Introduction of a Gel Actuator for Use in the Design of a Humanoid Robotic Finger

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***Abstract*- Humanoid robotic hands are the essential end effectors for completing tasks in human environments. The hands need to perform restraining power grasps and dexterous precision grasps fixed similarly to the position of human hand postures. Advanced universal robotic hands have previously utilized two actuator systems oft in the form of pulley cables and pneumatics. These systems often require large amounts hardware that cannot be contained in smaller structures like the humanoid robot Hubo. Hubo has shape adaptive hands that solely rely only a pulley cable system. To fully actuate each finger, one motor per degree-of-freedom (DOF) is required. Although there are three joints per finger there is only one motor per finger leading to under actuated fingers that fail to achieve precision gripping. A gel actuator has been developed for application in a newly designed humanoid robotic finger. By using this gel actuator in conjunction with an electromagnetic lock mechanism, one motor can power the three DOF robotic fingers. The expected advantage is a proportional, fully actuated hand that has improved precision grip while maintaining power grasp adaptability.**

INTRODUCTION

Humanoid robots are designed to function in the same spaces as humans by performing similar physical assignments and participating in human interaction. Robotic hands, those with four fingers and a thumb, have demanding responsibilities that will improve the efficiency and usefulness of the robot if they can establish a power grasp and precision grip. Human hands naturally regulate force and position according to the type of grasp while maintaining stability even in the presence of varying sized loads or slippage [1]. For performance replication, the humanoid robot's hand should be a universal robotic hand that can mimic human hand prehension and precision grip techniques in terms of hand positions and applied forces.

Human hands have 27 degrees of freedom with four degrees of freedom in finger and 6 degrees of freedom

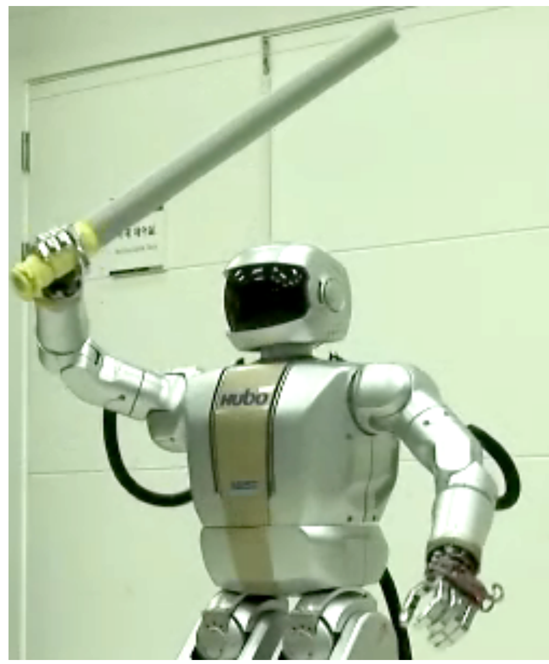

Figure 1: Hubo's current hand manipulation is limited to shape adaptive power grasping.

per palm. Hands generate large grip forces from their opposable thumb and adaptive palm in conjunction with long dexterous fingers. Power grasps are distinguished by large areas of contact between the grasped object and the surfaces of the fingers and palm and by little or no ability to impart motions with the fingers. A precision grip is used to ensure sensitivity and agility and is held with the tips of the robotic thumb and fingers.

In humanoid proportional robotic hands, precision grip has been difficult to achieve because it requires the presence of one actuator per joint. The challenge is that space is limited for enough actuators to activate necessary degrees of freedom [2]. Alternatively, many robotic hand designs sacrifice appearance and precision grip for shape adaptive power grasping. The Utah-MIT hand is composed of pulleys actuated by pneumatic pistons [3]. The end result is a large hand system with three fingers and a thumb. Similarly, Shadow Hand uses electric and pneumatic actuators to model 24 degrees of freedom [4]. However, like the Utah-MIT

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hand, its high cost and large size prevent it from being used in a humanoid robot. To accommodate hand space deficiency, Shadow Hand's pneumatic actuators and hardware sits in the forearm whereas the Utah-MIT hand has only three fingers and a thumb [3][4]. Additionally, Suzumori and Zang developed a pneumatic robotic finger. Each finger is a pneumatic actuator tube internally divided into three chambers. The finger bends according to differences in pressure between the chambers resulting in 3 DOF fingers that can dexterously manipulate objects or restrain them in an envelope grasp [5][6]. Obtaining force necessary for power grasping requires increasing the size of hardware that must be placed on the system. Although there is a large body of existing hand designs and technologies, each has constraints that prevent it from being suitable for Hubo, a humanoid robot.

