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Stress Detection System Based On EEG Signals.

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ABSTRACT:
Stresshasbecomeacommonemotionthatstudentsexperienceindaytodaylife.Severalfactorscontribute to their stress and proven to have a detrimental effect on their performance. Hence, stressbecomes ubiquitous in academic environment due to higher expectations in academic achievement, poortime management, and financial concerns. It has an adverse effect on the quality of their life affectingboth physical and mental health. It is a guarantor for depression and suicidal risks if left unnoticed overa longer period. The traditional stress detection system is based on physiological signals and facialexpression techniques. The major drawback is the uncertainty that arises due to numerous externalfactors like sweating, room temperature, anxiety. Some methods like hormone analysis have a drawbackof invasive procedure. There is a need for a method that is non-invasive, precise, accurate and reliable.Electroencephalography (EEG) is a perfect tool as it is a non-invasive procedure. Also, it receivesfeedback from stress hormones; it can serve as reliable tool to measure stress. This research work aimsto detect stress for students based on EEG as EEG displays a good correlation with stress. The EEGsignal is pre-processed to remove artefacts and relevant time-frequency features are extracted usingHilbert-Huang Transform (HHT). The extracted features are manipulated to detect stress levels usinghierarchical Support Vector Machine (SVM) classifier. The results revealed the efficiency of the systemtodetect stress in real time usingtheir brain wave.

Keywords: Stressdetection,Electroencephalography,Hilbert-Huangtransform,Supportvectormachine,Machinelearning.

I. INTRODUCTION

Students undergo stress in their everyday life. It is a necessaryevil that is triggered by demanding physiological activity. It isnotanegativeprocessatalltimes.Howeverundercertaincircumstances, it becomes a threat to mental health. Stress mayariseduetophysicaloremotionaldemands.Thephysicaldemands may be due lifting heavy weights or intense trainingforsports.Thebodyfacesphysicalstressors,invokessympathetic nervous system to maintain the balance [1]. Thestress hormones are released and regulate energy stores leadingto rise in blood pressure, increase in heart rate. The physicalstressors are temporary and can be controlled. Emotional stressarises due to work pressure, meeting up deadline, exams etc.Theseoccupationalstressorsaredifficulttoadaptanddealwith. If they persist, chronic stress sets in, which is a majorconcernfor seriousdisease like heart attack.

Stresscanhaveapositiveornegativeeffectonstudents.Positive stress called eustress provides opportunity for growthlikeimprovementinacademicperformance.Ifstudentscontinuetohavestress,itreachesanoptimalpointand becomes distress. It will have a negative impact on the bodyandmindcausinginsomnia,suppressedimmunity,frequentinfections, and migraine [2].

Studies[3-5]haveshownthehighprevalenceofstressinacademiccircle.Itaffectsstudentsirrespectiveoftheirbackground, culture, ethnic origin [6]. They experience stressduetothedemandsandexpectationsplacedonthem.Itbecomesworsewhentheyperceivethesituationisoverwhelming and find it difficult to cope up. It even makesthem to drop out from college [7].

Thereareseveralcontributorstoacademicstressamongstudents[8-12].Firstly,Collegelifeisdifferentfromschoollifeandplacemoreresponsibilitiesontheirshoulder.Theymay have to move away from family and hence, they have tomake significant changes and adjustments in their personal life.Secondly,theyfaceacademicworkloadslikeexam,assignment, meeting up deadline, compete with other students.Thirdly,theymayhavefinancialconcernsandmayfeelburdenedtopaytuitionfees.Stressmainlyarise

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sduetothree

factors,namelyacademic,interpersonalandintrapersonalskills.Table1showsthecategoryofstressandtheirstimuli.
Several approaches with different methods have been recordedin the literature for detecting stress. Stress is detected based onthe way an individual uses key strokes in keyboard [13]. Faceexpressionsare analysed to detect stress[14]. Some approaches use the temperature of the finger [15], humangestures [16] and eye blink [17] as a modality to detect stress.Recent techniques employ thermal imaging [18], physiologicalsignals[19,20] for stressdetection.

Table1. Stresscategoryandstimuli.

Category	Stimuli
Interpersonal	Quarrel with friends and parentsSplitupwithpartner Crisisinfamily Conflictwithroommate
Intrapersonal	Public speechFinancial constraintsPersonalhealthissues
Academic	Workload,meetingdeadlines Poor performance, inadequate resourcesFear of failure, poor time managementUnclearcontents,competitionwithpeers

The problem of stress in students has become a concern forpeopleacrossseveraldisciplines.Asthestresscancausevariousseriousillnesses,anearlyassessmentcouldsignificantlyreducetheindividualrisk.Inthisview,weproposeanewStudentHealthSystem(SHS),whichcoulddetect stress at early stages. Furthermore, it can improve theassessment of distress to provide therapies and counselling totackletheirnegativefeelings.Thisresearchworkadvancestowards this objective and detects stress in students. We haveidentified two primary stress factors among students, namelyacademic performance and time pressure. So we have designedstress stimuli that include these two factors and elucidate threelevelsofstress.Arithmeticquestionswithatimelimitaredesigned to induce stress as naturally as possible [21]. As thebrain is central for all emotions, we chose EEG as a window todetect stress. Also, due its high temporal resolution, it serves asanexcellent tool to servethe purpose.

