A Brain-Computer Interface for Controlling Mobile Robots

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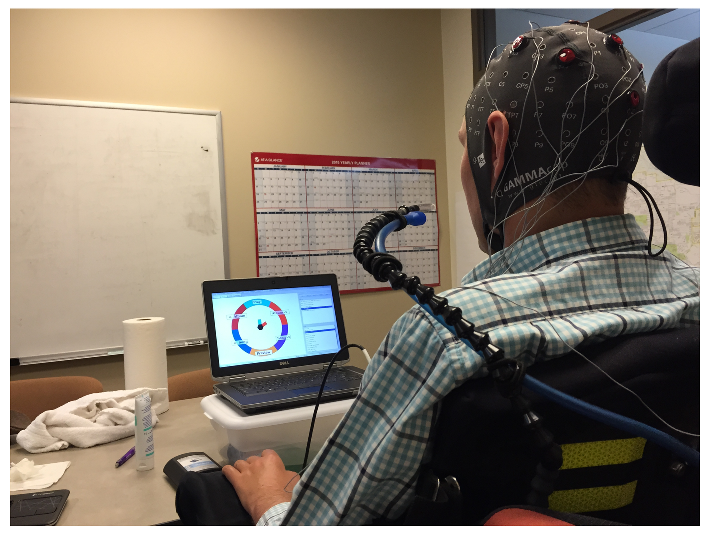
Brain-Computer Interfaces in Assistive Technology

Brain-Computer Interfaces (BCI) are systems for establishing a direct channel of communication between the human brain and a computerized device.

BCI utilize a communication protocol along with signal processing and machine learning algorithms to convey the user's intent to a computer system.

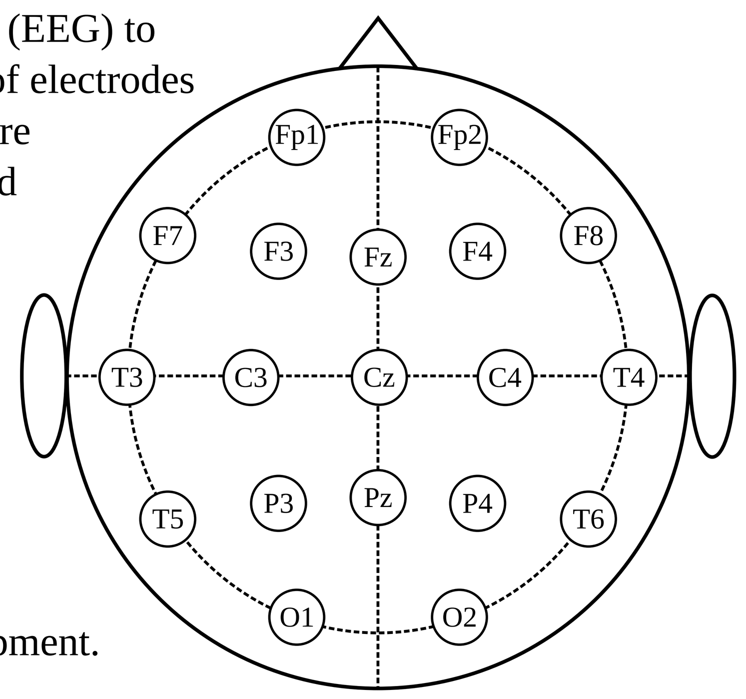


An important application for BCI is the development of assistive technologies for people with severe motor impairments.

For those who find it difficult to communicate or perform everyday tasks, even a somewhat slow BCI may prove to be an invaluable tool.

