Mobile robot control using a non-invasive BCI.

Exploring the Possibilities

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Outline of the Presentation

1. Project Overview
2. Theory, Methodologies and Concepts
3. Realization of the Project
4. Summary Part

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Overview

Project overview

The objective of this project was to explore the utilization of EEG readouts to control a BB8 robot. We aimed to develop a lightweight and robust classifier to interpret EEG signals and translate them into control commands for the robot. By combining the latest advancements in BCI and robotics, our goal was to bring the possibilities of EEG-controlled robots closer to reality.

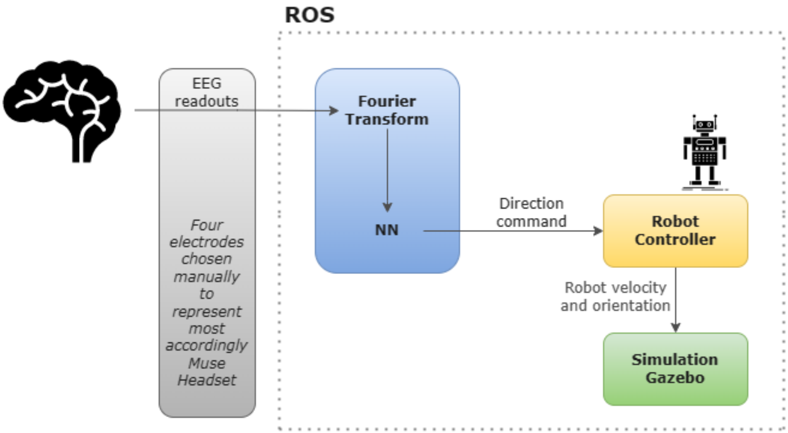

Figure: The overview of the project.

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Understanding the Electrical Activity of the Brain: The Basics

Brain activity

The brain is a complex system that produces electrical signals that can be recorded and analyzed. These signals, known as EEG signals, can be used to understand brain activity and control devices, such as a robot.

EEG Signals: The Principle of Operation

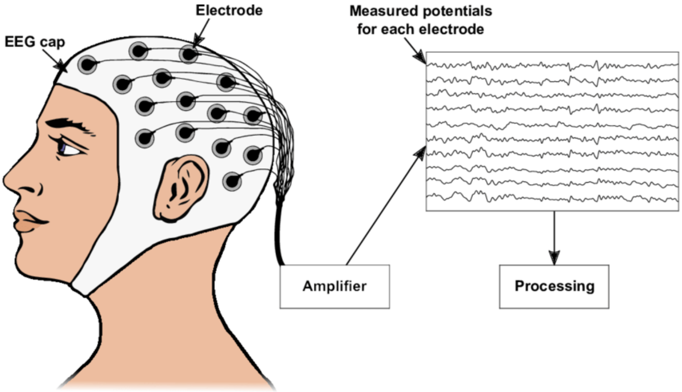

Figure: EEG - principle of operation [1].

EEG Signals and their Meaning

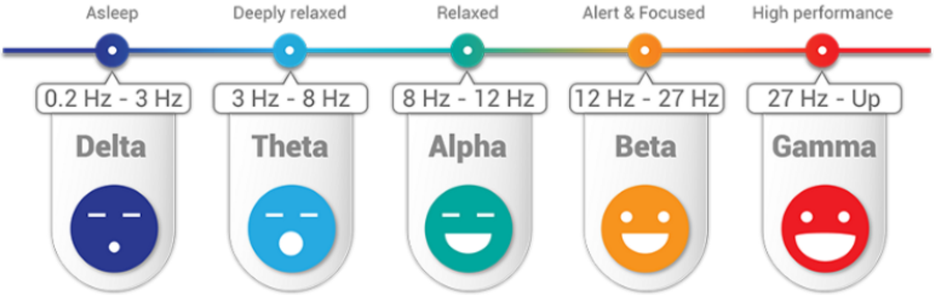

Figure: Five types of components of EEG signals and their meanings [3].

Translating Brain Signals into Control Commands

Brain-Computer Interface (BCI)

BCI technology involves extracting EEG signals from the brain and processing them to translate them into control commands. These commands can be used to control a wide range of devices, including robots.

Current Approaches and State of the Art in EEG Controlled Robotics

Why the Topic?

The field of EEG controlled robotics is rapidly growing, with many exciting advancements being made.

Our project aimed to contribute to this field by developing a novel approach to EEG controlled robots:

- FFT based signal feature extraction, without any usage of CNN.
- Motor activity as the examined mental stimuli, from electrodes not located at the motor cortex.
- Robust and lean classifier architecture.

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Choosing the Right Tools for the Job: Our Technology Stack

We carefully selected the technologies used in this project to ensure that we could deliver the best possible results.

Our technology stack included:

- **TensorFlow** for developing ML algorithms,
- **Gazeboo** for simulation environment,
- **ROS** for bringing everything together into one coherent system.

