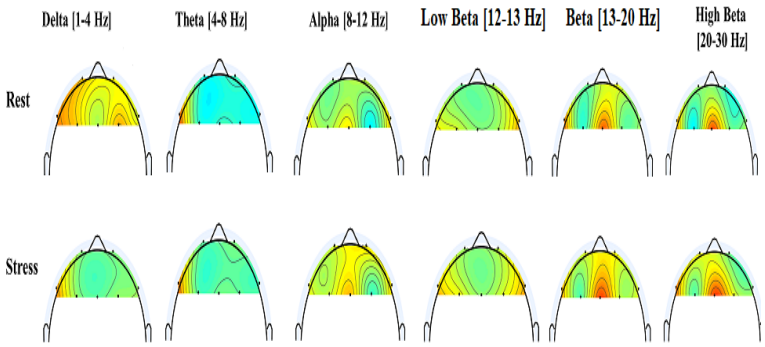


Figure 4.6: Beta band arousal from Stress

In Figure 4.6, we can see different states of brain of the participants. In the state 5 6, we can see the arise of stress by red spot and it has been identified by the Beta and High Beta band. Hence, beta band has the ability to determinate the stress. From the correlated data that has been collected from power of beta band, training set has been prepared with labeling of stress for classification. And the classification and stress detection process have been described in the next step.

4.1.4 Classification and Stress Detection

In this particular section, we will focus classification and stress detection. Any kind of classifier has the target to classify the EEG signals by employing machine learning technique. We apply SVM classifier on spatio-temporal feature namely energy that we derived from the function using EMD and STFT algorithms. Note that, we define class label for the feature in Section 2.3. Cross validation is a classification strategy that divides the test and training sets of data into complementary subsets and analyzes how well the anticipated model will perform. [44]. We have applied the training set and testing set on the same people but use different trials of each person. For example, trial one is used for training and trial two is used for testing. In our case, five-fold cross validation (i.e., M=5) has been applied for our study. One set is picked at random and set aside for testing, while the remaining M-1 has been utilized for training before getting the findings average. To produce an appropriate model of the SVM classifier, five-fold cross validation is applied to the training set. M-1, which means that 80% of the training set is chosen at random to create the SVM model, while the remaining 20% is observed to fit the model. The equation for the SVM [9] can be defined as follows:

$$S = sign[\sum_{m-1}^{n} \zeta_m \theta_m T(\vartheta, \vartheta_m) + c] \tag{4.4}$$

In equation 4, $T(\vartheta, \vartheta_m)$ is a kernel function where ϑ=(λ) & stress label from the power of beta band , ζ_m is the Lagrange multiplier [23], c is the bias term, ϑ_m is the training input and θ_m is the training output. We have used RBF kernel in our experiment and the function can be defined as

$$T(\vartheta, \vartheta_m) = \exp(-\left|\left|\vartheta, \vartheta_m\right|\right|^2 / 2\Delta^2) \tag{4.5}$$

where Δ controls the width of the RBF function.

In the next chapter 5, we are going to discuss and analysis about our experimental result and also going to compare it with the outcome of another study to prove the betterment of our study.

Chapter 5

Result and Experiment

5.1 Experimental Result and Analysis

In this chapter, we tend to evaluate the performance of our proposed method applying different indoor environments as shown in Table 4.1. Our proposed model and every details have been discussed in chapter 3. Here now we have the outcome of our proposed model. The attainment of the prospected method is correlated with a recently published high quality technique [52] in terms of accuracy. Moreover, we have added sensitivity and specificity of our corresponding approach in Table 5.1. The definitions of sensitivity, specificity, and accuracy [39] are shown below:

$$Sensitivity = ((t\rho)/(t\rho + f\eta)) * 100 \tag{5.1}$$

$$Specificity = ((t\eta)/(t\eta + f\rho)) * 100 \tag{5.2}$$

$$Accuracy = ((t\rho + t\eta)/(t\rho + t\eta + f\rho + f\eta)) * 100 \tag{5.3}$$

where $t\rho$ is true positive, $t\eta$ is true negative, $f\rho$ is false positive and $f\eta$ is false negative.

In Table 5.1, we present the experimental results of our proposed method for different indoor settings that we have considered in our study. The environments of Table 5.1 are already described in Table 4.1. In the Table 5.1, we have our result in terms of sensitivity, specificity and accuracy. Sensitivity identifies the true positive values , which in the situations where actually stress has been felt and it has been accurately detected by the system. And we also have the result of specificity which indicates the where stress has felt by the participants and the correct percentage that scenario of our proposed model. Lastly, we have accuracy of our proposed model, according to which elevator has the maximum percentage.

