

# BrainCon's Non-Invasive Approach to Thought-Controlled Wheelchairs



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Going beyond electric wheelchairs, the BrainCon project is creating a smart wheelchair that moves according to what a person is thinking. By using advanced technology, users would be able to control their wheelchairs using just their brain signals! Furthermore, these are not just any brain signals but imagined speech, which is less tiring than imagining movement. **THINK** meets with the team to find out more.

Electric wheelchairs are widely used, but they are usually controlled by the rider using a joystick. But what if there was a way to control a wheelchair using only brain signals? By sensing electroencephalographic (EEG) signals from the brain and using them to control a smart wheelchair, BrainCon aims to create a wheelchair that users can guide along with just their thoughts. This can all be done without resorting to invasive technology such as brain implants.

Dr Natasha Padfield, systems engineer at the Centre for Biomedical Cybernetics at UM, explains that the project stands apart by offering non-invasive solutions, as a lot of research requires brain implants to read the signals. Meanwhile, this project works with data from a cap with electrodes placed on the scalp. Many brain-computer interfaces (BCIs) one hears about are implanted in the brain via a surgical operation. These give much better signals, Padfield explains, but they are risky and very expensive.

'The EEG cap is more available and accessible as a solution than implants and is more comfortable. It makes it more likely for people to use it. People have the misconception that our area of research has already been studied, but the difference lies in the cap. The challenges arise from there, as we do not have implants directly in the brain,' Dr Ing. Marvin Bugeja, senior lecturer of Systems and Control Engineering, states.

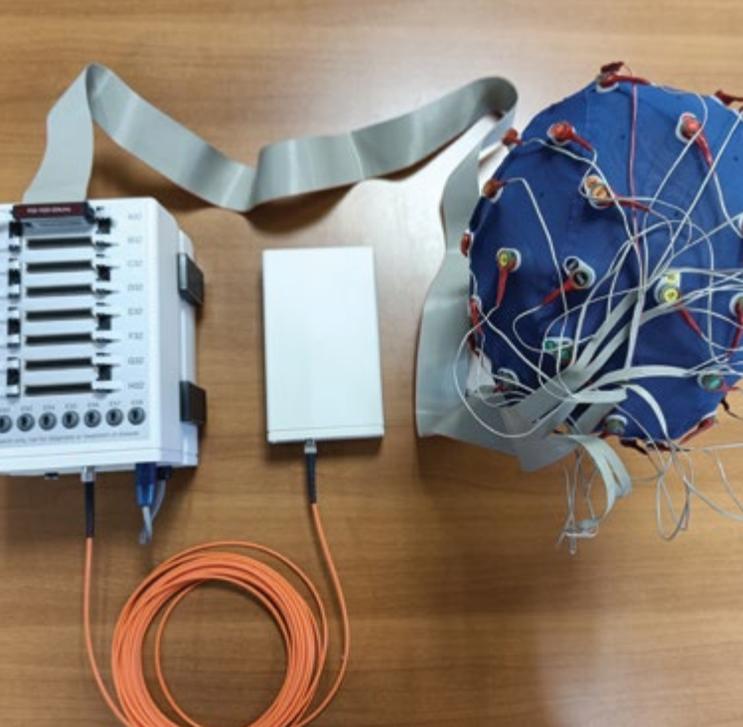
## IDENTIFYING THE RESEARCH GAP

Prof. Ing. Kenneth P. Camilleri, joined by Prof. Ing. Simon G. Fabri, Dr Tracey Camilleri, and Dr Ing. Marvin Bugeja, leads the team at the UM, which leverages the biomedical

engineering and the control engineering strengths of both the Department of Systems and Control Engineering and the Centre for Biomedical Cybernetics, leading to the development of the BrainCon initiative. Padfield, employed as a postdoctoral researcher, took previous department research on a smart wheelchair to the next level. The challenge was to eliminate the need for a joystick at all and use signal processing to convert EEG brain signals into commands: Left, Right, Speed Increase, and Decrease.

'A smart wheelchair fully controllable through thought is crucial for someone who has quadriplegia and even people with motor neuron diseases. When people have these diseases, their brain signals remain the same when exerting these commands, but their muscles are unable to do the movements required to activate a joystick, for example. BrainCon is mostly aimed at people who cannot use a joystick,' Padfield explains.

Padfield points out that in other research studies on this theme, motor imagery is often used. This refers to the idea that the person imagines moving one's hands, legs, or tongue. Imagining these movements sends specific brain signals from the EEG electrodes to a computer, which can then use software to interpret the signals. One does not have to execute the actual movements, as the signals are very strong in the motor cortex, where they can be detected accurately with EEG, a method to record the electrical activity of the brain. Nonetheless, it can be tiring to imagine these movements over a long period of time. Furthermore, these movements are not intuitive, such as when one tries linking tongue movements to 



Left to right: The BioSemi EEG recording equipment consisting of an amplifier (left) and cap with 32 sensors. The smart wheelchair being used in this project, developed by the Department of Systems and Control Engineering. Demonstrating EEG signals being recorded from a subject using the BioSemi EEG recording setup and displayed on-screen.

