'91 韓國自動制御學術會議論文集 1991. 10.22~24

SCARA Robot를 위한 4 자유도 End-effector 개발

오 세훈 (KIMM) C.B. Besant (Imperial College)

Four degrees of freedom robot gripper for assembly robots

Se-Hoon Oh (KIMM) C.B. Besant (Imperial College)

Abstract

A new end-effector has been devised and the problems resulted from using it with SCARA robots are discussed. The end effector has two modules: one composed of two ultrasonic motors and two encoders for controlling each finger, and the other module composed of two ultrasonic motors and two encoders for controlling the wrist. The wrist module adds two degrees of freedom to the SCARA type robot, which generally has four degrees of freedom. With independent finger actuation and touch sensors, the gripper under computer control can feedback information about part size and part presence. Ultrasonic motors with high torque and slow motion characteristics are used. The principle of ultrasonic motors is explained and the servo characteristics of ultrasonic motors are studied. They are controlled by the general motion controller (Hewlett Packard HCTL-1000) which is linked to an IBM-PC AT.

1. Introduction

Generally SCARA robots are best suited to light assembly work, for example, PCB assembly. However, the gripper is sometimes forced to keep to a particular orientation, for example, when the robot picks up the electrical component from part feeders or electrical tube feeders which has a slope to facilitate the chip movement.

Most robots used in assembly are SCARA robots, which generally have less than four degrees of freedom. To execute any position and orientation in a workspace, at least six degrees of freedom is required. Therefore, two axes must be added for the SCARA-type robot to have six degrees of freedom.

The research described, examines the need for further axes for SCARA robots and the type of gripper that would allow more general applications of the SCARA robot for assembly tasks. The present research deals with the hardware, software and control strategies required for the implementation of such a system.

2. Design Criteria for wrist

The end effector must have six degrees of freedom in order to position and orient a grasped object arbitrarily in space. Three degrees of freedom are required for placing a body in a designated point in space, and another three degrees of freedom are required for angular orientation. Positioning motion is usually performed by the major linkage of the manipulator, and orientation is performed by the wrist.

One of the most important criterion in any mechanism is the weight. For the wrist module, the following parameters should be taken into account[1]:

1. The number of degrees of freedom, including gripper options.
2. Points of intersection for the wrist; avoidance of unnecessary transformation for robot control.
3. Mobility of the wrist and gripper, and coordination with the arm.
4. Type of power transmission
5. Arrangement of the drive system.
6. Layout of the energy supply and signal lines.

7. Low inertia to the drive motor.
8. No backlash (if possible)

The answer to criterion (1) is related to the degrees of freedom of the SCARA robot. The robot has four degrees of freedom. Therefore, two extra axes are necessary for the robot to execute any orientation and any position within the workspace.

A considerable effort was made to satisfy condition(5) because the arrangement of the drive system can change its weight and size. Criterion (6) is negligible in most cases . The number of power lines and signals is up to 30 in the present scheme. Therefore, special attention is required in positioning electrical wiring. Accordingly, a special cover is required to maintain it free from foreign particles. The part arrangement of the wrist is shown in Fig.1. When the robot moves, the wrist does not need to rotate. A pneumatic brake is used to hold the wrist when the main robot is accelerated. This module can be used for a fine motion control.

When two joints becomes colinear, the movements of two joints generate the same motion of the end effector. This phenomenon is called a degeneracy. When this occurs in a wrist, one of the Pitch, Yaw and Roll angles is lost. The proposed wrist mechanism has a singularity cone in the centre of the workspace. Significant additional velocity and torque demands are placed on the wrist actuators inside this cone. Generally, the assembly operation does not need a harmonic cooperation between axes which require velocity control.

3. Design criteria for gripper

The robot gripper is the bridge between the robot and the environment around it. From the point of view of economy, the industrial robot has to forsake versatility and dexterity. However, in some cases, a gripper is required that can handle and manipulate many different objects of varying weights, shapes and materials.

Grippers commonly used in assembly tasks have a simple pneumatically actuated drive system. Although this is inexpensive and effective, it limits the variety of parts a single gripper can handle. Electric servo motor technology used in fully articulated robots was used in gripper technology [3]. Precise control of force and position is needed in the assembly of delicate mechanical and electrical parts. The sizes of electrical parts are quite different from each other and that means a large finger work space is required. A gripper under computer control can feedback information about part size and part presence. It may not be necessary to change the gripper with each new application with a computer controlled flexible gripper. This would allow immediate switching from one application to the next.

