Design and Construction of An Artificial Limb Driven by Artificial Muscles for Amputees

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Abstract

This work constructed an artificial limb equipped with artificial muscles or braided pneumatic actuators to drive an artificial limb for a patient who lost their arms. The idea was inspired by the human arm muscular system, which are the biceps brachii muscles and triceps brachii muscles. This artificial limb simulated the elbow joint movement. There are two artificial muscles arranged on the artificial limb similar to human arm muscles. A pair of artificial muscles was then lie in opposing pairs similar to the biceps brachii and triceps brachii in human muscles. The test was performed on an amputee wearing this artificial arm and perform simple tasks such as picking up objects, drinking water. The artificial arm movement is controlled manually by the foot-switch from the amputee. The patient has given good satisfactory for this artificial limb.

1. Introduction

People who had high-level arm amputations have very limited manipulation more than people who had lower-level arm cut off. Consequently these people have difficulty in living without artificial arm [1]. As seen in Figure 1 shows a person who lost two forearms trying to drink a glass of water with difficulty. There had been a number of studies in prosthetic arm such as in simulation of human arm movement [2].

Figure 1: A person with two forearms cut off trying to drink a glass of water with difficulty

2. Human Arm Muscular System

The human motion system consists of brain systems, nervous systems and muscle units. To create movement in human, the brain systems release the impulse signal. The signal is then sent through nervous systems. The muscle unit that is stimulated by the impulse from the nervous systems is then contract and cause the movement. In order to keep the equilibrium of motion, two groups of muscles have to function in opposing pairs which are flexor groups and Extensor groups. The Flexor groups are biceps brachii muscles, which located on the front part of the upper arm. The biceps brachii Muscles cause the flexion in human arm. The Extensor groups are triceps brachii muscles which lies on the back side or lower side of the upper arm. The triceps brachii muscles create the extension of the human elbow. [3,4]

The position of muscles is the important points for muscle function. The muscles lay down in the line of humerus bone. The position of biceps brachii muscles is anterior to the bone and insert in front to fulcrum point which give the elbow flexion function. The position of triceps brachii muscles is posterior to the bone and insert back to fulcrum point which provide elbow extension [5]. The human arm muscular system is shown in Figure 2 as in neutral position or as the forearm is perpendicular to the upper arm.

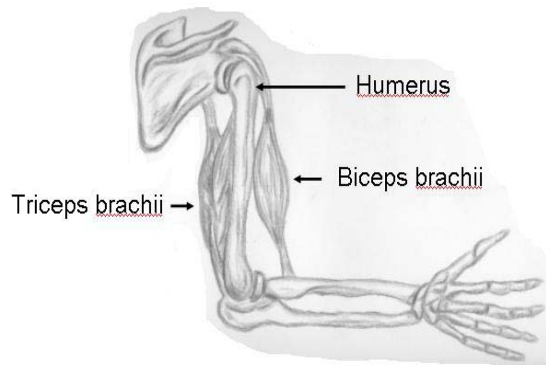

Figure 2: Human Arm Muscular System

3. Artificial Limb Design and Construction

The design of the artificial limb was inspired by the human arm muscular system which consists of two groups of muscles: flexor and extensor groups. These pairs of muscles are also attached in opposing pairs to the aluminum flat bar similar to humerus bone in human arm. The artificial limb construction is shown in Figure 3.

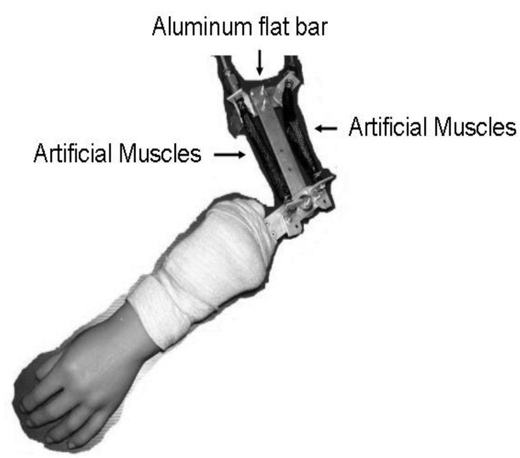

Figure 3: An artificial limb with artificial muscles

As the artificial muscle in the front contracts or on the left as shown in Figure 3, it causes flexion of the artificial forearm. In contrast when the artificial muscle in the back or on the right as shown in Figure 3 contracts, the artificial forearm extends. This movement is similar in the forearm movement in human arm.

