

## Design and Implementation of an Intelligent Virtual Instrumentation System for Vision based Object Sorting

C. Chandra Mouli<sup>1</sup>, P. Jyothi<sup>2</sup> and K. Nagabhushan Raju<sup>3</sup>

1 Senior Research fellow, Department of Instrumentation, Sri Krishnadevaraya University, Anantapur – 515 003, A.P., INDIA.

2 Research Scholar, Department of Instrumentation, Sri Krishnadevaraya University, Anantapur – 515 003, A.P., INDIA.

3 Professor, Department of Instrumentation, Sri Krishnadevaraya University, Anantapur – 515 003, A.P., INDIA.

### ABSTRACT

The present work describes the design and implementation of intelligent virtual instrumentation system for vision based object sorting by using robot arm. Particle and color object sorting was presented. It consists of two sections transmitter section and reception section. Transmitter section is a Personal Computer (PC) which initializes its processes based on the control signal provided by the reception section. Reception section is ARM microcontroller which initializes the PC and waits for control signal from PC. Particle and color objects moves on a conveyor belt, enters the illumination unit, where the image of the object was captured by a webcam and sends the image to PC. PC acquires the image, depending upon the user inputs; object of the image is classified and identifies the class name. Depending on the class name robot arm end-effector position was determined. There are four postures where the robot arm moves for object manipulation namely robot arm reset, grasping, picking, transit and placing. Set of each posture inputs is provided to the Inverse Kinematic (IK) model to calculate the joint angles of the robot arm and joint angles are transmitted through XBee module. ARM microcontroller receives the joint angles using XBee module and converts the joint angles into PWM signals for appropriate position of end-effector for object sorting.

**Key words:** Object Sorting, Robot Arm, Classification, PC, ARM Controller, and Inverse Kinematic.

**Corresponding Author:** C. Chandra Mouli

### INTRODUCTION

Grouping and tagging of objects with similar properties together, using image processing techniques and statistical classification algorithms for object sorting is the most attention grabbing research area in the field of instrumentation and automation. Sorting systems remain essential in numerous areas with diverse applications such as in manufacturing industry, libraries, factories, warehouses, pharmacies, supermarkets etc. Yang Tao discusses the advantage of image processing in sorting applications by implementing a

sorting system based on the hue extraction of an image from the image sensor and image processor performs a color transformation by obtaining a single composite hue value for each object for a piece of fruit to be sorted [1]. Thomas C. Pearson describes the object sorting system based on video image of an object [2]. MohamadBdiwi discusses about the control system and vision algorithms for library automation and book sorting using integrated vision/force robot control [3]. Roland Szabo implemented object sorting system based on color using robot arm where webcam is used to identify the color of the object and robot arm is used to place the object in appropriate place [4]. A vision based robot system was developed for 3D pose estimation and picking of the objects in which a video camera surrounded by eight flashes is used to capture the images and computer aided design tool is used to find the edges of the object using a fully projective formulation of Lowe's model based pose estimation algorithm [5]. RaihanFerdousSajal and associates designed an efficient machine vision algorithm for real time image analysis and recognition of different features of Bangladeshi bank notes by using an automatic banknotes sorting system [6].

Existing object sorting robot arm systems described in [7-12] generally works with CISC microcontrollers and they use wired embedded system to control robot arms for object sorting. The present work provides the detailed description and implementation of intelligent virtual instrumentation system for vision based object sorting by using robot arm. Particle and color object sorting was performed and the results were presented on various objects. Robot arm was calibrated to determine the actual kinematic parameters for sorting operation and the results are presented.

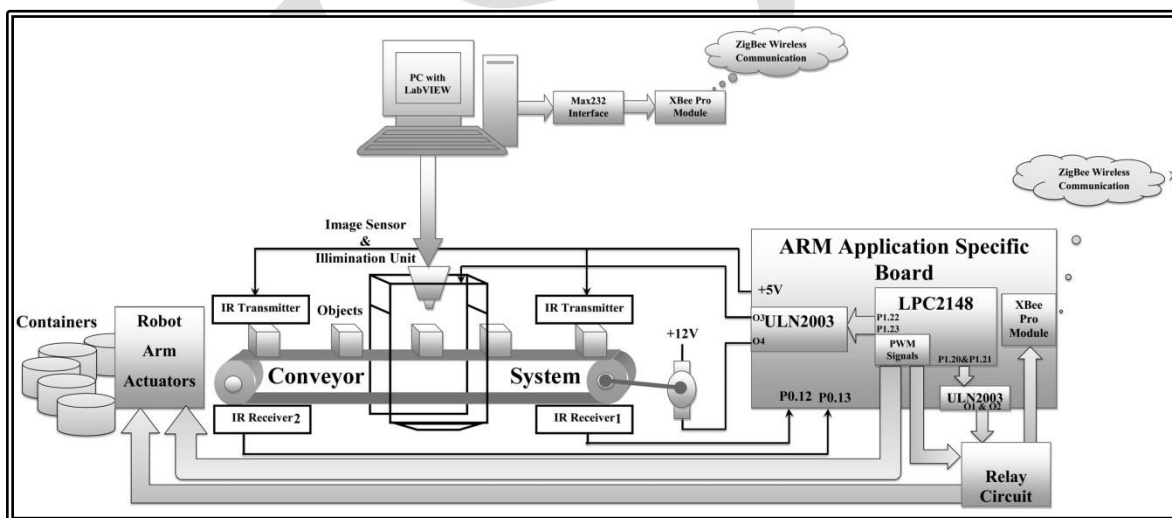


Fig 1: Block Diagram of Intelligent Virtual Instrumentation System for Vision based Object Sorting

