The Sixteenth International Symposium on Artificial Life and Robotics 2011 (AROB 16th '11),
B-Con Plaza, Beppu,Oita, Japan, January 27-29, 2011

Some Thought for the Mckibben Muscle Robots

Huailin Zhao[1] Xiaoqing Jia[2] Masanori Sugisaka[3]

[1] School of Electrical & Electronic Engineering, Shanghai Institute of Technology, China

[2] College of Logistics Engineering, Shanghai Maritime University, China

[3] Mec. & Ele. Course, Nippon Bunri University, Japan

Abstract: This paper introduces the background of the research. It summarizes the applications related with robots actuated by Mckibben muscles. Based on the robot joint structure, the robots are classified into two types. The paper indicates that the different modeling methods and the control algorithms are needed to the two types of the robots.

Keywords: artificial suit, Mckibben muscle, Modeling

1. Introduction

How to simulate the human behave and develop humanoid devices has been a hot spot and a difficulty in the robot field for times. As it is thin and light and soft and similar to the biological muscle, the Mckibben muscle has the special advantage for developing humanoid robots when it is used as the actuator to robots. Right just due to its above characteristics, the requirement for its connection to robots is not too high. The connection to robots can simulate the way by which the biological bones and muscles connect with each other in the animal joint. Based on this kind of connection structure and the appropriate control algorithm, the robot can imitate animals much better.

To the robot, in order to complete special tasks, it has to interact with the outer environment. A very important problem is the security, especially when interacting with human such as medical nursing. This means that the robot should keep stable and compliant at the same time when it is carrying out tasks accurately. The traditional robot, consisting of motors or fluid actuators and stiff linkers, is heavy and joint-stiff. So it is not suited to carry out these kinds of tasks, except the very complicated control algorithms are designed. But the McKibben muscle is inherently compliant – just like biological muscles. The robot actuated by it will act easily like animals. It will easily generate soft touching and relative safe operation. And human will feel the robot more like an animal than a machine.

The world should be welfare. The development of the robot capable of assisting elders, handicappeds, and patients is one of the main directions. Developing the devices capable of helping getting well for patients is one of the main tasks of the modern technology. It's expectant for the McKibben muscle to play an important role in these fields. In some places such as Japan, America, and Europe, the artificial assisted suit made of McKibben muscles has come out. The suit is called as "dressable robot". Besides, the bipedal robot actuated by McKibben muscles has been developed too. These artificial assisted suit or bipedal robot can only realize the main actions. They can't perceive the intention of human actions.

Usually, the McKibben muscle consists of an expandable rubber tube and a fiber weave mask. The outer fiber mask expands when the rubber tube stimulated by the pressured gas, pulls its two ends and shortens the McKibben muscle, just like the biological muscle contracts. The weave mesh changes its length and diameter by changing the incline angle. The pulling force F is linear to the gas pressure P and nonlinear to its length L, which can be calculated by formula (1) in which both b and n are the structure parameters. The maximal contraction ratio is usually less than 30%. Fig.1 shows its structure and the simple operation. It can output enough force and keep definite compliantness, so the robot actuated by McKibben muscles is suited to carry out the "environment friendly" tasks such as nursing handicappeds and snatching at fragile goods and so on.

$$F=Pb^2(3L^2/b^2-1)/(4\pi n^2) \quad (1)$$

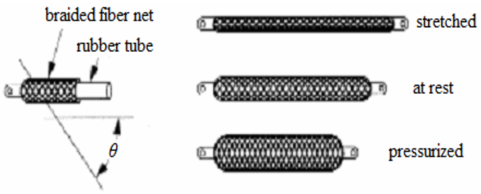

Fig.1 The Mckibben muscle

Our project aims at an artificial suit actuated by pieces of Mckibben muscles. The artificial suit can put on the human upper body including the two arms. Not only it can act like human arms, but also it can perceive automatically the action intention of the human arms and output the intended actions. But how to configure the Mckibben muscles in the artificial suit and how to model and design the control algorithm become the key problems.

