An Integrated Approach of Sensors to Detect Grasping Point for Unstructured 3-D Parts

Om Prakash Sahu, Bunil Balabantaray, Nibedita Mishra, and Bibhuti Bhushan Biswal

***Abstract*—Grasping of unstructured parts is a problem in automated assembly. In this paper, grasping of unstructured manufacturing parts is considered, where the parts are unambiguously seen first time via vision sensor. The problem lies on grasping these unknown parts, where the three dimensional view of parts is not available. For grasping efficiently, the end-effector is equipped with a vision and ultrasonic sensor. The demonstration is explained in details in the paper. The desired grasping point is found out by the bounding rectangle and image frame size contour to calculate the total number of the pixel on parts. Acceptable parts grasping point can be calculated in the presence of HSV noise. Experiments analysis is done on different unknown objects for evaluation.**

***Index Terms*—Vision and Ultrasonic sensor integration; robotics end-effector, grasping point.**

I. Introduction

Now a day vision system has been used in several applications of automated manufacturing industries, performing in harsh and unstructured environments. Such systems propose intelligent and flexible environment for assembly automation cell, particularly for such odd jobs as automated inspection in manufacturing environs. In a robotic end-effector vision sensor system for example permits a workspace where parts to be watched from numerous different positions, empowering a vision sensor system to find out several pixel points in two dimensions (2-D) from real-time multiple images. The observed calibrated sensory data can be used to recognize the parts, part measurement, part shape, position relation between objects and general work piece manipulation.

It is not adequate to use only one sensor. The proposed system to address this problem is to use numerous sensors and assimilate the sensory information to acquire a more precise outcome for part identification. In this paper, a 2-D vision sensor, provides the grasping position and an ultrasonic sensor, calculates the distance, are used. This sensory system is planned to work with a robot with a two-fingered end-effector. To reconnect exterior sensory data and robot end-effector to each other, high accuracy is needed. The mentioned sensors are placed judiciously around the wrist and end-effector of the KAWASAKI RSO6L robot shown in Fig. 1, and interfaced with the robot control system and sensory data are picked up to cooperate in the robot motion control program for the desired inspection and assembly operations.

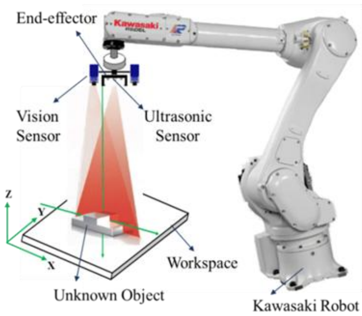

Fig. 1. Integrated sensors with KAWASAKI RSO6L robot.

II. Related Works and Review

In recent years various aspects of robotic technology has attracted many researchers. Rad and Kalivitis [1] proposed a methodology to design and evaluate the functionality of a low cost friction grip end-effector equipped with appropriate force and range sensors for general pick and place applications. Sintov *et al*. [2] introduced an algorithm for the search of a common grasp for a set of objects. The algorithm is based on the map of all feasible grasps for each object and the parameterization of them to a feature vector in a high-dimensional space. 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 addressed by Zhaojia *et al*. [3]. 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 presented by Hasimah *et al*. [4]. An electronic manufacturing system in order to solve multiple possible dynamic problems during the assembly process designed by C. Fei *et al*. [5]. Markus et al, [6] presented a novel grasp planning algorithm based on the medial axis of 3D objects and proposed an algorithm to be met by a robotic hand is the capability to oppose the thumb to the other fingers which is fulfilled by all hand models. Laser range data and range from a neural stereoscopic vision system is presented by Stefano *et al*. [7] and explained the estimate robot position is used to safely navigate through the environment. Ying and Pollard [8] described an approach that handles the specific challenges of applying shape matching to grasp synthesis. By processing images at various resolutions and object detection systems work using multiple sensors operation is addressed by Sahu *et al*. [9]. Osada *et al*. [10] proposed Algorithms which are used for Internet and

