A Brainwave-Control for Electric Chair and/or Artificial Arms

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Abstract

This project attempts to use the Electroencephalogram (EEG) signal from the brain to provide a new communication channel that allows palaysed individuals navigate freely by controlling their electric chairs. The project uses a low-end EEG-acquisition headset, which is the Neurosky Mindwave Mobile headset, to collect the EEG signals via a single electrode placed on the forehead, and an FRDM-K64F microcontroller to process the acquired signals and initiate the navigation commands that control an electric buggy. The electric buggy is used to simulate the electric chair movement. The project exploits the use of eyeblinks and the ERD/ERS signal to control the electric buggy by processing the acquired signal by the EEG headset. As an eyeblink causes a peak in the acquired EEG signal, the FRDM-K64 microcontroller detects this peak and uses it as the main control signal in the navigation process. The eyeblinks are used to initiate the navigation and to choose the direction of movement, while the Event-Related Desynchronization/Event-Related Synchronization (ERD/ERS) signal measures the attention level and it is used to move the buggy in the chosen direction.

Introduction

Introducing the problem

Every year, about 250 000 to 500 000 people suffer from spinal cord injury [1] and about 16 000 people are infected by ALS at any given point of time [2]. Sufferer from these diseases become partially or fully paralysed, hence they become incapable of moving voluntarily and independently to finish their daily tasks. Some spinal cord injuries and other diseases could be overcome with surgery, while there is not a cure for ALS until today, hence an alternative method should be found to allow ALS patients to move independently.

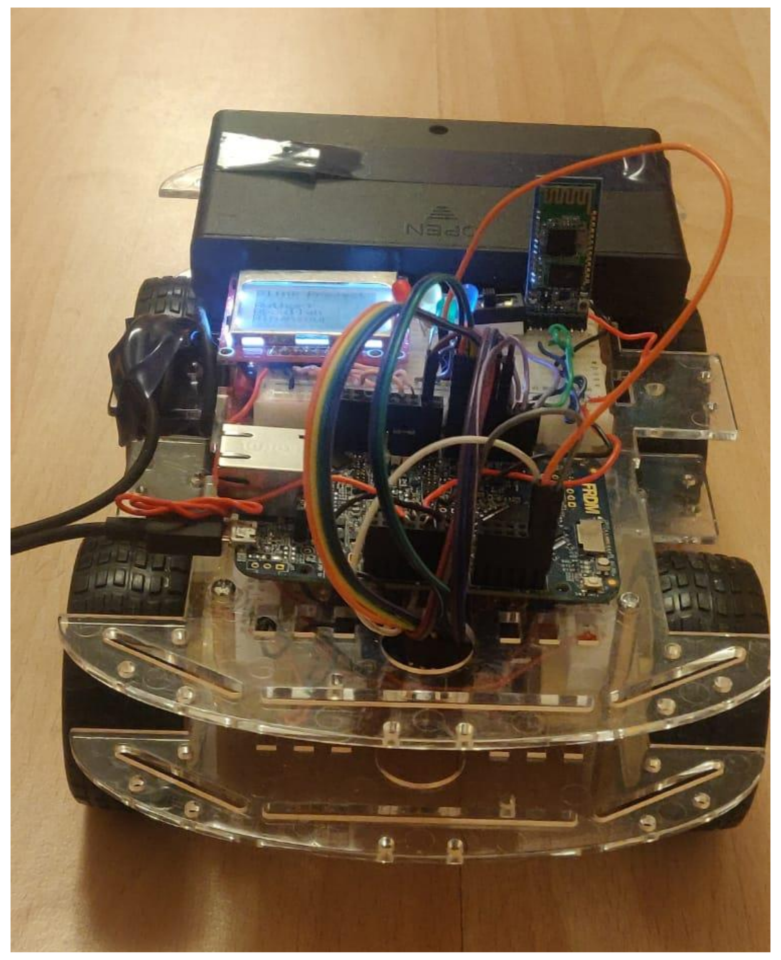

Figure 1: Buggy prototype

A possible solution

According to [4], ALS is a disease that affects the spinal cord and the motor neurons in the brain and causes a gradual loss of mobility. At the last stages of the disease, an ALS patient is not capable of any motor movement except the movement of the eye muscles [5]. Therefore, this project investigates the possibility of using an individual's thoughts to control an electric buggy, assisted his/her eyeblinks as a more robust signal.

