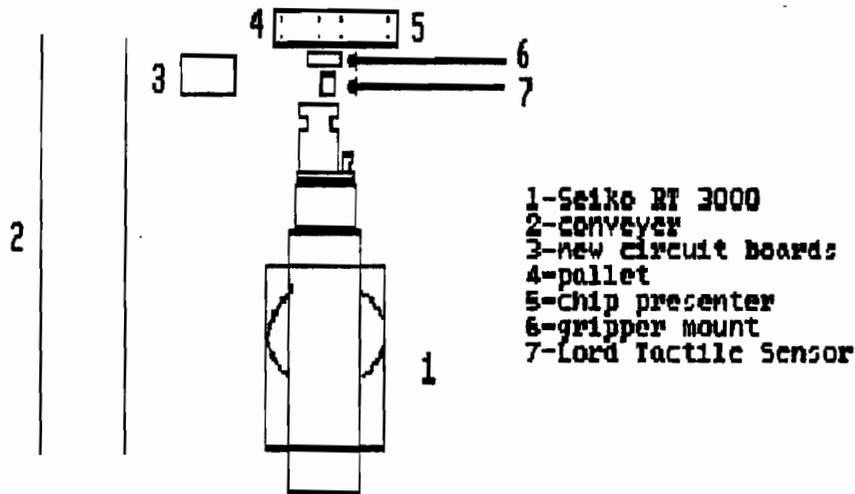


# TACTILE

SENSING  
IN PC BOARD  
ASSEMBLY

## Tactile sensing in PC Board Assembly

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### Abstract

With the advent of flexible manufacturing in printed circuit board assembly a requirement to locate PC boards accurately for chip insertion has developed. One method for this type of locating is the use of tactile sensing. This paper deals with the practical use of the Lord Corporation's tactile array for circuit board location with a Seiko RT 3000 robot. The robot and tactile array are being controlled completely from an IBM PC acting as a host processor, thus providing offline programming capability for the complete cell. The cost effectiveness of this system over machine vision systems is quite substantial due to the difference in systems costs and avoiding illumination problems associated with machine vision. Further cost savings are gained by the use of the Seiko RT 3000 to perform chip insertion operations thus eliminating the need for a separate chip insertion device.

## Introduction

Presently, small batch circuit board assembly is done manually due to the high cost of time required to set up and run automated chip insertion equipment. These automatic chip insertion machines require precise positioning of the circuit board which presently in this type of hard automation is more productively done manually. The use of robots for placement of the circuit boards for chip insertion is viable providing a very precise presentation of the circuit boards is made through the use of extensive hard tooling. Through the use of tactile sensing the need for precise presentation by hard tooling is eliminated. The tactile sensor would then be used to determine positioning of the boards as presented loosely on an inexpensive conveying system.

With today's increasing manufacturing costs the need for smaller inventories and reduced set up time can be achieved by designing a more flexible automated system while maintaining a minimum capital investment cost. This paper will discuss one such system using a Lord Tactile sensor with a Seiko RT 3000 robot.

## Project Scope

The project was first developed to investigate possible uses of a tactile sensing system using the Experimental Lord Tactile Sensor. To assess the feasibility and advantages of the Tactile Sensor in a practical situation the project was expanded to encompass an entire work cell around the premise of small batch PC-board assemblies. The work cell is designed for maximum flexibility and multiple variations of circuit board configurations while keeping the complexity and capital investment to a minimum.

## Tactile Sensors vs. Vision Systems

The major advantage of implementing a tactile system in comparison to vision is the fact of the major lighting problems encountered with vision systems. Even though tactile sensors have a similar problem related to pressure these are more easily overcome in industrial situations than controlling the lighting.

Another advantage is the cost of tactile sensors compared to the cost of vision systems. Even though a tactile sensor surface will wear out the overall cost of operating a system is considerably less due to the fact the the Lord can be operated by any host system, that can also control the robots operations. The vision system not only needs it's own computer, and cannot be controlled off line, the menus are also limited. An additional cost would be imposed for the algorithms required for part location.

Further disadvantages of vision systems would be the fact that the complexity of the mathematical calculations a vision system requires, would be slower then tactile sensing since the vision system would have to evaluate the entire set of input from the camera instead of only a few rows and or columns as in the tactile system.

### The Lord Tactile Sensor

We used the Lord LTS 200I Tactile Sensor revision 1.162. The operation of the sensor is controlled by an IBM XT via a RS232c communications port at 9600 baud (which is the maximum speed the sensor can operate at). No pre-processing is done by the Lord Tactile sensor controller. Each byte of information received by the computer corresponds to the amount of pressure on a particular sensing sight and sent to the computer in some predetermined order as specified by the command sent to the Lord Tactile Sensor by the computer. We used three different commands during the process of this particular operation. They are:

Zero sensor (<ESC>[?0L) - This command updates the internal zero reference to eliminate sensor drift caused by time and temperature. No data is sent back to the host system.

