N89-19863

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# INTEGRATION OF A COMPUTERIZED TWO-FINGER GRIPPER FOR ROBOT WORKSTATION SAFETY

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## ABSTRACT

A microprocessor-based controller has been developed that continuously monitors and adjusts the gripping force applied by a special two-finger gripper. This computerized force sensing gripper system enables the endeffector gripping action to be independently detected and corrected. The gripping force applied to a manipulated object is real-time monitored for problem situations, situations which can occur during both planned and errant robot arm manipulation. When unspecified force conditions occur at the gripper, the gripping force controller initiates specific reactions to cause dynamic corrections to the continuously variable gripping action.

The force controller for this intelligent gripper has been interfaced to the controller of an industrial robot. The gripper and robot controllers communicate to accomplish the successful completion of normal gripper operations as well as unexpected hazardous situations. An example of an unexpected gripping condition would be the sudden deformation of the object being manipulated by the robot. The capabilities of the interfaced gripper-robot system to apply workstation safety measures (e.g., stop the robot) when these unexpected gripping effects occur have been assessed.

## INTRODUCTION

The widespread application of robots has created a need for endeffector devices which can sense the force applied to handled objects. Other handled object characteristics such as its shape are also often required because the robot has to deal with several kinds of object materials of different texture.

Although these kinds of gripper capabilities are absolute necessities for so-called human equivalent robots, the mentioned endeffector functions can have specific purposes for some industrial applications. In this project, the proposed industrial gripper force sensor system can be fully utilized for handling part objects with only limited feedback information from the endeffector because:

1) The user enters the approximate gripper force that seems suitable for gripping a particular object while the robot performs a specified task.

2) If the robot's smart gripper controller then notices that the object cannot be safely handled within the program specified force bounds due to prescribed task acceleration and deceleration characteristics, it will stop the robot and wait for another user command that it recognizes to be more suitable for the particular part handling assignments, force-wise and robot movement-wise.

Thus, the robot can avoid improper and unsafe part handlings.

## GRIPPER DESIGN

In manipulating and moving objects with robots, force sensors in the gripper can provide important feedback information.

A smart gripper force sensor system using strain gages was designed to permit the handling of very delicate objects using a two-finger gripper (see Figure 1).

The details of the gripper fingers and force sensor design will be described in a paper to be presented at the International Conference on Ergonomics of Advanced Manufacturing and Hybrid Automated Systems this August 15th.

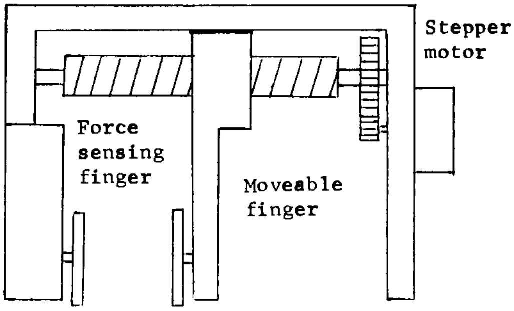



Figure 1. Two-Finger Gripper Hardware

SMART GRIPPER CONTROLLER

The signal from the gripper's sensor is amplified by a strain gage amplifier which sends a DC output voltage to the input of an A/D converter (see Figure 2). The voltage is processed through an A/D converter and sent to an 8-bit NEC Z80A computer through a 8255A PIO interface, where interface programs can be written in either Basic or Assembler languages. Also the stepper motor for the gripper drive is driven by a stepper motor driver board through another PIO interface. Further, the NEC computer communicates with GE P-50 industrial robot through another PIO interface.