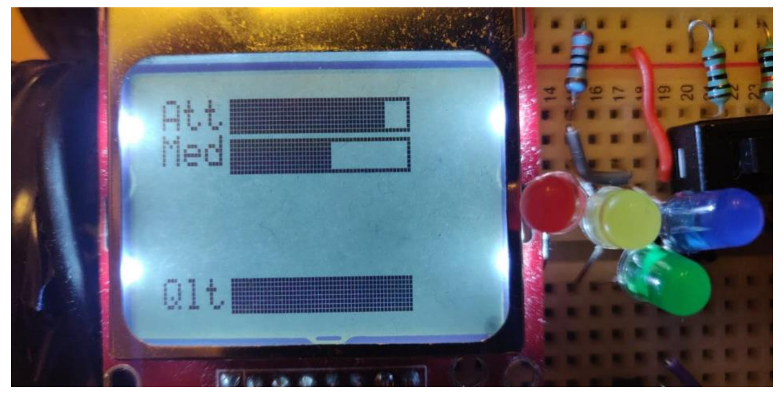

Figure 2: *: LCD display showing the Attention (Att) and Meditation (Med) levels and the Quality of the signal in filling-bars.*

Background

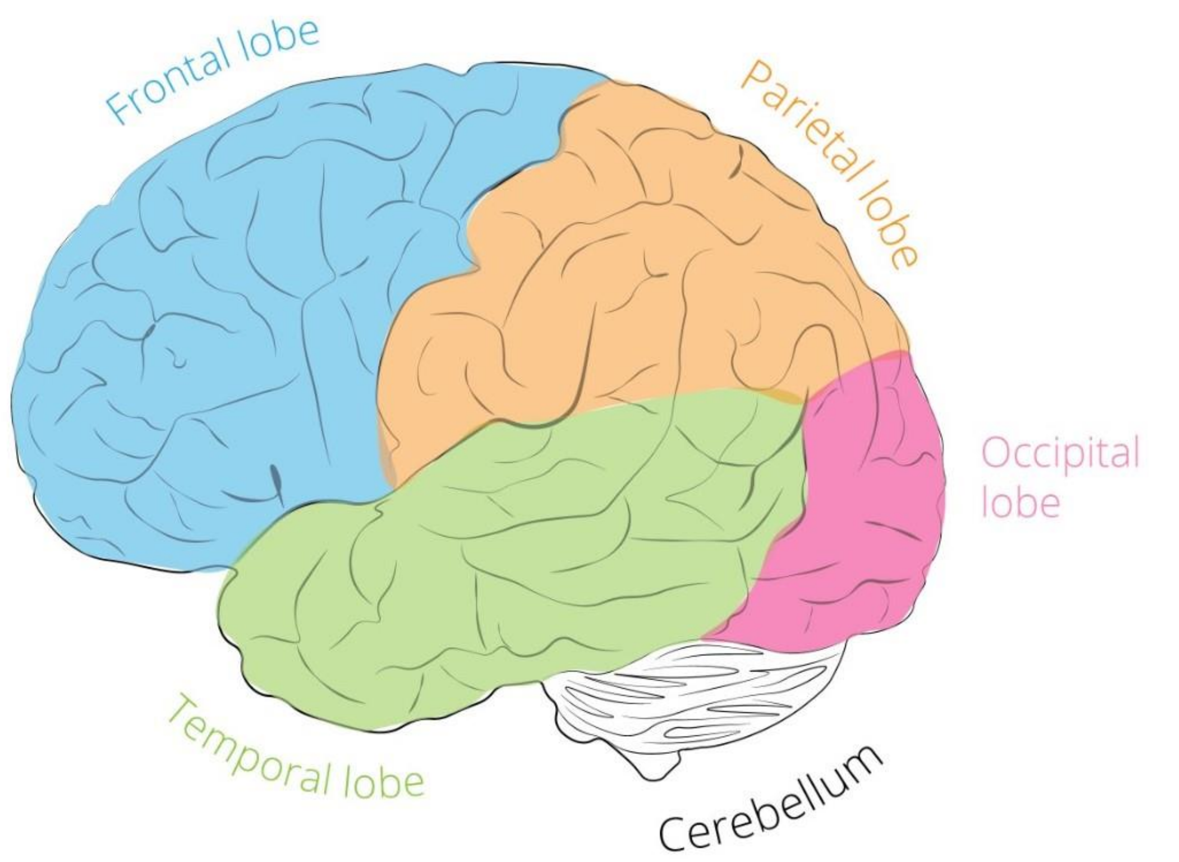

Figure 3: Illustration of the lobes in the cerebral cortex [3]

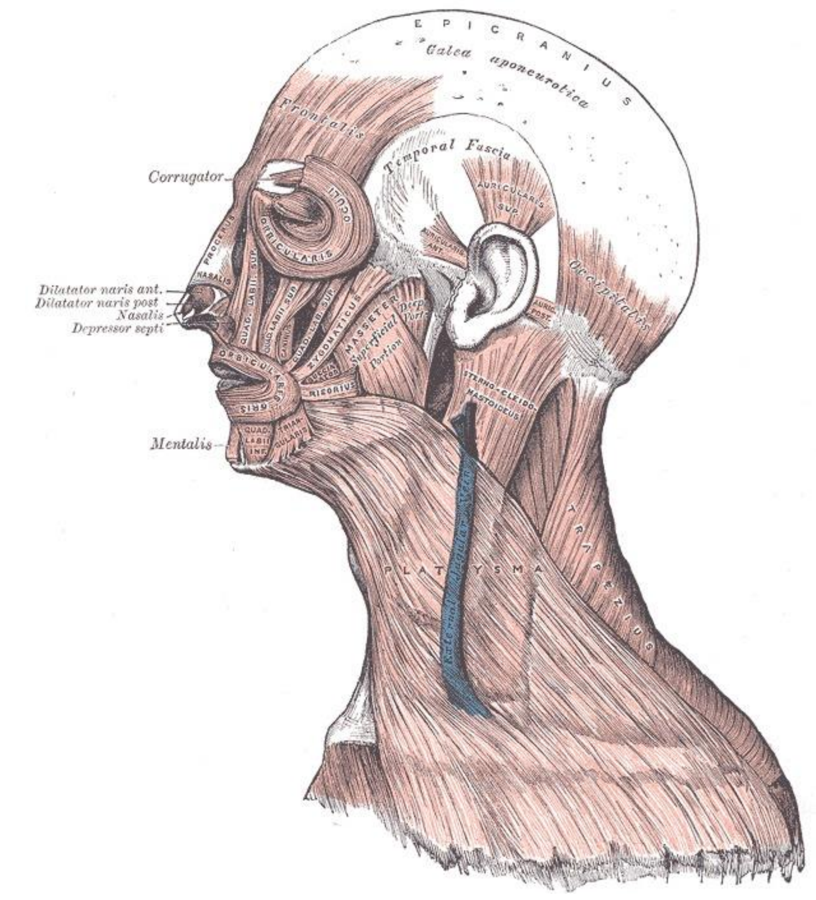

Figure 4: Human Anatomy, head and neck, Eye Orbicularis Oculi Muscles [4].