II. MATERIALS AND METHODS

Experimentalsetup

We conducted experiments on 6 healthy subjects who have nohistoryofpsychiatricproblemsorneurodisorders.Thepurposewasclearlyexplainedtothemandconsentwasobtainedfromthem.AwirelessEEGdevice,EmotivEpoch head set was placed according to international 10-20 system.The electrodes were attached to the scalp at position AF3, F7,F3,FC5,T7,P7,O1,O2,P8,T8,FC6,F4,F8andAF4 as showninFigure1.

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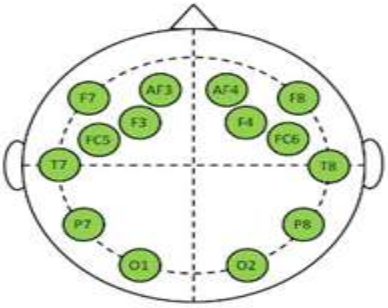

Figure1.Electrodeplacementonthescalp.

Limited mathematical questions with varying difficulty weregiven and they were requested to solve within a specific timelimit. The EEG was recorded while attempting to solve them.They self-report stress level according to National AeronauticsandSpaceAdministrationTaskLoadIndex(NASA-TLX)rating scale. The entire process took 20 minutes and repeated 5times to make a session as shown in Figure 2. The acquiredEEGsignalswereprocessedat512Hzandimpedancewaskept as low as 7 kΩ.

Figure2.Dataacquisitionprotocol.

This work was implemented in MATLAB 8.4 and the proposedmethodologyis depicted in Figure3.

EEGpre-processing

Raw EEG is contaminated with noise from different form andsources.AsEEGhasverysmallamplitude,filtering outunwanted noise is a critical step to extract useful information.We eliminated two primary noises (artifacts), namely powerline noise and ocular propertiesofthesignal,waveletdecompositionapproachusingbi-orthogonal waveletbior 3.9wasemployed.

Featureextraction

The purpose of this stage is to map EEG into the consequentstress state. An adaptive feature extraction technique HilbertHuangTransform(HHT)wasappliedtoextract relevantfeaturesintime-frequencydomain.Itistherelevantapproachtounearthinformationhiddeninthesignalconsideringthenon-stationarynature of the signal.
Itisperformed intwo steps[22].

artifacts that arise due to body movement.

- **Power line noise removal:** A combination of 0.75 Hz highpass and 45 Hz Finite impulse Response (FIR) filter wasused to filter out the noise.
- **Ocularartefactremoval:**TheEEGrhythmsliein thefrequency range of 0.3 Hz to 44 Hz. The ocular artefactoccursat0.1-16Hz.Inordertopreservethenatural
- **Decomposition:**Thepre-processedEEGsignalisdecomposedintoIntrinsic ModeFunctions(IMF).
- **Hilbert transform:** Instantaneous frequency is obtained byapplying Hilbert transform to each IMF obtained throughdecomposition process.

Instantaneousfrequencyisrateofchangeofphaseandcomputed as given below
$\omega(t)=1/2\pi\partial\theta_j(t)/\partial$ tand$\theta_j(t)=\arctan(H(c_j(t))/c_j(t))$WhereH[.] is Hilberttransform.

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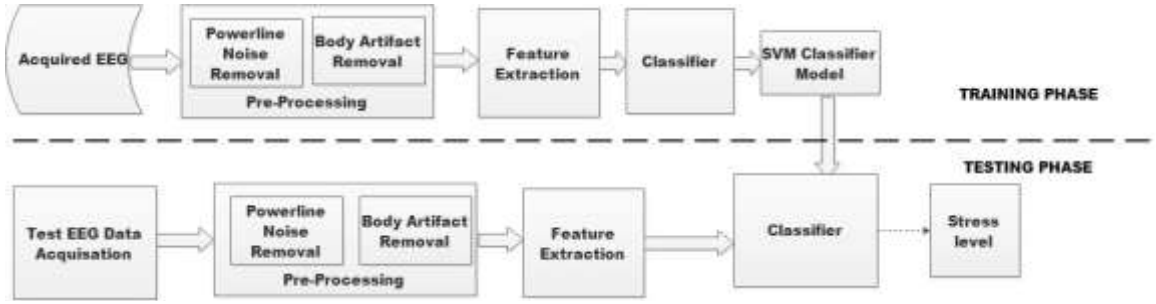

Figure3. Blockdiagramofproposedmethodology.

III. CLASSIFICATION

Theclassificationisuserindependentwhich meansdataacquiredfromallparticipantsareusedfortra iningtheclassifier.Thefeaturevectorobtainedthrough HTTisclassifiedintoneutralorthreelevelsofstress(stre ss-low,stress-mediumandstress-high).WechoseSupportVectorMachine(SVM)overo theralgorithmsforclassificationfortwo reasons. Firstly, it is insensitive to over fitting problem.Secondly, its ability for high generalization and accuracy withsmallertrainingsample.Itisthemostrobustclassifi cationalgorithm for real world scenarios and successfully applied inmanyproblemslikefacerecognition,handwrittench aracterdetection, intrusion detection etc. It is originally designed asbinary classification algorithm, but later it is improvised tomulticlass problems.

