A Study on Real Time Intelligent Control of a Three-Fingers Hand System

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Abstract:

We present an experimental performance for the validation of a robotic hand gripper for space applications. In particular this researches focus on the compatibility of the gripper with the Fara robot arm, developed by Esp. Co., Ltd. This hand gripper is the wide working space compared with its physical dimensions and the capability to deal with free-flying objects in no-gravity conditions. This capability is achieved by using force/torque sensor and by properly controlling and coordinating the gripper and the carrying arm. After a brief illustration on the main features of the gripper, the experimental activity is presented and the results achieved are discussed.

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, mainly in academic environment, see e.g. [1],[2] among many others, limited effort has been devoted to seek and evaluate alternative solutions, maybe 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.

Therefore, referring specifically to the case of space applications, a scenario could be considered in which operations have to be performed in a no-gravity environment, 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]-[8].

2. HAND GRIPPER SYSTEM DESIGN AND ANALYSIS

The gripper has been designed considering its installation on the FARA arm proposed. This system

Fig. 1: The hand gripper installed on FARA manipulator

aims to substitute the astronauts in periodical operations with a semi autonomous robotic device. The end-effector for the robot manipulator needs therefore compactness, simplicity and reduced weight as well as capability of operation even on irregular floating objects.

Besides the three 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.

The gripper has three one D.O.F fingers whose

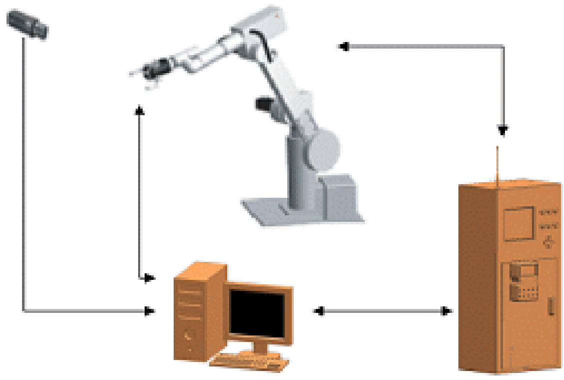

Fig. 2: The overall system.

distal phalange can move on a linear trajectory. These fingers are disposed radically, in a symmetric configuration as shown in Fig. 3. This kinematics configuration has several interesting features, as described in details in [4]-[6], including the capability of firmly grasping objects with irregular shapes and with a rather wide range of dimensions.

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.

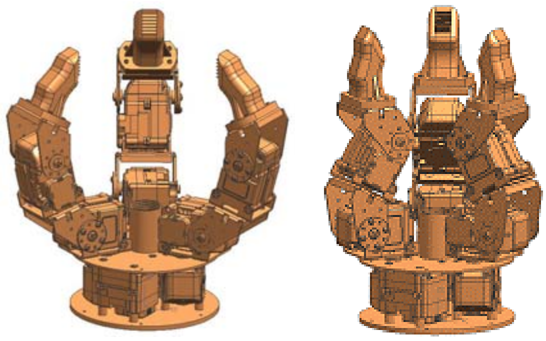

Fig. 3: The gripper in different configurations.

3. INTERLLIGENT 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 to use both real-time software and high-level environments for user interface.

At the moment, the servo control 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 kinematics1 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.

The force control is based on the same PI structure of the position and proximity controllers, and at the moment can be classified as a simple compliance control obtained by specifying the compliance parameter K, see Fig. 4.

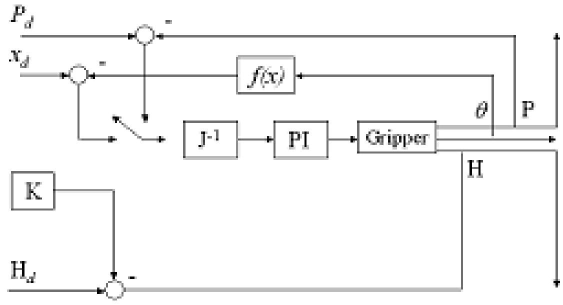

Fig. 4: Position/force control scheme.

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 an 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 Linux[10] 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 Linux environment) and the corresponding routines on the DSP board for the gripper control. It is possible to control the robot under Linux 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.

4. EXPERIMENT AND RESULTS.

Examples of these experimental results are shown in Fig. 6-Fig. 8. Set-up is shown in Fig. 5.