The human brain consists of billions of neurons that communicate with each other to via electrical signals to control the activities of the body. When thousands or millions of neurons become in sync with each other, the signals add up constructively and become measurable at the scalp [5]. This phenomenon forms the bases of Electroencephalogram study, and in this project Neurosky Mindwave Mobile uses the synchronization and desynchronization of these signals to measure the Attention and Meditation levels of the user. This method is called Event-Related Desynchronization/Event Related Synchronization (ERD/ERS) and it is measured from the Frontal Lobe, which is responsible for attentive focusing of the human and other functionalities.

Secondly, when the brain decides to contract a muscle, it sends an electric impulse to the muscle via the neural system. This electric impulse induces the muscle to release some chemicals that causes it to contract [4]. This phenomenon is exploited in this project to predict an eyeblink as the human eyelids are controlled by three division of the Orbicularis Oculi muscle on the face, as seen in figure 3. When an individual decided to blink, the motor neurons from the brain sends an electric impulse via the facial nerve to these muscles to contract. This signal is measurable at the same position as the ERD/ERS signal introduced previously.

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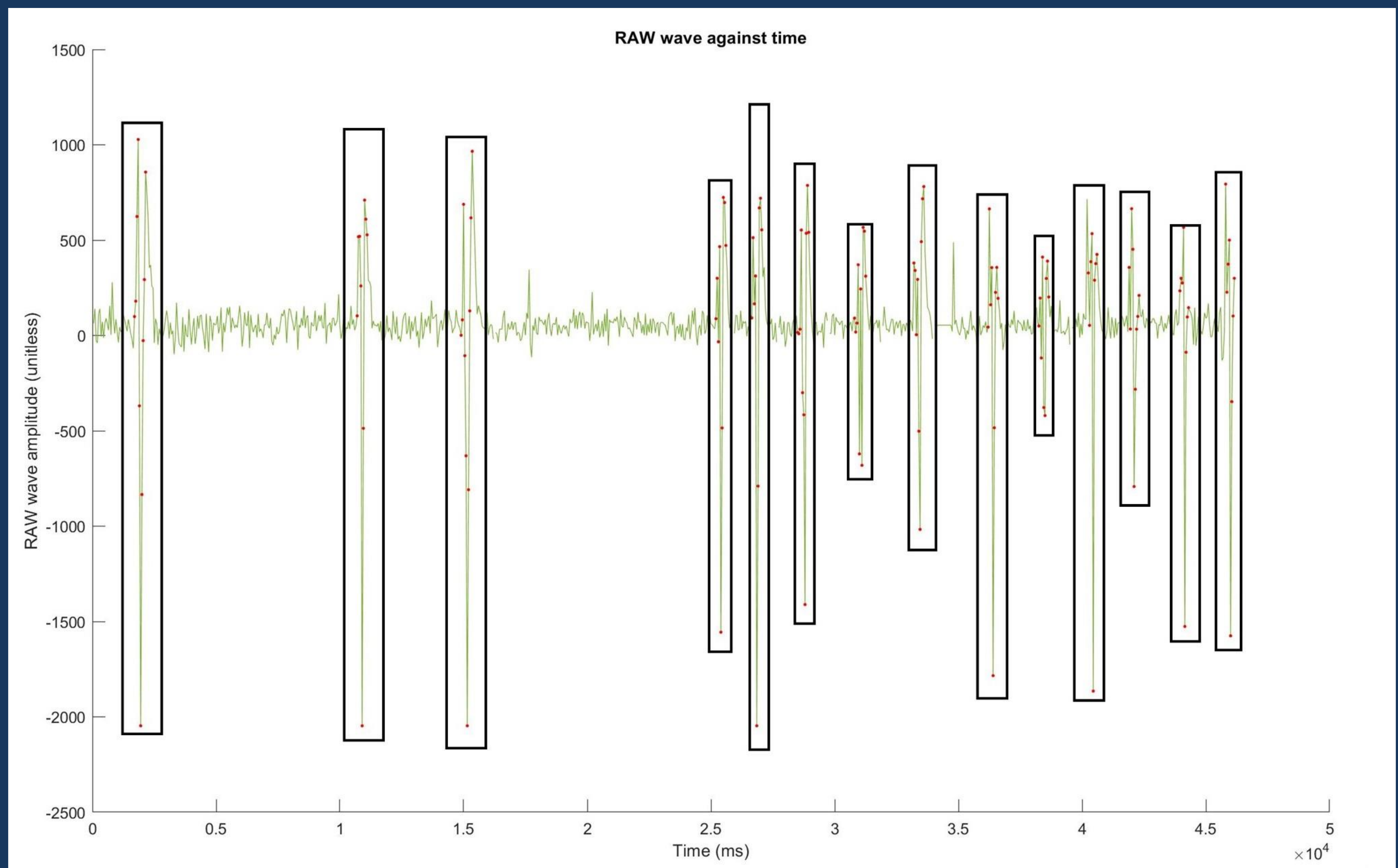

