**DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING**

**SYNOPSIS**

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| --- | --- | --- | --- | --- |
| **1.** | **Title of**  **the Project** | Developing a Brain-Computer Interface Framework for Real-Time Neural Signal Decoding and Speech Conversion | | |
| **2.** | **College and Department** | Sahyadri College of Engineering & Management, Department of Computer Science & Engineering | | |
| **3.** | **Name of the Students & Guide** | Gagan V | 4SF21CS049 |  |
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**Abstract** Development of communication capabilities for individuals with speech impairments is a significant challenge in the medical and assistive technology fields. Brain–computer interfaces (BCIs) that reconstruct and synthesize speech using brain activity recorded with intracranial electrodes may pave the way toward novel communication interfaces for people who have lost their ability to speak, or who are at high risk of losing this ability, due to neurological disorders. This project aims to develop an advanced Brain-Computer Interface (BCI) that translates real-time neural signals into spoken language, providing a novel communication method for individuals unable to speak due to conditions such as Amyotrophic Lateral Sclerosis (ALS) or severe brain injuries.

The key objectives of this project are to develop reliable methods for acquiring brain activity signals using Electroencephalography (EEG), create advanced algorithms to accurately translate neural signals into phonetic representations with minimal latency, and then implement a natural-sounding speech synthesis system to convert these phonetic representations into spoken language, and design the system to adapt to individual users' neural patterns for improved accuracy and usability.

To achieve these objectives, the project requires EEG equipment for capturing neural signals, high-performance computing resources for data processing and model training, and software frameworks such as TensorFlow or PyTorch for developing and training models. Additionally, large, annotated datasets of paired neural signals and spoken language are essential for training the models, along with diverse speech datasets to ensure the system can generalize across different voices and languages.

The methodology involves recording neural activity using EEG devices while subjects speak or imagine speaking specific phrases, preprocessing the raw neural data to remove noise, extracting relevant features that correlate with speech components, and training machine learning models to map neural features to phonetic representations. These phonetic outputs are then converted into audible speech using a speech synthesis engine. The system is validated using separate test datasets to evaluate performance metrics such as accuracy, latency, and intelligibility, and the models are refined iteratively based on feedback.

**Keywords:**

Brain-Computer Interface (BCI), Neural Signal Decoding, Speech Synthesis, Electroencephalography (EEG), Machine Learning, Signal Processing, Phonetic Translation, Assistive Technology, Communication Disorders

* **Introduction** Brain–computer interface (BCI) systems support communication through direct measures of neural activity without muscle activity. BCIs may provide the best and sometimes the only communication option for users disabled by the most severe neuromuscular disorders and may eventually become useful to less severely disabled and/or healthy individuals across a wide range of applications. This review discusses the structure and functions of BCI systems, clarifies terminology and addresses practical applications. Progress and opportunities in the field are also identified and explicated.  
    
  Brain–computer interfaces are a rapidly evolving technology that has the potential to revolutionize how humans interact with computers. BCIs measure brain activity and translate it into commands for a computer or other device, allowing users to control machines and devices using only their thoughts. Neurogadgets, ranging from moving robotic spiders and balls to more practical applications, are increasingly being used for entertainment purposes. However, what is more important is that Neurogadgets are also being developed to assist people with disabilities, such as those with paralysis of the limbs.  
    
  A brain–computer interface, sometimes called a neural control interface (NCI) or brain–machine interface (BMI), is a direct communication pathway between an enhanced or wired brain and an external device. They allow communication between the brain and various devices. The three main types of BCI signals are Non-Invasive, Semi-invasive and Invasive

1. Non-Invasive: Ther Sensors are placed on the scalp to measure the electrical potentials produced by the brain
2. Semi-invasive - The electrodes are placed on the exposed surface of the brain
3. Invasive - The micro-electrodes are placed directly into the cortex, measuring the activity of a single neuron

Electroencephalography (EEG) is one of the most important non-invasive neuroimaging modalities used in cognitive neuroscience research and brain-computer interface (BCI) development. High quality EEG is a necessity for BCI to produce the desired results. However, high sampling rate and high-sensitivity EEG amplifier hardware are extremely expensive and generally complicated to operate for collecting signals. Ideally, EEG amplifiers with high sampling rates and sensitivities are preferred to record high-resolution brain activities underlying different stimuli.

Most BCIs do not require surgery to implant electrodes and are therefore termed noninvasive BCIs. At present, almost all non-invasive BCIs measure brain activity with EEG sensors placed on the surface of the scalp. This review focuses mainly on such BCIs. BCIs that acquire signals from electrodes surgically implanted in or on the cortex or other brain areas are considered to be invasive. Electrocorticographic(ECoG)-based BCIs are invasive because they require surgery but are less invasive than intracortical BCIs since ECoG electrodes do not penetrate into the brain but, rather, lie on the brain’s surface.

* **Literature Survey (***Summary of relevant literature, research papers, or existing works related to the project. This is often presented in a table format listing key studies, methodologies, findings, etc***): 2-3 pages**
* **Problem Statement and Description** *(Describe the current scenario or existing solutions related to the problem. Write detailed problem statement):* **1 page**
* **Objectives** *(Clearly state the objectives of your project. Outline what you aim to achieve with this project, Maximum of 3 to 4 bulleted points)*
* **Proposed methodology: (***Block diagrams – DFD, use case diagrams, Architectural diagrams with necessary steps)*
* **Outcome of the work:** *3-4 bulleted points*
* **Work plan- Gantt chart** (*Project timeline showing key milestones and phases. Gantt chart visualizing the schedule, tasks, dependencies, and critical path.)*

**References** *(List of all the sources (books, papers, articles, websites, etc.) that were referenced or consulted during the project planning phase.)*