4. Control of Artificial Arm Movement

At this stage, the control scheme for the artificial arm movement is the feed forward control. No feedback position angle from the arm is required because the movement is manually controlled by the person who wears it. To control the movement, the foot-switch receives the signal from the wearer. The switch then send the command signal to the control unit. The control unit then send out the voltage approximately 4-6 volts to control the pneumatic valve which supplies the right amount of compressed air to inflate the artificial muscles. The computer processes the control scheme along with the control unit. The diagram of the arm control is shown in Figure 4.

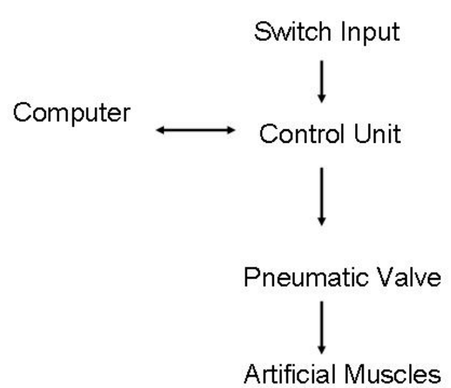

Figure 4: A diagram of the artificial arm control

The control unit hardware interfaced with the computer via the parallel port. The control program is written in C language. The control unit has an IC number LTC 1661, which is 10-bit digital to analog converters (DACs), to convert digital signal from computer to analog signal and then send the voltage in analog to the pressure regulator or pneumatic three-way valve. The valve then open the air into the muscle on one side according to the voltage signal. The foot-switch works upon the time period in holding foot-switch by the wearer. For example, the wearer holds the foot-switch long, the range of movement of the arm will become large but limited to the shortest range of contraction of the artificial muscles.

5. Experiment and Result

The flexion angle was measured when the artificial muscle in the front was inflated by the compressed air approximately 3 bar. The flexion angle was measured in about 45 degree similar to the extension angle is -45 degree from the neutral position as shown in Figure 2. The range is about 90 degree for total of flexion-extension angle. This result has been compared to the human arm movement at the range of motion of the flexion-extension which is about 150 degrees measured from the stretched arm in flexion [7].

In clinical application, an amputee wears the artificial limb prosthesis. The patient can control elbow motion by foot switch and can be trained for drinking a glass of water within thirty minutes training. He can also use this artificial limb lifting the weight of approximately 5 kg.

6. Conclusions

The artificial limb has been successfully constructed by the inspiration from human arm muscular system. The artificial limb was tested with an amputee and the patient has been able to perform simple tasks such as picking up objects, drinking a glass of water. The patient has been satisfied with the artificial limb which can be controlled manually by the foot switch. For clinical application, the amputee has been trained to use this artificial limb or prosthesis with approximately thirty minutes at a time.

References

[1] Atkins, D. J. Adult Upper-Limb Prosthetic Training, Comprenhensive Management of the Upper-Limb Amputee, Eds. D.J. Atkins and R. H. Meier, Springer-Verlag, New York, 39-59, 1989.

[2] Hungspreugs, P. , Heckathome. C. W., and Childress D. S. "Computer Simulation Tool for Upper-Limb Prosthesis Design", Proceeding of the 22nd Annual EMBS International Conference, Chicago, IL, July 23-26, 2000.

[3] Van De Graaff, Kent M. Human Anatomy updated 5th ed. Mc-GrawHill 2000.

[4] Morrey, B. F., Askiw, L. J., An, K.N., and Chao, E.Y.A.: Biomechanical Study of the Normal Elbow Motion. J. Bone Joint Surg, 63A: pp872-877, 1981.

[5] Agur A.M.R. Grant's Atlas of Anatomy, 9th ed. Baltimore, Maryland Silliams & Wilkins, pp 398-411, 1991.

[6] Hotchkiss RN. Fractures and Dislocations of the Elbow. In: Rockwood CA. Ir, ed. Fractures in Adults Vol. 1. Philadelphia, etc: JB Lippincott Company, pp. 929-1015, 1996.

[7] S. Laksanacharoen and S. Wongsiri, "Design of Apparatus to Study Human Elbow Joint Motion", The IEEE EMBS Asian-Pacific Conference on Biomedical Engineering 2003, Kyoto-Osaka-Nara, Japan, October 20-22, 2003