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Comparison Study of the Transradial Prosthetics and Biological Hand Using Motion Analysis Approach

N.A. Abd Razak, N.A. Abu Osman, W.A.B. Wan Abas and A.N. Ahmad Fu'ad

***Abstract*—This paper presents the comparison study of the motion analysis between the transradial prosthetics and the biological hand that focuses on the supination/pronation and flexion/extension movements. The design of the new transradial prosthetics is based on combining the new approach on both body-powered prosthetics and electric-powered prosthetics. Two servo motors were used to generate the transradial motion while the shoulder ultrasonic sensor functioned as the input for the biomechatronics system. This paper briefly describes the kinetics and kinematics data of motion analyses that focus on the degree of maximum and minimum rotation of each motion. The data analysis of the transradial prosthetics is compared with the biological hand motion.**

***Index Terms*—Transradial prosthetics, motion analysis, servo motor, ultrasonic sensor.**

I. Introduction

PROSTHETIC hand has different criteria with multiple functions and configurations. Transradial prosthetic hand, which is also known as below elbow prosthetics, needs to be developed [1]. Transradial prosthetics hand or also known as below elbow prosthetics needs to be well-developed [1]. Nowadays prosthetics is developed more for its function but it is not cosmetically pleasing [2]. Some designs of prosthetics hand aim more in its electronic controller and system rather than the outer part.

Brain computer interface (BCI) used a signal from the brain with the low cost and efficient electronics system [3]. Due to the weakness in the system, many amputees avoided to wear the robotic prosthetics hand because they felt as if they are being controlled by the robot [4].

The combination of the mechanical design with light electronic controller, or better known as biomechatronics, aims in fulfilling the requirements needed by the amputee. The criteria of the design are to focus on two main movements of the transradial system. They are supination/pronation and extension/flexion. These two main movements provide a lot of rotation in the hand movement system. A simple improvement of these two movements can introduce new achievement in the prosthetics field. Basically, this mechanism can be used to perform tasks that involve the movements such as opening a door, holding an object and rotating a steering wheel [1].

The major challenge faced by the amputee is the difficulty to perform several several daily activities such as dressing, feeding, taking bath and cleaning, and some other basic chores [5]. That is why the new design of the microcontroller that uses the sensor is hoped to be able to perform the similar motion and movement of the biological transradial hand.

Wrist flexion and extension movements usually take place when we want to open a door or when we raise our hand. Most people use the flexion movement to a maximum of 80° to 90º and the extension movement to a minimum of 70° to 90º. These degrees are the maximum and the minimum extensions, respectively, to which the tasks can be done during wrist flexion and extension movements. If we want to have higher degrees of the movements, then other aspects need to be considered such as finger and elbow extension and flexion [2].

The most important part of the hand is the arm and its rotation movement. This part is known as transradial part [6]. The transradial part consists of the ulna bone that is used to

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N.A. Abd Razak is a postgraduate student with the Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, Malaysia. (phone: 603-7967 7629; fax: 603-7967 4579; e-mail: nas_role85@um.edu.my).

N.A. Abu Osman is an associate professor with the Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, Malaysia. (e-mail: azuan@um.edu.my).

W.A.B. Wan Abas is a professor with the Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, Malaysia. (e-mail: drirwan1@gmail.com).

A.N. Ahmad Fu'ad is a postgraduate student with the Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, Malaysia. (email: nazmi@um.edu.my).

support the arm for the rotation to take place. The rotation of the arm operates based on what is known as the pronation/supination movement. Supination is the rotation of either the forearm or the foot. Supination in the forearm occurs when the palm faces interiorly or faces up. This action is performed by the biceps brachii and the supinator muscle. The supination is the opposite of pronation

In this study, the methodology of 3-D kinetics and kinematics measurements were applied to analyse the different characteristics of the transradial prosthetics and the biological hand motion. The Vicon system was used in this study to obtain the data. The study mainly focuses on the pattern of degree of rotation between the prosthetics and the biological hand.

II. Methodology

The prosthetic arm basically uses ultrasonic sensor to transfer any motion detection data to the microprocessor and microcontroller-based system as the input data. The ultrasonic sensor is one of the most accurate and reliable measurement tools to determine human motion intensity [8]. An ultrasonic sensor uses the transmitted and received wave to get the reflection of any motion within 0-15 cm. The sensor is attached to the amputee's shoulder to replace the tension cable in body-powered prosthetics [12]. The full figure of the mechanism is shown in figure 1. Instead of using only motion detection, the patient does not have to worry about training his muscle movement to operate the system as compared to the body-powered tension cable prosthetics.

