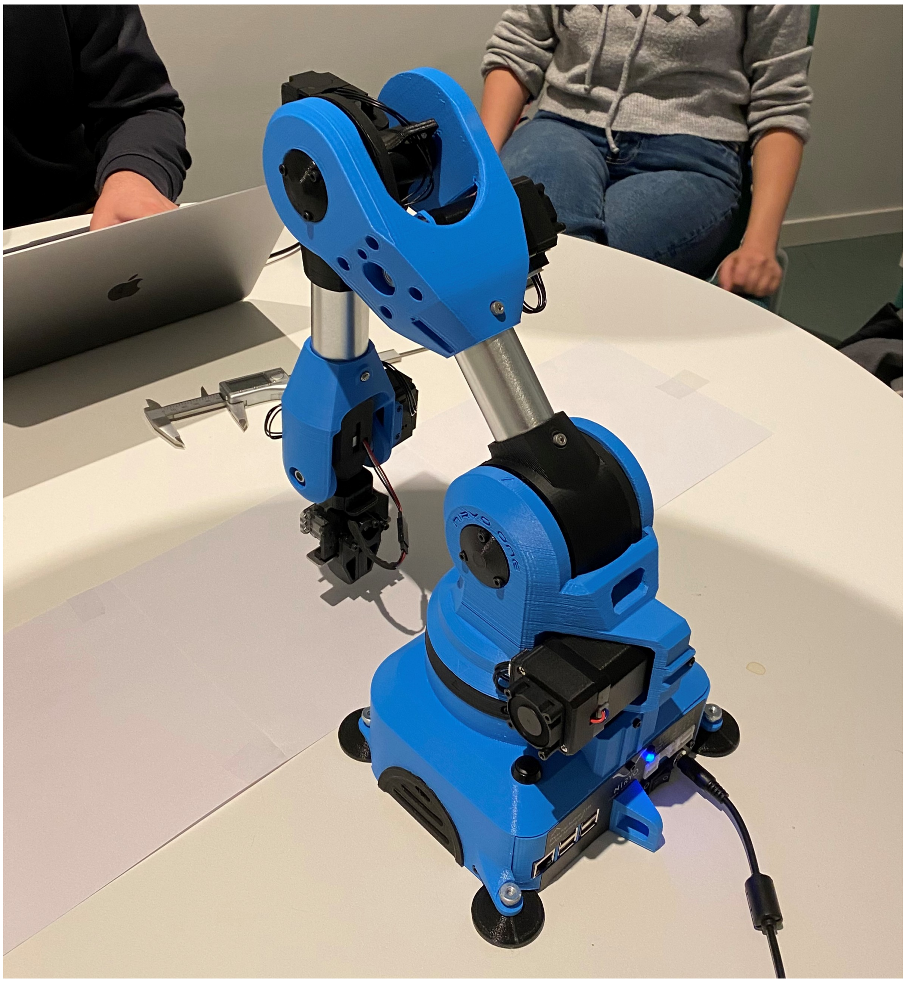

Medical Engineering Project
Final Short Paper

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January 9, 2022

1 Abstract

The lack of mobility makes it hard for handicapped people to take part in the everyday life of today's society and for a lot of tasks, external help is needed. This lack of independence can put people offside and costs a lot of money for additional care. Consequently, the goal of this project is to build and evaluate a control method for a robotic arm based on surface electromyography (EMG) signal of the human arm, where the user can move the robot with muscle contractions. Through experiments which test the accuracy and efficacy of the system, it could be evaluated that the user is able to reach different points and areas in a single line with increasing accuracy after multiple tries and in the centimeter scale.

2 Background

Being able to control a robot arm by muscle contraction can be useful for people with disabilities to regain their independence as well as for the industry for unusual, human-like processes. The main limitation of such a human-robot system is its efficacy and accuracy and to find an intuitive way of input and match the natural capabilities of the human body. This paper tries to tackle these limitations and contribute to their solution.