Non-Invasive BCI using Electroencephalography

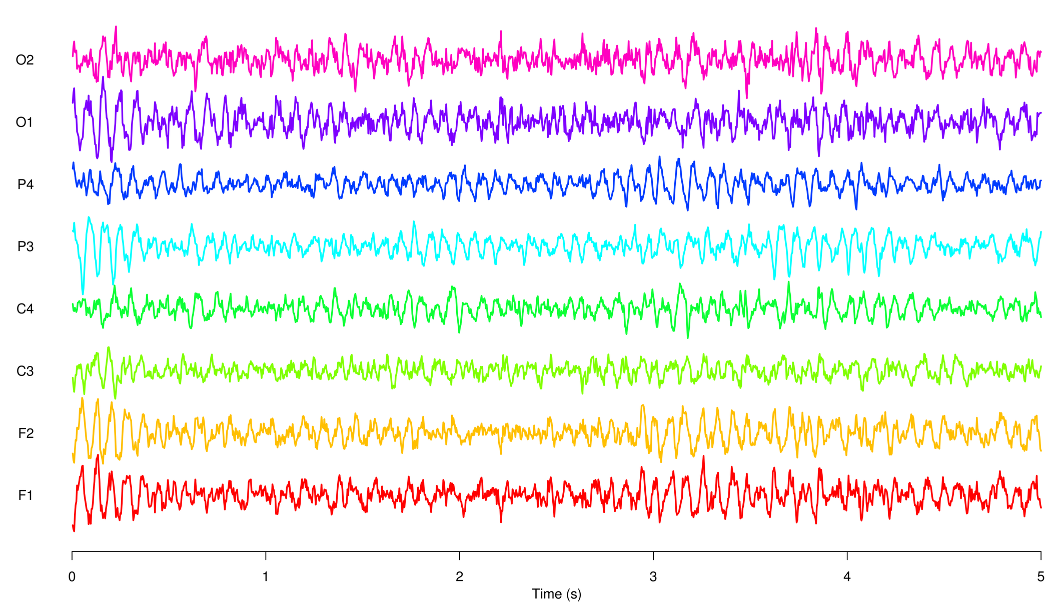
In our lab, we use Electroencephalography (EEG) to monitor brain activity. EEG uses an array of electrodes placed on the surface of the scalp to measure electrical potentials caused by synchronized firing of neurons.



We use EEG because it is non-invasive, portable and relatively affordable.

However, working with EEG is challenging because it is susceptible to interference from external sources, such as computers, power mains and medical equipment.

EEG also contains artifacts from internal sources, such as eye movement, heartbeats, breathing and muscle movement.

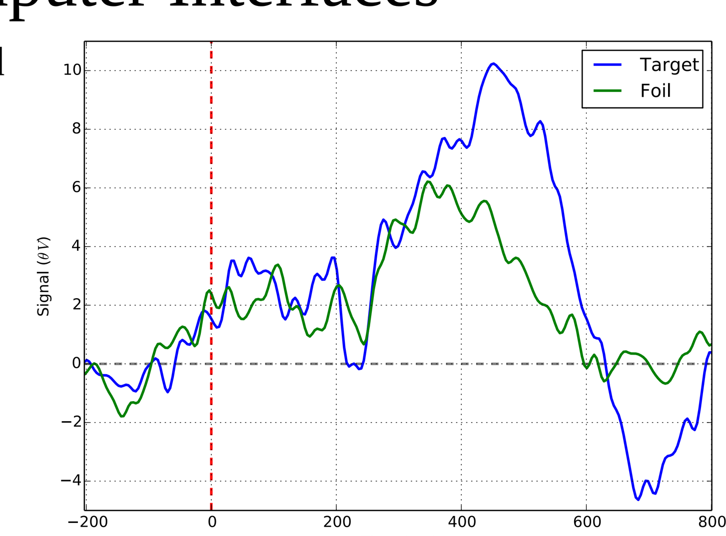


The brain is also very complex and is always performing multiple tasks simultaneously.

Separating desirable signals from noise and artifacts is challenging.

P300 Brain-Computer Interfaces

A number of approaches have been explored for constructing non-invasive BCI.



The P300 paradigm is currently considered to be one of the most robust and reliable approaches.

