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EXPERIMENTAL ANALYSIS OF SMA (SHAPE MEMORY ALLOY) ACTUATED ROBOTIC ARM

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ABSTRACT: *This paper presents the ideology of this research, which is to utilize advanced actuators to design and develop innovative, lightweight, powerful, compact, and dexterous robotic technology. The key to satisfying these objectives is the use of advanced or smart materials, such as Shape Memory Alloys (SMAs) to power the joints of a robotic arm, and other dexterous robotic hands. A new robotic arm actuated by Shape Memory Alloy (SMA) type artificial muscle has been developed in this paper. Different from typical geared motor, SMA actuator is lightweight and silent, however shows a little short stroke and small attracting force per each unit. In order to achieve enough output force and motion range of arm, multiple SMA type artificial muscles with special device which facilitates enough length are equipped in the arm. The fundamental properties of the SMA type artificial muscle including output force and electrical response were determined experimentally and considered for the design of arm mechanism. Besides, the structure of arm and whole system has been designed based on observation of human arm . The electrical hardware to control multiple shape memory alloy type artificial muscles has been also developed. Finally, the usefulness of the robotic arm has been investigated through experiments for lifting several types of objects.*

I. Introduction

The excellent functionality of the human hand ensures convenience and optimal performance of activities of daily living. However, the disabled who have physical disabilities of their hand experience difficulties in their works or cannot perform their tasks especially for manipulating general objects. As a useful device to support them, several types of prosthetic hands have been proposed. For example, a simple prosthetic hand just for appearance and a hook-shaped prosthetic appliance have been employed as fundamental and well-used devices. However, they show very limited functionality in general.

Meanwhile, robotic hands for manipulating objects have been investigated as robotics researches for both robot and the disabled. For the design of dexterous hand mechanism, minute observation and in-depth analysis on the structure of human hand have been carried out. Namely, mechanical structure and characteristics of human hand have been considered as a good model for design and control. However, there are differences between human and robotic system, which cause great obstacles to the design of actual robotic hand. Most of all, human hand is actuated by soft but strong actuator, i.e., muscle, which cannot be manufactured artificially with advanced technology so far. To cope with the problem, several alternatives have been proposed. Electric motor has been used as typical actuator for general robotic hand mechanism. For abundant torque to achieve holding force, gear train with high reduction ratio is required for general motor. Thus the size of the actuators becomes large, and they cannot be installed in the hand itself. Besides, soft actuation scheme like as human muscle cannot be realized because of the lack of back-drive capability in gear train of high reduction ratio. Therefore, most of robot hands utilize tendon device to transmit the power of motor being attached in the forearm apart from hand.

Though there has been much research accomplished on SMAs, there is still a need for new design methodologies and paradigms for lightweight, practical robotic arm or hands for robotic systems. It is believed that the key to satisfying these objectives is via the use of smart materials, such as, Shape Memory Alloy artificial muscles. The advantages of Shape Memory Alloys include, their incredibly small size, volume and weight; their high force to weight ratio; their low cost; and their anthropomorphic behavior. Their limitations include: the large length of wire required to create significant motion, limited life cycle, non-linear effects such as hysteresis phenomena, and bandwidth and efficiency restrictions. It is proposed that the novel design methodology and prototype fabrication discussed in this paper will aid in the advancement and the development of human-like muscle actuators for assistive robotic devices and practical robotic systems.

II. Objective

The main goal here is

1) To fabricate working model of SMA actuated robotic arm
2) Illustrate the compability of large motions in robotic systems that are actuated by SMA.
3) Illustrate the accuracy of robot arm by use of SMA
4) To analysis the SMA actuated robotic arm.

III. Scope of Problem:

Every day, we happily entrust more of our lives to automated machines at home and in our cities. These technologies deal with automated machines that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behavior, and/or cognition. Many of today's robots are inspired by nature contributing to the field of bio-inspired robotics.

The concept of creating machines that can operate autonomously dates back to classical times, but research into the functionality and potential uses of robots did not grow substantially until the 20th century. Throughout history, it has been frequently assumed that robots will one day be able to mimic human behavior and manage tasks in a human-like fashion. Today, robotics is a rapidly growing field, as technological advances continue; researching, designing, and building new robots serve various practical purposes, whether domestically, commercially, or militarily. Many robots do jobs that are hazardous to people such as defusing bombs, mines and exploring shipwrecks. The robotic hand will be useful in industry and for human anatomy where the end effectors is very important in robotics and automation. it will reduce human power and effort in industry.

IV. Mechanical Design

The mechanical design of a fingered, fourteen degree-of-freedom dexterous robotic hand, patterned after human anatomy, is currently being developed. To date, a lightweight aluminum four degree-offreedom finger prototype has been made (Figure 1). The robotic hand concept presented here is based on the use of Shape Memory Alloy artificial muscles composed of an equal ratio of nickel and titanium, to power the joints. However, it anticipated that othersmart materials, such as electrostrictive polymers, electrostatic devices, piezoelectrics, mechanochemical polymer/gels, shape memory polymers and shape memory alloys will be used either alone or in conjunction with the SMAs.

