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Design of Three-Finger Hand System

심병균[1*], 이우송[2], 박인만[3], 황원준[3], 김원일[4]
Byoung-Kyun Shim[1*], Woo-Song Lee[2], In-Man Park[3], Won-Jun hwang[3], Won-Il Kim[4]

<Abstract>

The focus of this paper is the designing a flexible three fingered hand system with 16 D.O.F for dynamic manipulation with an intelligent controller, and to build a useful database for dynamic manipulation based on the experimental results. The weight of the hand module is only 0.7 kg, but flexible motion and powerful grasping are possible. To achieve such a dynamic motion in a robotic hand, we have developed a flexible fingered hand with a control system incorporating image recognition system in which we deal with the problems of not only accuracy and range of motion but also the flexibility of hand. The fingers are arranged so as to grasp both circular and prismatic objects. In order to achieve the light mechanism, we reduced the number of joints and fingers as much as possible. We used three fingers, which is the minimum number to achieve a stable grasp.

Keywords : Three - Finger, Flexible Hand System, Wide Working Space, Flexibility

1. Introduction

The development of robotic hand gripper to execute automatic operations in space is foreseen to grow and cover a relevant part of the activities. With this respect, as already demonstrated in the industrial environment, a bottleneck is constituted by the end effector that often is a very simple device with poor sensoriality and limited operational capabilities. Besides the numerous prototypes of articulated robotic hands, developed in more than 30 years of research.[1)~2)] mainly in academic environment among many others, limited effort has been devoted to seek and evaluate alternative solutions, may be simpler from the mechanical point of view than a multi-fingered hand, but with sufficient dexterity to perform in any case non trivial operations on a wide range of objects. The breakableness or Breaking objects is possible and necessary in life of human with his hand. Therefore, We want to make robot whose hand is similar with the processing of human hand likely quality improvement and time saver etc..

Therefore, referring specifically to the case of space applications[3)], a scenario could be considered in which operations have to be performed in a no-gravity environment,

[1*]정회원, 교신저자, 경남대학교 첨단공학과,
E-mail:shimbk@kyungnam.ac.kr
[2]정회원, 성산암데코 연구소장, 工博
[3]정회원, 경남대학교 첨단공학과
[4]정회원, 경남대학교 기계공학부 교수, 工博

[1*]Corresponding Author, Dept. of Advanced Engineering, Kyungnam University.
[2]Director, R&D Center, SungSanamdeco Co. Ltd., Ph. D.
[3]Dept. of Advanced Engineering, Kyungnam University.
[4]Prof., School of Mechanical Engineering, Kyungnam University, Ph. D.

where objects cannot be constrained and are therefore free to float in space. At the moment, this gripper is installed on a six degree of freedom arm, see Fig. 1. In order to emulate the capabilities of the FARA arm and to develop suitable coordinating strategies taking into account the kinematics capabilities of the whole arm / gripper system.[4)~5)]

2. Hand and Gripper System Design

The gripper has been designed considering its installation on the FARA arm proposed. This system aims to substitute the astronauts in periodical operations with a semi autonomous robotic device. The end-effecters for the robot manipulator needs therefore compactness, simplicity and reduced weight as well as capability of operation even on irregular floating objects.

Besides the 16 D.O.F gripper, main objective of this research, the overall robotic system consists of the following main components: a 6 D.O.F arm with an "open control", a standard force / torque sensor at the wrist and a vision system. These components are schematically shown in Fig. 2.

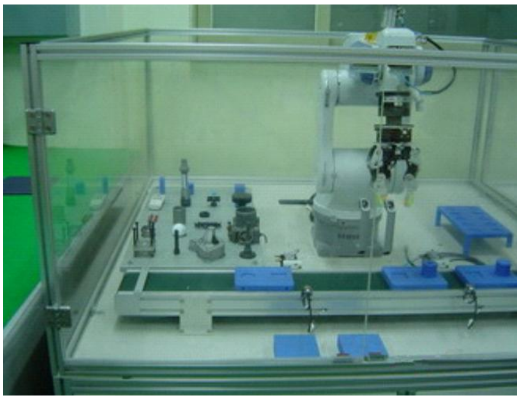


Fig. 1. The Three-Finger Hand System Installed on FARA Robot.