*Photos courtesy of the BrainCon team*

Left, Right, Forward, or Backward. Therefore, another objective of the project was to replace such signals with imagined speech instead, which is easier for the subject.

There is a significant research gap on this level, Padfield elaborates. Imagined speech has been studied in relation to controlling graphical user interfaces, but less so for physical devices such as a smart wheelchair. When controlling a moving object like a wheelchair, accuracy is essential, and the control must be reliable. Therefore, one of the key challenges of BrainCon is to stabilise the signals being decoded from the brain and avoid random misclassification from the data.

'If the subject becomes a bit distracted, there will be a lot of noise in the signals. The human body has a lot of electrical signals which we might capture that we do not wish to translate into commands. Sometimes, even if a person is paralysed, parts of their body may twitch slightly. Even electrical signals from light in a room can introduce noise,' Padfield clarifies.

## TURNING SPEECH TO MOVEMENT

Padfield and the BrainCon team have been working on a stabilisation technique for this system. The training algorithm is interactive, using a machine learning technique called reinforcement learning. The algorithm is trained on the individual. An initial 15-20 minute interactive session with the classifier software results in a more accurate and customised service. Padfield states that the researchers intend to test the actual, physical BCI wheelchair both with healthy participants and participants with mobility issues who have higher levels

of mobility. However, some individuals who have a high level of disability usually require a custom wheelchair that is not available to the research team. For these individuals, the BrainCon team has thus developed a simulation test via computer to get feedback from the patient.

During the project's inception, the BrainCon team worked with a doctor in the United Kingdom, Dr Andrei Agius Anastasi, to collect feedback from patients which could feed into their work. Agius Anastasi spoke to people with significant spinal cord injuries, and they were interviewed about what they would want out of a brain-computer interface, as well as what their perceptions and needs might be. While there had been interview-based studies of BCI applications, there was not much data specifically on BCIs being used with wheelchairs.

When asked what the main challenges of the research have been, Padfield indicates that the actual decoding of imagined speech is quite difficult. The team had to first go through a lot of different classifiers. Padfield explained classifiers as standard algorithms with various applications. While some are used for EEG data processing, they weren't specifically designed for the team's particular classification problem. 'Essentially they are like tools for anyone doing machine learning. We used some classifiers which have been popular in EEG signal processing and trained them with our data,' explains Padfield.

'The EEG works with 32 electrodes which produce a large amount of data. This data is reduced to a feature vector. The feature vector simplifies the data using a variety of statistics.



Some, such as mean and median are quite straightforward, while others are more complex, such as a summary of the frequency content in the signal. This condensed data is fed into the classifier which identifies what the person is thinking. However, due to the noise in the EEG data, and issues like the subject not always concentrating or being completely consistent in their thoughts, the classifier output tends to have misclassifications. We had to do some innovative maths to smoothen the classifier output and generate more accurate results,' elaborates Padfield.

Padfield warns that beyond the difficulty of smoothing the signals, they have had to deal with the subject's idle states. When the subject is not focusing on controlling the wheelchair, they may be imagining all sorts of things which might be falsely interpreted as potential commands for the smart wheelchair. In such a so-called idle state, they would not want their random thoughts to lead to the movement of the smart wheelchair. The challenge is that it can be hard to discern imagined speech from the idle state, and as you increase the number of imagined speech commands, the problem grows. 'One way to address this is to compromise and have two intuitive imagined movement commands and two imagined speech commands. This would be a stepping stone to a fully imagined speech-based system. So you might have, for example, imagined left and right-hand movements to turn left and right and then "speed up" and "slow down" as the imagined speech commands.'

As the team moves towards concluding the project, Agius Anastasi (having since returned to Malta) is set to

help the team train the software on patients from Karin Grech Hospital to put theory into practice. Padfield also explains that beyond the project itself, funding has already been won from MCST to explore research on speech imagery further. BrainCon highlighted the challenges of decoding such data, and the gaps in the literature present an opportunity to take this research to the next step, though people must still be recruited for this new initiative.

Looking at even longer timelines, the team might eventually opt to try and commercialise their research. However, as the product would be classified as a medical device, there is extensive testing needed and barriers which would need to be overcome, requiring more planning and preparation far beyond the project. Nonetheless, they have identified the Commercialisation Voucher Programme from MCST as a promising way forward to potentially make this info a reality.

The possibilities opened by new technologies and research in these fields offer boundless opportunity. Being able to control technology through thought alone offers the chance to significantly improve many people's quality of life. It also makes one wonder what other applications might be in store, affecting the world in unexpected and exciting ways. **T**

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