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Multiple Sensor Integrated Robotic End-effectors for Assembly

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Abstract

In industrial environment product assembly constitutes a major part in manufacturing. Introduction of automation in manufacturing activities has positively influenced the business in many counts. With the advent of new technologies manufacturing houses are willing to adopt new technologies and strategies to make their products more reliable and competitive. The present work deals with the development of a multiple sensor integrated robot end-effector which can be gainfully used for product assembly in industries. The sensors prescribed for the purpose help the assembly robot in identifying the correct part, navigation the robot arm and inspecting the assembly for its correctness. Experiments on these aspects have been conducted successfully and the relevant results are presented to explain the effectiveness and usefulness of the sensor integrated end-effector.

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Keywords: Sensors ; Robotics ; Assembly ; Manipulator ; PLC ; Microcontroller.

1. Introduction

Sensor- improved 'intelligent' system is the state-of-the-art of present day robotics research study. A multi-sensory robotic system allows the manipulator to accomplish any specified assembly task in the stipulated workspace with

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desired position and orientation of the respective joints and end-effector. Assembly of parts operation is one of the most time consuming activities in the industrial production of manufacturing and automation. There leftovers a great opportunity for operating the product and production economics through automation. Therefore considering the kind of task and complexities involved in the process, robotic technology comes out as the only option to do the job, particularly when there is a requirement for smaller repetitive tasks in production cycle. However, the environments in the industries are such that robots alone are not able to operate the inspection and assembly tasks efficiently. In order to task case of the uncertainties, dynamics and some other task-specific issues, the employed robot ought to be intelligent enough. Intelligence can be added to the robot through integration of necessary sensors with the robots. This particular work aim at developing a instrumented robotic hand system for part inspection and assembly tasks in an automated environment wherein the force/torque, proximity, ultrasonic and tactile (LTS) sensors are used to identify the correct part on workspace and to do some specific mating work. The all mentioned sensors are placed judiciously around the wrist and end-effector of the SCARA robot, interface with the robot control system and sensory data are picked up to corporate in the robot motion control program for the desired inspection and assembly operations. F. Caicedo [1] described a hardware and software infrastructure for carrying out tasks assembly and combination of four ultrasonic transducers with two force sensors in unstructured environments. Fumihito [2] analyse the balance of the adhesive forces between the objects, and proposed reduction method of adhesive force. J. Norberto Pires [3], Choon-Young Lee [4], propose a novel module and a new algorithm which are applied on mobile robot to avoid obstacles using three ultrasonic sensors with different beam widths. Object detection systems work in real-time is addressed by W. Zhang [5] by uses images processing at various resolutions. Giovanni [6] described the integrated sensor systems to evolution of assembly systems in the unstructured environments. Zhaojia Liu [7] address the problem of fast and automatic grasping of unknown objects with minimum number of robots features which are extracted from the scanned data are used for grasping point determination. Hasimah Ali [8] presents the development of vision-based sensor of smart gripper for industrial applications. This vision-based sensor has ability to detect and recognize the shape of the object after adopts image processing techniques. Fei Chen [9] designed an electronic manufacturing system in order to solve multiple possible dynamic problems during the assembly process. O.P. Sahu [10] previously focused on force/torque sensing aspects applied to industrial robotic assembly operations with SCARA robot to perform assembly operation, The present work uses all mentioned sensors in the robot end-effector to facilitate inspection of parts and correct assembly operation. Experiment work has been carried out to demonstrate the working of the sensor- integration robot manipulator for accomplishing the desired inspection and assembly operations.

2. Methodology

An experimental set- up was made to carry out mechanical assembly using a SCARA robot. A force / Torque sensor, Capacitive proximity sensor, Inductive proximity sensors, Ultrasonic sensors and Tactile (LTS) sensors were mounted on the wrist of the robot to facilitate the identification of correct part and to perform the desired joining operation either through pushing a part on to another or through screwing.