The gripper has three 5 D.O.F fingers. In each finger, the finger tip and 1 finger link can move on a linear trajectory by the linear motor but the other finger links and wrist part can move on an angle rotation trajectory by the Coreless DC Motors. These fingers are disposed radically, in a symmetric configuration as shown in Fig. 3.The Hand system has total 16 D.O.F, enough for Gripper to catch many type of flexible subjects. This kinematics configuration has several interesting features including the capability of firmly grasping objects with irregular shapes and with a rather wide range of dimensions.[6)~8)]

In this manner, it is possible to control the motion of each finger, its distance from the object and the forces applied on it during the grasp.

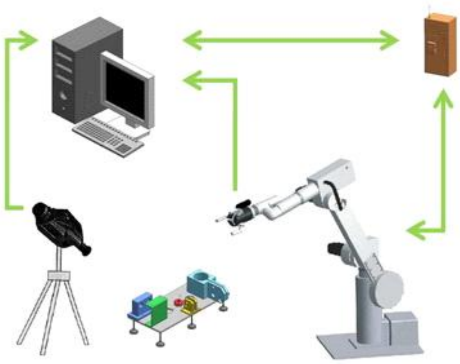


Fig. 2. The Overall Control System.

3. Intelligent Control of Robotic Hand

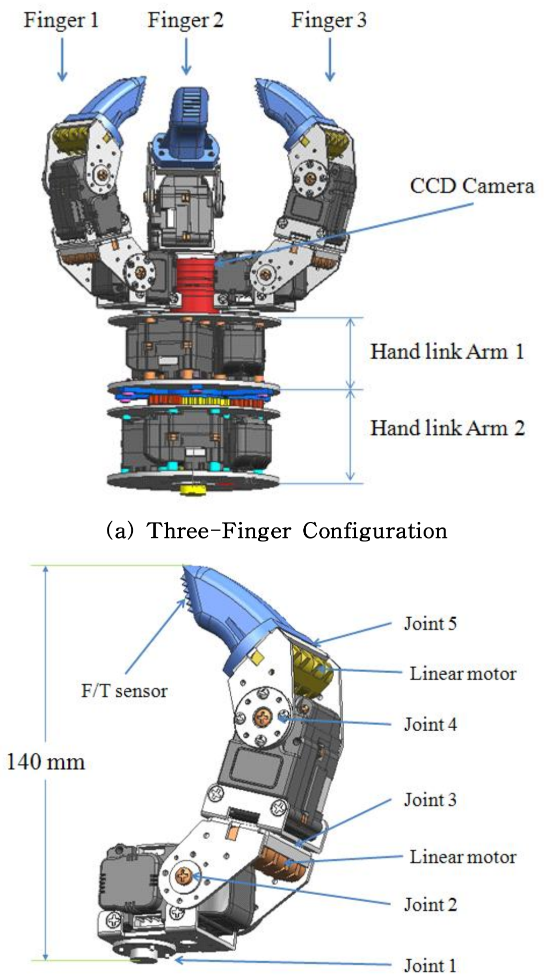
The real time control of the gripper is based, at the moment, on standard HW/SW components. The control is performed with a DSP (TMS320C31) board connected to the motor drives and to an input board for the sensors. This board has been purposely designed because of the relatively high number of signals to be acquired in real-time. Currently, the DSP is hosted on a PC. From the software point of view, besides a real-time kernel on the DSP board, an interface between the DSP and the PC has been developed, allowing using both real-time software and high-level environments for user interface.

Table 1. The Specification of Actuator

Motor type	Coreless DC Motors (Swiss MAXON Motor)
Operating voltage [V]	12~16
Max. holding torque [Kg·N·m]	0.385
Max. speed [sec/60deg]	0.167
Weight [Kg]	66×10^{-3}
Size [mm]	40 x 31 x 37
Gear ratio	193
Position resolution	1024
Operating angle [deg]	300
Torque control	1024 level

At the moment, the control system level has been implemented considering a simple logic switching between three classes of controllers: a position control (based on the position sensor), a proximity control (based on the proximity sensor) and the force control, based on the force / torque sensor. The set points and the controlled variables of the servo loops are considered according to two main modalities: position control or proximity control. In the first case, the absolute position of the fingertip is controlled by planning the desired motion with a fourth-order polynomial function and assigning the desired motion time. The controlled variable is the position x (the radial distance from the center of symmetry of the gripper) of the fingertip obtained by means of the forward kinematics from the joint position measured by the Hall Effect sensor.