Scan array (<ESC>[?1L) - This commands the sensor to measure the deflection of each sensor sight and communicates this data to the host system. The sensor scans from left to right and top to bottom with the first value at the top left corner (with the cable oriented to the bottom).

Scan sight (<ESC>[?4;x;yL) - This command measures the deflection of a single sensing sight as specified by the x y parameters in hexadecimal.

### Computer Algorithm

Three different computer algorithms are used in this process to allow for the accurate positioning of the circuit board for chip insertion.

The first algorithm calculates the angle offset. This is done by scanning the first and last row of the sensor pad and using the last active sensor element to obtain the angle by use of the Arctan function. (see fig 1a)

It was discovered, that with only one placement of the board on the sensor you would get an accuracy of +/- 3.5 degrees. To obtain a better accuracy it was decided to do four board placements 0.45mm apart (1/4 of a sensor element) so that we could average the four angles together to obtain more accuracy. This procedure was done twice to ensure that an angle of zero, in relation to the sensor, was obtained.

Once the angle was obtained the approximate location of the corner of the circuit board was calculated. This was done by use of the second algorithm, which is the first xy offset calculation. The computer first checks to ensure that the corner of the board is on the pad. To accomplish this the computer found the upper most sensor element in the first column of the pad. If the highest point was in the 16th row the computer had the robot move the board down 30mm which was usually sufficient for placing the corner of the board onto the sensor. During these calculations, the x offset is calculated but disregarded. After it is determined that the corner is on the pad, the computer uses the information from the first row and first column to determine the approximate location of the corner. This location is then transformed into an offset so that the robot moves to a specific location on the sensor pad for the next set of calculations. (see fig. 1b)

Once the board is brought into a specified area of the tactile surface we can commence with the third algorithm. We use a limited point by point scan to determine the location of the board to within 0.1mm. This is accomplished by small movements of the circuit board determined by the sensor elements activity. If we want the board to be on sensor element 5,10 the board would be placed on 6,11 by the last algorithm to start (this placement is done to within 0.9mm). If element 6,10 is active then the board would be moved down 0.1mm and if the element 5,11 is active the board would be moved to the right the same amount. After both elements are reading zero pressure the computer would then calculate the move to the pallet. (see fig. 1c)

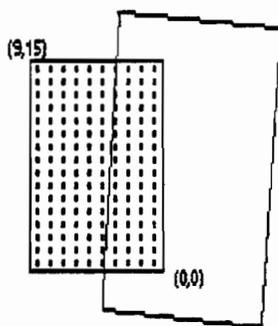


Fig. 1a

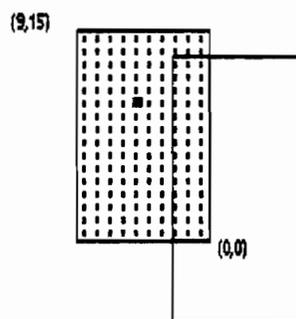


Fig. 1b

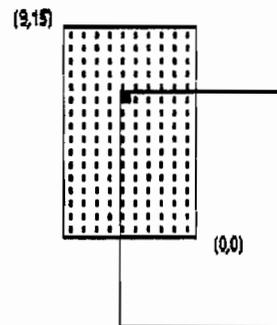


Fig. 1c

### The Work Cell

To create the robot work cell several considerations had to be made. First the endeffector had to be developed not only to do the circuit board placement but also to do the chip insertion. After considering several different options it was decided to use a two part endeffector. The first part of the endeffector which is physically attached to the robot is designed to pick up IC chips for insertion. The second part of the endeffector is designed to be picked up by the first gripper and consists of two suction cups which are used to pick up the circuit board for placement.

Once the endeffectors were developed then the layout of the work cell was the next consideration. The cell had to be laid out for utilization of time and equipment. The cell consists of the Seiko RT 3000, Lord LTS 200I, chip presentation machine, circuit board assembly fixture, bin for unassembled boards and

conveyer to assembled boards to the next work station. Due to the unavailability of a proper chip presentation machine we have simulated this by securing a separate circuit board, with the chips mounted, in a fixed location for demonstration purposes.

