Compliant and Compact Joint Mechanism for a Child Android Robot

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***Abstract*—We have developed a compact joint mechanism for a child android robot "Affetto", which is designed for more intuitive and close physical human-robot interaction. The joint mechanism has 26 DOFs (3 in neck, 1 in chest, 2 in waist, 5 in each arm, 5 in each leg) in its latest version. All of them are driven by pneumatic actuators (air cylinders and air vane actuators), which provide them with compliance and agility. Such flexible and compact joint mechanism will enable safe and casual physical interaction with appropriate soft coverings our project team is now developing.**

I. Introduction

Flexibility is one of the most important features for humanoid robots to move adaptively in real environment. Many studies [1], [2], [3], [4], [5], [6] have attempted to realize large number of compliant joints with a wide range of motion (ROM) so that the robots can move around and physically interact with humans dynamically and smoothly without breaking their body parts by absorbing shocks from the environment effectively.

A pneumatic actuation system has been applied to several humanoid robots [7], [8], [9], [3], [10] because of its properties advantageous for realizing compliant robots: First, pneumatic actuators can generate sufficient power to drive joints without reduction gears. Second, they are tough against overload since the actuator itself has no electric devices. Third, we can utilize compressibility of air to realize joint compliance.

Ishihara *et al.* [11] developed 22 dof small humanoid upper body robot "Affetto", which are actuated by pneumatic cylinders. Currently, we developed a leg part with 10 dofs for Affetto and re-designed its upper body so that it can be attached to the legs. In this paper, we introduce a 26 dof humanoid joint mechanism re-designed for Affetto (Fig. 1).

II. Mechanism

Pneumatic actuators are divided into two main classes: One is made of soft materials such as rubber or polymer gel which have flexibility in various directions while it is difficult to control due to its high flexibility. Another is made of hard metal and has flexibility only along with its output axis. Pneumatic cylinders in the latter class are relatively easy to control and, therefore have been applied to several robots.

Ishihara *et al.* [11] developed 22 dof small humanoid upper body robot "Affetto" by using two types of pneumatic cylinders: linear and rotary vane cylinders. The motion of the linear cylinder is converted to joint rotation by a slider crank mechanism, which is a kind of four-bar linkage. It improves the freedom of arrangement of cylinders and therefore can make the robot compact.

Currently, we developed a leg part with 10 dofs for Affetto and re-designed its upper body so that it can be attached to the legs. In this re-design process, numbers of its waist joint was decreased from 4 to 2 to prepare enough space for the leg's hip joints. On the other hand, joint torques of the remaining 2 waist joints and joint range of motions of its chest are increased because more efficient arrangement of their link mechanism for them was realized by using newly available space.

Its leg's hight is 477 mm and total weight of both legs is 4.5 kg. Cautious adjustment of joint link parameters such as lengths of cylinder stroke, crank, connecting rod, and other optional links, realized desirable balance among joint torques enough to support the 5 kg upper body with both knees bent at 90 degrees, almost the same degrees of ROMs with those of humans, and high backdrivability.

III. Control System

Control system of the re-designed Affetto is almost the same with the one introduced in the previous study [11]. Compressed air is sent to proportional flow control valves (Festo MPYE-5-M5-010-B), which can regulate their output air flow rate. The output air from these valves are sent to air cylinders' air ports through air tubes. In our system, each air cylinder has two air ports to push or pull its cylinder rod.

The air pressures in air tubes near each cylinder can be measured with pneumatic pressure sensors (PSE530 series made by SMC corporation) and each joint angle can be measured by potentiometers (RDC50 series made by Alpine Electronics, Inc.). The sensor signal voltages from these sensors are sent to A/D converter modules (ADI12-8(FIT)GY made by Contec) connected with a control PC. The PC calculates the desired control voltages at a frequency of 100 [Hz] to achieve target sensory states and commands the D/A converter modules (DAI12-4(FIT)GY made by Contec) to apply control voltages to valves.

IV. Conclusion

We have developed a compact joint mechanism for a child android robot, which is designed for more intuitive and close physical human-robot interaction. Every joint is actuated by pneumatic power and therefore it is compliant to external

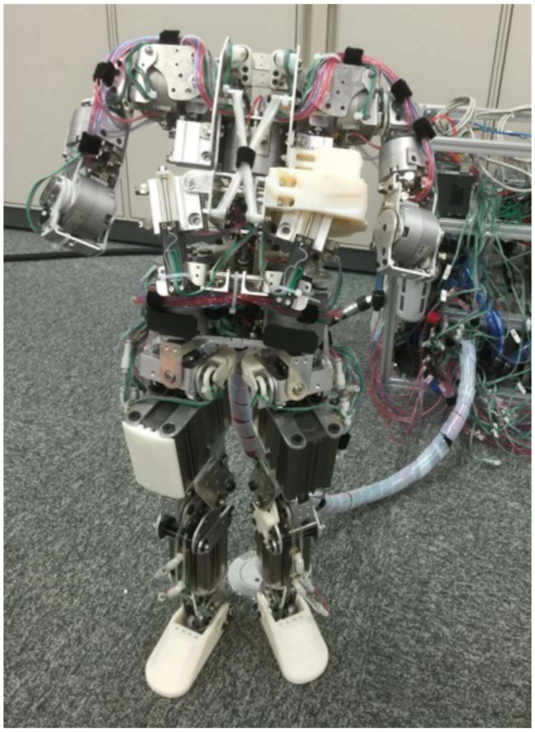

Fig. 1. Joint mechanism of Affetto.

forces. Although this joint mechanism should be covered with soft coverings, it is a desirable research platform to evaluate such soft coverings or test effective motor control algorithms for flexible body.

ACKNOWLEDGMENT

This work was supported by a Grant-in-Aid for Specially Promoted Research No. 24000012 and for Young Scientist (B) No. 15K18006.

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