In the second case, the controlled variable is the distance of the finger with respect to the approached object. This modality is activated when the finger is sufficiently close to the object. The controlled variable is now the distance from the object, as measured by the proximity sensor. This information can be used both to start the grasp of the object (if all the fingers are at the same distance from it) or to maintain constant the distance between the finger and the object.



(b) One-Finger Configuration

Fig. 3. The Structure of Three-Finger Hand System.

The Force / Torque control of each finger is based on a classical PI controller, a difficulty has been the compensation of non-linearities caused by the actuation system, in particular a relevant (and non constant) dead zone and the nonlinear characteristic of the hall effect F/T sensors. Which have widely been used in measuring inertia force, monitoring forces of variable directions and intensity. This F/T sensor provides precise, reliable force sensing performance in a compact commercial grade package. The F/T sensor operates on the principle that the resistance of silicon implanted piezo resistors will increase when the resistors flex under an applied force. The load is applied to a stainless steel plunger transmitting force to the silicon sensing element. The sensor packaging incorporates a modular construction and use of innovative elastomeric technology and engineered molded plastics which allow for load capacities of 4500grams overload. At the moment F/T control can be classified as a simple compliance control obtained by specifying the compliance parameter K (Fig. 4).

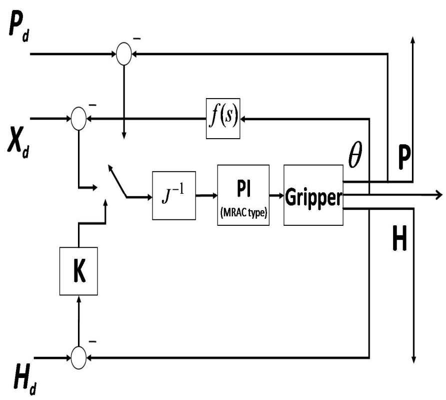


Fig. 4. The Scheme of the Position and Force Control.

Obviously, a proper switching logic between the above three control modalities must be adopted in the different phases of the execution of the tasks in order to ensure a smooth behavior of the gripper.

The prototype of the gripper has been installed on a 6 D.O.F anthropomorphic robot, a FARA with open- control architecture, a PC connected to the standard robot controller C and equipped with a force / torque sensor on the wrist. The open control architecture allows in particular synchronizing the tasks of both the gripper and the arm for micro-motion during task execution.

The real time OS chosen for this application is Windows XP[9] running in our case on a Pentium IV PC. This PC may carry out the robot position control, based on the feedback provided by the position sensors, the wrist force / torque sensor and by the vision system. At the same time, the operating system allows the communication between the robot control task (executed as real-time procedure in the Windows XP environment) and the corresponding routines on the DSP board for the gripper control.

It is possible to control the robot under Windows XP in two main modalities. In the first, the servo loops for each actuator are performed, the standard robot controller. In this modality, a new position set point is generated by the PC every 10 msec. In the second case, the PC performs directly the control of each actuator, with a sampling period of 1 msec.

Table 2. The Specifications of F/T Sensor

No	Items	Specifications
1	Load Range	0-0.5Kg
2	Linearity	± 10^{-2} Kg N.s.
3	Repeatability	± 10^{-2} Kg
4	Material	Plastic Body
5	Temperature Range	53 to 104 °F
6	Output	0.024 mv/v/g
7	Bridge Resistance	5k ohms nominal
8	Excitation	5 Vdc
9	Safe Overload	4.5×10^{-3} Kg
10	Model	LPM 562 - Micro Force Sensor

4. Experiment and Results

Examples of these experimental set-ups shown in Fig. 5, the results are shown in Fig. 6 - Fig. 7. In Fig. 6, the three fingers first approach a fixed object until each of them is at a desired distance from it, then the contacts are applied. Fig. 7 shows an experiment involving force control of grasping the object. In Fig. 7, phase 1, 2 are the preparing phase to grasp the object. Phase 3, 4 shows the application force is controlled, in this case, the reference force is changed during hand system force to show the effectiveness of the force control. At the end, the phase 5 shows the object is released and the force is null. In this fig. 7, D(mm) is the distance, F(N) is the force applied to the hand.