The human finger consists of three links, which are connected by three joints, i.e., the distal interpharangeal (DIP), proximal interpharangeal (PIP) and metacarpophalangeal (MP) joints as displayed in Fig. 6. The prosthetic finger developed has the same structure as human finger. The prosthetic finger is operated by two SMA type AMs. One is attached to the second link for rotation of the DIP and PIP joints. The other is attached to the third link and responsible for rotation of all joints in the finger. The two SMA type AMs are installed inside the finger and several stoppers are used for the generation of effective torque at the joints. As a result, all three joints of the finger can be controlled by the two SMA type AMs, which allows the finger to grasp an object with irregular shape. Reversely, for opening motion of the finger, pre-loaded pulling force of the wire attached in its backside and connected to the spring in the palm of the hand works effectively.

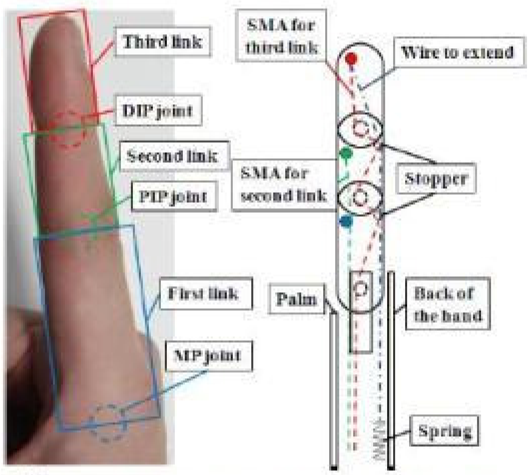

Fig. Structure of human finger and prosthetic finger.

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Fig. shows the motion of the prosthetic finger to grasp an object. All joints cooperate with each other for grasping motion because they are connected together by the two SMA type AM and a wire connected to reverse spring. According to the geometry of the object, motion of some joints is constrained by the contact between link and object and other free joints continue closing motion, then the shape of finger is changed for grasping resultantly. For the independent operation of multiple SMA type AM, namely in order to ensure that the AMs are solated with each other, Teflon films are inserted between the AM strings in the finger mechanism. The stroke of each SMA type AM is approximately 5% of its natural length. In order to achieve the sufficient stroke of finger motion, small pulleys that lengthen the total length of each SMA type AM are built in the palm of the hand. Fig. 8 shows the first and the second finger of the prosthetic hand. Both have same structure with each other. The third and the fourth finger is operated by one SMA type AM for closing motion and one spring for reverse motion

Motion Experiment of Prosthetic Finger

In order to grasp object of various geometry, thefingers should be folded according to the object' shapenaturally. The motion of finger under the condition ofvarious constraints has been tested experimentally.

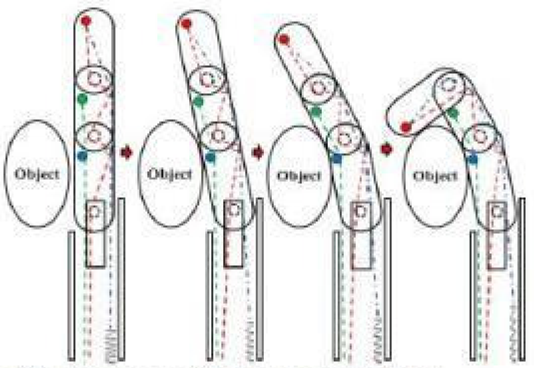
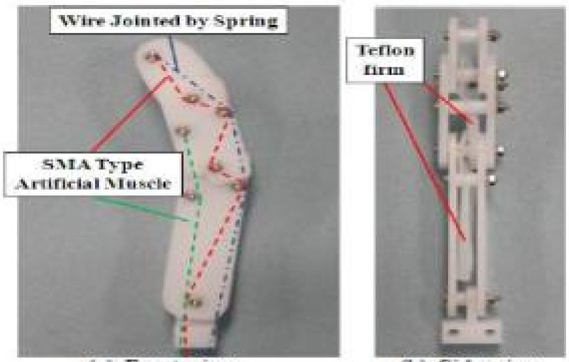
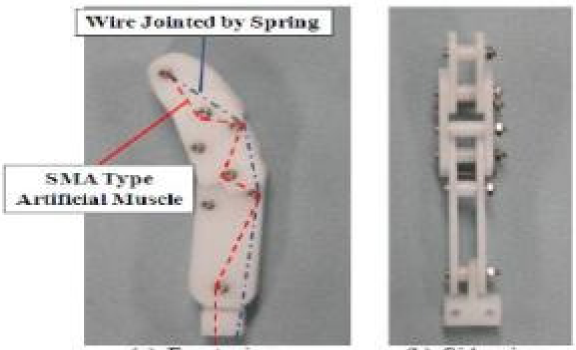


Fig. Grasping motion of the prosthetic finger



(a) Front view (b) Side view

Fig. First and second prosthetic fingers.