The sensor that functions as the input will then generate the data into the microcontroller system that is placed inside the transradial part. This part of the transradial also consists of two servo motors that operate as the replacement of motion of the extension/flexion and supination/pronation movements. The servo motor also has its degree of rotation limit similar to the transradial movement of the biological human hand. Servo motor is able to generate a maximum of 30 Nm of torque, which is greater than the required power to do daily tasks that usually need only around 10-30 Nm [1]. Servo 1 can generate the pronation/supination movement while Servo 2 is used in flexion/extension movement. The power supply for the system comes from the 9 V battery that is well-known because it is very light in weight and long lasting.

The experiment to test the capability and the similarities of the prosthetic hand with the biological hand was conducted at the Motion Analysis Laboratory, Department of Biomedical Engineering in University of Malaya. Eight cameras of Vicon motion analysis system were used to collect and analyse the movement data from one transradial prosthetics user. The subject was a 57-year-old man who suffered from congenital defect on his left arm. The transradial prosthetics only covered 40% of the length of his defective hand. He had already worn the body-powered prosthetics for about 12 years and had already changed it twice due to the increment of the size and weight of his body. 16 spherical reflective markers were placed from his lower limb till his shoulder, transhumeral, and transradial. The markers were placed on the body and the parameter of each segment was collected, namely the shoulder depth, elbow width, wrist circumference, and hand thickness. The kinematic model that covers the upper limb and lower limb was created using the Vicon bodybuilder software and the upper limb joint angles were calculated [1].

The subject completed four simulated transradial basic movements, which are the pronation, supination, flexion and extension. For the extension/flexion movement, the subject was asked to use the transradial prosthetics and move from the initial position and to the final position. The maximum and minimum were based on the degree of rotation. The subject repeated the task for three times with the transradial prosthetics and then the results were compared to the other hand movement. Basically, the subject was asked to do each task separately, such as moving the flexion from the initial position until the maximum position. The procedures for the supination/pronation movement were also the same and the results were recorded in the Table 1 and in the graph in Figures 3 and 4.

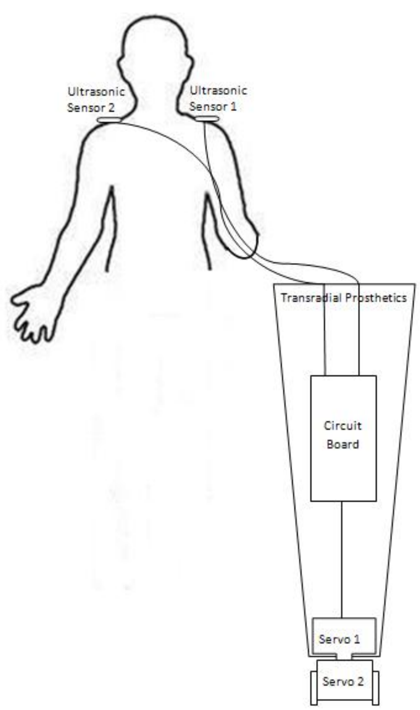

Fig. 1. Structure of the new transradial prosthetics system.

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III. Results and Discussion

All of the trials for each task were normalised and averaged as stated in Table 1. The table simplifies the results by taking the relevant values and the average of maximum, minimum and range of each motion of the transradial movement. A problem occurred at the marker that was placed at the wrist as the position was only marked with one marker and the degree of rotation may change its reliability. While doing the flexion movement, the range of normal hand motion is 20.7º in average, while the prosthetics gave a result of 22.9˚ in average. The maximum degree of the flexion movement of the hand is usually 85-90º but the value depended on how we stretch our muscle to reach that position [2]. The degrees of rotation for extension movement for normal hand and prosthetics hand were about 57º and 41º, respectively. The transradial prosthetics gave lesser value due to the decreased capability of the servo motor after several tests but the degrees obtained were already enough to do daily tasks that involved the extension movement (see figures 2 and 3). These two extension and flexion movements show that the requirements to do daily tasks such as opening a door or filling a cup can be achieved.

For the pronation movement, the degree of rotation of the prosthetic hand was about 55.7º, which is almost the same with the biological hand, 50.4º. The pronation movement for the daily task can go to the maximum degree of rotation of 85º-90º. Even though the requirement is higher, the degree of rotation of the biological hand in doing daily tasks and the degree of rotation of the prosthetics hand were quite similar to each other. The supination movement usually takes only about 50-55º of degree of rotation to do the daily tasks, which is similar to the degree of rotation for the biological hand, which is about 50º of degree of rotation. But, the transradial prosthetics showed higher degree of rotation that almost achieved the target, which was 89.3º at the maximum degree of rotation.