## PRINCIPLE

Basic principle of object sorting was explained in [15] and Fig 1 shows the block diagram of present work. Objects on the conveyor system moves one by one from one end to other end. Objects enters into the image sensor and illumination unit for image acquisition. With the help

of sensors, conveyor belt engages for a while by stopping the motor, when objects enter into the illumination unit. Image is acquired and sent to PC for classification. Software package in the PC classifies the image and calculates the robot arm joint angles by evaluating Inverse Kinematics (IK) based on the object in the image. Joint angles were transmitted by using wireless communication to the microcontroller. Microcontroller receives the joint angles and converts the joint angles into corresponding PWM signals to run the robot arm actuators for end-effector positioning. Robot arm grasps, picks and places the objects in the containers depending on the class of the object.

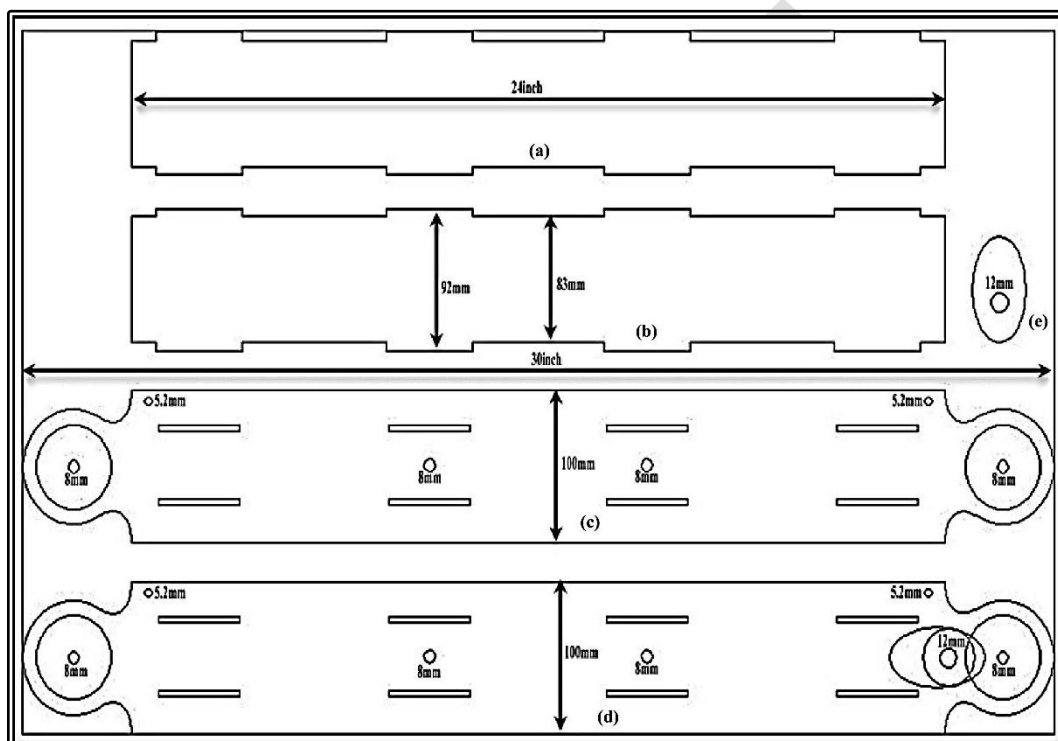


Fig 2: Mechanical Drawing of Conveyor System

## HARDWARE FEATURES

Hardware features of the present work contains of

- Image Sensor
- PC
- LPC2148 ARM Application Specific Board
- Robot Arm
- Relay Circuit
- Conveyor System
- Illumination Unit

Hardware details about image sensor, PC, LPC2148 ARM application specific board, robot arm and relay circuit was explained in [14, 16]. Conveyor system and illumination unit were explained in subsequent sections.

## CONVEYOR SYSTEM

A conveyor system is a mechanical assembly unit or a mechanical handling system which moves the objects from one place to another place. It allows speed and efficient way of transporting wide variety of materials in material handling and packaging industries. In the present work a conveyor system was designed and controlled. It consists of belt, IR sensors and DC motor.

Idlers form the supports for the carrying and return of the belt. A structure supports and preserves the alignments of the idlers, pulleys and supports the driving machinery 12VDC motor. Pulleys supports and moves the belt to control its tension.