Figure 5: RAW wave signal amplitude with peaks that correspond to blinks.

Effect of an eyeblink on the EEG signals

The electric impulse produced by the brain to contract a muscle causes a peak in the EEG signals obtain from positions near the Orbicularis Oculi. These peaks are predictable in the raw EEG waves, as it could be seen in the graph in figure 5. The signals contained within the rectangles corresponds to the eyeblinks, while the small noisy signal is the raw EEG wave.
The amplitude of the peaks caused by an eyeblink could be seen to vary depending on the strength of the peak. The peak signals in the graph above correspond to voluntary blinks of different strength, while in-voluntary eyeblinks were found to have smaller peaks, at around -100 per unit, while the weakest voluntary eyeblink had a value of around -200 per unit.

Test	Length of the test in minutes	Total number of blinks	Correctly detected blinks	Not detected blinks	Erroneous blinks	Blink detection rate
1	2:13	52	45	7	0	86%
2	2:09	40	40	0	12	100%
3	2:08	42	42	0	0	100%
4	2:00	40	40	0	20	100%
5	2:01	36	36	0	3	100%

Predicting the blink with a threshold

Test 1: The threshold value was set to -500. The user was stationary throughout the test.
Test 2: The threshold value was reduced to -150. The user was stationary throughout the test.
Test 3: The threshold value was set to -200. The user was stationary throughout the test.
Test 4: The threshold value was set to -200. Tested with slight body movements.
Test 5: The threshold value was set to -200. Tested with slow movements of a rolling chair to simulate the electric wheelchair movements.

The experimental work done on the raw EEG signals show that the voluntary eyeblinks cause a predictable peaks in the EEG spectrum that are differentiable from the involuntary eyeblinks in amplitude. Furthermore, it has been found that a voluntary eyeblinks lasts for approximately 200 ms to settle and follows a specific pattern. The amplitude of the EEG signal rises to a positive unitless value, as measured by the Neurosky Mindwave Mobile, and falls to a large negative value before it settles. This pattern may be used with powerful processing techniques using machine learning methods to differentiate the signal from the sources of noise, such as the movement of the body and the vibrations caused by the movement of the chair.