Building the System: An Overview of the ROS Architecture

Robot Operating System

Our approach to system engineering involved developing a robust and scalable ROS architecture. This allowed us to bring all the components of the system together and ensure that it could perform optimally.

Building the System: An Overview of the ROS Architecture

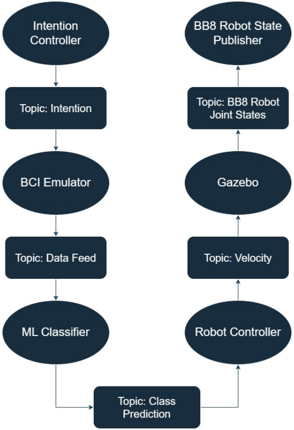

Figure: Diagram presenting utilized ROS architecture.

Working with the Data: Fitting the EEG Signals to Control Commands

Our approach involved fitting the EEG signals from the EEG Motor Movement/Imagery Dataset [6][2] dataset to the electrodes in order to train our classifier effectively.

Data Engineering

Data engineering was a critical aspect of our project, as we needed to work with EEG signals recorded from electrodes.

In that aspect, the data were prepared by chunking the EEG timeseries from the dataset (explanatory variables), and labeling the parts to the corresponding actions from the original experiment (targets). Processed data were fed directly to the classifier.

Working with the Data: Dataset Specification

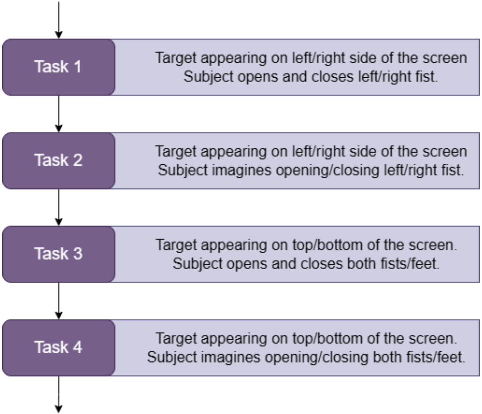

Figure: The experimental tasks sequence used for acquiring the signals in utilized dataset [2].

Working with the Data: Exemplary Set of Data

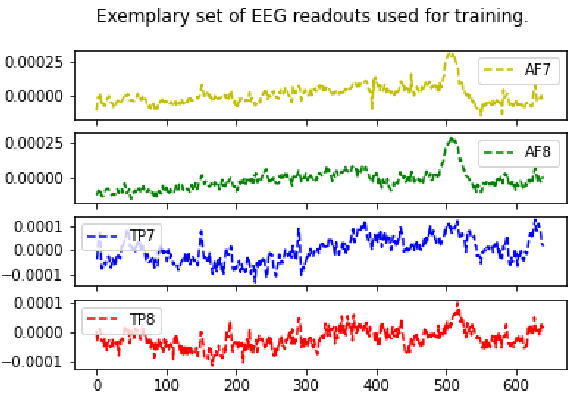

Figure: The exemplary set of signals from chosen electrodes from the dataset [2].

Finding the Right Fit: Our Approach to Classifier Development

A crucial part of our project was developing a classifier that was both lightweight and robust. We adopted a paradigm that focused on developing a classifier that could effectively interpret EEG signals and translate them into control commands for the robot.

Data preprocessing

Using Fast Fourier Transform at the network's preprocessing layer, we were able to encapsulate the critical information about different signals and their characteristics.

Finding the Right Fit: Classifier

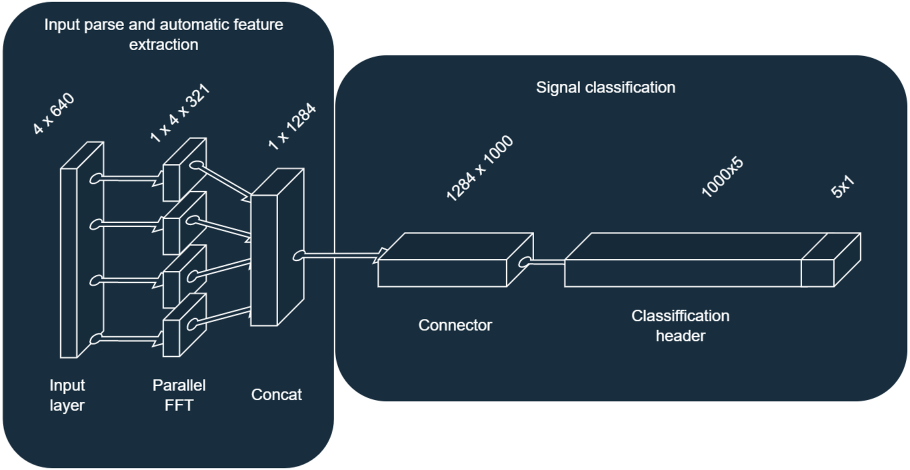

Figure: Outline of the proposed architecture.