In 2013, a specific interface enabled to control a pick and place robotic arm in real time using the EMG signals acquired from the forearm of the user. The EMG signals were acquired with the help of surface electrodes attached to the user's skin. By extracting the required features from the signals the arm is controlled. Finally, it was found that muscle fatigue or adjustments of contraction level were the most important factors in controlling the robot[1]. In 2020 Minjie Chen et al.[2] obtained the EMG data from the forearm of a user, extracted the features, classified and identified the gestures by using the SVM (Support Vector Machine) algorithm and then transmitted them to the robot, controlling its movement. The experimental results show that the system's overall gesture recognition accuracy rate can reach up to 90 percentage. It realized the real-time interaction between human and robotic arm, which proved the feasibility of using surface electromyography signals to control the robotic arm and control external equipment for other physiological electrical signals in the future. However, because the EMG signal is easily affected by factors such as muscle fatigue and sweating, the recognition results were unstable, and the operator needed to maintain a posture for a long time to continue force exertion, which is poor in experience. Hussein F. Hassan et al.[3] used a similar method, but additionally used the LDA (Linear Discriminant Analysis) and K-NN (K-Nearest Neighbor) to classify the seven hand movements they used. The research group around Arlene John [4] used three different muscles of the upper arm to control a robot. Recently, another project with innovative performance was done by Mingxing Lyu et al[5]. The motivation behind this paper was that the existing robotic devices for rehabilitation were expensive, technologically complex and had a low training intensity. They used the signals of an easy-to-do EMG sensor, processed it using a Kalman filter to then control the exoskeleton autonomously. They also newly designed a game to motivate the patients during rehabilitation to improve their recovery. Furthermore, they discovered that the time lag of the EMG signal could be significantly reduced by using a Kalman filter.

The contributions of this paper are the building of a prototype system that converts EMG signals into a robot arm movement and the evaluation data that shows that it is possible to control a robot arm in a straight line in both directions. The system was tested for its accuracy and efficacy by setting up multiple targets to reach. It was found that the system could reach the targets in under a minute with a precision in the centimeter scale.

3 Design

3.1 Hardware

The system used in this project consists of an EMG acquisition instrument and a robot. The former is the open-source OpenBCI ganglion board with a sampling frequency of 1kHz. The EMG data obtained by the acquisition module in packaged and is then sent to the PC through a Bluetooth dongle for analysis and processing. The device is powered by four 6V AA batteries pack and snap electrodes.
The robot arm used in this project is the Niryo One, a collaborative and open source 6-axis robot. For communication with the robot, a TCP client is used on top of the Python API.
The input system consists of the EMG electrodes, which are applied before and after the muscle. Additionally, a ground electrode is applied onto a part, where there is no action potential. In this case, this electrode is stuck to the elbow.

3.2 Software

The connection to the OpenBCI Ganglion board is made through the OpenBCI graphical user interface (GUI) and a Bluetooth dongle. The acquired EMG data from the board is streamed using a lab streaming layer (LSL) from GUI and processed in Python. Initial processing, which includes a 50HZ Notch filter and a 5 - 50 Hz bandpass filter, is already done in GUI.
The interface used between the robot and computer is called Niryo One Studio, which can be used for direct motion control of the Niryo One robot. This tool was only used in the beginning of the project, but was not for the evaluation part as the connection to the robot was conducted directly through the python script.
The biggest part of the project was the design of the python code that connects the EMG signal and the robot arm movement. The code can be reviewed on the following github page [7].

4 Evaluation

To evaluate the system, two tests were made to measure the accuracy and efficacy. They were performed three times on one person. The threshold to detect a muscle contraction was determined before the evaluation. It was set to 25% [6] of the average maximum value of 20 single contractions done by the test person (For the raw data, see appendix). For every person, this evaluation has to be repeated and the threshold adjusted accordingly.
In both tests, the Niryo is placed onto a table. In front of it, some paper sheets are arranged in a straight line. The tip of the robot arm is set up into the middle (centre point). This point is automatically taken in by the robot arm after starting the code. The movement performed by the robot is limited to the line (2D). The furthest point the robot arm can reach are marked as maximum (25.5 cm to each side measured from the centre point).

