Title of the project:-

“OPTOSIS: Portable Optical Brain-Computer-Interface and Orthosis for Movement Restoration after Stroke.”

Joint Initiative of the following Institutions:
1. Institute of MedicalPsychology and Behavioral Neurobiology, Eberhard – Karls Universität, Tuebingen, Germany(EKUT)
2. Sri Chitra Tirunal Institute of Medical Sciences and Technology, Thiruvananthapuram, India(SCTIMST)
3. TECNALIA, Donostia, SanSebastian, Spain(TEC)
4. Bogaziçi University, Turkey(BU)

DBT Grant number:
BT/IN/New Indigo/02/CK/2013 dated 26.03.2013

First year –Summary

- Functional near infrared spectroscopy (fNIRS) is an emerging non-invasive optical neuro imaging technique that monitors the hemodynamic response to brain activation. Functional electrical stimulation is a technique that uses electrical currents to activate nerves innervating extremities affected by paralysis resulting from spinal cord injury (SCI), head injury, stroke and other neurological disorders and it is primarily used to restore function in people with disabilities. This research employs a novel closed-loop BCI based on functional near infrared spectroscopy within the framework of a tested motor learning protocol incorporating FES, for rehabilitation of upper limb motor function in stroke survivors.

- The closed loop BCI based on fNIRS and FES feedback (as shown in the figure) is developed and tested.

- The handedness of the subject will be tested and the weaker hand is modeled for the stroke affected hand for the healthy subject study, which is ongoing on the collaborator side.

- The purchase procedure for the fNIRS equipment is at the final stage with tender being floated already.
Fig 1: fNIRS-FES BCI loop architecture

Fig 2: fNIRS FES BCI used for initial experiments (at the collaborator side)

Publications (having impact factor ≥5 or <5 separately)


Technologies in pipeline for development

- Development of an indigenous low channel near infra-red spectroscopy system with basic brain oxygen monitoring is underway. This in long term can be used for BCI loop.

Human Resource Strength trained for acquiring higher degrees or research skills
JRF was sent to Institute of Medical Psychology and Behavioral Neurobiology, University of Tubingen, Germany for a three months training programme, to study about the working of fNIRS equipment and to work for the establishment of the fNIRS-FES BCI loop. During the internship which extended from last week of March 2014 to first week of June 2014, he could take part in some of the initial experiments for setting up the BCI-FNIRS system which is vital for a flawless functioning of the loop.

Second year - Summary

Functional near infrared spectroscopy (fNIRS) is an emerging non-invasive optical neuro imaging technique that monitors the hemodynamic response to brain activation. The purchase procedure for the fNIRS equipment is complete. The equipment purchased is of NIRSport 8 x8 by NIRX LLC Inc. This has eight sources and eight detectors, which can be used to have a maximum of sixty four channels to obtain signals of interest from desired brain regions. The probe could be arranged for different montages in accordance with the area to be investigated. The motor montage which the pilot study has been started for acquiring images form healthy volunteers is given in figure 1. This pilot study is intended to aid in getting the knowhow of equipment handling and also obtaining meaningful results for the trial session of both hand-finger tapping task. This in-turn could be considered to be a precursor for the original objective of the study which is to localize the motor cortex activity and classify signals for neurofeedback through functional electrical stimulation. The overview of the study is given in figure 2.

Fig 1 Top Left:- Shows the probes and channel locations, Top Right:- Channel arrangement with gain calibration map, Bottom:- Actual positions of sources and detectors for recording
With the results from fNIRS equipment for the simple motor task of both hand fingers tapping the localization of signals for neurofeedback can be performed. The existing task based paradigm has an audio stimulus asking the subject to start finger tapping of the “Left” and “Right” hand accordingly. For the rest phase “Rest” is being told to the subject to restrain from doing the task.

The proprietary software NIRS lab is used for the post processing. The results show the activation map of the activity. Each channel could be carefully studied for the purpose of identifying the desired channel for feedback. This pilot study has to be continued for a sufficient number of subjects so as to establish the results. One of the results obtained is as shown in the figure 4.
Fig 4. Threshold SPM map of finger tapping for one subject

Short communications/Abstracts and communicated papers

- Presented a poster titled “Resting State FMRI can Serve as a better option for analyzing language networks: A study for the identification of Language networks, its connectivity in 10 healthy controls” at 3rd International Conference on Cognition, Brain and Computation during December 5-7, 2015, IIT Gandhinagar, Gujarat
- “Functional near infra-red spectroscopy (fNIRS) - a potential brain monitoring tool”, oral presentation at ‘SYNAPSIS’ held at TKMIT, Kollam, Kerala

Technologies in pipeline for development

- Development of an indigenous low channel near infra-red spectroscopy system with basic brain oxygen monitoring is underway. This in long term can be used for BCI loop.
- Language lateralization studies using fNIRS is in the pipeline which can translate to a presurgical language function analysis tool cheaper and simpler to fMRI

Third year Summary

- A detailed protocol for the study has been developed and is waiting to be tested. A fNIRS machine from NIRx LLC. is installed at our department.
• A Phd thesis with title “fNIRS(functional Near Infrared Spectroscopy) imaging for resting state functional connectivity in post stroke motor recovery” is ongoing from the research lead obtained from the project.