2.1. Models/Scheme

The primary objective of the robot is to pick and manipulate the correct part for assembly and to carry out the operation for mating the parts to build the final products with the help of applied integrated sensor. The specification of the F/T sensor used for the purpose is as follows. The Six axes force/torque sensor (Model No.: 9105-NET-GAMA - IP65), mounted on the wrist of a SCARA robot fitted with suitable gripper, is used to sense the force and/or torque coming on the manipulator during any 'obstacle encounter'. Two proximity sensors both capacitive (Model: CR30-15DP) and inductive (Model: E2A-S08KS02-WP-B1-2M) are mounted in the robot gripper to detect the presence or absence of any object; the specification of the proximity sensor used for the purpose is as follows. These sensors give ON-OFF type signals, which are being interfaced with Programmable logic controller (PLC). Ultrasonic Sensor (Model: MA40S4R/S) and Tactile Sensor (Light Touch Sensor Model: EVPAA) is also mounted on the end-effector of a SCARA robot to sense the distance of the target object from the end-effector, and to indicate the applied pressure of the gripper to the targeted object respectively. All above mentioned sensor are mounted on the wrist and end-effector of a SCARA robot used for inspection and assembly jobs. The all integrated sensors and the SCARA robot are shown in fig1 (a) (b) (c) (d) and Fig1 (e) respectively. Fig. 2 shows the schematic diagram of integrated sensors mounted on the SCARA robot end-effector.

Make/Model: MTAB Engineers Private Limited India.
Axes: Five axes
Pay Load: 1.5 kg

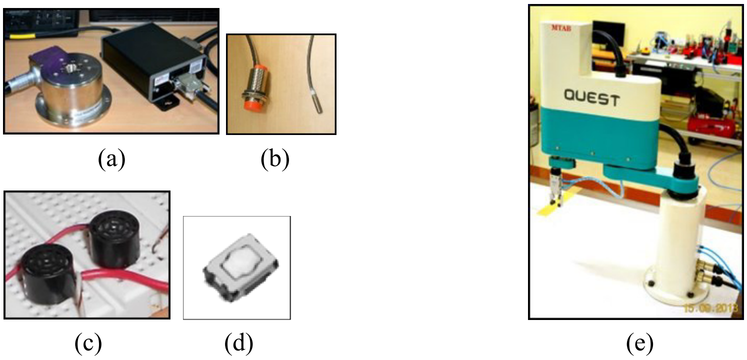


Fig. 1. (a) F/T Sensor with ATI DAQ system (b) Proximity Sensor (c) Ultrasonic Sensor (d) Tactile (LTS) Sensor (e) SCARA robot

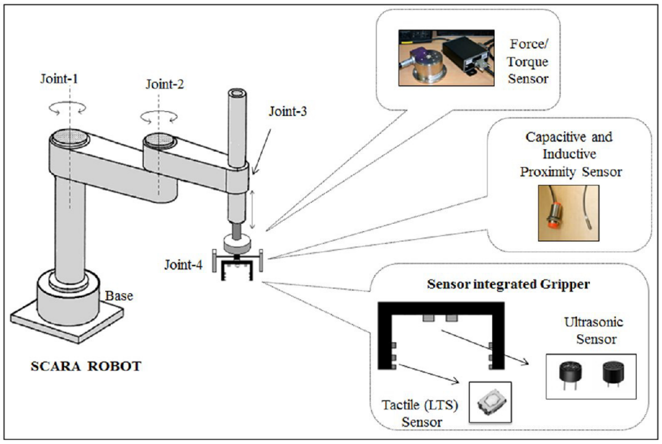


Fig. 2. Schematic diagram of integrated sensors with SCARA robot

1.1. Interfacing and Data Collection Technique

The scheme of interfacing of all mentioned sensors with SCARA robot, F/T sensor was connected to PC through ATI DAQ system as represented in fig.3. The data acquisition system converts the transducer signals from analog voltages into digital. This data is processed by MATLAB 2012a. Capacitive and inductive proximity sensors are interfaced and experimentally controlled by PLC and programming in the ladder diagram using the PLC software Machine-addition. Similarly Ultrasonic and tactile (LTS) sensors are interfaced by using the microcontroller are shown in fig.3.