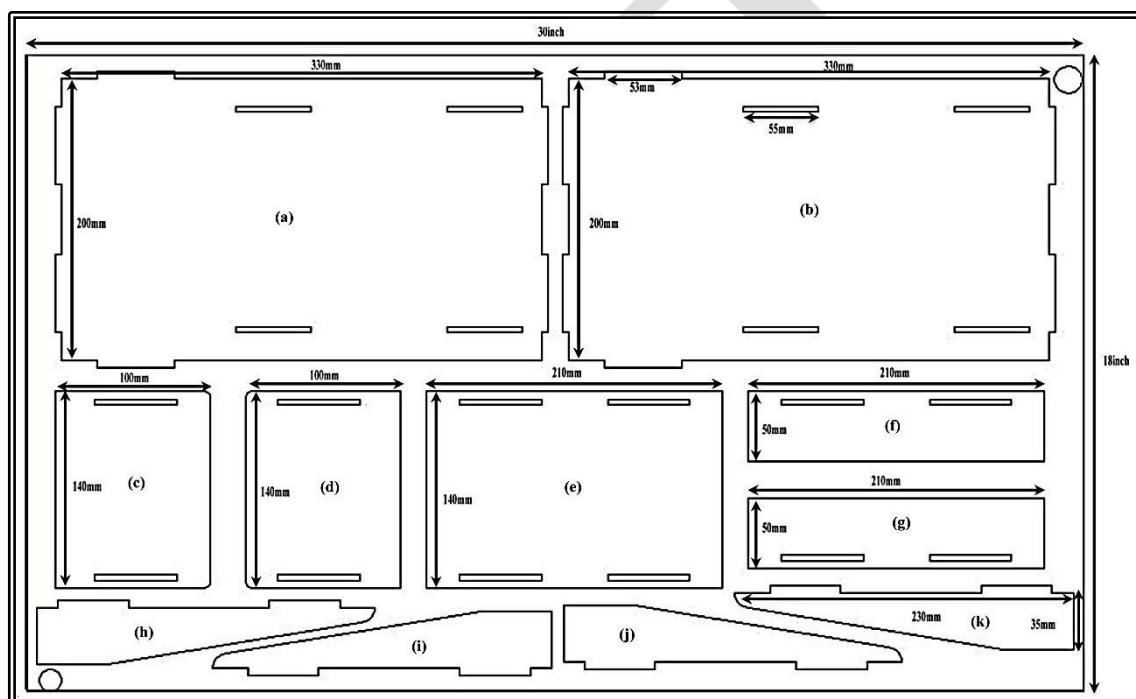


Fig 3: Mechanical Drawing of Illumination Unit

The body of the conveyor system was designed with 4mm thickness and 24x32sqinch white acrylic sheet. The mechanical design on the sheet was shown in Fig 2. With the help of a computerized wood carving machine the sheet was carved accurately for the conveyor system parts. In the figure (a) & (b) are 24inchx83mm idlers with four grooves of length 92mm. (c) & (d) are structures of 32inchx100mm size. Each structure has 8mm holes at two ends for pulleys. They contain 4mm rectangular shaped holes to fit the grooves of the idlers in (a) & (b) and 5.2mm holes on the top of each structure to fix the IR sensors. In (d) it contains a 12mm hole for fixing 12VDC motor with the help of (e). Four 5mm bearings were fixed to the wood pulleys to rotate freely without friction. Two idlers are fixed so as to fit into the structures by keeping the 5.2mm holes to the top. Two sets of IR transmitter and IR receiver are fixed at each end of the structure to stop the DC motor whenever the object is interrupted

in between transmitter and receiver, hence acts as object sensors. One set of sensor stops the DC when the object enters into the illumination unit and another set is used only at starting point.

Belt forms the moving and supporting surface on which the conveyed objects rides. It is the synthetic and tactile element that should be selected considering the object to be transported. Hence a 3inch elastic belt was used for object transportation. Conveyor system was controlled by using LPC2148 ARM microcontroller.

## ILLUMINATION UNIT

Illumination unit plays a vital role in the classification process to acquire the images with constant light intensity. Illumination unit used in the present work was designed by using a 4mm thickness and 30x18sqinch white acrylic sheet. Fig 3 shows the mechanical drawing on the sheet and the sheet was sliced accurately by using wood carving machine. As shown in Fig 3, (a) & (b) are two stand slices with 330x200sqmm height and length. Each stand has four 53x4mm grooves and four 55mmx5mm rectangular holes to fit with the side walls of the unit. (c) & (d) are the side walls of the unit with 140x100mm length and height that contains two rectangular holes each. (f) & (g) are the bottom supporters with 210x50mm length and breadth. (h), (i), (j) & k are the side supporters with 35mm breadth and 230mm length that was sliced in a training fashion for the stability of illumination unit and each one has two 53x4mm grooves.

