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Implementation Of Barcode-Based Package Sortation System With Picked & Placed Robotic Arm

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Abstract: *As far as logistic automation growth is concerned with the material handling and conveyor system makers, are getting utmost exposure in the industries like automotive, pharmaceutical, packaging and different production plants. This research deals with implementation of pick and place robot by using Arduino for any pick and placed function with barcode-based package sortation system, contains a belt conveyor system and an articulated robotic arm. Package sorting is the act of separating package by a scheme with ZIP code or barcode. A barcode is an optical, machine-readable representation of data that describes something about the object that carries the barcode. Linear sortation system and palletizing robot with mechanical gripper are used in this system. The main purposes of this system are to sort packages based on barcodes (with standard barcode **UTYCC** & **UTYCCPRE**), and to pick sorted packages and place 12 sorted packages in 2 rows & 3 columns in 2 layers. Three belt conveyors are used to move and separate packages. A USB webcam is fixed on the conveyor system to scan barcodes. Barcode scanning will be accomplished by digital image processing. Inspection process is considered for non-standard packages under the predefined height. A servo motor is used to divert non-standard packages from the main conveyor. Counting process is considered to count the numbers of diverted packages and sorted packages. Articulated robot arm is implemented to pick sorted packages and place 12 packages in 2 rows & 3 columns in 2 layers. In this system, computer vision and digital image processing based barcode scanning is accomplished by a console program. This program is developed on personal computer/laptop by using Microsoft Visual Studio IDE software. It is written in C++ programming language. DC motors are used to drive conveyor system and sensors are also used for feedback data. The system procedure is controlled by Arduino Mega by using C programming language. USB serial communication is used between Arduino Mega and personal computer for decoded barcode data transmission and control decisions. Therefore this system is an integrated system of computer science and automation technology.*

Keywords: *Barcode-based, Sortation, Picked & Placed, 5-DOF articulated robot, 2 rows & 3 columns.*

1. INTRODUCTION TO LOGISTICS AUTOMATION:

Logistics automation is the application of computer software and/or automated machinery to improve the efficiency of logistics operations. Typically this refers to operations within a warehouse or distribution center, with broader tasks undertaken by supply chain management systems and enterprise resource planning systems. Logistics automation systems can powerfully complement the facilities provided by these higher-level computer systems. The resources managed in logistics can include physical items such as food, materials, animals, equipment, and liquids; as well as intangible items, such as time and information. A logistics automation system may provide in *Automated Goods In Processes*, *Automated Goods Retrieval for Orders* and *Automated dispatch Processing*.

Barcode-based package sortation system mainly comprises with Conveyor System, Automatic identification and data capture (AIDC), and Industrial Robot. A complete warehouse automation system can drastically reduce the workforce required to run a facility, with human input required only for a few tasks, such as picking units of product from a bulk packed case. Even here, assistance can be provided with equipment such as pick-to-light units. Smaller systems may only be required to handle part of the process.

Sortation systems offer a highly accurate and efficient means of sorting, routing, consolidating, and diverting a wide range of package types. These systems are used for the purposes of order selection, processing, packaging, palletizing, storing, and shipping. Sortation systems can transport packages ranging in shape, weight, and size from sheets of paper to fully loaded packages. This systems generally fall into two groupings: linear sortation systems and looped sortation systems. Linear sortation system or line sorters sort in a straight line. These systems induct product at one end and move them along their length, diverting them to one or both sides depending on the type of unit along the way. Line sorters can be either chain or belt driven and have diverting mechanisms that are either integrated into the sorting conveyor or mounted to it.

An industrial robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks. A robotic arm is a type of mechanical arm, usually programmable, with similar functions to a human arm. The basic components of an industrial robot are the manipulator, the end effector, the power supply, and the controller.

A robot's movement can be divided into two main categories: arm and body (shoulder and elbow) motions, and wrist motions. The individual joint motions associated with these two categories are referred to as degrees of freedom. Each axis equal to one degree of freedom. Typically, industrial robots are equipped with 4-6 degrees of freedom. The wrist can reach a point in space with specific orientation by any of three motions: a pitch, or up-and-down motion; yaw, or side-to-side motion; and a roll, or rotating motion. The manipulator, therefore, is the part of the robot that physically perform the work. The points that a manipulator bends, slides, or rotates are called joints position axes. Manipulation is carried out using mechanical devices, such as linkages, gears, actuators, feedback devices. Position axes are also called the world coordinates. The world coordinate system is identified as being a fixed location within the manipulator that serves as an absolute frame of reference.