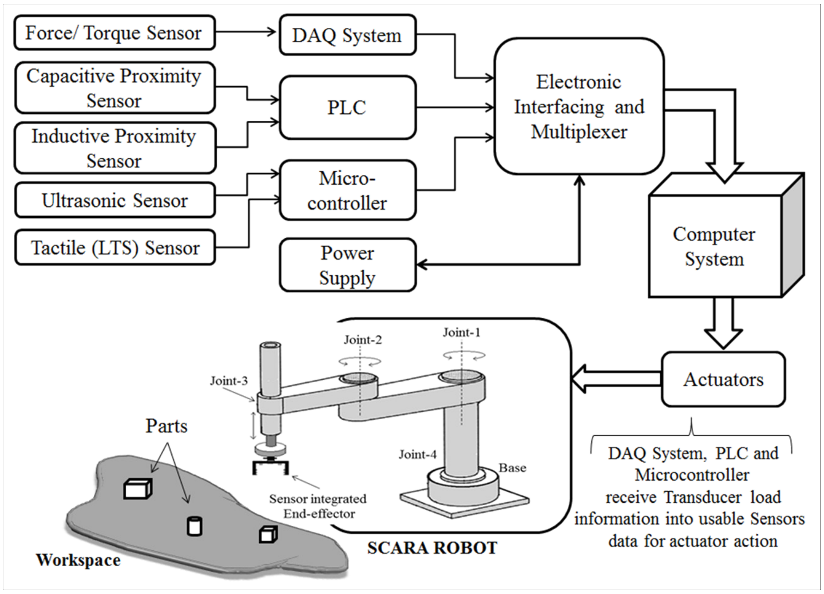


Fig. 3. Scheme of interfacing of all mentioned sensors with SCARA robot

1.2. Data utilization

Table-1 represents the three performed experimental assembly task performance datasheet, first one is the identification of part, for this operation it is required to measure the weight of the part in considered tolerable range. Inspection of parts is also considered via measuring the touch and distance. Similarly for another assembly task Pushing and screwing has to measure the weight and pick and manipulate the correct part for assembly and carry out the operation for mating the parts.

Table 1. Experimental task performance datasheet (considered)

Parts	Force(s) to perform Assembly task	Tolerable range	Material properties	Inspection of parts	Assembly task
a	2.5 N	1%	Metallic	Touch and Distance	Identification
b	4 N	0.5 %	Metallic	Touch and weight	Pushing
c	1.5 N -m	1%	Metallic	Touch and weight	Screwing
n	n	n	n	n	n

1.3. Calibration and Experimentation

In order to conduct the experiments and to ensure the correctness of the setup, the instrument was calibrated. This was done by applying required apparatus of known voltages on the mentioned sensors and recording the output in terms of voltage and output display signal. Fig.4 represented the Flow chart of complete proposed process.