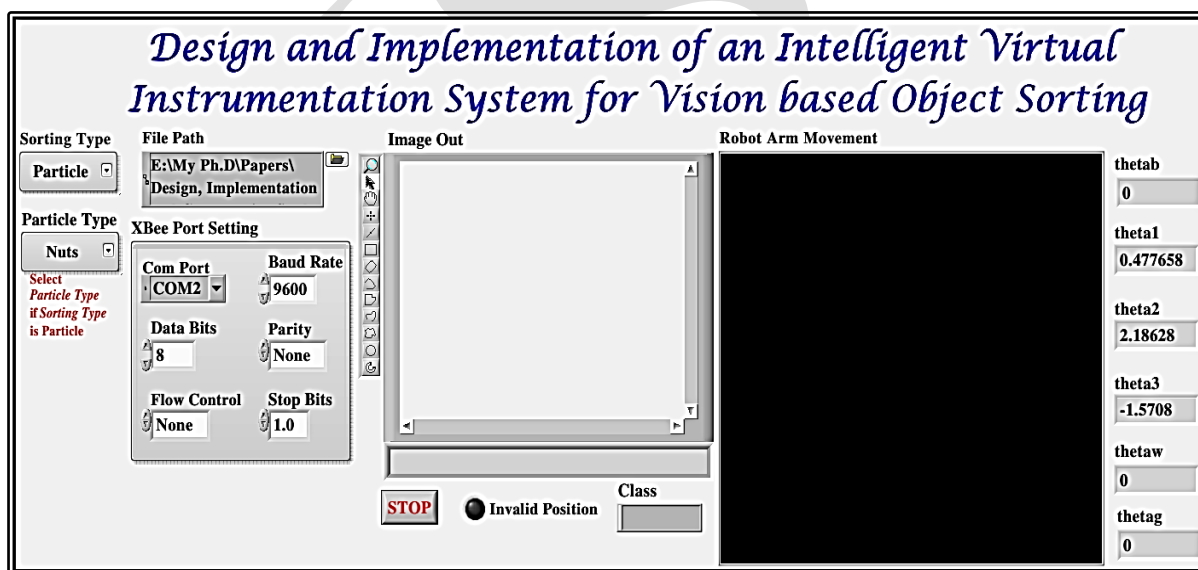


Fig 4: Front Panel of the Present work

Image sensor was equipped with illumination unit to capture clear and optimal images with ease. Illumination unit consists of 12V LEDs which are connected in series and fixed in such a way that the lighting was focused on the object. 35 LEDs are connected with 7 arrays and each array contains three LEDs and 3 current limiting resistors.

## SOFTWARE FEATURES

Software features of the present work have been divided into two parts LabVIEW and embedded 'C'. LabVIEW was programmed on PC and performs the classification, robot arm IK and ZigBee transmission procedures. Embedded 'C' was programmed for LPC2148 and performs ZigBee reception, conveyor system control, illumination unit control and PWM procedures.

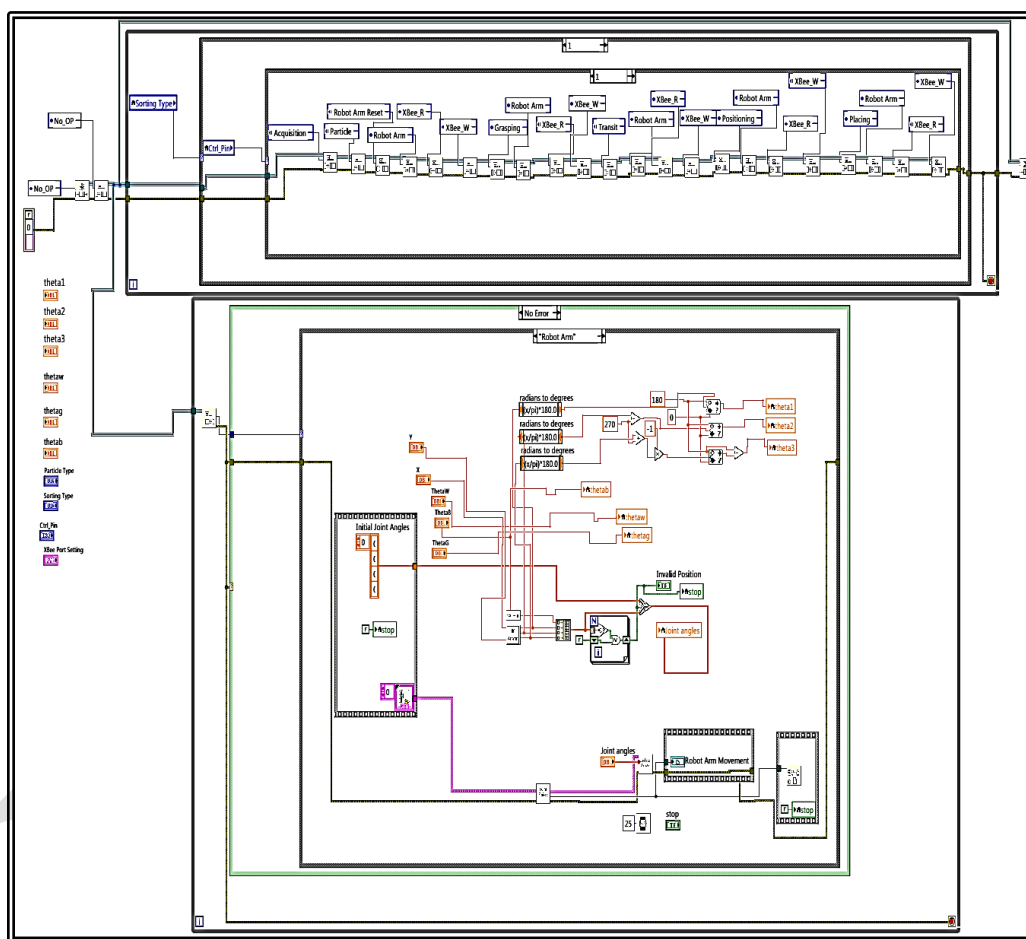


Fig 5: LabVIEW Block Diagram of the Present Work

## LABVIEW and Embedded 'C'

LabVIEW program contains front panel and block diagram. Front panel is a kind of Graphical User Interface (GUI) which acts as interface between user and the block diagram of LabVIEW. It contains inputs control elements and output indicator/display elements. Block diagram contains the actual program which guides the front panel inputs through outputs. Fig 4 shows the front panel of the present work contains *Sorting Type*, *Particle Type*, *File Path*, *XBee Port Setting*, *Image Out*, *STOP*, *Invalid Position*, *Class*, *Robot Arm Movement*, *thetab*, *theta1*, *theta2*, *theta3*, *thetaw* and *thetag*.