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local storage search, face recognition, image processing or parts grasping in assembly lines. However, such methods deals with parameterization of the geometry of the objects and cannot be applied for grasping. Biswal *et al*. [11] developed a multiple sensor integrated robot end-effector which can be gainfully used for finding the best grasp for a set of objects. This is done by using a predefined parameterization of the object surface and the hand poses, a method which inspired this work. The novelty of the present paper is that the object recognition is performed by integrating the vision sensor as well as the ultrasonic sensor matrix. The exact shape regarding surface of the target object is obtained by vision sensor. Other geometric information regarding dimension and location of the target object is obtained by ultrasonic sensor matrix.

III. Methodology

One of the requirements of an autonomous robotic assembly system is that, it should be able to recognize the desired parts. A method proposed to identify the parts through extraction of their several identifying features and then the robot end-effector is moved to grasp and manipulate the parts to perform the required task. Here force / Torque sensor, proximity sensor, vision sensors, ultrasonic sensors and tactile (LTS) sensors were mounted on the wrist of the robot to facilitate the identification of correct part to perform the desired mechanical assembly industrial operation using a KAWASAKI RSO6L robot.

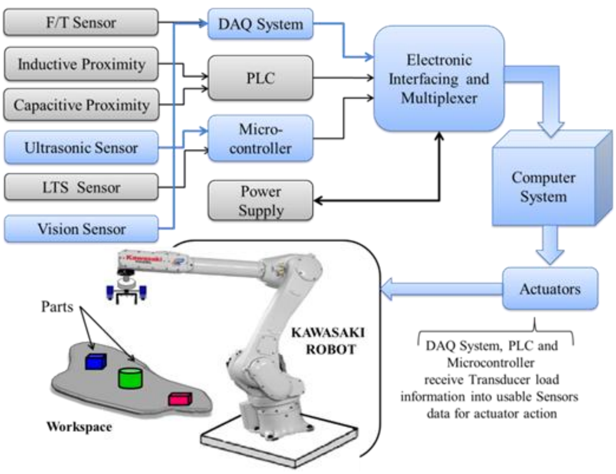


Fig. 2. Integrated sensors with KAWASAKI RSO6L robot.

A. *System Components and Models/Scheme*

The primary objective of the robot is to recognize, pick and manipulate the correct part for assembly and to carry out the operation to build the final products with the help of applied integrated sensors. The specification of the 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 KAWASAKI RSO6L robot fitted with suitable gripper, is used to sense the force and/or torque coming on the manipulator during an 'Obstacle encounter'. Two proximity sensors both capacitive (Model: CR30-15DP) and inductive (Model: E2A-S08KS02-WP-B1-2M) are mounted on 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 LabVIEW. Ultrasonic Sensor (Model: MA40S4R/S) and Tactile Sensor (Light Touch Sensor Model: EVPAA) is also mounted on the end-effector of a KAWASAKI RSO6L 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.

B. *Interfacing and Data Collection Technique*

The scheme of interfacing of all mentioned sensors with KAWASAKI RSO6L robot, vision sensor is connected to NI PXIe -1082 through DAQ system. The data acquisition system converts the transducer signals into digital image or pixels. This data is processed by LabVIEW (2013) function of Vision and Motion with vision assistant. Similarly Ultrasonic sensors are interfaced by using the microcontrollers are shown in Fig.2. It is an important feature to percept interactive information in unconstructive environment to an intelligent robotic hand.

C. *Sensors for Distance Calculation and Position Detection*

Sensors like vision sensor and ultrasonic sensor, to judge 2D surface, position, distance and shape of the parts in workspace, are used for sufficient information acquisition to provide a better decision capability and guide the autonomous manipulator as well as the end-effector to recognize the object and parts.