Most mechanical assembly tasks need a small magnitude of accurate motion during part mating. The response and fidelity of force or position control at the robot arms are poor for very small movements. Therefore, small movements at the gripper without moving the main robot arms are a very effective method for achieving a fine motion.

In order to solve many of the problems associated with flexible grippers, the following design criteria [4] were adopted:

1. A completely parallel finger motion
2. Adjustable gripper opening to accommodate various part sizes .
3. Location of gripper fingertip at precise positions.
4. Independent finger actuation .
5. Control of gripping force [within 2 Kg]
6. Minimal backlash and friction .
7. Easily exchangeable fingers.
8. Position repeatability to 0.02 mm
9. Total weight 250 g

The most difficult task in this project was to make the hand light and compact. It was also important to know what kind of configuration should be adopted. Fig.2 shows that a compact design is possible with a motor mounting plate used for the adaptor between the wrist and the gripper. The encoders reside between motors, and this makes a great contribution to compactness.

4. Ultrasonic Motor

Ultrasonic motors have been developed for practical use by Panasonic[5] and Shinsei Co.[6]. These motors use progressive ultrasonic waves. The disk type ultrasonic motor has a simple structure, composed only of a stator and a rotor. The stator has an elastic body normally made from stainless steel, and two kinds of piezoelectric ceramic adhered by deviating in phase by 1/4 wavelength so as to generate travelling waves on the elastic body. In order that the ultrasonic motor can generate torque, it is necessary to apply an appropriate pressure to the contact surfaces of rotor and stator. Conical springs make this pressure being controlled using an adjustable
A variation of speed can be easily obtained from 10 to 1 and it can start or stop within 1ms. Its performance in drooping characteristic is the same as that of a DC motor and the maximum conversion efficiency of this motor is 45 percent.
The driving principle of the ultrasonic motor is quite different from the conventional current-magnetic motor. It has many different characteristics as follows:

1. Small size, light weight, low speed and high torque. The motor has no winding and a simple and thin structure.
2. Possibility of gear-less, brake-less structure. Conventional motors are not capable of producing high torques at low speeds and gears has to be used.
3. Excellent controllability: Controlling the position of the ultrasonic motor is as easy as in the case of D C motor.
4. Quick response because of large torque and small rotor inertia
5. Free from magnetic noise, since it does not rely on a magnetic field.

4.1 Servo Control Card

The HCTL-1000 is a general purpose motion control IC made by Hewlett Packard. The Fig.3 shows the block diagram of the servo control system. The system has a host processor, an amplifier, a motor and an encoder. The HCTL-1000 has a quadrature decoder for encoder signals and a 24-bits counter to keep track of the position.

The HCTL-1000 is controlled by a bank of 64 8-bit registers, 32 of which contain command and configuration information necessary to run the controller chip properly. The register number is the address. The other 32 registers are used by the internal CPU. It also provides a digital filter to achieve a better control.

5. Algorithm for Peg-in-hole

Much analysis has been carried out to determine strategies that guarantee a successful insertion when the peg is partly in the hole using chamfer. [7, 8, 9, 10]. If uncertainty is larger than the tolerance of the hole, a strategy should be devised to ensure that the peg can find the hole

Several strategies are considered here :

1. Chamfer: Chamfers either the peg or the hole increases the possibilities of ensuring the peg can fall into the hole. This technique is mostly an effective use with RCC [9, 10]
2. Tilting the peg : Tilting the peg expands the range of tolerance of the hole [11].
3. Search : When the peg contacts the top surface, it is sliding in certain directions until it falls into the hole.
4. Biased Search: This is a modified method of the search. There are three different regions in this set : One region to the right of the hole, one region to the left of the hole and the one region in the hole. The peg is put at a certain biased offset position to the hole, then the peg approaches the hole.
5. Dynamic Approach : The moving direction is determined by the information based on using force sensors.

Search operation used here is a kind of biased search shown in Fig.4.

The sliding motion **B** can be executed by moving the fingers together or the pitch axis in the wrist, The swing motion **C** is obtained by moving the roll axis in the wrist. If a vertical motion is observed during the search , stop the search motion, because this means that the gripper has found a hole. Then, the next step is to execute the insertion motion.

As explained in the previous section, a large insertion force is needed to insert a peg into a hole during the two-point contact. Reducing the positional error postpones the occurrence of two-point contact. Consequently, the algorithm used here is able to reduce position error and gives as much compliance as possible.

As shown in Fig.5, adaptive selection of search pattern [12] is employed.