The results for biological hand gave general rotation to do daily tasks as the subject did not even stress his muscle up to give the maximum degree of rotation. But, the values collected by the Vicon motion analysis were reliable to do the common tasks in daily life. On the other hand, the prosthetic hand gave greater degree of rotation to do the daily tasks. Some of the results showed lower degree of rotation. This was due to the lack of power source after doing several trials. It also depended on the servo motor rotation because the motor needed to have its own moment of inertia to generate a motion. The degree of rotation also depends on the programming system of the microcontroller and also on the capability of the motor. However, the objective to produce a transradial prosthetic hand that shows similar capability like normal hand has been achieved.

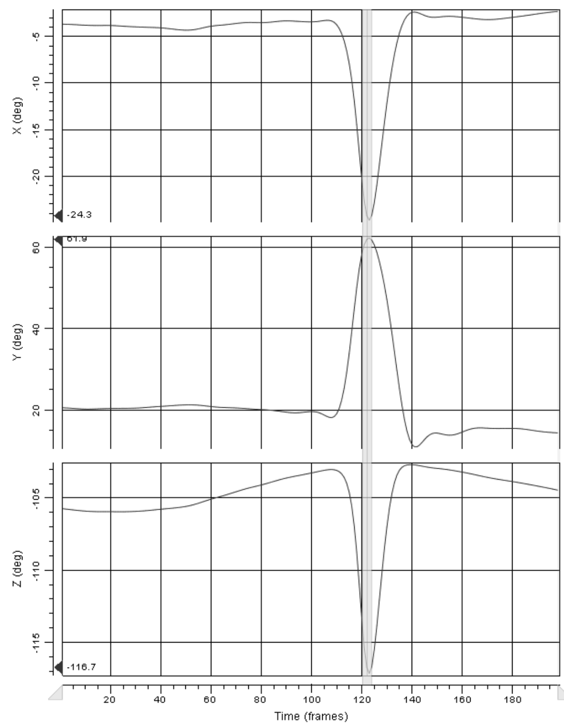

Fig. 2. Extension motion analysis of the prosthetics.

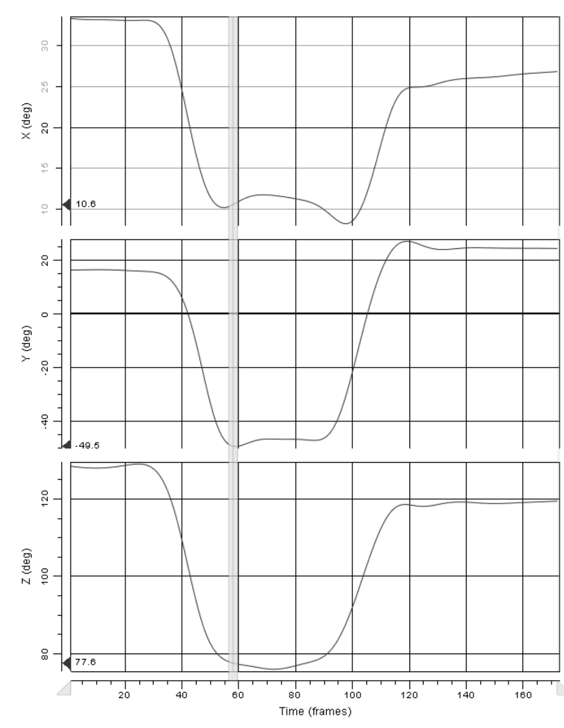

Fig. 3. Extension motion analysis of human.

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TABLE 1
THE MAXIMUM, MINIMUM AND RANGE OF MOTIONS (IN DEGREES) DURING EACH TASK

Type of Motion	Maximum Degree (normal)			Minimum (normal)		Degree	Range	Maximum (prosthetics)		Degree	Minimum (prosthetics)		Degree	Range
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3		Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	
Flexion	51.4	34.7	146.7	31.9	22.9	125	20.7	18.7	32	-124	-2.7	19.2	-104	22.9
Extension	-38	-31.1	-73.8	-11.2	26.2	-131	57	-24.7	62	-117.1	-3.6	20.5	-105.7	41
Pronation	9.4	2.6	-124	11.1	-5.6	-68.6	55.7	-24.4	4.7	-70.6	-10.5	28.5	-121.1	50.4
Supination	10.2	-47.2	78.4	33.2	16.2	128.4	50	-29.2	17	-28	-7.2	15.8	-117.4	89.3

IV. CONCLUSION

The objective to design a transradial prosthetics that has similar criteria to the biological hand has been achieved. The movement of each part of the transradial prosthetics has also been measured by the Vicon motion analysis and the result showed that the method and the technique were able to reach a new achievement in prosthetics. The methodology of using motion sensor to replace the body-powered technique has also been successfully achieved besides the minimum requirements to do basic movements namely pronation/supination and flexion/extension movements that have similarities with the biological hand.

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