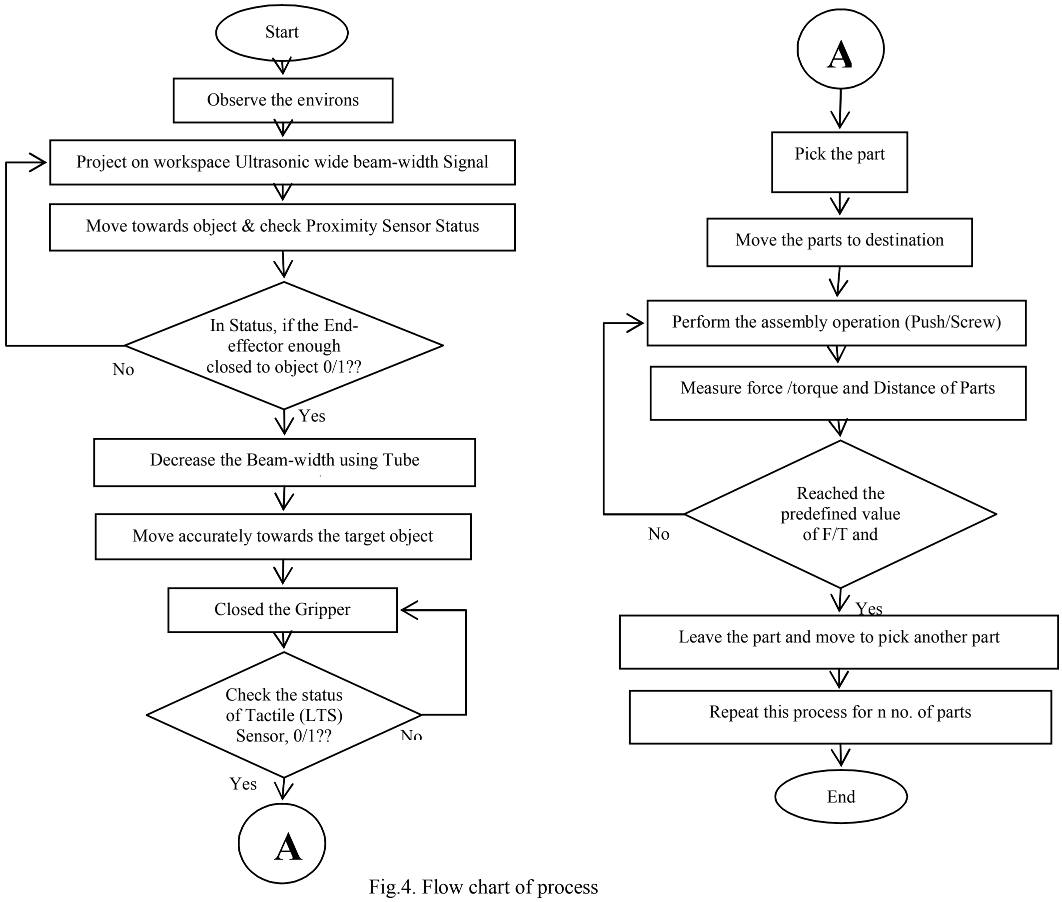


Fig.4. Flow chart of process

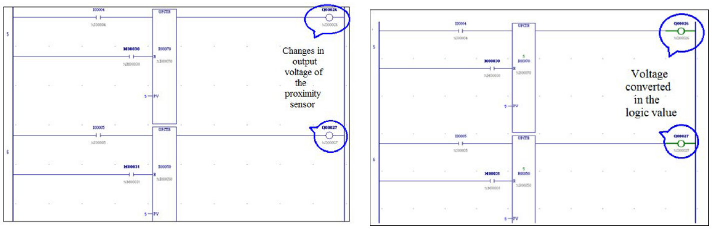
A correlation between the applied force/torque and the output voltage was established through experiment has been done in previous research paper [10]. This correlation was used to determine the weight of the part being manipulated during assembly and to do the necessary mating operations for part assembly. The mating operations considered in the present work are simple pushing and screwing. The force/torque required to do the necessary mating operation was also predetermined through experiments as discussed in previous research paper [10]. Now the extended experimental views of all mentioned sensor using microcontroller and PLC system are described below.

Proximity sensors are interfaced by the help of a PLC (programmable logic control). The channel voltage states of a PLC are 24 volt and 0 V. It means the channel pin will be at logic 1 at 24 volt and at logic 0 at 0 V. Proximity Sensor will give 24 V during a presence of an obstacle in front of the sensor face and 0 V during the absence of obstacle in front of the sensor face with a predefined set range shown in fig 5(a) and fig. 5 (b).

(a) (b)

Fig. 5. Experimental views of Proximity Sensor using programming logic controller

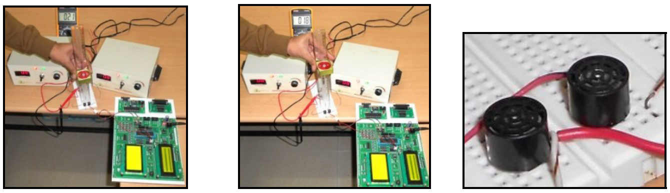
The output voltage of the proximity sensor is sensed and converted to a logic value by the help of channel of the PLC. According to the requirement the ladder diagram has been installed shown in fig-6.