TABLE 1: Sensors for Distance and Position

Type of Sensor	Model	Descriptions
Vision sensor	BASLER scA640-70 fm/fc	Resolution up to 2000 x 2000 Frame Rate up to 100 fps
Ultrasonic sensor	MA40S4R/S	5V, Product mass-0.7g, Detecting distance - 0.2-4 m

Selected sensors for distance, position and vision are listed in Table I. Selection of these sensors are based on the follow principles: (1) better grasping capability with respect to distance and range; (2) higher accuracy in identification; (3) detection accuracy invariant to shape and material of the parts; (4) adaptive to changing environment.

IV. Experimental Setup and Calibration

All sensors are calibrated. Several experiments are conducted to verify the correctness of the setup. Kawasaki RSO6L end-effector are interfaced with vision and ultrasonic sensor and projected on objects in the workspace shown in Fig .5.

Fig. 4 shows the flow chart of proposed methodology for part verification of the desired parts in the workspace using vision and ultrasonic sensor, whereas Fig. 5 demonstrates experimental Set-up and calibration of sensors with KAWASAKI RSO6L robot with the end-effector to identify the parts properties.

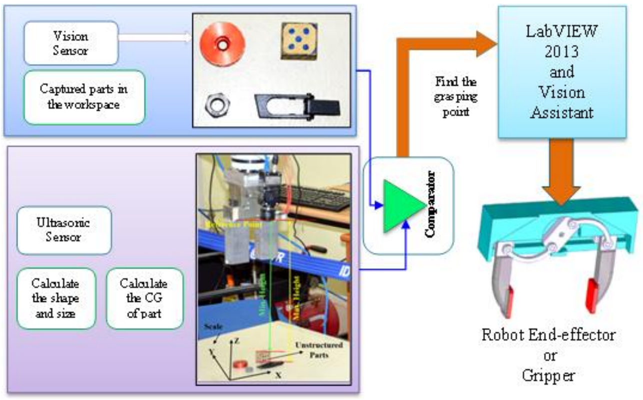


Fig. 3. Scheme of interfacing of all mentioned sensors and data processing.

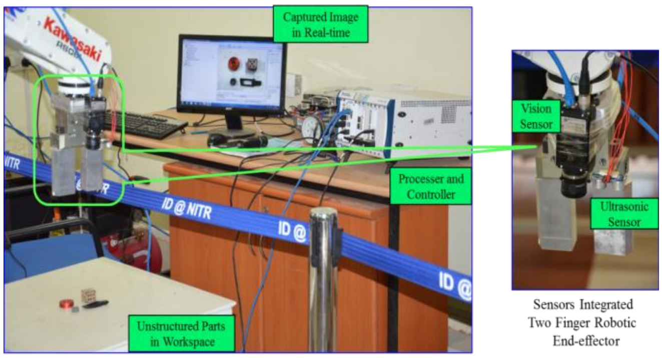


Fig. 5. Experimental set-up and calibration of sensors with Kawasaki RSO6L robot.

The preliminary operations depend on the communication protocol of the end-effector that is chosen to be compatible with the robot. At the moment, the 2-Finger Robot end-effector is consistent with three communication protocols are: Ethernet/IP, TCP/IP, and RS232 are shown in the figure.