After finding the hole, the peg will slide into the hole until jamming or wedging occurs. When the vertical motion stops, the search mode in the x-y plane is actuated. The gripper follows the predetermined path until the vertical motion resumes. If the search motion fails, the grip force decreases in order to give a little more compliance which enlarges the circle of the jamming free area. Then the predetermined path begins again. The peg may encounter the jamming again. This time, the search pattern begins from P1 to P2 following the direction from P0 to P1. In the same manner, the search move continues towards the jamming free area.

6. Conclusion

The wrist and gripper was designed for SCARA robot. Its gripper and wrist motion gives additional degrees of freedom to the robot. An ultrasonic motor was selected as an actuator. This has greater ratio of torque over weight compared to other electrical motors.

References

[1] Warnecke, H. J., Schraft, R. D., and Wanner, M. C. "Handbook of Industrial Robotics" Ed. by Nof, S.. John Wiley & Sons pp44 -79, 1985.

[2] Stackhouse, T. H. "A new concept in robot wrist" Proceedings 9th International Symposium on Industrial Robotics, pp589 - 598, 1979.

[3] Kempf, M. and Wu, C. A. , "Design of fully programmable electric servo robot gripper" Proceedings 17th International Symposium on Industrial Robotics, 1985.

[4] Wright, P. K., and Cutkosky, M. R. "Design of grippers" in Handbook of Industrial robotics, ed. S. Nof. New York: Wiley 1985.

[5] Tokushima, A., Harao, N., Takahashi, K., Sugano, N. and Inaba, R. "Ultrasonic Motor" National Technical Report [Japan], Vol. 33, No. 5, pp 542 - 550, Oct. 1987.

[6] Shinsei Corporation "A new concept in motors ultrasonic wave oscillation drive energy" J E E, pp 42 - 44, Jan. 1988.

[7] Cho, H. S., Warnecke, H. J. and Gweon, D. G. "Robotic assembly: a synthesizing overview" Robotica vol. 5 pp 153-165, 1987.

[8] Simunovic, S. N. "Part mating theory for robot assembly" Proceedings 9th International Symposium on Industrial Robotics, Washington DC. U. S. A. pp183-193, 1979.

[9] Drake, S. H. Watson, P. C. and Simunovic, S. N. "High speed robot assembly of precision parts using compliance instead of sensory feedback" Proceedings 9th International Symposium on Industrial Robotics, Washington, D C, U.S. A. pp135-152, 1979.

[10]Whitney, D. E. "Quasi-static assembly of compliantly supported rigid Parts" Journal of Dynamic Systems, Measurement, and Control 104, pp65-77, March 1982.

[11]Inoue, H. "Force feedback in precise assembly Tasks" Artificial Intelligence Laboratory, Massachusetts Institute of Technology, 308, 1977.

[12]Takeyasu, K., Goto,T. and Inoyama, T. "Precision insertion control robot its application"Journal of Engineering for Industry B 98-4, 1976.