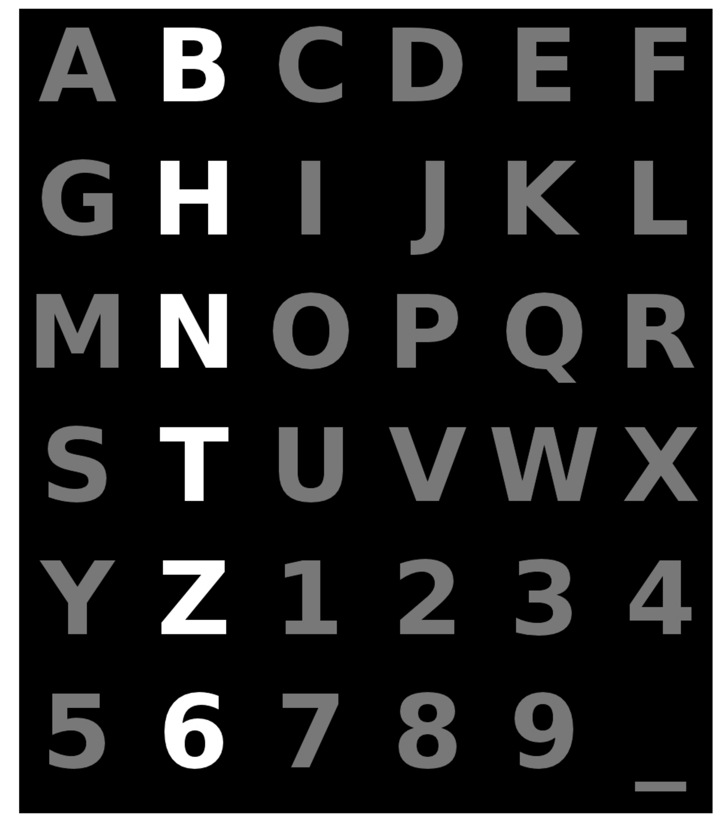
The P300 Event-Related Potential (ERP) is a positive deflection in the EEG signal over the centro-parietal region of the brain following the presentation of a "rare but expected stimuli."

In other words, if a BCI user is looking for a particular stimuli, the BCI can identify when the target item appears.

By combining EEG and machine learning algorithms with an interface that presents such stimuli, a BCI can be constructed that allows a user to select items from a menu simply by attending to the desired menu item.

Grid-Based Interfaces

The typical approach to constructing a P300 based BCI utilizes a grid layout.



For example, a virtual keyboard or "speller" can be constructed by creating a grid of characters.

The rows and columns of the grid are then flashed in random order for several trials.

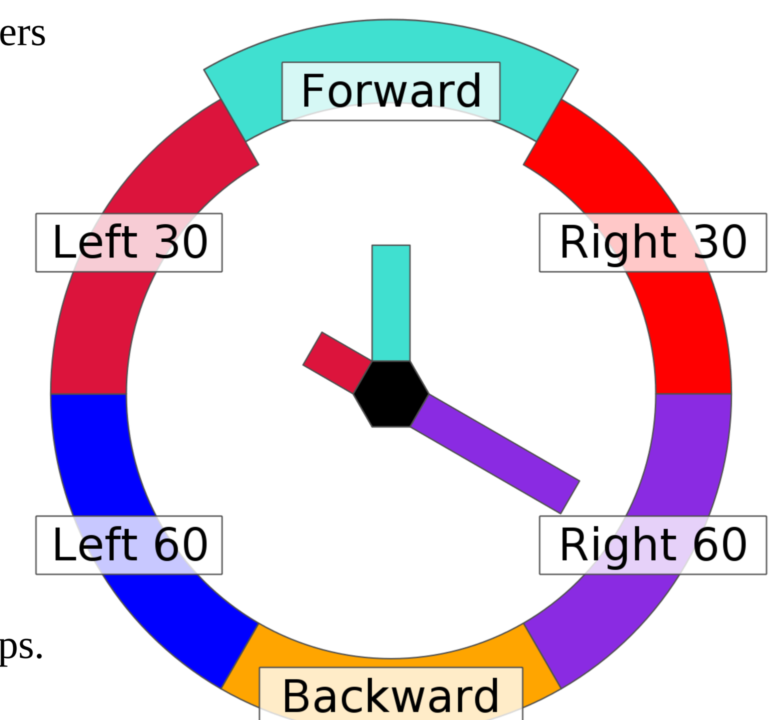
The user can select the desired character by attending to the character that they wish to type.

The BCI then attempts to identify which row and column were selected by using a machine learning algorithm to detect a P300 ERP.

Although the grid speller approach can be very useful and reliable, it is somewhat taxing to use due to the large number of flashing stimuli.

Pie-Menu Interface

Our approach for controlling mobile robots differs from the traditional grid speller.



Instead, we use a circular pie-menu with the possible selections placed around the menu.

The menu items then "jump" away in a random order while the user attends to the item they would like to select.

We then use a regularized variant of Linear Discriminant Analysis (LDA) to identify P300 responses that occur when the desired item jumps.