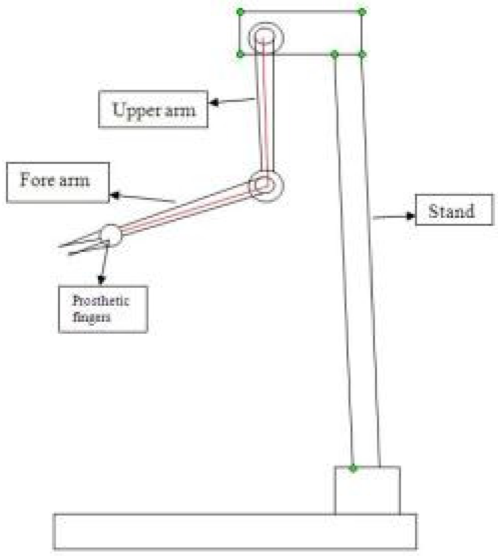


(a) Front view (b) Side view

Fig. The third and fourth prosthetic fingers.

Figs. show the motion of the prosthetic finger when the first and the second finger are constrained, respectively. The authors examine the motion of the prosthetic finger when each link of the prosthetic finger is fixed. From these experiments, it can be confirmed that the prosthetic finger has the capability to grasp an object of irregular geometry.

Development of Robotic Arm



The robotic arm developed in this research isdisplayed in Figs. Fingers designed in theprevious section are employed for the development of the robotic arm. The arm are arranged based on the geometry of human hand, and the SMA type AM actuators are equipped in the arm for compactness. Two SMA type AMs are attached to the first and the second link in order to reinforce the grasp force. To save space, the third and fourth link supporting the first and the second link are actuated by single SMA type AM, respectively.
As shown in Fig. 14, the dimensions used for thedesign of the prosthetic hand are decided based on the average data of general human hand.

Conclusions

In this paper, a light and quiet prosthetic hand using SMA type AM was developed. It was designed based on the structure of human hand. And the driving mechanism of each finger was designed not only to achieve the powerful grasping force but also to rotate all joints according to object's shape simultaneously. Its capability to grasp objects in daily environment was tested through experiments. As future work, more
SMA type AMs needs to be employed to strengthen the grasping force of the prosthetic hand. It will also improve the usability of the hand and allow to be applied in actual life.

References

1) Pfeiffer, C., K. J. DeLaurentis, and C. Mavroidis. "Shape Memory Alloy Actuated Robot Prostheses: Initial Experiments." Proc. of the 1999 IEEE International Conf. on Robotics and Auto., Detroit, Michigan, May 1999. 2385-2391
2) Development of shape memory actuated ITU Robot Hand and its mine clearance compatibilitySavasDilibal∗, R. Murat Tabanli, Adnan Dikicioglu
3) Design and Characterization of a Novel Hybrid Actuator using Shape Memory Alloy and D.C Motor for Minimally Invasive Surgery Applications
4) A. Jaffar, M.S. Bahari, C.Y. Low, R. Jaafar, Design and control of a multifingered anthropomorphic robotic hand, International Journal of Mechanical and Mechatronics Engineering 11 (4) (2011) 26-33.
5) Y. Kimura, T. Nakamura, Development of the robot hand using wire type artificial rubber muscle, JSME 11-5 (2011) 1A1-106.
6) Honma D., Miwa Y. and Iguchi, "Micro Robots and MicroMechanisms Using Shape Memory Alloy to RoboticActuators," J. of Rob. Sys., Vol. 2, No. 1, pp. 3-25, 1985
7) I. Yamano, T. Maeno, Five-fingered robot hand using ultrasonic motors and elastic elements, in: Proceedings of the 2005 IEEE International Conference on Robotics and Automation, 2005, pp. 2684-2689.
8) K. Suzumori, S. Wakimoto, T. Kanda, M. Takahashi, T. Hosoya, E. Takematu, Development of power robot hand with shape adaptability using hydraulic McKibben muscles, in: Proceedings of IEEE International Conference on Robotics and Automation, 2010, pp. 1162-1168
9) N. Tsujiuchi, T. Koizumi, H. Komatsubara, T. Kudawara, M. Shimizu, Development of robot hand with pneumatic actuator and construct of master-slave system, in: Proceedings of 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007, pp. 3027-3030.
10) Y. Kimura, T. Nakamura, Development of the robot hand using wire type artificial rubber muscle, JSME 11-5 (2011) 1A1-106.