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Electric wheelchair with forward-reverse control using electromyography (EMG) control of arm muscle

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Abstract. Muscle dystrophy can occur in the body's organs of human movements such as the legs, thighs, upper arms, palms and fingers of humans so that the sufferer cannot use limbs. Electric wheelchair is not effective for people with muscle dystrophy disabilities, because users have limitations such as defect of the hands. Given these circumstances, this research proposes an electric wheelchair with controlled by electromyography (EMG) which is placed on the arm muscles. This Electric wheelchair use 2-channel electrodes for sampling muscle signal. This research was conducted in Balai Besar Rehabilitasi Sosial Penyandang Disabilitas Fisik (BBRSPDF) Surakarta, Indonesia. The results of the first grip strength testing are less than 35.8 kgf that indicates weakness of the hand grip. The same thing in the second treatment is a weakness in the handle because of n less than 35.8 kgf. The result of robustness test, spherical movement is not robust with a value 0.756 and. 0.000. The result of cylindrical movement is fully robust with a value 0.001 and 0.000. The result of lateral movement is fully robust with a value 0.000 and 0.000. The result of tip movement is fully robust with a value 0.000 and 0.029. The result of hook movement is not robust with a value 0.109 and 0.000.

1. Introduction

Muscle dystrophy or muscular dystrophy is a disorder that involves the progressive loss of muscle mass and the consequent loss of strength. Myotonic dystrophy can occur in the body organs of human movements such as the legs, thighs, upper arms and human palms, resulting in patients unable to use limbs. Wheelchairs are the best solution to offer easy daily mobility, especially for people with muscular dystrophy or disabilities in upper and lower limbs. Manual wheelchairs are tools that are used by people who have disabilities and weakness in members of the body to be able to move from one place to another. The wheelchair user at least requires one person as an assistant to encourage, this makes it difficult for users independently and easily. Wheelchair operation involving assistants for persons with disabilities is not possible to carry out continuously in daily activities. So, the use of a control system in an electric wheelchair needs to be developed to adjust the user's ability.

Iksal and Darmo's research, has made a wheelchair-using joystick control [1]. The operation of this wheelchair using a lever in the form of a joystick to move forward, turn right and left, and stopping or braking the wheels of his wheelchair. But it is difficult for Muscle Dystrophy users who have limited hand gestures such as defects of the fingers, muscle, or another limb, it will difficult to use it Bima Triwahyu and Eko Research, has made a wheelchair-using Wireless with Equipped Safety Controls EMG Parameters [2]. However, this research uses EMG as a safety parameter in a wheelchair. In research Choi and Sato, an electric wheelchair controlled using EMG sensors on the neck and arm muscles user is created [3]. However, this wheelchair only uses 2 channels to move forward and backward. Because an application of EMG sensors is still limited, so in this research is the development of EMG sensors as motion control. This research can be further developed in developing control systems in electric wheelchairs and will develop Electric Wheelchair using Electromyography approach. EMG is a method for measuring, monitoring, and analysing each electrical signal using various types of electrodes. Muscle electrical signals can be obtained by designing EMG electrodes placed on the surface of the skin in the muscles taken by the signal data. EMG sensors will detect contractions in the arm muscles. the captured muscle signal will be received in the form of an analogue signal and will be converted into a digital signal using Arduino ATMega 328p. This processed signal will be translated as a back and forth movement in a wheelchair. Wheelchairs will be driven using a dc motor that will rotate according to the amount of signal captured. The wheelchair will move forward when the biceps muscle is active, moving backward when the biceps muscle is flexor.

2. Methodology

2.1. Electromyograph signal
An electromyography detects the electrical potential produced by muscle cells when contracting this cell, and also when the cell is stationary. An electric source is the potential of the surrounding muscle membrane - 70mV. EMG measured potential coverage between less than 50 μV and above 20-30 mV, depending on the muscle observed. [4] Measurements on the surface electromyogram using the electrode surface whose value depends on the amplitude, time and frequency. The surface electrode is disposable which consists of a metal electrode made of Ag-AgCl, electrolytes, and adhesives to stick to the skin surface [5].