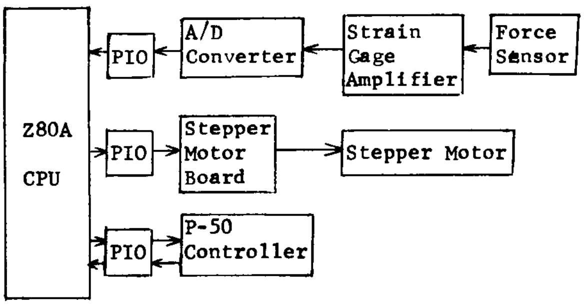



Figure 2. Control Computer Interface

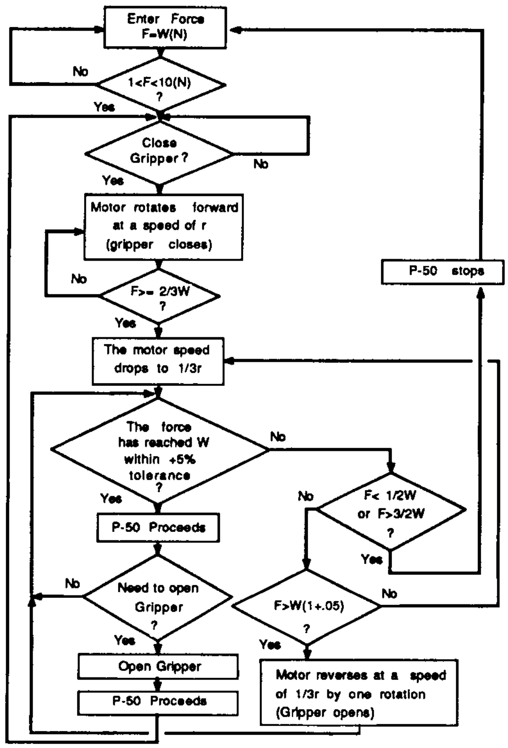



Figure 3. Flow Chart of Force Control Logic.

GRIPPER CONTROL LOGIC

During robot operation, the two-finger gripper maintains the user specified force; that is, the forward and reverse rotations of the stepper motor are controlled by the output signals from the smart gripper controller. As the gripper force approaches the specified force, the forward and reverse rotations of the stepper motor are slowed down to one-third of full speed.

In this developed smart gripper system, improper part handling force was defined as $F < 1/2\ W$ or $F > 3/2\ W$, where W is the user specified force. If the measured force exceeded the defined safe range during robot task operation, the robot automatically stops and waits for the user to enter another specified force (see Figure 3). Thus, the smart gripper controller provides a robot safety scheme in its handling of objects.

SMART GRIPPER OPERATIONS AND CIRCUITRY

The operational logic and interface communications for the smart gripper controller will be described by means of the following pick-and-place illustration.

<u>Grasp (Position B)</u>

When the robot gripper reaches its part grasp location (position B) from its home position, after 1 sec. the P-50 controller output port 04 turns on (see step 01 in Table 1 and Figures 4 and 5). Thus, the I/O port A0 of the Z80A is then grounded and the Z80A starts its A/D conversion. The stepper motor then starts rotating, causing the gripper to close.

When the specified force is applied to the object, relay 1 closes (see step 02 in Table 1). The P-50 robot then proceeds to the part release location (position A) for the gripper.

Transfer (Move B → A)

While the object is being transferred, the stepper motor can rotate forward and reverse according to the continuous force feedback. If the force is too big or too small owning to some physical, etc., change, where a proper gripping operation is now impossible, then the P-50 robot stops and waits for another force input from the Z80A. Relay 2 is activated to initiate this servo-stop of the P-50 robot.

Release Location (Position A)

When the P-50 endeffector reaches its release location (position A), after 1 sec. the P-50 controller output port 05 is turned on (see Step 03 in Table 1). Then the motor reverses and the object is released by the gripper.

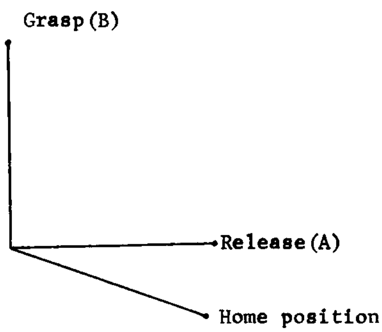
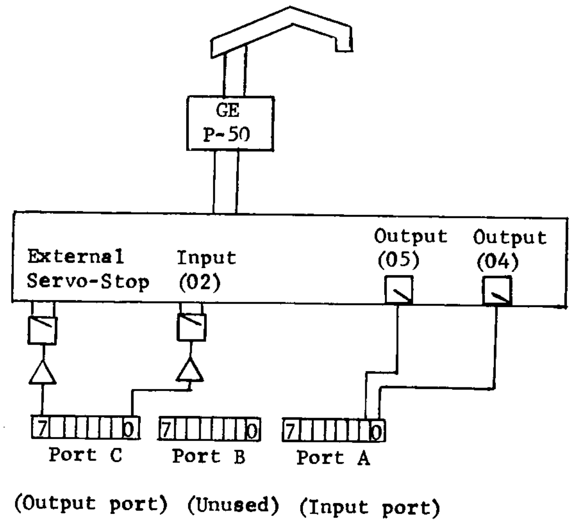