A number of laboratory experiments have been performed both on single finger modules and sensorial / actuation subsystems in order to test the efficiency of each finger structure and of the control system. The validation has also included verification of the procedures for the object approach, based on the use of both the distance and the position sensor information, and the use of the force / torque sensors.

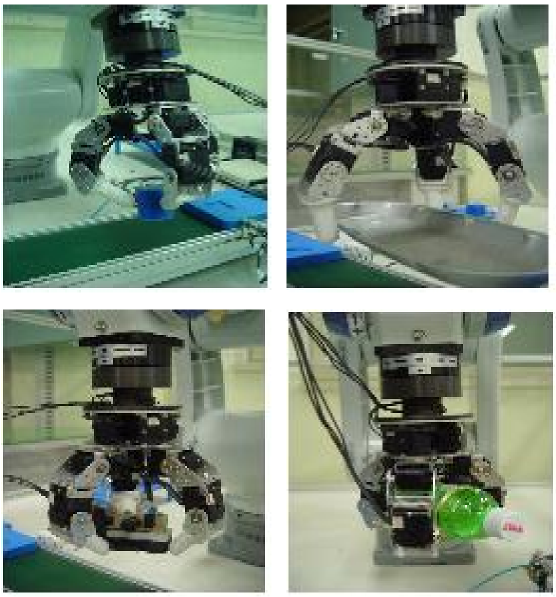


Fig. 5. Various grasping posture.

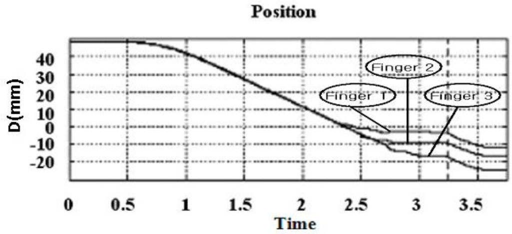


Fig. 6. The Trajectory of the Floating Object Grasping.

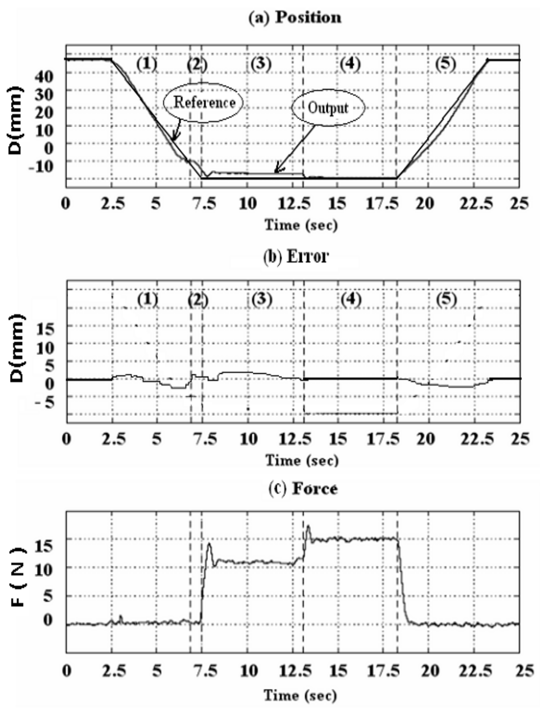


Fig. 7. Experimental Results about Grasping Test of Three-Finger Hand System.

Concerning the approach and contact phases, it must be observed that the possibility of independently moving the fingers has noticeably increased the capability of grasping moving objects. As a matter of fact, the object may be tracked with a coordinated movement of both the arm and the fingers. Once the motion is tracked, the grasp may be firmly applied without losing contact.

5. Conclusion

We have presented a new technique to design and control of a three-fingered with 16 degrees of freedom robotic gripper for real application.

In this research, we have proposed a very large workspace with respect to its body size, and is capable of operation both on small and on large objects; its sensory equipment seems to be sufficiently rich and more than adequate for the expected tasks. In the future research, it will include the refinement of the current version of the gripper and the conclusion of the verification phase, in particular with respect to the force control and to the possibility of applying simple manipulation procedures on the grasped objects in working environments.

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