Control system of the cell was the next consideration. Since both the Lord Sensor and the Seiko RT 3000 are capable of communications through an RS 232c port we decided to use an IBM PC as the master controller of all the system operations. This was done for many reasons. First of all the Seiko could not directly communicate with the Lord Sensor because of the lack of variable manipulation allowed by its programming language. Secondly, timing problems between the Lord Sensor and Seiko robot would have been too complex for parallel processing. (see fig. 2)

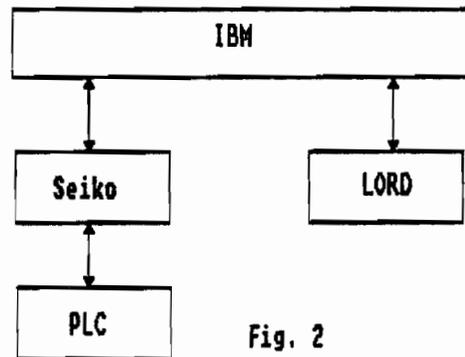


Fig. 2

Due to the limitations imposed upon us, an Allen Bradley PLC-4 was incorporated into the cell to control the track motion, pallet stop and the secondary gripper functions. The Seiko RT 3000 robot does have the input/output capabilities to control the entire operation even though we were unable to utilize these functions.

### Cost Effectiveness

This system has been developed to have a minimal initial equipment cost. Cost analysis of the system shows the following results:

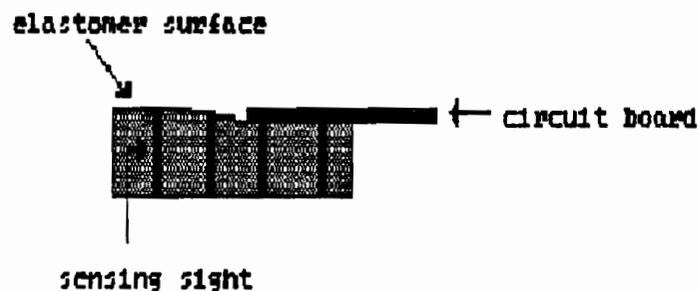
	<u>Tactile</u>	<u>Vision</u>
Seiko RT 3000	\$33,500	\$33,500
Sensing device	\$5,875	\$35,000
Endeffector	\$1,000	\$1,000
IBM or compatible	\$1,600	\$1,600
Chip Feeder	\$15,000	\$15,000
Programmable controller	\$2,000	\$2,000
Extras		\$5,000
	=====	=====
	\$58,975	\$93,100

The approximate cost of the system we developed has a cost savings of approximately \$34,000 over a vision equipped system. Since we are using the Seiko RT 3000 for both board placement and chip insertion, the need for a separate chip insertion device is eliminated thus creating a savings of \$50,000+. Thus, by using the tactile system for placing the board, utilizing the robot to its full potential, the total savings on equipment for this flexible work cell is in excess of \$84,000.

### Development Problems

The major problem encountered in this project was due to the dependency of the tactile sensor to pressure. Like lighting with vision systems, if the pressure on the pad varies, your measurements will also vary making the placement of the board impossible. Even though the robot can apply constant pressure to the pad, our pneumatic gripper and even the table in the work envelope, were flexible enough to allow pressure changes on the tactile pad. This problem can be solved very easily by properly manufactured equipment. The pressure problems we encountered in this project were easily solved compared to lighting problems with vision systems.

Another major problem with the tactile pad is due to the elastomer covering the tactile surface. Do to its flexibility, you can get false readings. We did apply a filter so that this would not occur but a much more sophisticated procedure would have to be developed to determine the actual location of the board instead of the readings caused by the tactile elastomer surface.



Another problem that was encountered was the flexibility of the circuit board. We had to add an extra piece to the gripper to support the circuit board to maintain a reasonably accurate pressure while on the pad. If this piece was removed or jarred the sensor would give a false reading and the circuit board would not be placed accurately. This was caused by a change in the pressure as seen by the sensor which affected the filters and offsets used in the computer program.

### Cell Improvements

During the course of working on this project we have come up with many improvements that could be made to improve the flexibility of the work cell.

The first of these improvements is the addition of a bar code reader. This would allow for many different types of circuit boards to be produced without the down time to change computer programs. The bar code reader would control which of the subroutines for chip insertion would be executed.

The second major improvement would be to add a pneumatic drilling head to the endeffector assemblies. The drilling head would be picked up in a similar fashion to the existing second gripper but

without compliance. This head would then be programmed using the robot to drill the holes required for the specified circuit board. This head eliminates the need for the circuit board to be punched or drilled after printing. The board could be delivered directly to the cell from the printing and etching process thus creating a savings not only in equipment cost and also but in time between stations and the need to orient the part more than once. This drilling system would only work well with circuit boards not requiring plated through holes.

Combining these two improvements could conceivably create an even larger savings in equipment and production costs at an additional capital layout of only \$4,500.

### Conclusions

Through the research on this project we have concluded that tactile sensing is a viable alternative to other sensing systems. After the time spent in the past few months developing this system, we feel that within the foreseeable future the use of tactile sensing will be largely accepted in industry.

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