2. NEED STATEMENTS:

In recent years in industry and daily routine works are found to be more attracted and implemented through automation via robots. The system is so designed that it eliminates the human error and human intervention to get more precise work. The selection for the most appropriate design of robotic structures in new application process and evaluation of all the alternative structures, needed to be done by considering requirements from multiple application areas. Then performance data corresponding to each robot structure needs to be treated for performing quantitative comparison. However, one type of robot structure exhibiting superiority for all the considered evaluation criteria is seldom found. Adding to the complexity, the degree of suitability of a given robot structure often depends on where in the workspace most of the tasks will take place. Therefore, there is a need for research to develop evaluation methods, which can aid the robot designer in the early stages to identify the best robot structure among a given set of alternatives.

3. EDUCATIONAL GOALS:

- To develop an evaluation method, which can be applied in the early stages of the design process, for selecting the most suitable robot structure for executing new processes in emerging application areas,
- To familiarize the students with the design process- from brainstorming, initial design, prototyping, testing, revising, to final production and competition.
- To allow students to experience the perilous designer/builder interface.
- To spark student's interest in Science and Technology.
- To improve the manufacturing processes' speed, efficiency, quality, productivity by purchasing a automation system with robotic arm.

4. APPLICATION AREA:

This research can be applied for the manufacturing lines in factories, picked & placed operation, material transfer, automated assembly, metal cutting, welding, taping, machining, welding, painting & adhesive operations. It can be easily fitted with almost any tool, including a hand-like clamp, a welding torch, a camera, or other sensors that can be relayed to computer and allows to perform a large variety of tasks.

5. PROPOSED SYSTEM DESIGN:

The overall proposed system has two main portions. The first portion of the system is barcode-based package sortation conveyor system and another part is picked and placed robotic arm. The following figure is the overall proposed system design of the pick & place robotic arm.

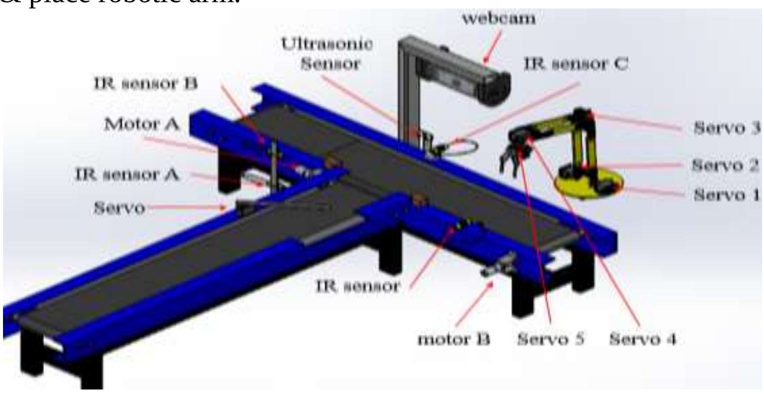

Figure:1 Modeling of Proposed System Design

6. METHODOLOGY:

This research adopts through the design as a research methodology, which is based on the action-reflection approach in an experimentation setting. The experiential knowledge is gained on how to evaluate for the robot structures based on various requirements. This is done by carrying out simulation-based evaluation tasks on serial and parallelogram linkage articulated structures.