Table 5.1: Sensitivity, Specificity and Accuracy for stress detection

Environment	*Sensitivity%*	*Specificity%*	*Accuracy%*
Automated Door	80.67	91.99	89.85
Elevator	86.85	95.82	95.85
Narrow Corridor	82.90	95.88	95.77
Open Space	84.65	93.86	92.44
Moving Object	79.89	89.44	87.78
Sound	80.57	92.83	91.13

Out of the six experimental settings, the maximum accuracy of our proposed method is 95.77% and the minimum accuracy of our proposed technique is 87.78% . These are the results that we have obtained for our purposed model. To find out the most stressful place and overall performance we have the following ROC curve.

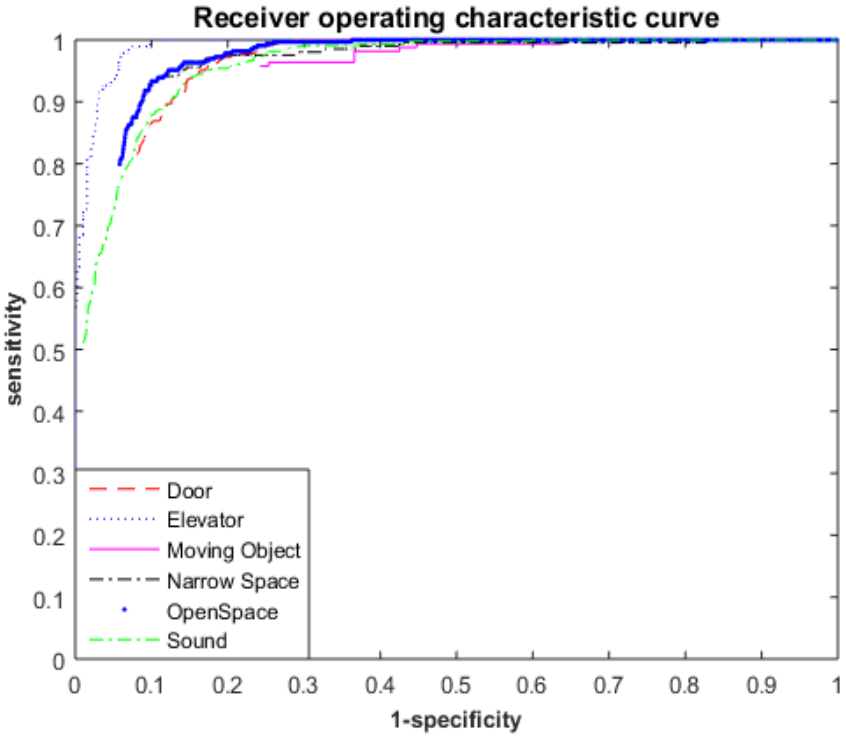


Figure 5.1: Receiver Operating Characteristic (ROC) curve.

The performance of the classifier is estimated by Receiver Operating Characteristic (ROC) plot shown in Figure 5.2. ROC emphasize the attainment of the system by plotting the fraction of true positives from positives, i.e, true positive rate ($t\rho$R) vs. the fraction of false positives from negatives i.e, false positive rate ($f\rho$R). ($t\rho$R) acknowledged as sensitivity and ($f\rho$R) is one minus the specificity or true negative rate [34]. From Figure 5.2, we observe that the stress detection for Elevator is higher whereas the stress detection for Moving object is lower.

5.2 Comparison with Co-related Study

We have compared our result with similar paper [52] to prove the better outcome of your suggested method. In the paper [52], they have used random classifier (RF) for the classification. And we have implemented SVM classfier, as already mentioned in section 2.4. These two models have four common scenarios , hence we have compared those four only and skip the other two environment that we have used in our study.
For better understanding and comparison between the outputs of the indoor environments of our study, we have this bar chart below according to the value we have got, so that we can easily analyze the result.