A number of laboratory experiments have been performed both on single finger modules and sensorial/actuation subsystems in order to test the

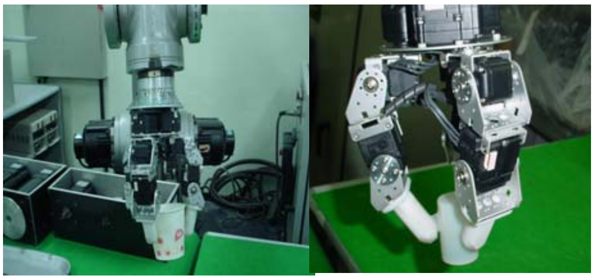

Fig. 5: Experiments set-up

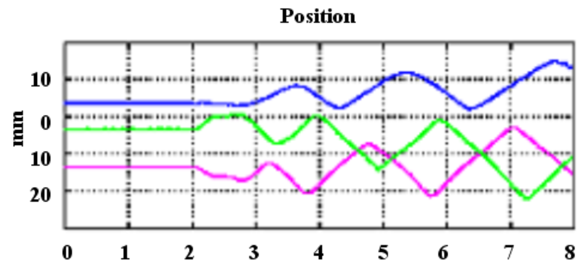

Fig. 6: Tracking a moving objects by exploration with the proximity sensors and computation of the normal directions.

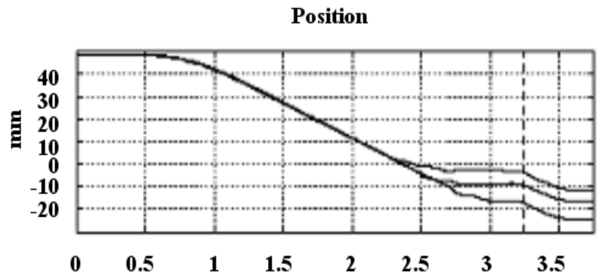

Fig. 7: Grasp of a floating object

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.

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 loosing contact.

Finally, an experiment involving force control is shown in Fig. 9.

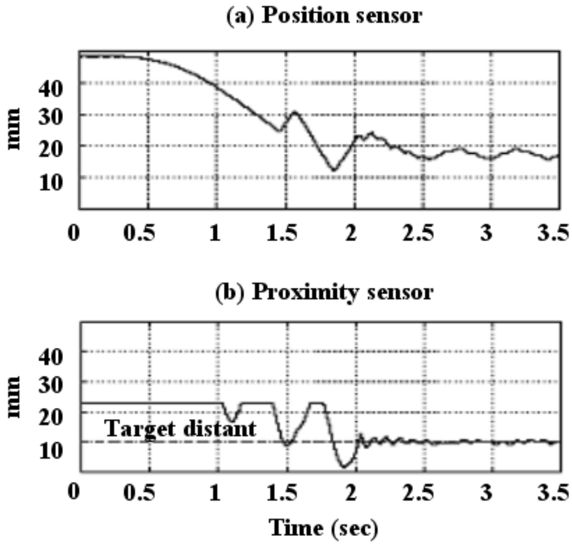

Fig. 8: Measurements of the position (a) and proximity (b) sensor.

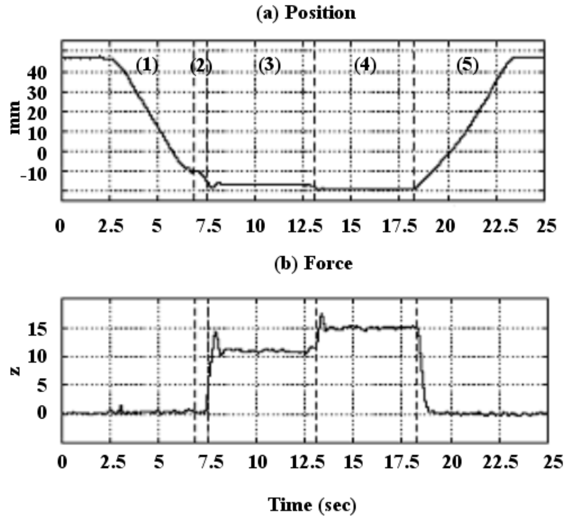

Fig. 9: Motion of the finger (a) during an approach and a gasp and force applied on the object (b).

5. CONCLUSION

We presented a new technique to control of a three-fingered with 12 degrees of freedom robotic gripper for real application.

It presents 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. Future improvements will concern 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.

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