*Sorting Type* and *Particle Type* are front panel silver control elements. *Sorting Type* is used to select type of sorting among *Particle* & *Color* and if *Sorting Type* is *Particle* then *Particle Type* is used to select the type of particle among *nuts*, *bolts* & *electronic spares*. If *Sorting Type* is *color* then no need to select the *Particle Type*. *File Path* is the control element which is used to feed the classifier file as input to the *Classification VI*. If *Sorting Type* is *particle* then select particle classifier file else select color classifier file. *Image Out* shows the image under inspection. *STOP* and *invalid Position* are the Boolean variables used to stop the classification process when robot arm end-effector position goes invalid. *Robot Arm Movement* is 3D Picture Control VI which is used to observe the robot arm transformation in simulation. *theta<sub>b</sub>*, *theta<sub>1</sub>*, *theta<sub>2</sub>*, *theta<sub>3</sub>*, *theta<sub>w</sub>* and *theta<sub>g</sub>* are 64-bit numeric indicators used to display the joint angles of the robot arm.

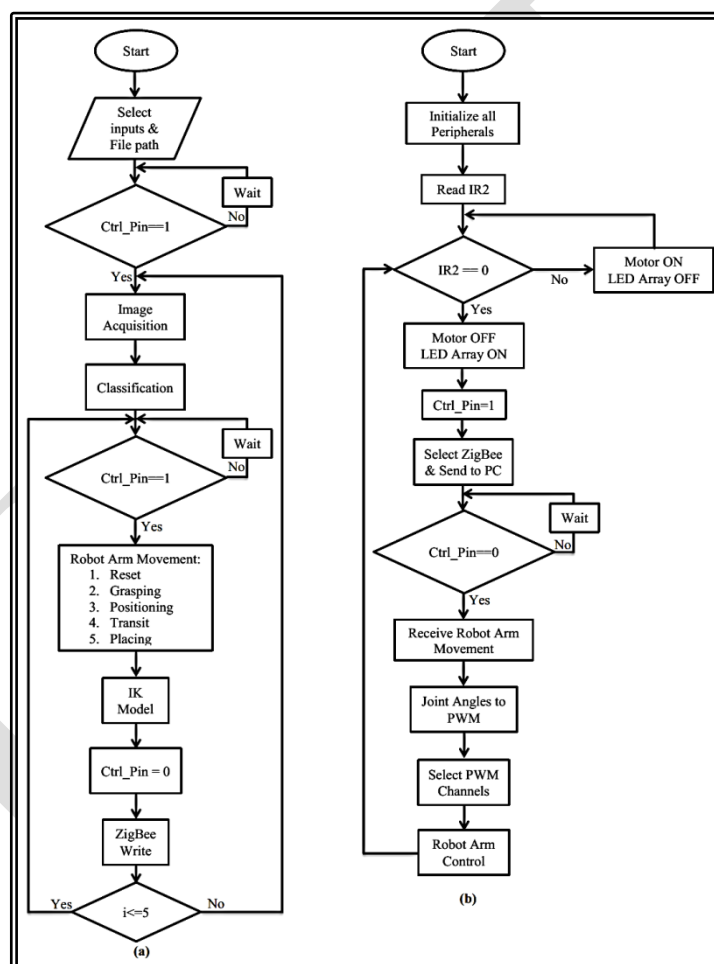


Fig 6: Flow chart (a) LabVIEW (b) LPC2148 Microcontroller

Fig 5 shows the LabVIEW block diagram of the present work. Total block diagram was designed and divided into sub programs such as *Acquisition*, *Particle*, *Color*, *XBee\_R*, *XBee\_W*, *Robot Arm*, *Robot Arm reset*, *Grasping*, *Picking*, *Transit* and *Placing*. *Acquisition* acquires the image from the image sensor through USB. *Particle* is the classification program for all particle types. Particle classification was performed by keeping lower thresholding value as 10 and higher thresholding value as 254. *Color* is the classification program for color

bottles classification. Color classification was performed by keeping luminous value on and resolution in medium. Particle and color classification was explained in [17]. *XBee\_R* and *XBee\_Ware* ZigBee read and write programs. *XBee\_R* reads the *Ctrl\_Pin* status from microcontroller and *XBee\_W* writes robot arm joint angles followed by *Ctrl\_Pin* status to the microcontroller. *XBee\_R* and *XBee\_W* were explained in [18]. *Robot Arm reset, Grasping, Picking, Transit* and *Placing* are the movements of the robot arm. Each movement has its own coordinate system and depending on the *Class* coordinate variables varies. *Robot Arm* evaluates the IK model of the robot arm and displays the robot arm movement on the front panel. IK model and implementation was explained in [16].