2.2. Placement of electrode
In this Research, the electrode will be placed on wrist flexor muscles, wrist extensor muscles, shown in Figure 1. When the user's muscles are active, the muscle will produce a high potential difference that can be used as a parameter wheelchair direction of motion [6].

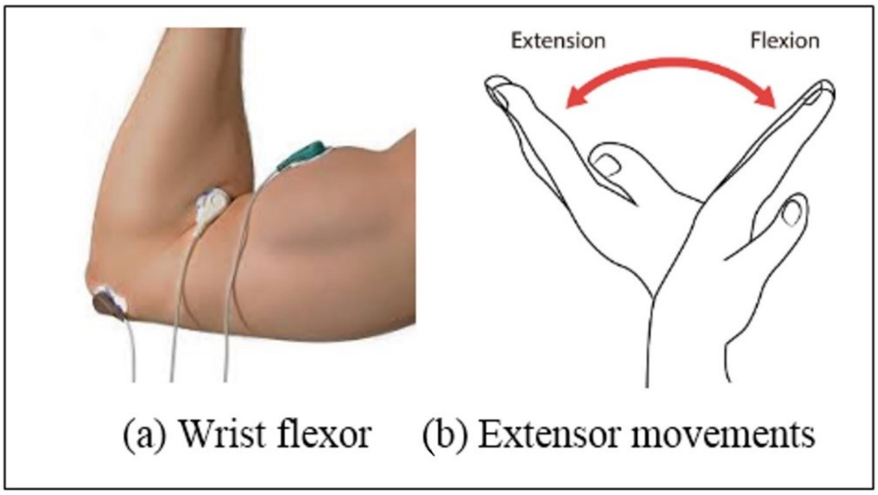

Figure 1. Placement of electrode.

2.3. Signal conditioning using muscle sensor
The sequence of the signal conditioning circuit in this research is shown in Figure 2. This research use myoware muscle sensor to receive muscle signal and then forwarded to ATMega 328p Arduino for processing the analogue signal into a digital signal.

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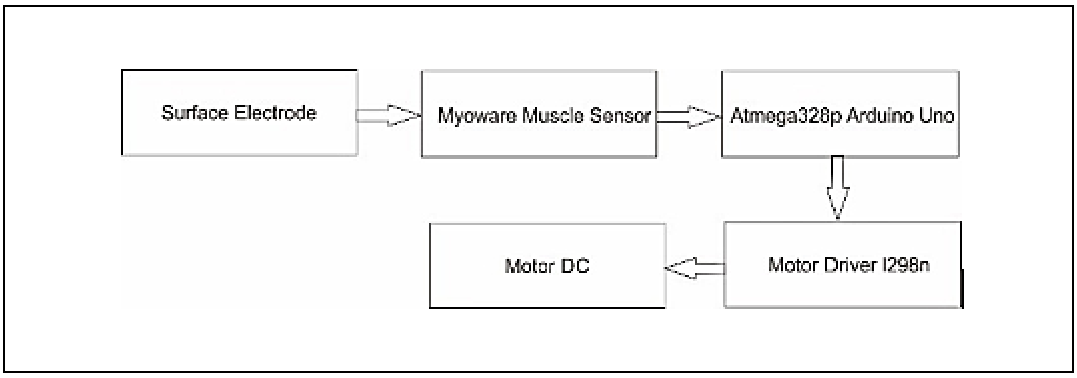

Figure 2. EMG signal conditioning.

2.4. Functional block system diagram

From Figure 3, explained what tools and materials will be used in designing a wheelchair control system. To map the movement of the arm muscles become wheelchair movement, the required potential difference is read by electrodes. ATMega 328p Arduino as a signal processing microcontroller that is forwarded to the motor driver as shown in Figure 3 and Figure 4.