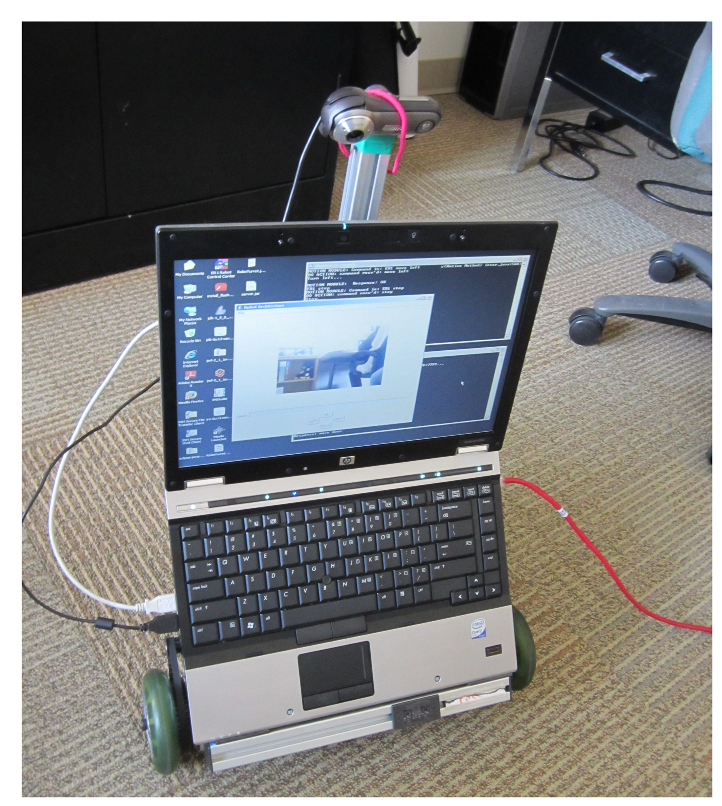
A bar grows toward the selected menu item after all sections of the menu have jumped. After several iterations, a menu item is selected.

The pie menu approach is less intrusive because it does not involve flashing.

Additionally, the pie menu provides the user with real-time feedback and may be more intuitive for some types of control.

ER1 Robot

Our initial experiments with controlling mobile robots utilized the ER1 robotics platform.



The ER1 configuration used for these experiments is essentially a laptop on a cart with wheels and a camera. Communication is performed via a wireless connection using sockets.

The pie-menu for controlling this robot consists of six items: Forward, Left 30, Left 60, Backward, Right 60, Right 30. Each menu item either turns or moves the robot by a small amount.

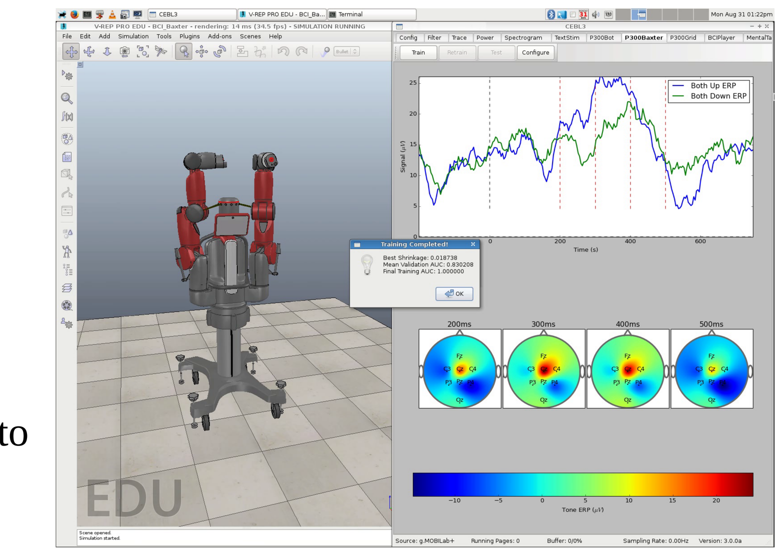
The portable g.tec g.MOBILab+ EEG system was used to acquire EEG signals.

Over the course of several demonstrations and experiments, approximately five users have successfully demonstrated an ability to drive the ER1 robot using this BCI.

Although this system is somewhat slow to operate, it demonstrates a proof-of-concept.