2. The applications

There have been many applications about the robots related with our problems. Fig.2 shows the photos of the related robots actuated by Mckibben muscles. Fig.2(a) shows a robot which's arms are actuated by Mckibben muscles[1]. Fig.2(b) shows a bipedal robot designed by Shadow Robot Company which's legs are actuated by Mckibben muscles[2]. Fig.2(c) shows a bipedal robot designed by Oita University which's legs are actuated by Mckibben muscles too[2]. But the connection structure is different from that in Fig.2(b). Fig.2(d), Fig.2(e) and Fig.2(f) show the artificial suit actuated by Mckibben muscles which are designed by Tokyo University of Science[4]. Fig.2(g) shows an assisted device which can help the patient's ankle.

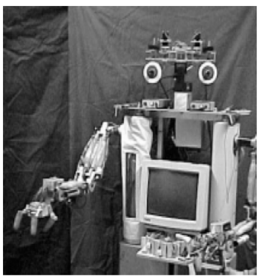

Fig.2(a)

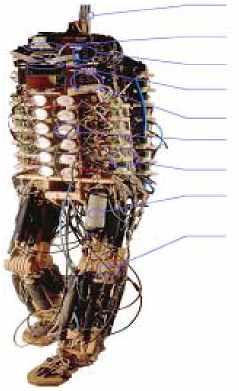

Fig.2(b)

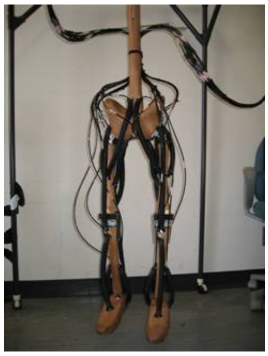

Fig.2(c)

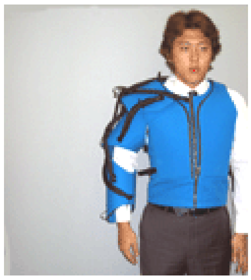

Fig.2(d)

Fig.2(e)

Fig.2(f)

Fig.2(g)

Fig.2 The applications

3. The two types of robot joints

To all the different applications, the structure of the robot joint can be classified into two types on whole. One is the "regular" structure with which two Mckibben muscles parallel to each other in the same size connect with each other by a pulley, such as Fig.2(a) and Fig.2(b). The other one is the "irregular" structure, such as Fig.2(c), Fig.2(d), Fig.2(e), Fig.2(f) and Fig.2(g). Fig.3(a), Fig.3(b) and Fig.3(c) show that the robot joint with "regular" structure can be analyzed as one-input and one-output system. Fig.3(d), which is the configuration of Mckibben muscles in the robot shown in Fig.2(c), can be used to represent the robots with the "irregular" joint structure. Fig.3(e) shows the relationship between the three inputs and the one output. With three Pressure inputs, it can't be simplified as one-input and one-output system.

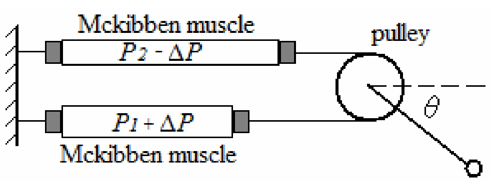

Fig.3(a)

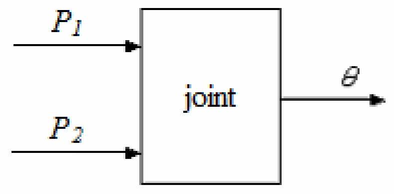

Fig.3(b)

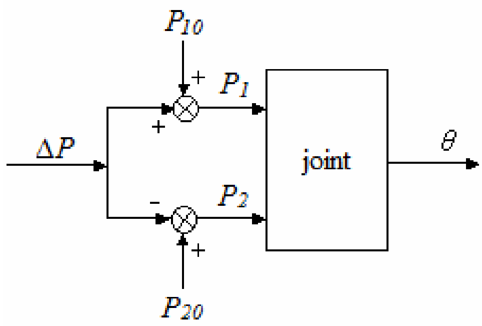

Fig.3(c)