Finding the Right Fit: Comparison of State-of-Art Methods

We compared the performance in terms of accuracy with some of the current state-of-art methods.
The ones with best performance found were the EEGNet [5] and ShallowConvNet [4].

Network	Accuracy
FFNet (fine-tuned)	0.807304
EEGNet	0.560261
ShallowConvNet	0.500783

Table: Best performing architectures.

Simulation: Intention Controller and BCI Emulator

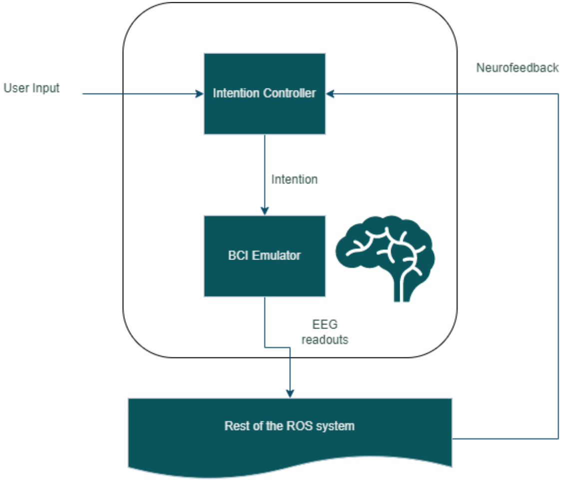

Figure: Intention controller and BCI emulator nodes.

Simulation: Gazebo Environment

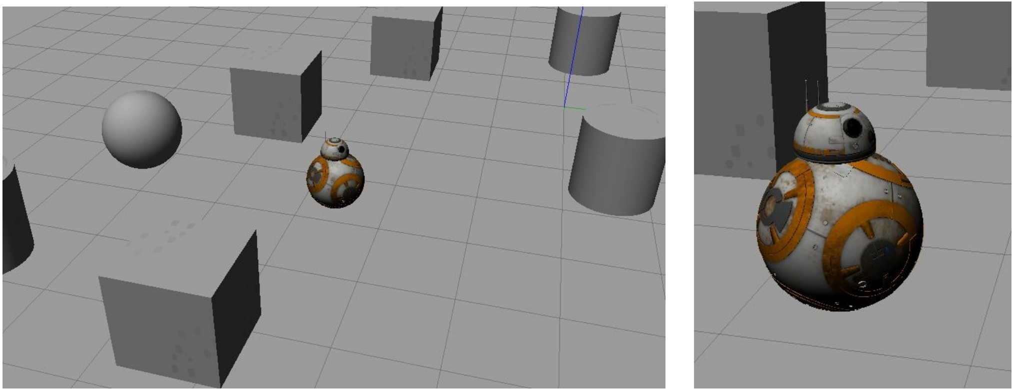

Figure: Simulation in the Gazebo environment.

Video Presentations

- Video 1
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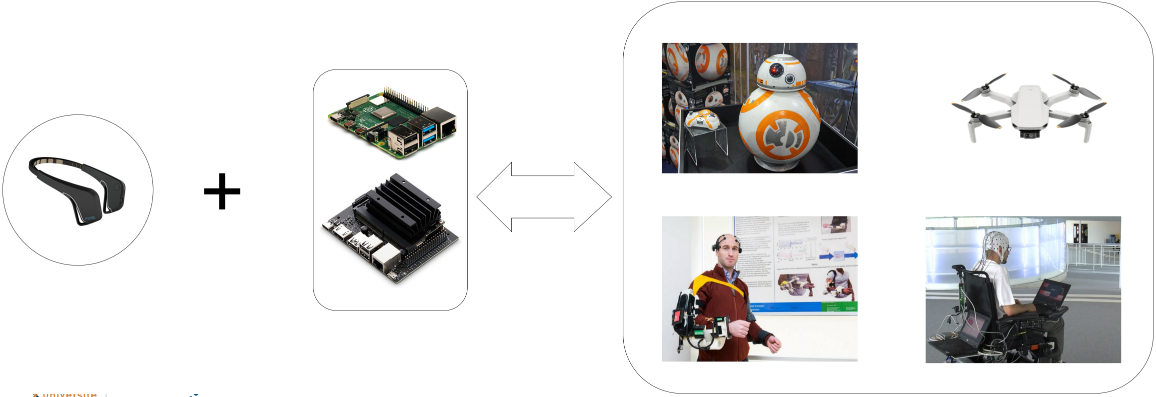
Bringing it to Life: Potential Real-World Applications

The work done in this project can be considered a small step towards making affordable BCIs a reality, and is to be used in a wide range of real-world applications, including rehabilitation and assistive technology.



Proof of Concept: The Results of Our Efforts

The results of the project are very promising. We managed to obtain an architecture and classification system which can potentially enable users to control the mobile robots with little to no effort. The system has the potential to be scaled up and will serve as a valuable basis for people wanting to build "mind-controlled robot" solutions.

The End.

Thank you for listening!

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