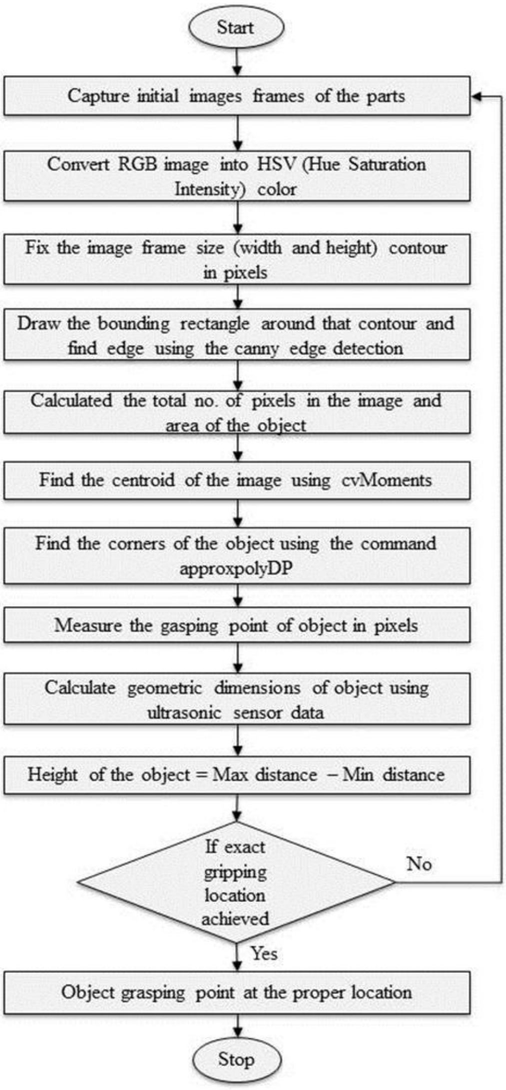


Fig. 4. Flow chart of proposed methodology.

The project includes the use of image processing to find the grasping point of an object, therefor the grid size functions of the vision and ultrasonic sensor is calibrated shown in Fig. 6.

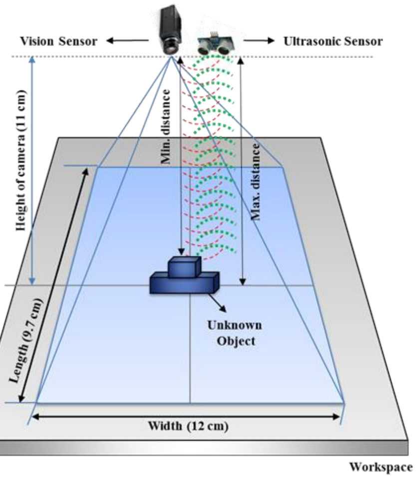


Fig. 6. Calibration of vision and ultrasonic sensor (a) grid size functions of the camera and target in centimeters.

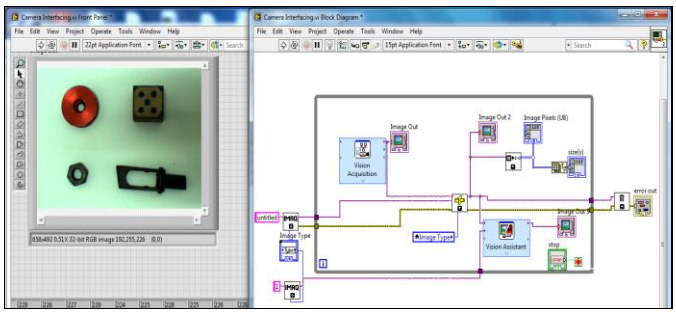


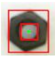
Fig. 7. Interfacing of camera using LabVIEW in front panel and vision assistant function coding in block diagram.

Grasping point is the position at which the robotic arm can grasp the object, which is generally be nearer to the center of mass of the object. OpenCV is an open source library written in C++ which helps mainly for real-time operations. A working environment is required to use this library as per our requirements. So software called "Microsoft Visual Studio 2013" is used, which is interfaced with OpenCV. And finally create a DLL file to import the code in the LabVIEW 2013 for interfacing of camera using LabVIEW in front panel and vision assistant function coded in block diagram show in Fig. 7.

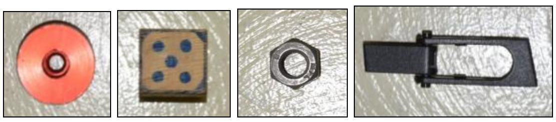
V. RESULTS

First the image frame size (width and height) is found out which is in pixels and is later converted to centimeters. The contour of the object is found out by varying the HSV ranges using the track bars. Now count the no of contours that are detected for that HSV range presented in Table II.