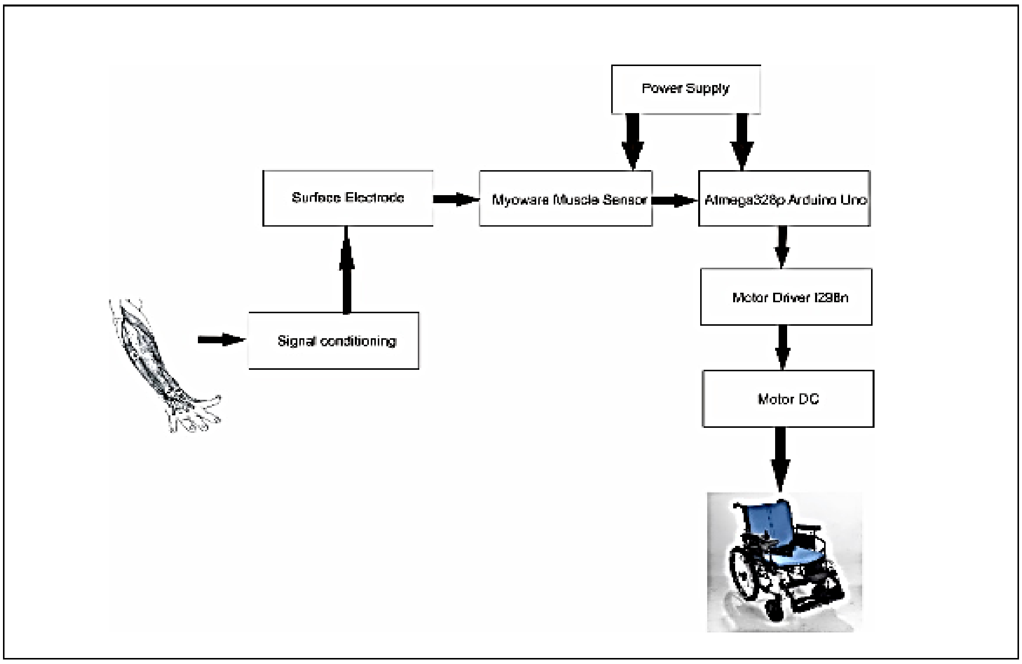

Figure 3. Functional block system diagram.

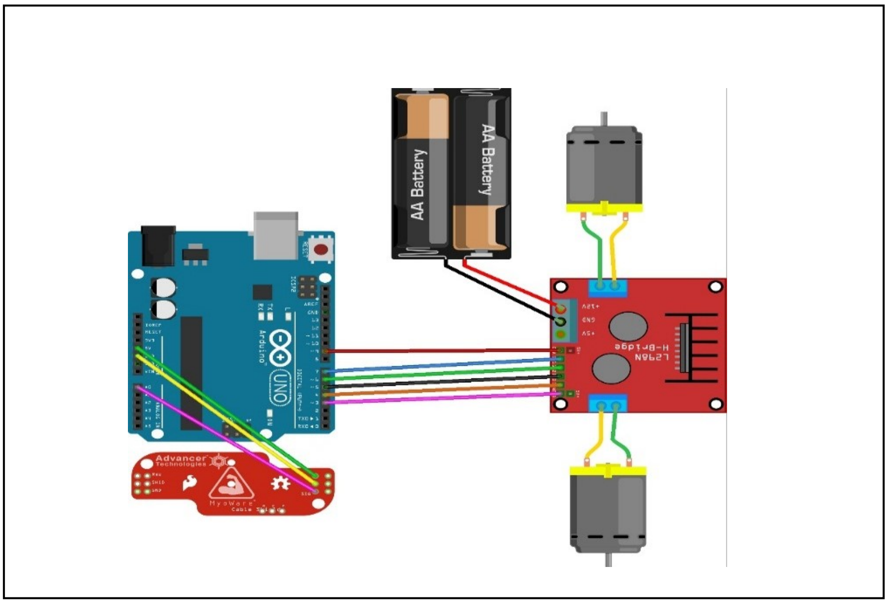

Figure 4. Implementation design of EMG wheelchair control.