To initialize the process of sorting two objects are placed manually, one in the illumination unit and other at IR2. Fig 6: (a) shows the flow chart of the LabVIEW program. It starts by selecting/setting the inputs and file path. Here inputs refer to the *Sort Type*, *Particle Type*, *XBee Settings* and *File Path* refers to the classifier file path. LabVIEW control executes the *XBee\_R* to read the *Ctrl\_Pin* from LPC2148 and waits until it is equal to 1. Then most recently captured image was acquired by the *Acquisition* program. Classification process starts depending up on the inputs and classifies the object in the image. Depending upon the class name of the object robot arm movements such as reset, grasping, positioning, transit and placing is going to feed on by one as inputs to IK model. IK model calculates the correct joint angles, transmits the *Ctrl\_Pin* as 0 and joint angles.

Table1. Actual positions of the robot arm end-effector for the present work

Position	Inputs				Output				
	X	Y	ThetaB	ThetaG	thetab	theta1	theta2	theta3	thetag
<b>Reset</b>	12	-2.13	0	90	0	101.5	0	14.7	90
<b>Grasping</b>	12	-2.13	0	16	0	101.5	0	14.7	16
<b>Picking</b>	12	1.89	0	16	0	120.6	0	14.4	16
<b>Transit</b>	12	1.89	15	16	15	120.6	0	14.4	16
<b>Placing</b>	12	-4.36	15	90	15	90.7	0	18.6	90

Fig 6: (b) shows the flow chart of the embedded 'C' program on LPC2148 microcontroller. The program first initializes all the peripherals required for the current operation such as GPIO ports, UART and PWM channels. As shown in Fig 1, conveyor system uses two pairs of IR sensors to sense the object on the belt. Two IR transmitters and two IR receivers are used. IR transmitter was supplied with 5V to transmit IR light rays and IR receiver continuously obtains them. These rays are interrupted when object was presented between them. Here IR receivers provide zero voltage when there is an object, keeping this into consideration IR receiver2 was used as sensor. IR receiver1 and IR receiver2 (as designated in Fig 1) are used to control the conveyor system and LED arrays in the illumination unit. In the present work only IR receiver2 (IR2) is used and IR receiver1 kept idle for future use. LPC2148 reads the signal from IR2 checks whether the output is equal to zero or not. If yes 12V DC motor will goes off and LED array goes on from P1.22 and P1.23 of LPC2148 through ULN2003. Then *Ctrl\_Pin* is set to 1, select ZigBee communication through relay circuit by setting P1.20 & P1.21 of LPC2148 through ULN2003 and sent to PC. Wait until PC



completes the classification operation and sends back the Ctrl\_Pin and joint angles. PC resets the value of Ctrl\_Pin to zero and sends it along with the calculated joint angles. Joint angles are converted into PWM signals. Select two PWM channels (PWM4, PWM6) by resetting P1.20 & P1.21 relay circuit. Calculated PWM signals were sent to for robot arm end-effector was controlling. Then loop continues to the next object. Embedded 'C' for wireless robot arm control was explained in [16].

## RESULTS AND DISCUSSIONS

From the comparative study of nuts, bolts and color bottles it is known that for nuts and bolts classification NN (Nearest Neighbor) algorithm and Sum (Manhattan) Distance metric, for electronic spares NN and Euc (Euclidean) distance metric yields the best results and for color bottles MMD (Minimum Mean Distance) and Sum distance are used in the present work. Hence the classifier file for each category was trained by using the above constraints.

Table2. ThetaG and ThetaB Values for each category

Object Type	ThetaG	ThetaB
4mm Nuts	12.8	15
5mm Nuts	16	45
6mm Nuts	19.2	75
10mm Nuts	32	105
12mm Nuts	38.4	135
15mm Nuts	48	165
4mm Bolts	12.8	20
5mm Bolts	16	60
6mm Bolts	19.2	100
10mm Bolts	32	140
12mm Bolts	38.4	180

(a)

Object Type	ThetaG	ThetaB
Battery	83.2	20
POT	19.2	60
Relay	48.6	100
Toggle Switch	51.5	140
Blue	140	30
Cyan	140	90
Green	140	150
Orange	140	30
Pa Green	140	90
Pink	140	150
Red	140	30
Sky Blue	140	90
Yellow	140	150

(b)

IK model for the present robot arm for various end-effector positions in its workspace was explained in [16]. But to sort the objects into the containers, robot arm was calibrated to determine the actual kinematic parameters for the present work. The operations of the robot arm are reset, grasping, picking, transit and placing. Reset is the position of the robot arm end-effector near to the object on the conveyor system with open gripper. Grasping is operation for the end-effector to grab the object. Lifting the object was done with picking operation. Transit is the operation where robot arm travels from conveyor system to the container. Releasing the object into the container is done with placing. Table1 shows the calibrated values of all operations of robot arm for 5mm nut. Values of ThetaG and ThetaB vary depending on the type of object. Table2 (a) and (b) shows the values of ThetaG and ThetaB for each category.

In the present work experimentation has been conducted on 420, 350, 280 and 63 real time images of nuts, bolts, electronic spares and color bottles respectively were selected by the manual experts. Black colored nuts and bolts, multicolored electronic spares were selected to compare the sorting method. From Table 3 it shows the object sorting results for the four categories.