Figure 4. P-50 Operational Sequence with Safety Sheme.

Table 1. Control Logic Step Sequence

| Step | P-50 Timer | P-50 Output | P-50 Input | Comments |
|---|---|---|---|---|
| 00 | | | | Home Position |
| 01 | T1 ON (1 sec) | 04 ON | | P-50 moves to position B. After 1 sec, gripper closes to the specified force. |
| 02 | | | 02 ON | When the force reaches the specified value, the P-50 proceeds, maintaining the force. |
| | | | External servo stop | If the force exceeds the range; F<(1/2)*W or F>(3/2)*W, P-50 stops. W is a specified force. |
| 03 | T2 ON (1 sec) | 05 ON | | When the P-50 reaches position A, after 1 sec the gripper opens. |
| 04 | | | | End of Program |



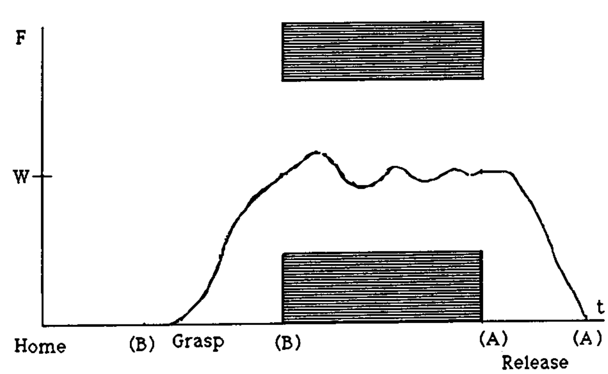

8255A I/O Ports of NEC Z80A Computer

Figure 5. Z80A Interface Connection

EXPERIMENTAL STUDY

Experiments were performed to learn how accurately the endeffector was able to handle deformable objects (see Figure 6). These pick and place tasks were conducted at various robot speeds.

Although complete numerical results have not yet been obtained, the designed and developed smart gripper has shown excellent observed performance in the handling of lightweight deformable objects (see Figure 7).




* Shaded areas define unsafe forces.

Figure 6. Example of Controlled Gripper Force.

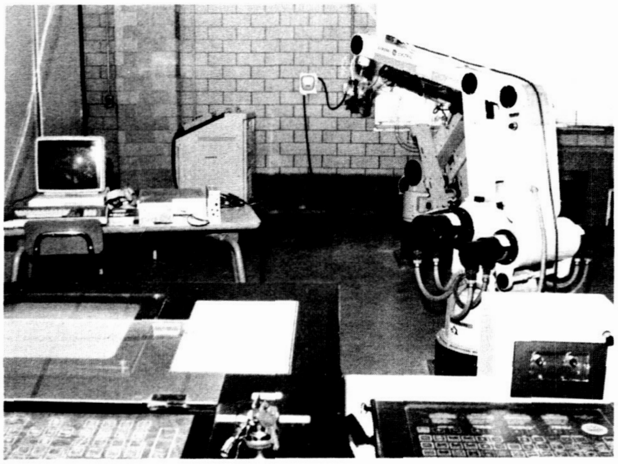


Figure 7. Experimental System.

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CONCLUSIONS

This project has been conceptually successful in the development of a low cost gripper force sensor system that was able to handle lightweight deformable objects during a pick-and-place task with safety. This system was conceived and constructed with controller interface provisions that stops the robot if the gripper force exceeds a specified unsafe force range.

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