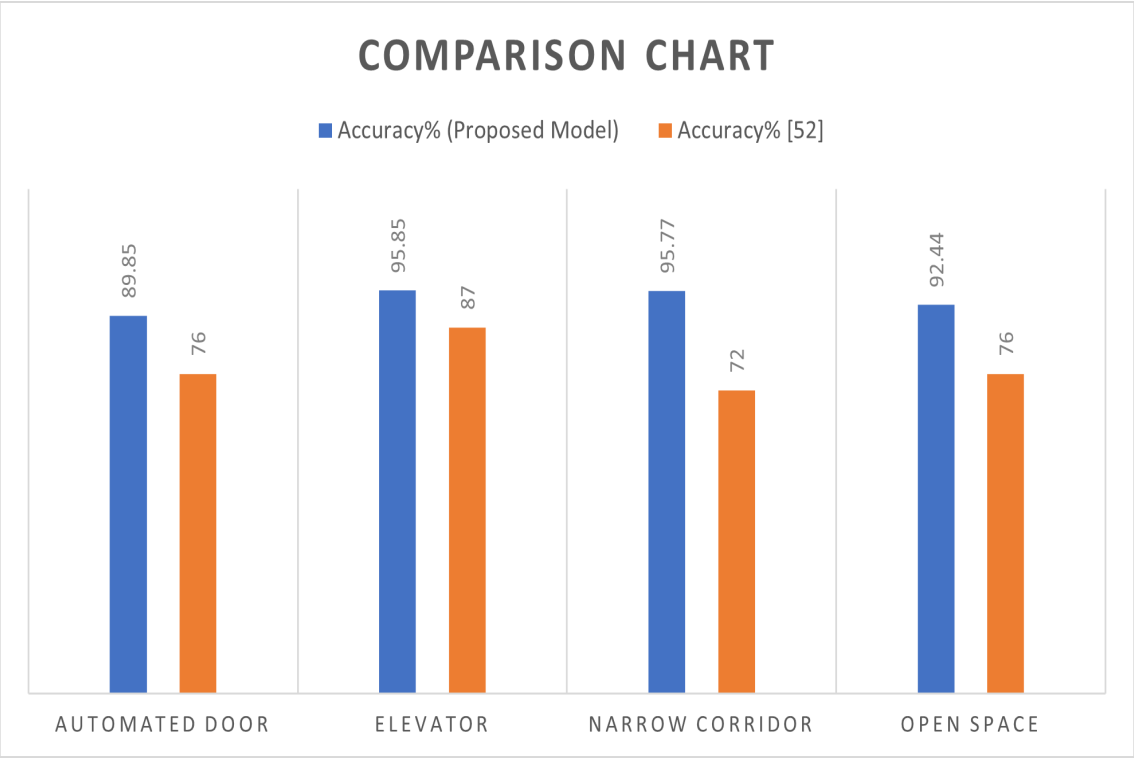


Figure 5.2: Comparison of outputs of different indoor environments

From Figure No 5.2, we observe that the accuracy of our suggested methodology is higher than the accuracy of the existing technique [52] for every indoor environmental setting. The maximum accuracy of our proposed method is 95.77% and the minimum accuracy of our proposed technique is 87.78% , whereas the maximum accuracy of the existing technique[52] is 87% and the minimum accuracy of the existing technique is 72%. Note that, the minimum accuracy of our suggestive method is higher than the maximum accuracy of the existing technique that demonstrates the superiority of our corresponding method. The high accuracy of our proposed method indicates that our approach is more successful to detect stress of VIP.

From the above bar chart, we can visualize that for Elevator, we have the highest accuracy, whereas moving object has the lowest which have seen in the Table 5.1 . Again, the outcome is same for specificity and sensitivity.

In the chapter 6 which is the last chapter of the study, briefly the overall outcome has been described along with the future scope.

Chapter 6

Conclusion & Future Work

6.1 Conclusion

Stress is an important factor in mental and psychological health of every person. Hence, the detection of stress is also an significant factor, specially when it is considered for visually impaired people as it will have an extra-ordinary impact on their overall communication and association. This study presents the method for detecting stress in visually impaired people applying Empirical Mode Decomposher ition (EMD) and Short Term Fourier Transform (STFT), and Support vector machine (SVM). EMD and STFT are used to extract features considering spatio-temporal information from EEG signals and afterwards support vector machine has been employed to determine the stress level. The work of the suggestive methodology is compared with a recently published high quality technique for stress detection. The experimental results indicate superiority of the suggestive technique in comparison with the existing technique. The overall accuracy of our proposed method is 92.14 % whereas the overall accuracy of the existing method is 77.75% that indicates our method is more successful than the existing method to detect stress of VIP. For the purpose of construct any kind of mobility system for the VIP's who are partially or fully blind, the detection of stress for certain scenario can provide a better understanding of their situation or challenge they face. In future, we intent to identify the stress for the VIP's using different modalities like electrodermal activity (EDA), blood volume pulse (BVP) and heart rate (HR) along with EEG and likewise not only from the indoor areas but also from various outdoor situations.

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