DESIGN OF AN INTELLIGENT PROSTHETIC ARM

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ABSTRACT

This paper presents a novel way of developing the intelligent prosthetic arm design. The prosthetic arm consists of two segments which are the forearm and the four fingers. The prosthetic arm's design was based on human arm anatomy. where the artificial muscles are used as the actuators. The four finger movement was driven by the tensile force by four artificial muscles similar to the tendons. The artificial muscles are inflated by the compressed air at pressure 1-4 bar. The Electromyographic (EMG) signal will be used to control the arm movement. The arm will benefit for patients who still have upper arm muscles.

1. INTRODUCTION

The human arm is very complicated and recent research in prostheses has not yet been able to duplicate its fine movement. The SEVEN research group in Sweden designed systems that used the myoelectric signals to control the upper extremity prostheses [1]. The early work of Otto Bock or Variety Village electric hands were found to be too bulky and not easy to use [2].

Generally, prosthetic arms are built with electric motors, where the movements are far from natural. The motors are also more suitable for heavy mechanical systems engineering. Pneumatic technology is capable of soft interactions and compliance [3].

The artificial muscles was first invented by McKibben to help the movement of polio patients in the 1950s. They are also called McKibben muscles or braided pneumatic actuator. They were powered by compressed air [4]. Lately, Klute has constructed lower limb prostheses using artificial muscles to help patients to walk [5]. Recent studies also show interested in the study of human arm motion [6], [7].

The Mechatronics Laboratory at King Mongkut's Institute of Technology North Bangkok has been working in closely with a medical doctor from Prince of Songkla University. The cooperative work has been good for both groups. We have gained valuable knowledge into medical sciences. The medical doctor has been able to use our engineering aspect to help construct medical equipments.

The first prototype of the prosthetic arm had one degree of freedom at the elbow joint demonstrated the simple feed forward control by foot switch as shown in Figure 1 [8]. With the experience from design and construction of the first prototype of prosthetic arm we hope to further develop what we have learned and make an intelligent prosthetic arm.

Fig. 1. The first prototype of the prosthetic arm

In this paper we describe the design of an intelligent prosthetic arm based on human muscular systems. The arm will have the forearm and four fingers driven by artificial muscles. The intelligent prosthetic arm will be able to use the EMG signals to control the movement.

2. HUMAN ARM ANATOMY

In the upper arm, two groups of muscles have to function in opposing pairs (flexor groups and extensor groups) to move the elbow joint. The biceps brachii muscles cause flexion in human arms. The extensor groups are triceps brachii muscles which lie on the posterior of the upper arm [9], [10].

The position of the biceps brachii muscles is anterior to the bone and inserts in front of the fulcrum point, which allows it to create elbow flexion. The position of triceps brachii muscles is posterior to the bone and inserts behind the fulcrum point, which allows it to create elbow extension [11]. The human arm muscular system is shown in Figure 2.

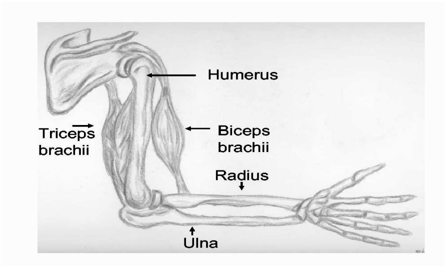

Fig. 2. **Muscles that move forearm at the elbow joint**

In finger flexion movement, there are two major muscles which are the flexor (FL.) digitorum profundus and flexor (FL.) digitorum superficialis. The extensor digitorum communis used to extend the finger as shown in Figure 3.

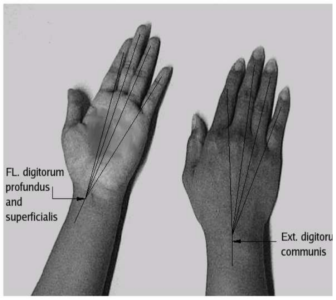

Fig. 3. **Muscles that move the four fingers**

3. ARTIFICIAL MUSCLES

The artificial muscles was used in this work due to its soft movement and high power to weight ratio. Its weight is only 0.2 kg not including the connectors at both ends. The artificial muscles or rubbertuators consist of the inner rubber tube where the natural rubber latex through the valcanizing process have been used. The rubber tube was made by dipping the mould into the rubber latex and dry at room temperature which is around 32 degree of celsius in Thailand.

The outer shell is the braided sleeve. The assembly of the rubbertuator is shown in Figure 4 where one side is the air inlet and the other side is closed end. In this experiment, the diameter size of 20 mm with the length of 120 mm have been tested in the arm.

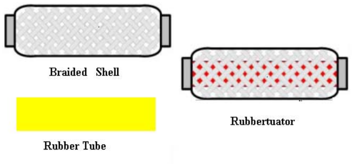

Fig. 4. **Artificial muscles**

When the artificial muscle was infalted by compressed air, it contracts and causes the radial expansion and tensile forces at both ends. The maximum tensile force of this artificial muscle is about 110 N.