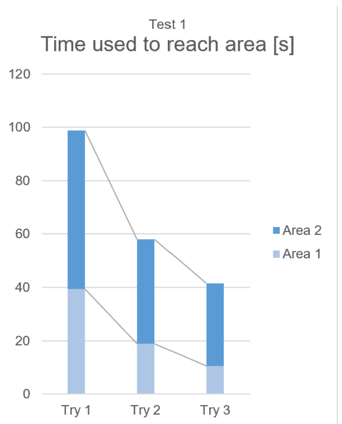

Figure 1: Results for Test 1

Test 1: In the first test, the efficacy of the system is tested. For that, the user has to move the robot arm into two areas each with a width of 5 centimeter. The test subject first has to reach Area 1 marked 17.5 to 22.5 cm into the negative direction from the centre point. Once that area is reached, the robot arm has to be moved to Area 2, 10 to 15 centimetres away from the centre point into the positive direction. The time to achieve this task is measured.
In figure 1 the results are presented. They show a learning curve, as the test person was able to complete the task faster over the course of the testing. Therefore, the efficacy of the robot arm can be improved by getting more used to the system. To determine the "limit of efficacy", further testing has to be made.
Although the time to reach Area 2 was always longer than to reach Area 1, which can be explained by the fact that the distance that needed to be covered was longer too (minimum of 17.5 centimetres vs. minimum of 40 centimetres), the decrease of total time is mostly due to the shorter time used to reach Area 1. The time to go from Area 1 to Area 2 did not change as much, when comparing the results of the different tries.

Test 2: The second testing is done to determine the accuracy of the system. In an one minute time period, the test subject is asked to move the tip of the robot arm as close as possible to an indicated point on the sheets. In ten second intervals, the position of the robot arm is marked (relative to the starting point in the middle of the line). After the time is up, the location closest to the point that the test person was able to reach is extracted as the indicator of the accuracy of the system. This test is performed with two points. Point 1 is marked 11 centimetres into the negative direction, Point 2 22 centimetres into the positive direction.
The results are shown in figure 2. Both graphs show that the test person could get closer, and in some cases even reach the point completely, quicker. Consequently, the continuous work with the robot arm enables the user to control it more precisely.
Comparing the test results from point 1 and point 2, it can be observed that the accuracy for point 2 was much better. The reason for this could be that the muscle that steers the robot arm to the positive direction (in the direction of point 2) gives a clearer EMG signal than the other arm. Because both arms are used for reaching both points due to potential corrections, this conclusion is only a hypothesis. More tests have to be conducted to give a clearer statement.

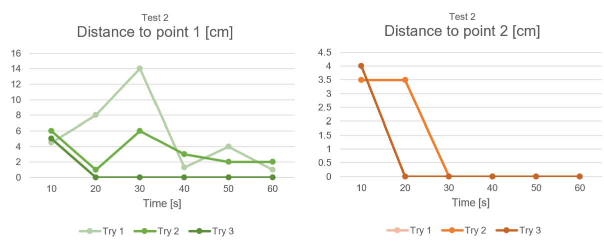

Figure 2: Left: Results Test 2 for point 1, Right: Results Test 2 for point 2

5 Conclusion

The system enables the test person to use muscle contraction, that is collected in a EMG signal to control the Niryo One robot arm with a good real-time performance. With training, both the efficacy and accuracy of the system improved.

6 References

[1] Real Time Control of Robotic Arm Using Electromyogram (EMG) Signals ; Shital B. Sonone1, G. D. Dalvi2.

[2] M. Chen, H. Liu. Robot arm control method using forearm EMG signals. In proceedings of MATEC Web of Conferences 309, 04007, China, 2020.

[3] H. Hassan, S. Abou-Loukh, I. Kasim Ibraheem. Teleoperated robotic arm movement using electromyography signal with wearable Myo armband. Journal of King Saud University – Engineering Sciences 32 (2020) 378–387. Saudi Arabia, May 2019.

[4] A. John, A. E Vijayan, S. AP. Electromyography based control of Robotic Arm using Entropy and Zero Crossing Rate. In proceeding of AIR '15, Goa, India , July 2015.

[5] Development of an EMG-Controlled Knee Exoskeleton to Assist Home Rehabilitation in a Game Context by Mingxing Lyu et al.

[6] Determination of an optimal threshold value for muscle activity detection in EMG analysis Kerem Tuncay Özgünen, Umut Çelik 2 and Sanlı Sadi Kurdak Çukurova University, Department of Electrical and Electronics Engineering, Adana, Turkey

[7] KTH Royal Institute of Technology (2022), Medical Engineering - Project Course , URL https://github.com/KTH-HL2032/MedEng_project_G7