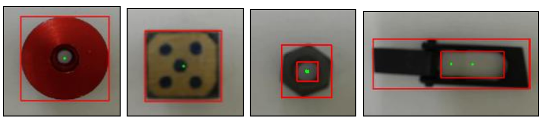
TABLE II: PIXELS AND THRESHOLD VALUE OF UNSTRUCTURED PARTS

S N	Name of Object	Shape of Object	Orientation	Width of the Rectangular Box		Distance from the centre cordinate		Pixel value of object	Object area in Rectangular	Threshold Value					
										Hue Value		Saturation Value		Intensity of Light	
				X-axis	Y-axis	X (cm)	Y (cm)		cm^2	HL	HH	SL	SH	VL	VH
1	Circular		Horizontal	3	3.49	6.54	6.45	27817	10.49	54	196	49	196	65	200
2	Square		Horizontal	3	2.95	6.99	6.08	26568	8.86	80	199	82	197	75	200
3	Hexa		Horizontal	1	1.83	7.11	6.77	5650	1.83	49	199	44	194	38	200
4	Unshaped		Horizontal	6	2.1	6.17	7.82	21611	12.6	192	192	70	194	61	200

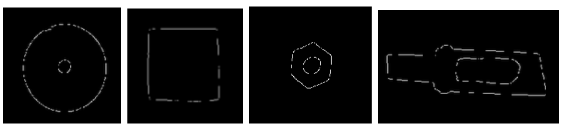
We considered the contour with largest area, which is the contour of interest. Draw the bounding rectangle around that contour. Using the canny edge detection the edge of the contour is found out. The total no of black pixels in the image is calculated. Total no of pixels in the image is the product of width and height of the image and the number of black pixels are counted and subtracted to get the total number of pixels on the object is contributing in the image. Now the centroid of the image is found out using cvMoments and the center is marked with green color. And the corners of the object are found out using the command approxpolyDP and are also marked with green color. Now the edge pixels of the image are found out and the image is divided into the pixels towards the left and those pixels towards the right making the first detected pixels as the reference. We found out the pixel of minimum length on the left side and also on the right side. These two points are the minimum or gasping point of the object. These two lines are shown in blue and red color, are shown in Fig. 8 steps by step.



(a) Four different types of unstructured parts to recognize.



(b) The image frame size is found in pixels and converted to centimeters.



(c) Using the canny edge detection the edge of the contour is found.

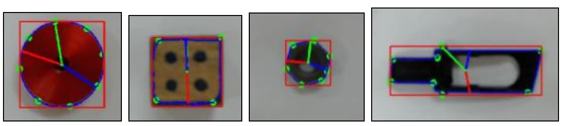


Fig. 8. (a) Four different types of unstructured parts to recognize (b) The image frame size is found in pixels and converted to centimeters (c) Using the canny edge detection the edge of the contour is found (d) Gasping point of the object with two lines are shown in blue and red color.

VI. CONCLUSIONS

This research paper proposed an efficient method to control end-effector grasping position combining a constant 2-D vision sensor with an ultrasonic distance sensor mounted in a two-fingered robot end-effector. This sensor arrangement is a substitute to more difficult and expensive 3-D vision systems for industrial application. In this submission the vision sensor gives the direction vector to originate objects top views or features. Meanwhile the vision sensor is only two dimensional; the perfect range from the vision sensor to the object is desired in order to guesstimate the precise part parameters. This distance can be achieved by the ultrasonic distance sensor, mounted in the robotic end-effector in such a way that it is calculating the diffidence nearly parallel to the alliance of the vision sensor. The sensory information is used for grasping control and can be used for part identification, part shape and size. Subsequently a grasping point is achieved by opening the end-effector wider, according to the object. The calibration of the system is presented briefly.

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