(a) (b)

Fig. 6. Experimental views of ladder diagram using programmable logic controller

MA40S4R/S ultrasonic transmitter activated with 40 KHz (10 V p-p) square pulse. That pulse is generated by microcontroller and feed directly to the transmitter. For the accuracy of the pulse width of the generated square pulse we have used the internal timer of the microcontroller. Once the transmitter gets activated it will transmit the 40 KHz and almost 10 V p-p square pulse signal. The transmitted signal will be transmitted through the air and finally reflected by the target object at the other end. Reflected signal will be received by the receiver placed just beside the transmitter. The received signal will be amplified by the help of an op-amp(IC-LM741) represented in fig-7.



(a) (b) (c)

Fig. 7. Experimental views of Ultrasonic Sensor using micro- controller

The novel technology in this paper is the ultrasonic sensor and the proximity sensor in communication with each other. The beam width of the transmitter will be controlled by the proximity sensor status and the position of outer tube, which can be controlled by the actuator.

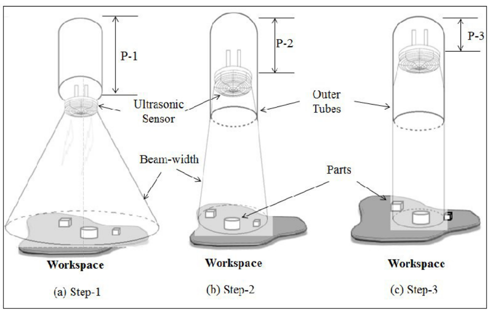
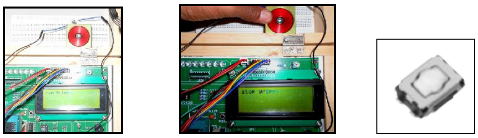


Fig. 8. Identifying the parts metallic properties using ultrasonic sensors with movement of outer tubes

Initially the proximity sensor status will be zero and the transmitter will transmit ultrasonic wave with wide beam angle at position P-1. With this wide beam angle it will observe the total work space with a lesser accurate result for any particular object. A controller unit will check the proximity status continuously. If the end-effector reaches enough close to the target object the proximity status will jump to logic 1 from logic 0. Once the controller senses this status change by the help of an actuator it will enclose the transmitter with in a tube at position P-3. By this, the beam width of the transmitter will get narrower and will focus only on the target object. A narrower beam width will help us to give a more accurate result as shown in Fig.8. Tactile (LTS) Sensor is interfaced by the help of a microcontroller (AT89S52) represented in fig.9. Terminal 1 of the (LTS) Sensor is connected to a 5 VDC supply and terminal 3 to a port pin of the microcontroller. If the applied pressure is not enough the (LTS) Sensor will be in open condition. After receiving per-defined pressure it will close the internal connection between terminal 1 & 3 and the 5 VDC at the supply terminal will be available at terminal 3. Microcontroller will sense the pin status continuously. If the pin status is 0 V or at logic zero it indicates enough pressure not yet been applied and it will run the gripper. Once the pin status will jump to logic 1 or 5 VDC it will indicate enough pressure have been applied and the microcontroller will stop the gripper. The above operation will be performed by a simple logical program.

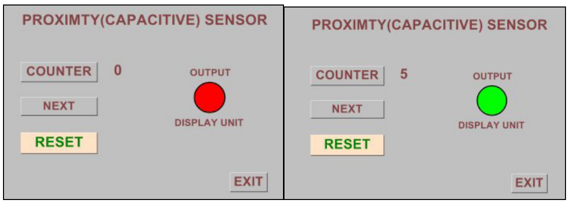


(a) (b) (c)

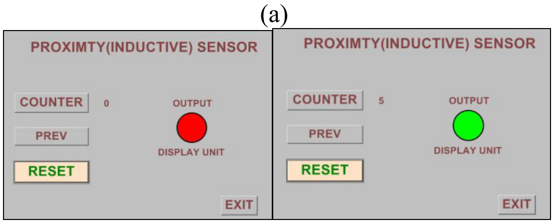
Fig. 9. Experimental views Tactile (LTS) Sensor using micro- controller

3. Results & Discussion

The required Steps to do the necessary task such as inspection and assembly operation are determined through experiments. Proximity sensor is interfaced to a PLC by the help of Machine Design (for hardware) and Cimplicity (PLC software). For each pulse generated by the proximity sensors will increment the counter of the ladder diagram. Pre-set value is defined as 5 (randomly). After each 5 count the virtual LED color on the screen will change from red to green color. Reset button will reset the counter. By using the above logic we can control the channel voltage status as per our requirement. Experimental output display using programming logic controller views of proximity capacitive sensor and proximity inductive sensor are shown fig.10 (a) and (b) respectively.