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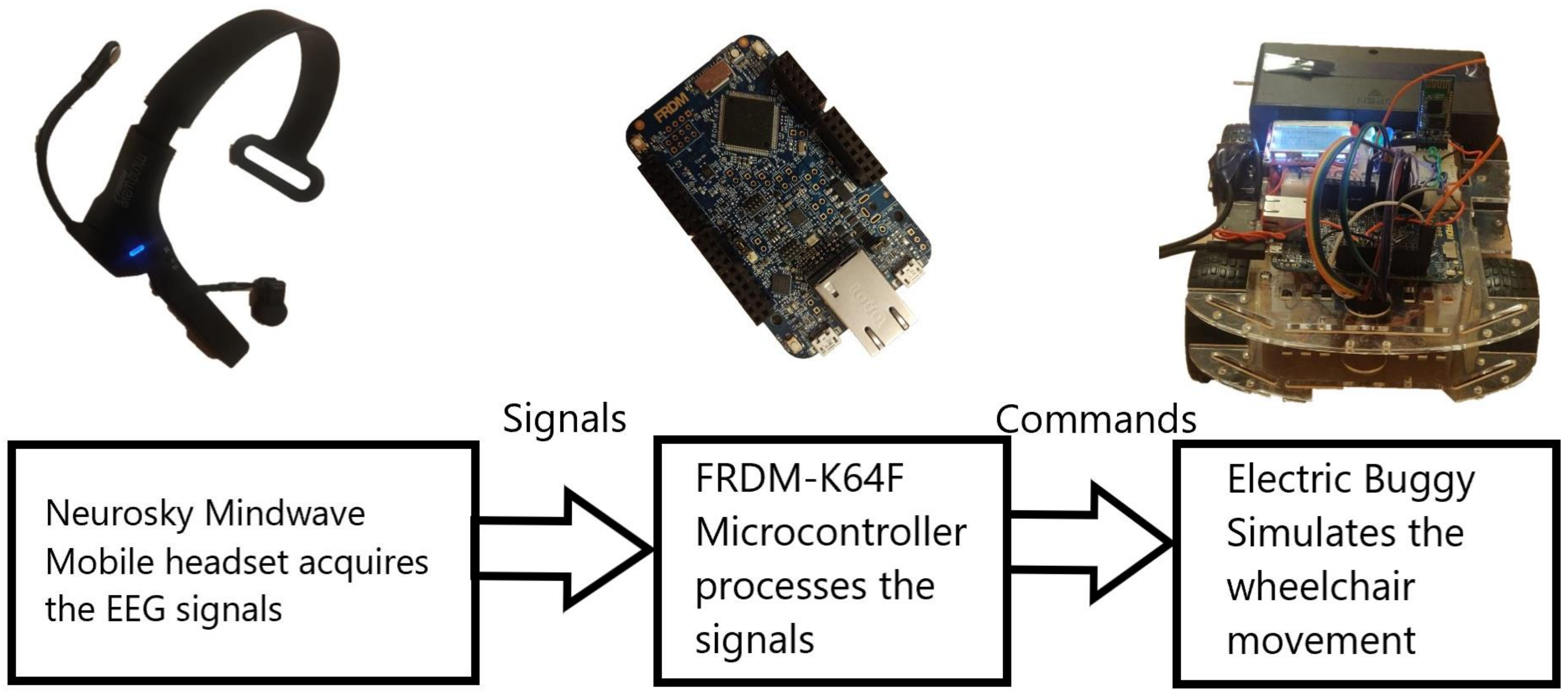

Figure 6: Overview of the system

Overview of the system

The system that was developed makes use of Neurosky Mindwave Mobile headset to acquire the EEG signals from the brain. The acquired signal sent to an FRDM-K64F microcontroller via Bluetooth. This microcontroller processing the signal to predict the eyeblinks and uses it with the attention level to implement the navigation process by controlling the electric buggy and the displaying feedback indicators to the user. The four-wheeled electric buggy is used to simulate the electric wheelchair movement.

Bibliography

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Navigation process

The navigation starts when the user blinks two consecutive blinks within a short period of time. When the navigation processes is initiated, the user should blink 0 to 5 further blinks to choose the direction of movement.

Once the direction of movement is chosen, the a LED indicator lights up to give a feedback to the user. The user should either confirm the direction by focusing his/her attention, which is predicted by the Neurosky Mindwave Mobile headset, or blink once to exit the navigation and repeat the process.

Conclusion

The project proposes a potential solution for ALS patients by providing a new communication channel that would allow the users to move voluntarily and independently. The results have shown that the eyeblinks are predictable at the surface of the skin if it was acquired from a position near the Orbicularis Oculi muscles and that the attention level of the user affects the EEG signals acquired from the same facial position. The system yet need further improvements to make 100% safe for a vulnerable individual.