Total 70 objects of each category 4mm, 5mm, 6mm, 10mm, 12mm and 15mm diameter nuts are used for sorting. 68, 65, 64, 66, 63 and 70 nuts of 4mm, 5mm, 6mm, 10mm, 12mm and 15mm were sorted correctly while 2 nuts of 4mm were sorted to 10mm container, 3 and 2 nuts of 5mm were sorted to 4mm and 10mm containers, 4 and 2 nuts of 6mm were sorted to 5mm and 12mm containers, 1 and 3 nuts of 10mm were sorted to 4mm and 5mm containers, 1, 5 and 1 nuts of 12mm were sorted to 4mm, 5mm and 6mm containers respectively.

Table 3. Object Sorting Results for Nuts, Bolts, Electronic Spares and Color Bottles

Sorting Method	Nuts				Bolts				Electronic Spares				Color Bottles			
	T	C	I	A	T	C	I	A	T	C	I	A	T	C	I	A
Manual Sorting Method	420	408	12	97.14	350	336	14	96	280	280	0	100	63	62	1	98.41
Proposed Sorting Method	420	396	24	94.29	350	328	22	93.71	280	223	57	79.64	63	60	3	95.24

Total 70 objects of each category 4mm, 5mm, 6mm, 10mm, and 12mm diameter and 1 inch bolts are used for sorting. 70, 65, 70, 57 and 66 bolts of 4mm, 5mm, 6mm, 10mm and 12mm were sorted correctly while 4 and 1 bolts of 5mm were sorted to 10mm and 12mm containers, 8, 4 and 1 bolts of 10mm were sorted to 12mm, 5mm and 6mm containers, 4 bolts of 12mm were sorted to 10mm container respectively.

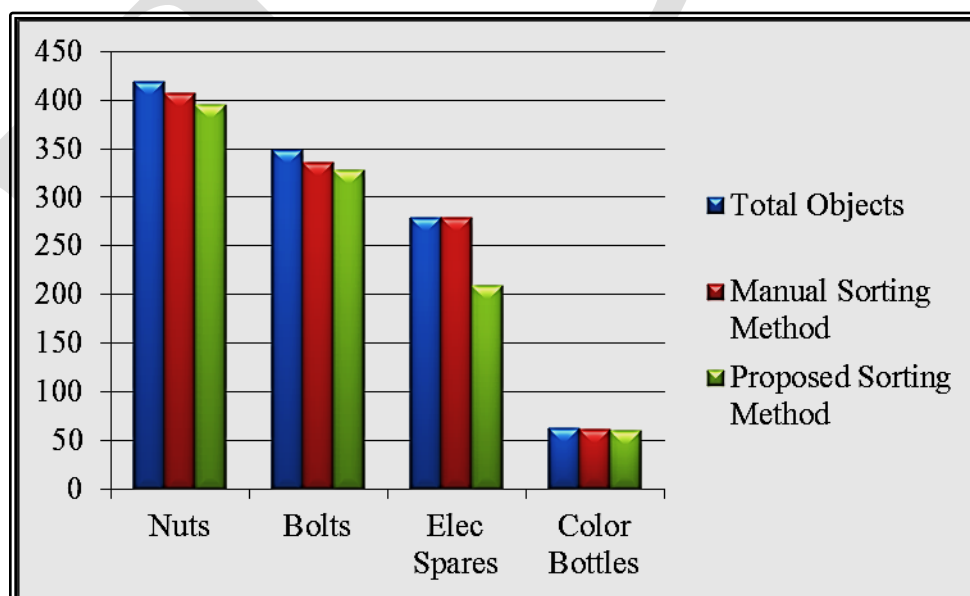


Fig 7: Comparison of Existing and Proposed Sorting Method

Total 70 objects of each category Battery, POT, Relay and TS electronic spares are used for sorting. 53, 64, 55 and 51 electronic spares of Battery, POT, Relay and TS were sorted correctly while 4, 7 and 6 Batteries were sorted to POT, Relay and TS containers, 1 and 5

POTs were sorted to Relay and TS containers, 2 and 13 Relays were sorted to POT and TS containers, 1, 4 and 14 TSs were sorted to Battery, POT and Relay containers respectively.

Total 7 color bottles of each color blue, cyan, green, orange, parrot green, pink, red, sky blue and yellow were used for sorting. Only three colors were chosen to sort at a time and sorting process was performed three times for total nine colors. 6, 7, 6, 7, 7, 7, 6 and 7 were sorted correctly while 1 blue bottle was sorted to cyan bottle container, 1 green bottle was sorted to parrot green bottle container and 1 sky blue bottle was sorted to blue bottle container.

Table3 shows the object sorting results for all categories. Where T = Total number of Objects, C = Correctly Sorted Objects, I = Incorrectly Sorted Objects and A = Accuracy (%). Table3 shows the correctly sorted objects, incorrectly sorted objects along with the accuracy percentages for both manual sorting method and proposed sorting.