2.5. Robustness test on EMG signal
After retrieving muscle signal data to the research subject. a digital signal that has been captured by Arduino ATMega 328p will be stored and then the robustness test is performed. robustness test conducted on 2 treatments carried out by the subject of the study. This test aims to determine how reliable the control system is to be developed and which treatments can be read well by the sensor.

The robustness test is divided into two statistical tests. The first statistical test is a normality test to find out whether the digital signal data can be processed or not. After that, a paired t-test was conducted on 2 treatments that had been carried out on the subject of the study. This test calculates the difference between the value of two variables for each case and tests whether the average difference is zero.

3. Results and discussion

3.1. Result of hand grip test for signal conditioning
Grip Strength is the force applied by the hand to push or stress the object with a gripping motion. The griping movement, helped by the arrangement of the triceps and biceps muscles that work in the opposite direction. This test is done using a handgrip dynamometer. this test is needed to determine the parameters of the research subject. The test results are in the form of how strong the respondent's strength is in testing the handgrip. Strength indicator in the handgrip test based on gender, age, body position, left-handed or right-handed on the research subject.

Handgrip testing was carried out on 6 research subjects. Testing was carried out with 2 different treatments for each research subject. In the first treatment, the subject sits upright with the hand position hanging. The second treatment, the subject in a sitting position perpendicular to the position of the hand forms 90 degrees.

The research subjects consisted of men and women aged 24 years, given treatment by carrying out an upright sitting position on the chair, the position of the hands forming a 90-degree angle placed on a flat plane. The man weighs 48 kilograms and has a history of muscular weakness, whereas the woman weighs 39 kilograms and suffers from muscle weakness in the wrist. In the first treatment, we found a weakness in the handle because of $n < 35.8$ as shown in Figure 5. The same thing in the second treatment is a weakness in the handle because of $n <35.8$ as shown in Figure 6.

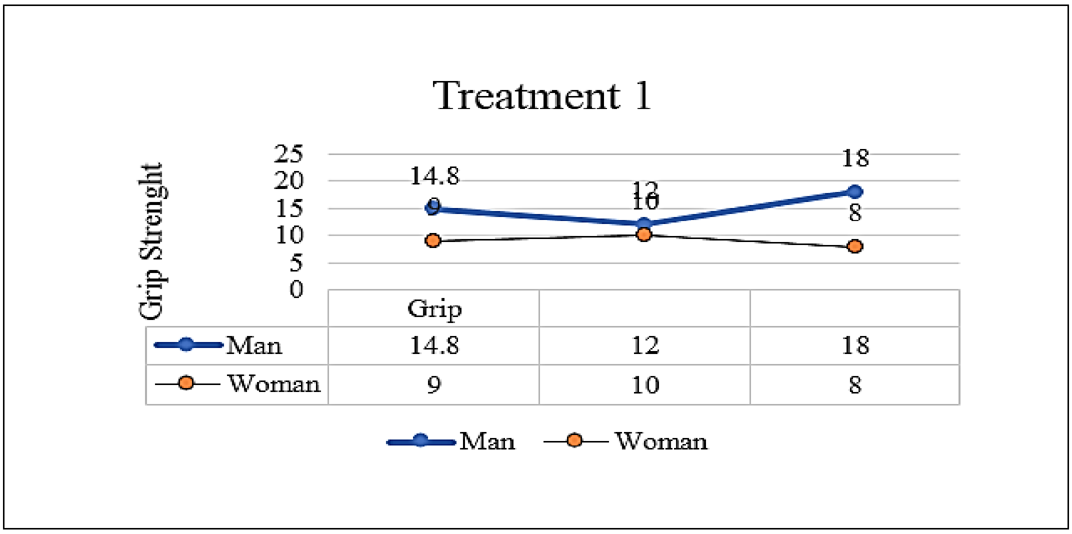

Figure 5. Graph of the treatment grip strength.