Forstressdetection,weimplementedhierarc hicalSVM.Itutilizes a decision tree structure with a SVM at each node toconstruct a hyper plane decision boundary. The tree is createdsuch that the classes at each parent node are divided into twoclasses, representing child nodes. The process iterates until theleaf nodes contain only a single class. Following a path fromthe root node to a leaf node leads to a classification of a newpattern. The instantaneous frequency value obtained for all fiverhythms of EEG is used as feature vector to train the classifier.Figure 4 illustrates the training process of algorithm for stresslevel classification.

Due to smaller training dataset D, a 10-fold cross validationwas adopted. The dataset D is divided into 10 subsets D_1, $D_2 \ldots D_{10}$. Out of which one set is randomly chosen as teat datasetand remaining subsets are used for training. The entire crossvalidationprocedureisrepeated10timestoimpro veclassificationaccuracy.

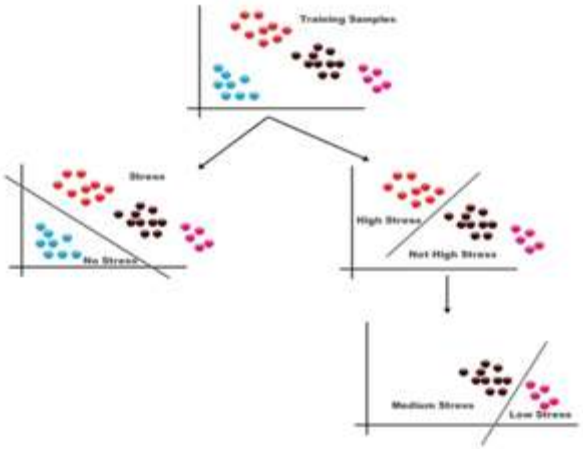

Figure4.HierarchicalSVMforstressclassification.

IV. RESULTS

Theperformanceofthestressdetectionsystemwasevaluatedthrough Classification Accuracy(CA). It iscomputed as

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$$CA = \frac{Number\ of\ correctly\ classified\ instances\ in\ training\ set}{Total\ number\ of\ instances\ in\ training\ set} * 100$$

Overall performance is calculated as

$$Performance = \frac{CA\ for\ each\ fold}{Total\ number\ of\ folds}$$

The performance of SVM is higher than other three classifieralgorithms. The accuracy rate of SVM is 89.07%, the accuracyrateofLDAis70.166%,QDAis76.833%andKNNis 72.667%. The accuracy rate for four classifiers is depicted inFigure5.

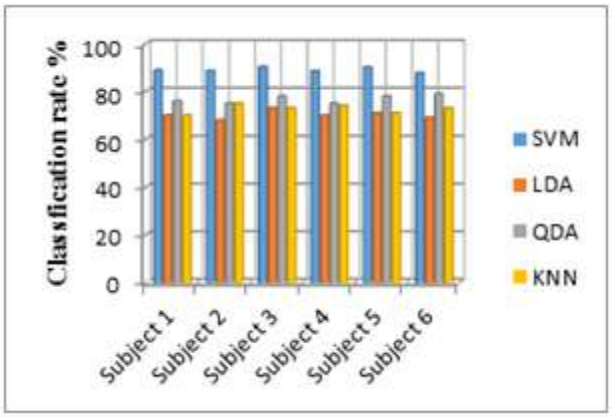

Figure5.Classificationaccuracyfordifferentclassifiers.

Theperformanceforeachsubjectacrossfiverhythmsof EEGisshownin Table 2.

Table2. Classificationaccuracyacrossfiverhythms.

EEGRhythmsaccuracy(%)	Delta	Theta	Alpha	Beta	Gamma	Avg
Subject 1	80.89	91.89	90.02	92.86	89.24	88.98
Subject 2	81.57	90.93	91.34	91.24	88.05	88.63
Subject 3	85.24	91.36	94.32	90.3	90.36	90.32
Subject 4	83.29	92.76	86.88	89.42	90.57	88.58
Subject 5	87.05	89.29	91.49	90.88	91.88	90.12
Subject 6	83.7	85.6	90.92	91.24	87.49	87.79
Average						89.07

The highest accuracy is obtained in alpha band and the averageclassification accuracy is 89.07%.

V. CONCLUSION

This study proposed an EEG-based stress detection system forstudents.Determiningstresslevelforstudentsstudy inginhigher academic institution is crucial to prevent from majorhealth risks. In a study with 6 subjects, we have shown thatEEG is a reliable tool to detect stress levels. We applied time-frequency analysis to extract useful information from EEG andimplementedhierarchicalSVMasclassifierandobtainedaccuracyof89.07%.Theresultsreportedthefeasibilityofusing EEG for stress detection, which important for clinicalinterventionand prevention ofphysicalandmentalhealthproblems.

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