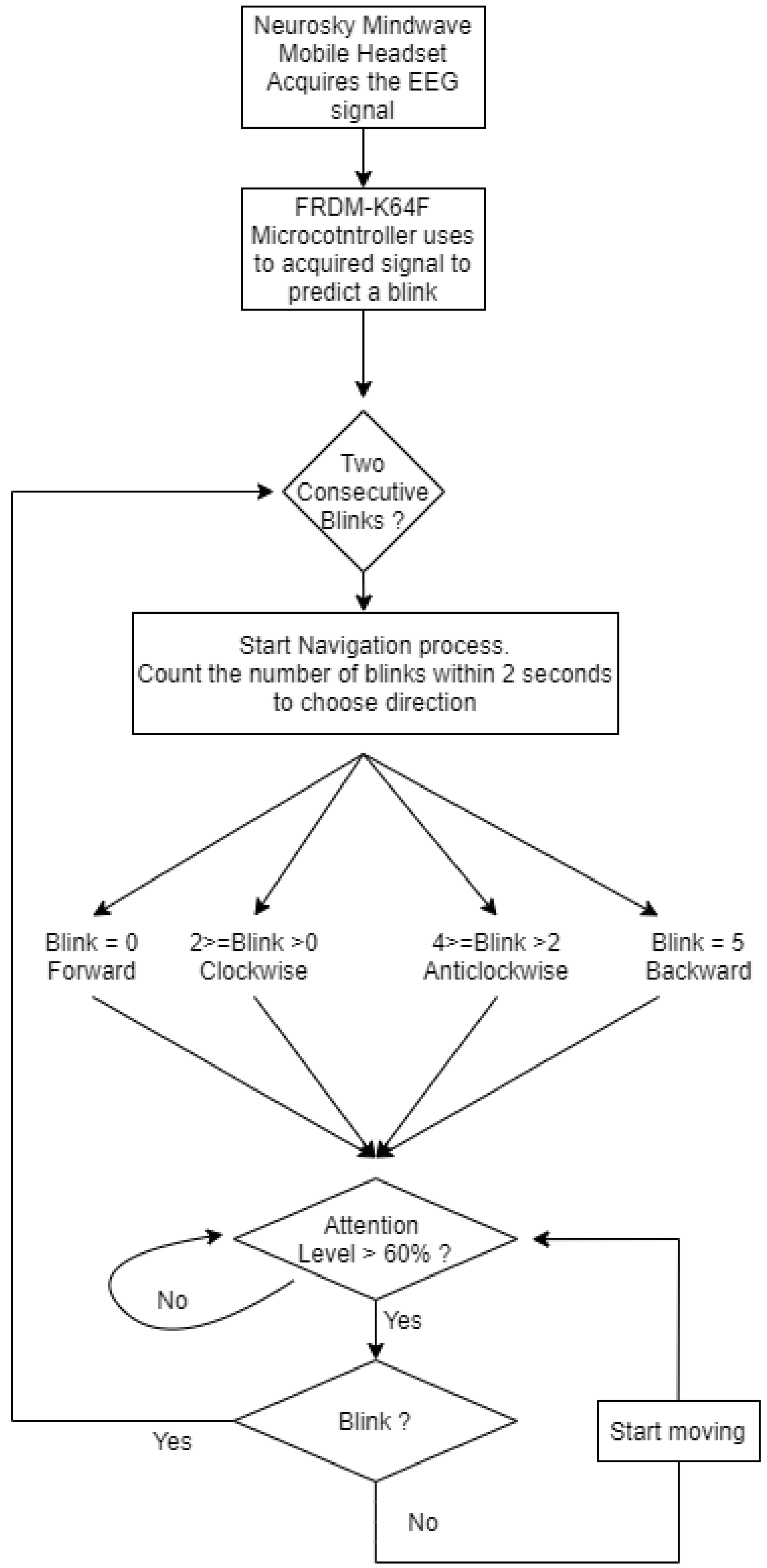

Figure 7: Navigation process