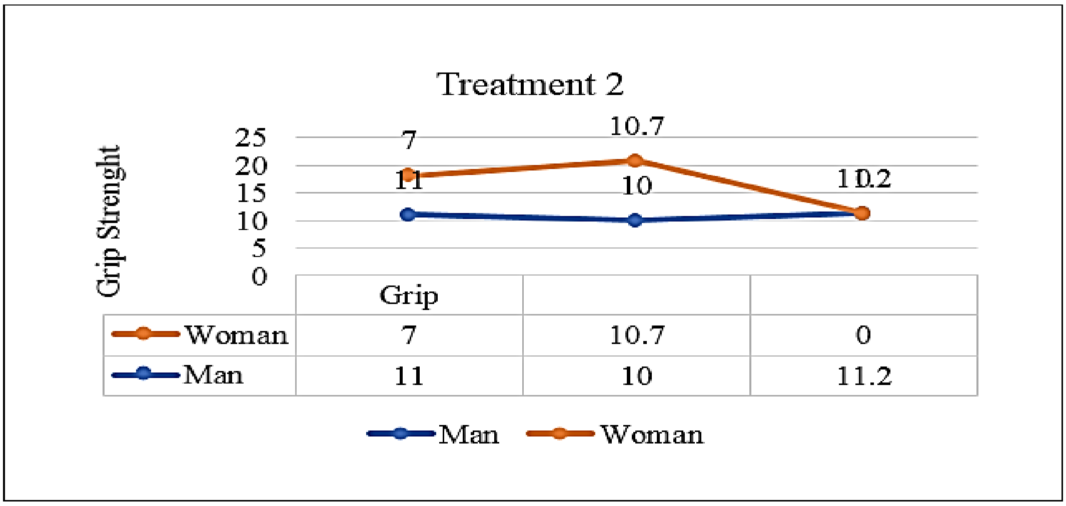

Figure 6. Graph of the second treatment grip strength.

3.2. Robustness test

Data obtained through the basic grips, namely the power grip and precision grip consisting of spherical grasp, cylindrical grasp, lateral grasp, tip grasp, and hook grasp. The spherical grasp movement is carried out where the respondent grasps a shaped object with a diameter of 45 mm. Cylindrical grasp, the respondent was asked to do a grasping motion on a cylindrical object with a diameter of 30 mm. Lateral grasp is a grip that is done for thin-sized objects, to do this type of grip the respondent is asked to hold the card with dimensions of 70×50×3 mm. Grasp tip is a grip with the type of precision grip, respondents are asked to pick up small objects with dimensions of 3×5×5 mm.

The last grasping motion is a grasping hook, respondents are asked to make movements such as braking movements on a motorcycle, to simulate this, respondents are asked to grasp the grips on the hand gripper and the object diameter is 20 mm. Each type of movement is repeated thirty times, after which the respondent is given a rest for two minutes, then the respondent is asked to make a grasping motion until the respondent feels tired. After that, respondents were given a ten-second break for the power grip type and five seconds for the precision grip type. Then the respondent grasped for thirty repetitions. Respondents were given a break of three minutes before taking their next grip measurement.

Table 1 presents a recapitulation of the normality of signal data tests for respondents 1. In table 1 it can be seen from the 5 parameters that have been calculated that there are all parameters whose data are normally distributed, this is known from the significant value that is greater than the alpha value. So, these data can be further processed for robustness tests.

Table 1. Recapitulation of normality test 1.