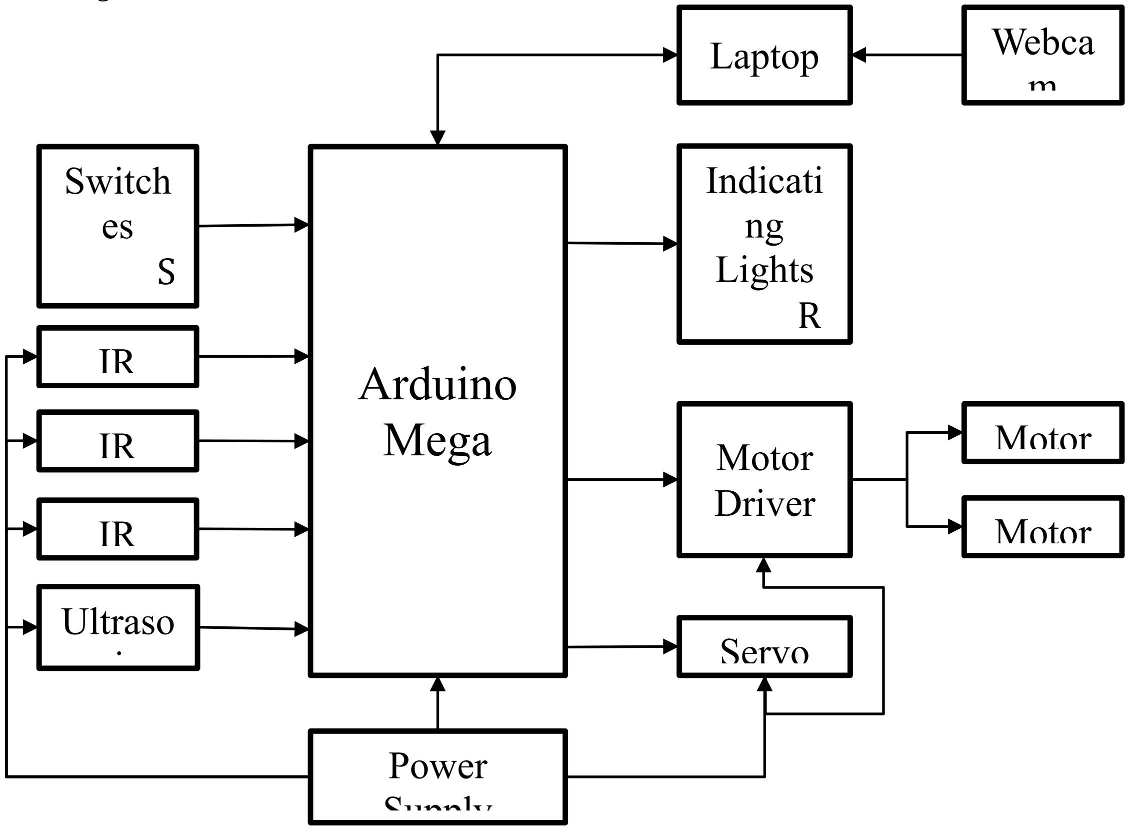

Figure:2 Block Diagram Of Conveyor System

Package sorting is the act of separating package by a scheme with ZIP code or barcode. Linear sortation system and palletizing robot with mechanical gripper are used in this system. Inspection process will be considered for non-standard packages. Two belt conveyors will be used to move and separate packages. A USB webcam will be fixed on the conveyor for capturing images of barcodes. Barcode scanning will be accomplished by digital image processing. The packages will be separated to their desired ways. Counting process will be considered for non-standard packages & sorted packages.

Articulated picked and placed robotic arm has been fabricated to pick and place for 12 packages in 2 rows & 3 columns in 2 layers. This system can be utilized in shipping & global ecommerce, delivery service, courier, express and parcel, food & beverage, pharmaceuticals & cosmetics palletizing industries, etc.

7. OPERATION OF THE SYSTEM:

In conveyor system, ultrasonic sensor is used to detect object along the conveyor. If package is detected, DC motor 1 will rotate to drive conveyor 1. After that, IR sensor 1 is used to detect package in front of it. When it is detected, conveyor 1 stops running and IR sensor 2 is used object detection in front of it. If package is detected, conveyor 1 is started running again. If not, the system will decide that the package is under non-standardized height.

And then servomotor will separate it by diverting it from conveyor 1. IR sensor 3 is used to detect package after a few seconds. If the package is detected, conveyor 1 is stopped running. Barcode scanning process is accomplished by using webcam that is installed in the system. Decoded barcode names are sent to the microcontroller via USB communication.