• A M.tech Clinical Engineering final year project thesis entitled “classification of functional near infrared spectroscopy signals towards brain computer interface implementation” is successfully completed from the research lead obtained from the project.

• A study on “Functional Near Infrared Spectroscopic imaging for language lateralization during verb generation in normal subjects” was carried out and the results are submitted for publication.

• More projects using Optical Imaging for analyzing cortical connectivity in stroke subjects are being conceived.

“CLASSIFICATION OF FUNCTIONAL NEAR INFRARED SPECTROSCOPY SIGNALS TOWARDS BRAIN COMPUTER INTERFACE IMPLEMENTATION”

SUMMARY

• Stroke rehabilitation is a combined and coordinated use of medical, social, educational, and vocational measures to retrain a person who has suffered a stroke to his/her maximal physical, psychological, social, and vocational potential, consistent with physiologic and environmental limitations. Evidence from clinical trials supports the premise that early initiation of therapy favourably influences recovery from stroke. One of the latest reliable, exiting and proven ways of rehabilitation is by BCI based on fNIRS.

• For targeting all range of Stroke impairments, we developed three paradigms. First paradigm was designed for classifying brain state in motor execution active and rest states. Second paradigm was designed for classifying brain state into motor execution and motor imagery The same paradigm was also used for classifying brain state into motor execution, motor imagery and rest states. Third paradigm was designed for classifying brain state in VR motor imagery and rest states. Motor imagery stimuli can also be better given with help of virtual reality. Replacing 2D paradigm (NIRstim) stimuli with VR stimuli, the functional response of stimuli can be increased and experiments can be conducted at ease, due to easy implementation of both motor execution and motor imagery task with VR.

RESULTS:-

• Physiological noises from acquired signal were removed by novel wavelet transformation. Effect of differentiating signal, post noise reduction was studied. Its effect on each experiment was reported. A new strategy for detecting optimal features for classification purpose, from features
Mean, Variance, Skewness, Kurtosis, Peak, Sum of peaks and Number of peaks was designed and evaluated for designated four experiments and results are evaluated. RF was used both for feature selection and classification. LDA score and LDA_optimal model were used for classification. Robustness of three models was compared with respect to F1 score and best model for each experiment was evaluated. Average F1 scores of the classifiers are given in the table below. The run time of models was also studied. The average run time of LDA is 0.0560 seconds and the average run time of LDA_optimal is 0.0514 seconds. Finally the optimal features for each experiment were established.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Average F1</th>
<th>Average F1</th>
<th>Average F1</th>
</tr>
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<tbody>
<tr>
<td>Motor Execution vs Rest</td>
<td>82.79</td>
<td>73.04</td>
<td>72.48</td>
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<tr>
<td>Motor Imagery vs Motor</td>
<td>79</td>
<td>70.5</td>
<td>69.5</td>
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<tr>
<td>Motor Imagery vs Motor</td>
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<tr>
<td>Motor Imagery vs Rest</td>
<td>79</td>
<td>62.5</td>
<td>64.5</td>
</tr>
</tbody>
</table>

- fNIRS(functional Near Infrared Spectroscopy) imaging for resting state functional connectivity in post stroke motor recovery”

Summary

Early stroke rehabilitation is critical for enhancing motor recovery, but the optimal time window for specific neuro-rehabilitation has yet to be expounded. The intensity and duration of the rehabilitation scheme are also important factors that influence effectiveness. Recent guidelines in
knowing the mechanism of neurological impairment indicates that study of methods to reduce the impairments. Various studies have shown that some brain regions in normal adult brain have the capability to change in structure and function during learning. This is referred to as Brain plasticity. Cortical plasticity is moderately defined in different functional brain imaging studies. Optical neuroimaging is one of the promising approaches to elucidate on functional components of reorganisation of affected brain regions after stroke.

Current Status:-

a) fNIRS Motor experiments on healthy volunteers:

Data acquisition protocol has been formulated.

The task for pilot study was right and left hand finger tapping

Data acquisition of total of 20 healthy controls has been completed after obtaining IEC clearance

Data processing and analysis for the pilot study ongoing.

fNIRS-MRI anatomical coregistration problem is addressed with different approaches and a solution is obtained.

Functional connectivity within the channels used in motor montage is analyzed using FC-NIRS software.

PRELIMINARY RESULTS.

• Data were preprocessed and GLM analysis was done. The results are shown in the figure below.

• Promising results were obtained from resting state data analysis.

• Correlation maps for all the channels after group analysis were obtained.
Details of Seminars/Conferences:-

- “Biomedical Engineering - Past, Present and Future”, oral presentation at Mar Baselious College of Engineering

- “Optical Neuro-Imaging: A new research Niche”, oral presentation at FDP in Research opportunities in the field of Biomedical Engineering held at Govt. Model Engineering College

- Conference on Recent advancements in MRI and MRS, Department of NMR and MRI Facility