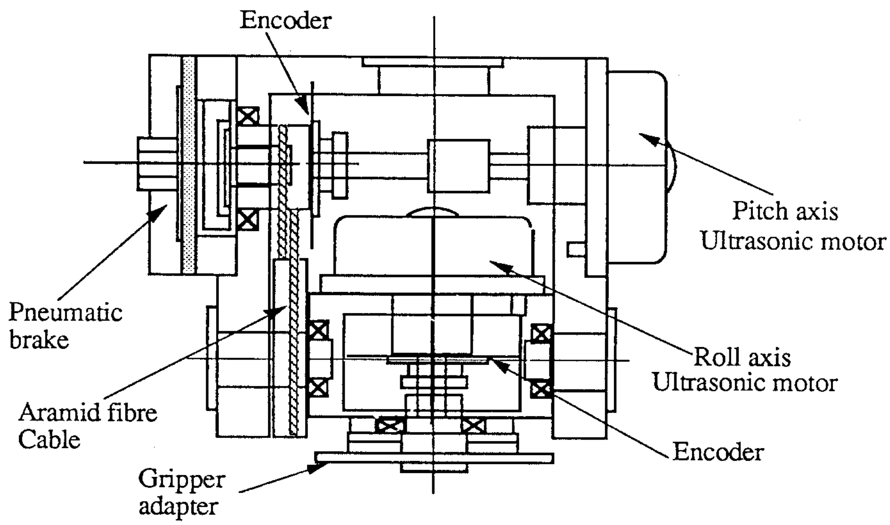

Fig.1 The part arrangement of the wrist

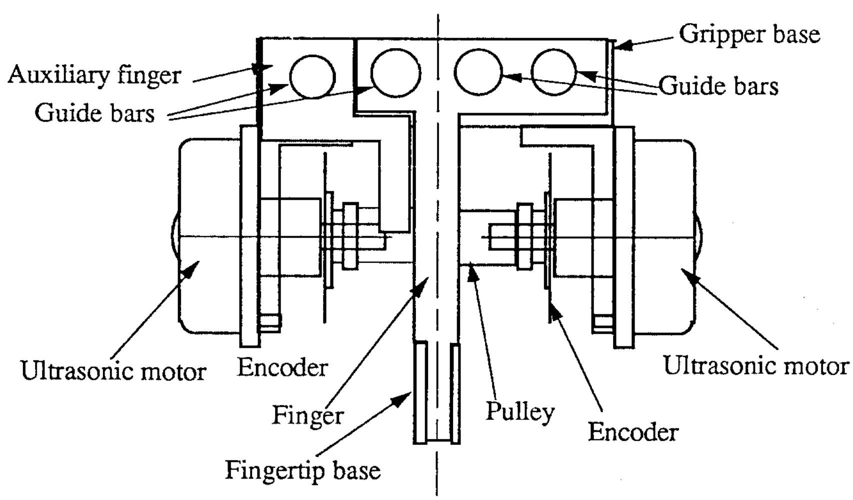

Fig.2 Part arrangement of the gripper.

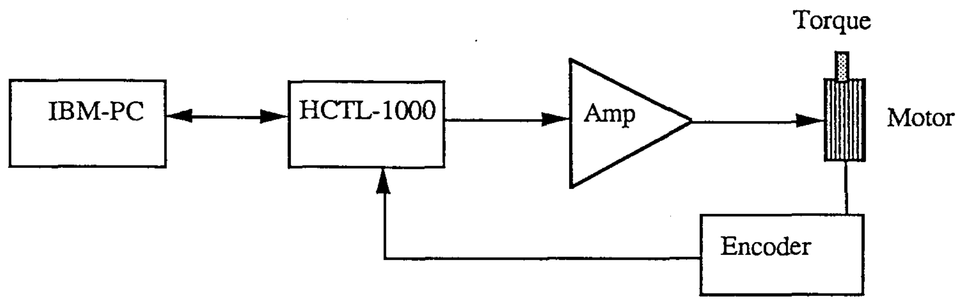

Fig.3 Block diagram of servo control system.

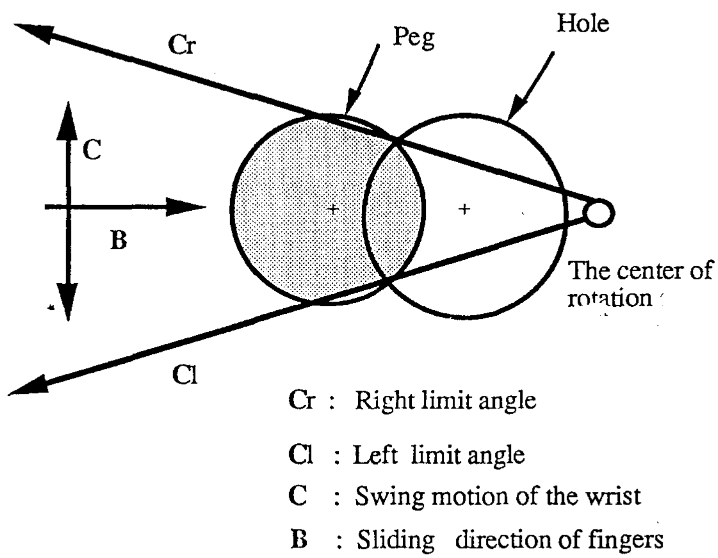

Fig.4 The method of finding a hole.

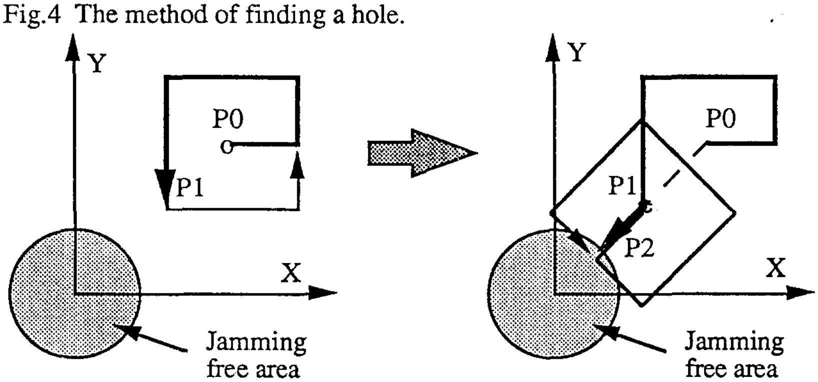

Fig.5 Adaptive selection of search pattern