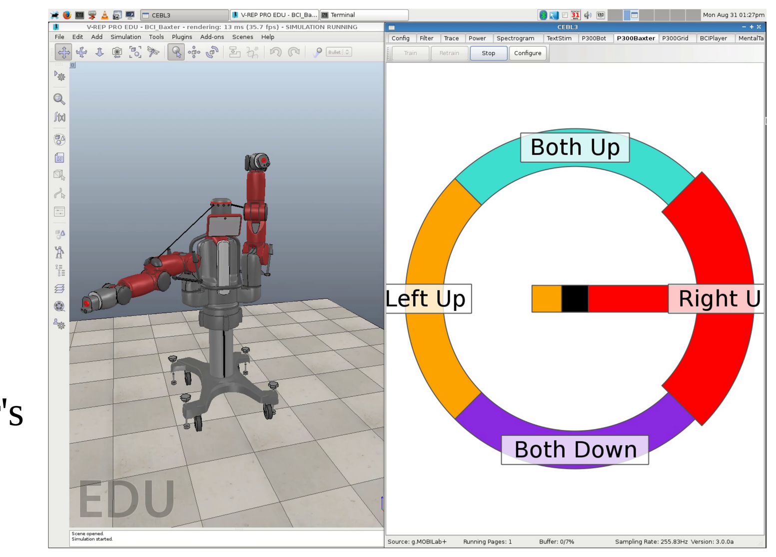
Baxter Robot

In order to perform more sophisticated tasks, we have begun exploring the Baxter robotics platform.



The Baxter robot is an affordable and versatile human-like robot with arms, grippers, cameras and a display.

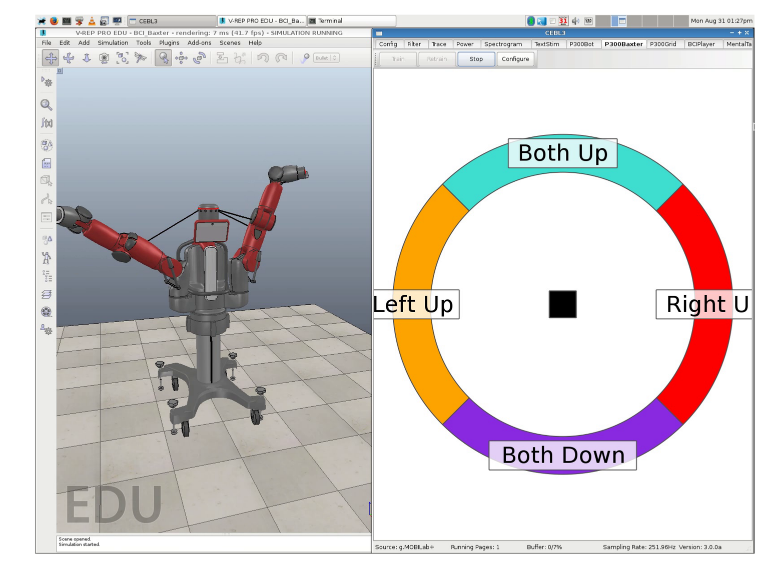
Since we do not currently have access to a Baxter robot, our initial experiments use the V-REP robotics simulation platform to control a 3D virtual model of a Baxter robot.



The simulator is controlled using sockets, which allows communication over a wireless connection.

Our pie-menu currently contains four items that raise or lower each of Baxter's arms: Both Up, Left Up, Both Down, Right Up.

So far, only a single able-bodied user has used this interface. They were able to control the interface with approximately 90% correct selections after four stimuli presentations.



This experiment demonstrates that it is possible for a user to send instructions to a Baxter robot using this style BCI.

This work also puts in place a framework for future experiments with Baxter robotics platform.

Goal-Directed Control

Our eventual goal is to be able to control robots in a way that is useful for people with motor impairments.

Several major improvements will be required in order to achieve this goal:

First, improvements in the the speed and reliability of BCI would be helpful for achieving better control.

Second, the robot should be capable of analyzing its environment and making intelligent decisions about which tasks it is able to perform.

This would allow the BCI interface to give the user more "goal-directed" menu choices. For example, pick up a cup, fill up a cup, drink from a cup.

In addition to our ambitious goals concerning the control of robots, we also believe that this work will lead to a number of advances related to the control of simplier assistive technologies, ranging from spellers and environmental controls to electric wheelchairs and prosthetic limbs.