4. CONCEPTUAL DESIGN

The arm design at the elbow joint was based on the two muscles installed in opposing pairs similar to biceps and triceps in human. The flexion of the four fingers were pulled by the four artificial muscles similar to the flexor (FL.) digitorum profundus and flexor (FL.) digitorum superficialis. In the extension stroke, the four fingers are pulled by the four pieces of steel measuring tape acting like springs. At each of the fingers, the artificial muscle is basically pulled against the force of a spring which is inserted inside the finger.

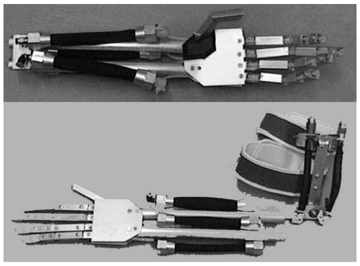

Fig. 5. **Conceptual Design of Prosthetic Arm**

5. CONTROLLER

In human, the motion system consists of brain systems, nervous systems and muscle units. To create movement, the brain releases impulse signals. The signal is then sent through the nervous system. The muscle unit that is stimulated by the impulse from the nervous system then contracts and causes the movement.

This intelligent prosthetic arm will use the Electromyographic (EMG) signal to send the commmand to open or close the pneumatic valves. The schematic diagram of the controller is shown in Figure 6.

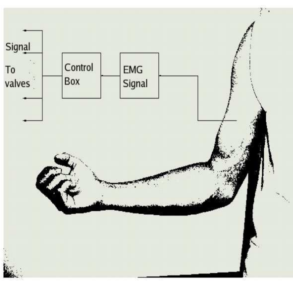

Fig. 6. **EMG signals taken from muscles**

The signal must be processed in the filtering and amplify due to its low in magnitude and noise in the EMG signal. The controller will then transmit the signal to open or close the pneumatic valves to control the artificial muscles movement.

The pneumatic diagram shows one artificial muscle connected via the 3/2 way pneumatic valve by FESTO shown in Figure 7. The artificial muscle functions like the single acting pneumatic cylinder where the same port of the compressed air in and out.

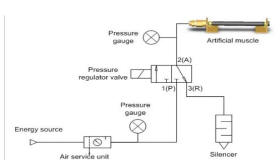

Fig. 7. **Pneumatic diagram**

The feedback sensors will be used if necessary, otherwise the arm will only be controlled by the EMG signals. The arm will stop moving if there is no EMG signal and will start moving again when senses the EMG signal.

6. CONCLUSIONS

The intelligent prosthetic arm is being developed based upon the human muscular systems. Much of the work had been done on manual testing the arm but not yet implemented the EMG signal. The work will continue on taking the EMG signal from human muscle to control the movement of the artificial muscles. The technologies necessary to construct the intelligent prosthetic arm are being developed. The artificial muscles have already been constructed and tested with the first prototype of the prosthetic arm. It was shown that the artificial muscles are sufficient to perform human arm movement.

7. REFERENCES

[1] R. Sorbye, "Myoelectric controlled hand prostheses in children," *Int. J. Rehab. Res.*,, vol. 1, pp. 15–25, 1977.

[2] John G. Webster, Albert M. Cook, Willis J. Tompkins, and Gregg C. Vanderheiden, *Electronics Devices for Rehabilitation*, Chapman and Hall Ltd, London, 1985.

[3] N. Tsagarakis and Darwin G. Caldwell, "Improved modelling and assessment of pneumatic muscle actuators," in *Proceeding of the 2000 IEEE International Conference on Robotics and Automation*, San Francisco, CA, USA, April 2000.

[4] Bertrand Tondu and Pierre Lopez, "Modeling and control of mckibben artificial muscle robot actuators," *IEEE Control Systems Magazine*, pp. 15–38, 2000.

[5] G. K. Klute, J. Czerniecki, and B. Hannaford, "Development of powered prosthetic lower limb," in *Proc. 1st National Mtg. Veterans Affairs Rehab. Research and Development Service*, Washington DC, October 1998.

[6] S. Laksanacharoen and S. Wongsiri, "Design of apparatus to study human elbow joint motion," in *The IEEE EMBS Asian-Pacific Conference on Biomedical Engineering*, The border of Kyoto-Osaka-Nara, Japan, October 20-22 2003.

[7] David W. Franklin, Frances Leung, Mitsuo Kawato, and Theodore E. Milner, "Estimation of multi-joint limb stiffness from emg during reaching movements," in *The IEEE EMBS Asian-Pacific Conference on Biomedical Engineering*, The border of Kyoto-Osaka-Nara, Japan, October 20-22 2003.

[8] S. Wongsiri and S. Laksanacharoen, "Design and construction of an artificial limb driven by artificial muscles for amputees," in *PSU-UNS International Conference 2003*, Prince of Songkla University, Hatyai, Songkla, Thailand, December 11-12 2003.

[9] Van De Graaff and Kent M., *Human Anatomy*, McGrawHill, 5th edition, 2000.

[10] B. F. Morrey, L. J. Askiw, K.N. An, and E.Y.A Chao, “Biomechanical study of the normal elbow motion,” *Bone Joint Surgery*, vol. 63A, pp. 872–877, 1981.

[11] Agur A.M.R. Grant, *Atlas of Anatomy*, Silliams and Wilkins, Baltimore, Maryland, 9th edition, 1991.