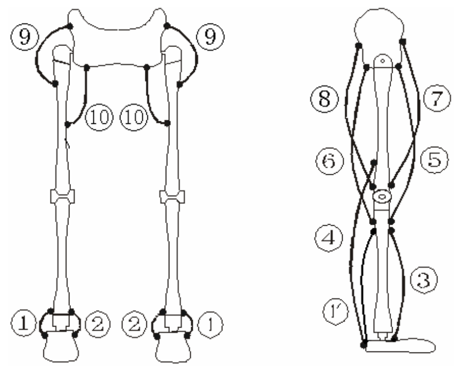

Fig.3(d)

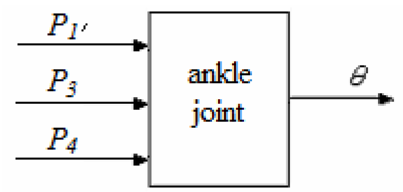

Fig.3(e)

Fig.3 The "regular" structure and the "irregular" structure robot

4. How to model and control the robot

To analyze the robot, the model of it should be established. And to control it, the control algorithm should be designed. To the "regular" structure robot joint shown in Fig.3(a), the pressures of the two McKibben muscles vary relatively instead of independently. At the initial, the two pressures of the two Mckibben muscles are P_{10} and P_{20} respectively. When the joint bends, P_1 increases by ΔP and P_2 decreases by ΔP at the same time. Contrariwise when the joint stretches, P_1 decreases by ΔP and P_2 increases by ΔP at the same time. The change of ΔP leads to the change of both P_1 and P_2 in the opposite direction. In this way the joint angle can be regulated. Therefore the joint system can be considered as a single input (ΔP) and single output (θ) system. At this rate, the system is simplified and the control algorithm for it may be simpler.

But to the "irregular" structure robot, the structure parameters are not "regular". Different from the "regular" structure joint system, there are more than two Mckibben muscles to actuate one robot joint, such as shown in Fig.3(d) and Fig.3(e). The lengths of them are different and they are not parallel to each other. And there is coupling between the neighbor robot joints. So how to model the robot system will be a great challenge.

As to the application shown in Fig.2(g), the robot joint structure can be either "regular" or "irregular".

With the above application examples, the operation to the Mckibben muscles is mainly based on the operation experiences. Few literatures explain their modeling and the related control algorithms.

Anyway, we are going to configure the Mckibben muscles in "irregular" structure. And our project aims at the following:

1. Modeling of the artificial suit physically. The key is the configuration of Mckibbe muscles;
2. Designing the neural network based intelligent control algorithm;
3. Automatic sensing the behaving intention and complete the action rapidly.
4. Realizing the main actions of the human arm.

Based on the literature and the above applications, the elbow joint can bend larger than 100 degrees. The shoulder angle can get to about 90 degree, and so on. Comparing with human[5]. The robot arm joints' rotation angles may be 70-90% of the human's. One of the main reasons is that the contraction ratio of the Mcibben muscle is less than that of the human muscle's[6].

5. Conclusion:

Based on the characteristics of the Mckibben muscles and the different applications, it is possible to develop an artificial suit which can realize the main action of the human arm. And most of the related applications configure the Mckibben muscles in "irregular" structure. But how to model and control it are the key problems. The achievable angles will be less than the human's. They may be 70-90% of the angles which the human arm joints can realize.

References

[1] Kazuhiko Kawamura, R.Alan Peters, D.Mitchell Wilkes, W.Anthony Alford, Tamara E.Rogers. ISAC: Foundations in Human-Humanoid Interaction，IEEE Intelligent Systems，Jul.2000，p38-45.

[2] http://www.shadow.org.uk, 2010.11

[3] Masanori Sugisaka, Kouta Imamura, Kouji Tokuda, Naoki Masuda, A new artificial life body: biologically inspired dynamic bipedal humanoid robots, Artificial life and robotics, Vol.8(1), 2004, p1-4

[4] Hiroshi Kobayashi, Takamitsu Aida, Takuya Hashimoto, Muscle suit development and factory application, Journal of Automation Technology, Vol.3(6), 2009，p209-213

[5] R. Nakamura, H. Saito, Fundamental kinesiology, 5th edition, Tokyo, Japan: Ishiyaku Publishers, 2000

[6] Ching－Ping Chou, Study of human motion control with a physiology based robotic arm and spinal level neural controller:doctor dissertation, Washton Univ., May.1996.