## CONCLUSION

In this paper overall wireless object sorting system was designed and implemented by using virtual instrumentation and classification techniques. Fig 7 shows the comparison results for manual sorting method and proposed method with total number of objects. It shows that nuts, bolts and color sorting has high accuracy than electronic spares sorting for the proposed method. This is because nuts and bolts are black in color while electronic spares are in color hence nuts and bolts were well suited and electronic spares are not suited for image thresholding. Nuts and bolts were classified depending on the circularity feature and degree of elongation feature while electronic spares were classified based on features explained in [17]. From the practical experimentation of present work it is known that the calibrated robot arm end-effector positioning was more accurate than uncalibrated one [16]. In the calibration,  $\pm 1\text{cm}$  precision of robot arm was reduced by determining the actual kinematic parameters and adjusting the joint angles through embedded 'C' programming. Classification algorithms in real time implementation shows more accuracy than [14, 17].

## REFERENCES

- [1] Yang Tao, Method and Apparatus for Sorting Objects by Color, *U.S. Patent 5 339 963*, Aug 23, 1994.
- [2] Thomas C. Pearson, Machine Vision Apparatus and Method for Sorting Object, *U.S. Patent 5 703 784*, Dec 30, 1997.
- [3] Bdiwi, M.; Suchy, J., Robot control system with integrated vision/force feedback for automated sorting system, *Technologies for Practical Robot Applications (TePRA), IEEE International Conference*, 23- 24 April 2012, p p.31,36.
- [4] Szabo, R.; Lie, L., Automated colored object sorting application for robotic arms, *Electronics and Telecommunications (ISETC), 2012 10th International Symposium*, pp.95,98, 15-16 Nov. 2012.
- [5] AmitAgrawal, Yu Sun, John Barnwell, Ramesh Raskar, Vision Guided Robot System for Picking Objects By Casting Shadows, *International Journal of Robotics Research*, vol. 29 no. 2-3, pp.155-173, February 2010.
- [6] B.Gabrya, L. Petrakieva; Combining labeled and Unlabelled data in the design of pattern classification systems, *International Journal of Approximate Reasoning*, 2004.

- [7] Vishnu R. Kale, V. A. Kulkarni, Object Sorting System Using Robotic Arm, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 7, July 2013.
- [8] Dharmannagari Vinay Kumar Reddy, Sorting of Objects Based on Colour By pick And Place Robotic Arm and with Conveyor Belt Arrangement, Int. J. Mech. Eng. & Rob. Res. 2014, Vol. 3, No. 1, January 2014.
- [9] Vishnu R. Kale, V. A. Kulkarni, Automation of Object Sorting System Using Pick & Place Robotic Arm & Image Processing, Proceedings of 3rd IRAJ International Conference, 5th January 2014, Mumbai, India. ISBN: 978-93-82702-51-1.
- [10] N.I. Giannoccaro, L. Spedicato, A. Lay-Ekuakille, A Smart Robotic Arm For Automatic Sorting of Objects With Different Tags, 4th Imeko TC19 Symposium on Environmental Instrumentation and Measurements Protecting Environment, Climate Changes and Pollution Control, June 3-4, Lecce, Italy, 2013.
- [11] Vikas S. Zilpe, Shahrukh Pathan, Pranita Choudhary, A Smart Robotic Arm for Automatic Sorting Of Objects With Different RFID Tags, Discovery, 2014, 18(54), pp: 111-114, [www.discovery.org.in](http://www.discovery.org.in).
- [12] Monal S. Telgote, Ganesh S. Sable, Object Sorting System in Matlab using Robotic Arm, International Journal of Science and Engineering Investigations vol. 2, issue 22, November 2013.
- [13] Vindhya Devalla, Dr. Rajesh Singh, Amit Kumar Mondal, Vivek Kaundal, Design and Development of Object Recognition and Sorting Robot for Material Handling in Packaging and Logistic Industries, International Journal of Science and Advanced Technology (ISSN 2221-8386) Volume 2 No 9 September 2012.
- [14] C. Chandra Mouli, P. Jyothi and K. Nagabhushan Raju, Comparative Study of Supervised Classification Algorithms for WOSRAS, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 2, February 2014, pp: 7188 – 7193.
- [15] P. Sudhakara Rao, A. Gopal, R. Revathy and K. Meenakshi, Colour Analysis Of Fruits Using Machine Vision System For Automatic Sorting And Grading, Journal of Instrumentation Society of India 34(4), pp. 284-291.
- [16] C. Chandra Mouli, P. Jyothi and K. Nagabhushan Raju, Modeling and Implementation of Wireless Embedded Robot Arm for Object Sorting, IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 9, Issue 4 Ver. III (Jul – Aug. 2014), PP 35-44. e-ISSN: 2278-1676, p-ISSN: 2320-3331.
- [17] Design, Implementation and Comparative Study of Supervised Classification Algorithms for Object Sorting [In Press]
- [18] C. Chandra Mouli, P. Jyothi, K. Nagabhushan Raju, C. Nagaraja, T. Bheemalingaiah and M. Ashok Kumar, Implementation of serial communication in LabVIEW to interface with 8051 based microcontroller, Research Journal of Engineering & Technology, Vol.3. Issue.4, pp.7-9, ISSN 0974-2824.
- [19] U.S. Ragupathy, B. Venkatesan and P.T. Sasikkannan, Fault Identification and Classification in Textile Web Materials using Particle Analyzer, 3rd International Conference on Intelligent Computational Systems (ICICS'2013) April 29-30, 2013 Singapore. pp: 63-66.