(a)



(b)

Fig. 10. Experimental output views of (a) proximity capacitive sensor (b) proximity inductive sensor using PLC

Ultrasonic sensor transmitter is interfaced to microcontroller by the help of the KEIL (Embedded C) software. The output voltage of the receiver is amplified and measured by the help of a microcontroller. The distance and the co-responding voltage values are plotted in the Microsoft excel. Using the plot the robot can sense the distance by sensing the receiver voltage. Experimental output data and Graphical view of ultrasonic sensor are shown in Table-2 and fig-11 respectively.

Table 2. Experimental output data of ultrasonic sensor

Distance (cm)	Voltages (mV)
1	57
2	55.3
3	51
4	49.5
5	41
6	35
7	32
8	31
9	29.5
10	29.1

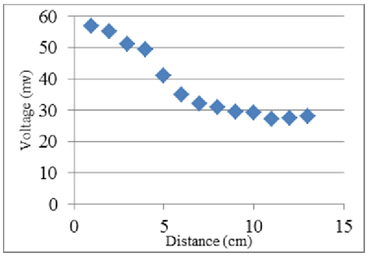


Fig. 11. Graphical Representation of experimental data

Tactile sensor is interfaced with microcontroller by the help of the KEIL (Embedded C) software. When the applied pressure is not enough, the LCD screen will display “start griper” and when the applied pressure will be enough the LCD screen will display “stop griper”.

4. Conclusion

An attempt has been made to equip the end-effector of an assembly robot to work intelligently in a product assembly environment. Force/torque, proximity, ultrasonic and tactile (LTS) sensors are used for carrying out the necessary assistive work during assembly. The sensors are controlled with the help of PLC and microcontroller and they are integrated in such a manner that they form an integral part of the robot arm. The experiments are conducted successfully for sample product assembly tasks. The development of such an end-effector is definitely a step for word in automation assembly process.

References

[1]. Fumihito A, Hitoshi I,and Kouichi I, Integrated Micro End effector for Dexterous Micromanipulation , Seventh IEEE International Symposium on Micro Machine and Human Science, 19961; 49-157.
[2]. Norberto Pires J, Force/Torque Sensing Applied to Industrial Robotic Deburring, Submitted to Sensor Review Journal, MCB University Press, UK, 2002; 1-19.
[3]. Choon-Young Lee, Ho-Gun Choi, Jun-Sik Park, Collision Avoidance by the Fusion of Different Beam-width Ultrasonic Sensors, IEEE, SENSORS; 2007; 985-989,.
[4]. Giovanni De Micheli, An Outlook on Design Technologies for Future Integrated systems, IEEE transaction of CADICS, 2009; 777-787.
[5]. Zhaojia Liu, Hiromasa Kamogawa, Jun Ota, Fast and Automatic Robotic Grasping of Unknown Objects, IEEE International Conference on Robotics and Biomimetic, 2011; 1096-1101.
[6]. Hasimah Ali, Tei Chen Seng, Low Hoi Hoi, Mohamed Elshaikh, Development of Vision-Based Sensor of Smart Gripper for Industrial Applications, IEEE 8th International Colloquium on Signal Processing and its Applications, 2012; 300-304.
[7]. Fei Chen, Kosuke Sekiyama, Pei Di, Jian Huang, Toshio Fukuda, an Intelligent Robotic Hand for Fast and Accurate Assembly in Electronic Manufacturing, IEEE International Conference on Robotics and Automation, Saint Paul, 2012; 1976-1981.
[8].Sahu OP, Biswal B B, Force / Torque Sensor Integrated Robotic Manipulation for Assembly Operations, IEEE conference, India, ICRESE, 2013; 955-959.