II. HUBO'S CURRENT HANDS

Hubo's pulley driven hands can firmly envelope objects of various shapes and sizes but not precisely grip an object. The hands are responsible for forming each of the prehension postures as well as subsequent combinations of prehension postures. Achieving a humanlike combination of strength and dexterity is challenging in a machine the size of a humanoid robot. The presented actuator and finger is designed for Hubo who is 1.27 meters in height. Each of its fingers is 92 mm in length x 18 mm in width x 18 mm in depth. Presently, a Maxon gear powered cable and pulley system uses a grip wire and a release wire to turn finger joints. The hand can powerfully envelope an unidentified object but since each finger has one cable system powered by one motor, each of the joints on a single finger move interdependently. In this under actuated hand, distal (DIP) and middle (MIP) joint movement is dependent on proximal (PIP) joint movement, which allows Hubo to do shape adaptive power grasping but not precision grasping. [7]

III. PROPOSED DESIGN

A. Gel Actuator

The proposed finger is based off of the success of a gel actuator prototype. In the prototype, gel is situated in an anisotropic silicone tube with an aluminum joint between the gel and tube. Manufacturing difficulties emerge in molding a fluid actuated material. When a force is exerted on a flexible material, such as rubber or latex, their isotropic properties cause expansion in many directions. To prevent this behavior, an anisotropic external finger shell was made that inhibits expansion in the radial direction when pressure on the gel elongates the rubber finger. The shell was molded from RTV silicone rubber with spirally embedded nylon fibers.

Afterwards, a latex tube filled with ordinary cationic polymer gel was inserted into the silicone rubber tube. Finally, an aluminum joint was placed between the latex tube and silicone rubber tube to guide bending when a normal force was applied to the face of the latex tube. The model has one joint and one degree of freedom.

B. Full Finger Design

In the proposed design, the gel is fixed in a 130 cm long anisotropic silicone shell above three aluminum joints that are attached in the shell to represent the proximal, middle, and distal joints of human fingers. A DC motor driven linear actuator is internally located in the hand and extends to force the gel towards the tip of the silicone shell. As the weight shifts to the end of the finger, the inertial moment rotates the finger downward. Importantly, the design includes a magnetic coil lock mechanism at each joint that causes one motor to be responsible for three degrees of freedom. A magnetized coil will inhibit bending at it's joint while a released coil will allow bending at the joint when the gel is forced towards the tip of the shell.

VI. CONCLUSION

To improve the versatility of Hubo and other adult sized humanoid robots requires adaptive hands that behave similarly to human hands. Although existing hand technologies can achieve power grasping and precision grip, size and space constraints prevent compatibility within Hubo. Instead, a gel actuator has been developed for implementation in a robotic finger. The expected advantage is a proportional, but more dexterous robotic hand.

REFERENCES

[1] MacKenzie, Christine L., and Thea Iberall. *The Grasping Hand*. Amsterdam: North-Holland, 1994.

[2] Xiong, Caihua, Han Ding, and You-Lun Xiong. *Fundamentals of Robotic Grasping and Fixturing*. Vol. 3. Singapore: World Scientific, 2007. Print. Manufacturing Systems and Technology.

[3] S.C. Jacobsen, E.K. Iverse, D.F. Kutti, R.T. Johnson, K.B. Biggers, "Design of the Utah/M.I.T. Dextrous Hand". Center for Engineering Design, University of Utah.

[4] "Shadow Robot Company: Products Page." *Shadow Robot Company: Creators of the Worlds Most Advanced Robot Hand*. Web. 21 July 2010. <http://www.shadowrobot.com/products.html>.

[5] K. Suzumori, Shoichi Iikura, and Hirohisa Tanaka, "Flexible Microactuator for Miniature Robots", Proc. of IEEE Micro Electro Mechanical Systems, 1991 pp. 204-209.

[6] L. Zhang, Y. Quinghua, B. Guanjun, R. Jian, "Research on Novel Flexible Pneumatic Actuator FPA", IEEE Conference on Robotics, Automation and Mechatronics. 2004: 385-389.

[7] Illwoo Park, J.Y. Kim, Jungho Lee, Jun-Ho Oh. "Mechanical Design of the Humanoid Robot Platform, HUBO KHR-3", IEEE-RAS Conference on Humanoid Robots, 2005: 321-326.