Control for Bending and Stretching Action of Bipedal Robot with Artificial Muscles

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Abstract—This paper describes a humanoid robot system recently developed in our laboratory. We developed the bipedal robot system driven by artificial muscles which are controlled by electro-pneumatic regulator. At this stage, this robot is able to stand up and sit down. In addition, this robot is able to bend and stretch by controlling the artificial muscles appropriately. In this paper, we introduce the bipedal robot system and the control system briefly. Also, we show briefly how to control the artificial muscles to obtain the bending and stretching movement of the robot.

I. INTRODUCTION

This document shows a brief description for a bipedal humanoid robot driven by artificial muscles developed recently in our Artificial Life and Robotics laboratory at the University of Oita, Oita, Japan [1]. The system consists of the lower and upper limbs, 22 artificial muscles connected to them, 22 channels electro-pneumatic regulator to control the compressed air pressures, one air compressor which feeds the compressed air to the electro-pneumatic regulator and the controller which generates various control signals by a PC. The bipedal humanoid robot system is illustrated in Fig.1.

At this stage, this robot is able to stand up and sit down, and is able to bend and stretch by controlling the artificial muscles appropriately. In this document, brief descriptions of the control system for the humanoid bipedal robot and the method how to control the artificial muscles. In Section II, we report the system of the bipedal humanoid robot and the structure. Section III shows the control system, the home position of the robot, and a movement of bend and stretch. The conclusions will follow in Section IV.

II. THE BIPEDAL HUMANOID ROBOT SYSTEM

A. Size of The Bipedal Humanoid Robot and Sizes and Arrangement Form of Artificial Muscles

The size of the bipedal humanoid robot is given in Fig.2 and sizes and the arrangement form of the artificial muscles are shown in Fig.3. The material for each bone and joints is wood called as “KARIN” in Japanese which is hard. Hip-joint, knee-joint, and ankle-joint are made of wood KARIN. The femur, caput femoris, and collum femoris are made of one wood “KARIN”. Tibia and fibula are summarized as one bone and made of one wood “KARIN”. Foot is made of wood “KARIN”. The hip-joint is sphere joint, knee-joint is hinge joint, and knee-joint is sphere joint.

The artificial muscles consist of the following components shown below.

1. :Achilles tendon=120mm
2. :musculus fibularis longus et brevis=120mm
3. :musculus tibialis
4. :musculus tibialis anterior
5. :musculus triceps surae
6. :musculus quadriceps femoris
7. :hamstring
8. :musculus gluteus maximus
9. :musculus iliopsoas
10. :musculus gluteus medius
11. :adductor

Totally, 22 artificial muscles are connected to the artificial lower limbs and the sizes of the lower and upper limbs are 2/3 of the sizes of a human body.

B. Prototype of Bipedal Humanoid Robot Made on An Experimental Basis

The bipedal humanoid robot made on an experimental basis is shown in the picture given by Fig. 4. The lower limbs are shown in this picture. The pressures of 22 artificial muscles of the bipedal humanoid robot were determined for one home positions of standing up by using another program written by Visual Basic and Visual C++. The picture of the bipedal humanoid robot is illustrated for one of the home position of standing up.

From the picture, we see that the knee-joint and ankle-joint are bending a little toward the front direction in this home position of the robot. The picture in the left hand side in Fig.4
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shows right skew view and the picture in the right hand side shows side view. If we choose another pressure values for 22 artificial muscles, we are able to make another home position by controlling the artificial muscles. We do not discuss this problem in detail in this report.

III. CONTROL SYSTEM AND HOME POSITION FOR STAND UP

We are able to control the air pressures of 22 artificial muscles by using the controller PC for the electro-pneumatic regulator shown in Fig.1. We have developed a program for determining the values of air pressures in the artificial muscles for a home position of the lower limbs (both legs) standing. Also, we can get the values of air pressures in the artificial muscles for a position of the lower limbs half standing. Therefore, by switching the two positions at a certain speed, the bipedal humanoid robot is able to take the action of bending and stretching repeatedly.

This program provides us with a tool to determine the various shapes of the lower limbs of the bipedal humanoid robot. Hence, we are able to create various modes of motions using this program as a first stage and, thereafter, various complex movements are synthesized according to our desire.

The characteristics of the artificial muscles for receiving the air and relieving the air is different so that the artificial muscle have to be controlled based on this characteristics. Appropriate control laws how to generate a various walking pattern will be considered in the future by considering this characteristics, feedback signals from touch (force) sensors on the foots, angle sensors, velocity sensors, acceleration sensors, gyro sensor, etc., and the timers. At this stage, sensors are not installed on the lower limbs of the bipedal humanoid robot. The central pattern generator (CPG) was used to generate the bending and stretching action.

IV. CONCLUSION

In this report, the brief description of our results on the control method is given for the bipedal humanoid robot controlled by artificial muscles, which was recently developed at Artificial Life and Robotics Laboratory (Sugisaka’s Laboratory) of the University of Oita. There exist problems to be solved for achieving walking, running, jumping actions of the bipedal humanoid robot. The material of each joints stated above have to be replaced by non frictional joints such as solid artificial joints used for human being. We are now making an improved lower limbs which have the solid artificial joints. Hence, we are able to control the three joints more accurately without frictions for yielding smooth action of the lower limbs using a new technique such as cerebellum-type controller, namely, neural network, genetic algorithm, particle swarm optimization controllers. These topics are now under investigations in our Artificial Life and Robotics Laboratory.

REFERENCES


Masanori Sugisaka: graduated from Doctor Course in Electrical Engineering at Graduate School of Kyushu University, Fukuoka, Japan in March 1973. He became a Research Assistant in the Department of Electrical Engineering at Oita University where he is a Professor in the Department of Electrical and Electronic Engineering since 1988. He was a Visiting Professor at Drexel University from September 1980 to August 1981 and was a Visiting Professor at the Korea Advanced Institute of Science and Technology (KAIST) for the 1996-97 academic year and became a Researcher at Bio-Mimetic Control Research Center at the Institute of Physical and Chemical Research from 2002 till now. His research interests are in the areas of Systems Modeling, Learning Control, Artificial Brain Research, and Artificial Life and Robotics. He founded the International Symposium on Artificial Life and Robotics (AROB) in 1996 under the sponsorship of Ministry of Education, Culture, Sports, Science and Technology (Monkasho) from 1996, Japanese Government. He was the General Chair of the AROB since 1996. He published a new Journal, Artificial Life and Robotics, Springer, in 1997 and is the Editor-in-Chief of the Journal since 1997. He is a member of SICE, IEEJ, RSJ, IEICE, ISCIE, Japan.

Fig. 2 Sizes (Dimensions) of the bipedal humanoid robot

Fig. 3 The form of arrangement and sizes of artificial muscles

Length of artificial muscles: ①②: 120mm, ①’: 120mm, ③: 240mm, ④: 400mm, ⑤, ⑥: 320mm, ⑦, ⑧: 300mm, ⑨: 160mm, ⑩: 140mm

Fig. 4 Pictures of bipedal humanoid robot made on an experimental basis (Left side: Left front view of a standing home position, Right side: Side view of a standing home position)