Parameters	1	df	Significant	Decision
Spherical Grasp	0.05	30	0.214	0.013
Cylindrical Grasp	0.05	30	0.232	0.000
Lateral Grasp	0.05	30	0.134	0.655
Tip Graspg	0.05	30	0.142	0.001
Hook Grasp	0.05	30	0.223	0.696

Table 2 presents a recapitulation of the normality of signal data test for respondents 1. In Table 2, it can be seen from the 5 parameters that have been calculated that there are all parameters whose data are normally distributed. This is known from the significant value that is greater than the alpha value.

Table 2. Recapitulation of normality test 2.

Parameters	df	Significant	Decision.
Spherical Grasp	30	0.152	0.013
Cylindrical Grasp	30	0.232	0.000
Lateral Grasp	30	0.141	0.655
Tip Graspg	30	0.120	0.001
Hook Grasp	30	0.203	0.696

Table 3 presents a paired t-test recapitulation of signal data for respondents 1. In Table 3, it can be seen from the 5 parameters that have been calculated that there are 3 parameters whose data are significantly changed. This is known from the significant value that is greater than alpha (df) value. Significant means that this movement is reliable and can be used as an input to the control system. And there are 2 parameters that not robust just because has a significant value > 0.005.

Table 3. Recapitulation of paired t-test 1

Parameters	df	Significant	Decision.
Spherical 1 Spherical 2	29	0.756	Non Significant
Cylindrical 1 Cylindrical 2	29	0.001	Significant
Lateral 1-Lateral 2	29	0.000	Significant
Tip 1 Tip 2	29	0.000	Significant
Hook 1 Hook 2	29	0.109	Non Significant

Table 4 presents a paired t-test recapitulation of signal data for respondents 2. In Table 4 it can be seen from the 5 parameters that have been calculated that there are all parameters whose data are significantly changed. This is known from the significant value that is greater than the alpha value.

Table 4. Recapitulation of paired t-test 2.

Parameters	df	Significant	Decision.
Spherical 1 Spherical 2	29	0.000	Significant
Cylindrical 1 Cylindrical 2	29	0.000	Significant
Lateral 1-Lateral 2	29	0.000	Significant
Tip 1 Tip 2	29	0.029	Significant
Hook 1 Hook 2	29	0.000	Significant

3.3. Discussion

From the results of research and data processing, it is known that the value of the type of movement of each subject is in a range of different frequencies. From the results of data processing, it is also known that spherical parameters are fully robust to the treatment given. This is known through the results of paired T-tests conducted on each subject between parameters with a value obtained of 0.756 for respondents 1 and 0.000 for respondents 2. Likewise, with the results of cylindrical data processing. From the results of data processing, it is also known that cylindrical parameters are fully robust to the treatment given. This is known through the results of paired T-tests conducted on each subject between parameters with a value obtained of 0.001 for respondents 1 and 0.000 for respondents 2. Then, on the type of lateral data processing are fully robust to the treatment given with a value obtained of 0.000 for respondents 1 and 0.000 for respondents 2. On the type of Tip data processing are fully robust to the treatment given with a value obtained of 0.000 for respondents 1 and 0.029 for respondents 2. On the type of Hook data processing are fully robust to the treatment given with a value obtained of 0.109 for respondents 1 and 0.000 for respondents 2.

4. Conclusions

The design of EMG-based control systems with forward-reverse movements can run well and can be relied upon using 3 basic types of grips that are cylindrical, lateral, and tip. The result of the spherical movement is not robust with a value of 0.756 and 0.000. The result of the cylindrical movement is fully robust with a value 0.001 and 0.000. The result of lateral movement is fully robust with a value 0.000 and 0.000. The result of tip movement is fully robust with a value 0.000 and 0.029. The result of hook movement is not robust with a value 0.109 and 0.000. However, the movement is limited by the threshold amount set to synchronize with the RPM carried out by the DC Motor. Further studies are needed to determine the amount of speed based on EMG parameters and develop the movement directions of the wheelchair.

5. References

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