And then, these names are checked whether it is as the same as predefined name. When it is matched, DC motor 2 is rotated to drive conveyor 2 according to matching results whether clockwise or anti-clockwise. After 3 seconds, the process will start again due to endless loop program.

In palletizing robot, robot arm is set at predefined home position after the system starts. And then, IR sensor is used to detect object n. If package is detected, number of package is count up starting from zero.

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Robot arm moves to predefined hold position that its path is free from obstacles in order to avoid collision. After that, robot will move to predefined pick position. The gripper is opened to its maximum aperture and engaged to package and then it is closed to grip the package.

After gripping the package, the robot arm is moved to package's desired place position. And the gripper is opened to release the package at its place position. If IR sensor is detected again, it is assumed that another package is at the pick position. The robot arm is acted the process from the start again.

The robot arm is programmed to pick and place 12 packages. They are placed in order of 2 rows, 3 columns and 2 layers. The desired place position of each package is varied according to its desired location. If the number of package is counted as 12 by IR sensor, the process is reset. And the robot arm is picked and placed again starting from package number 1. The operation flowcharts of the systems are shown in Figures 3 and 4.

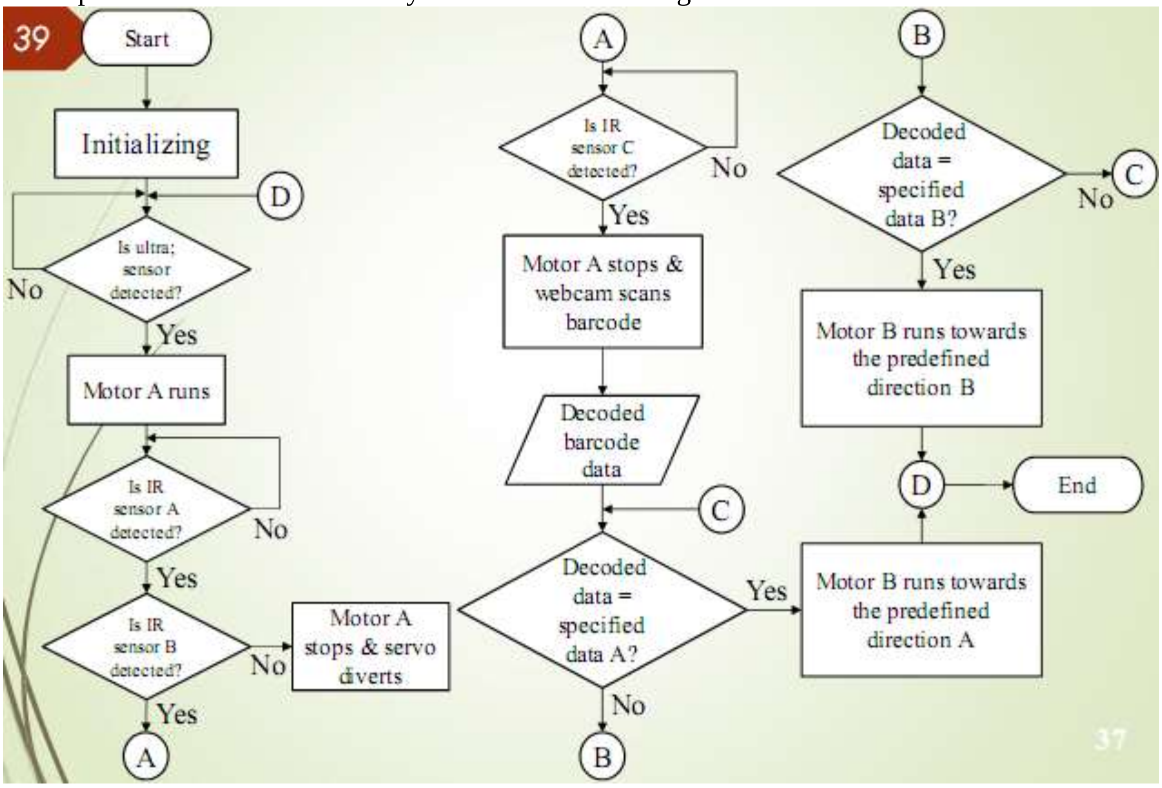


Figure:3 Flow Chart of Conveyor System

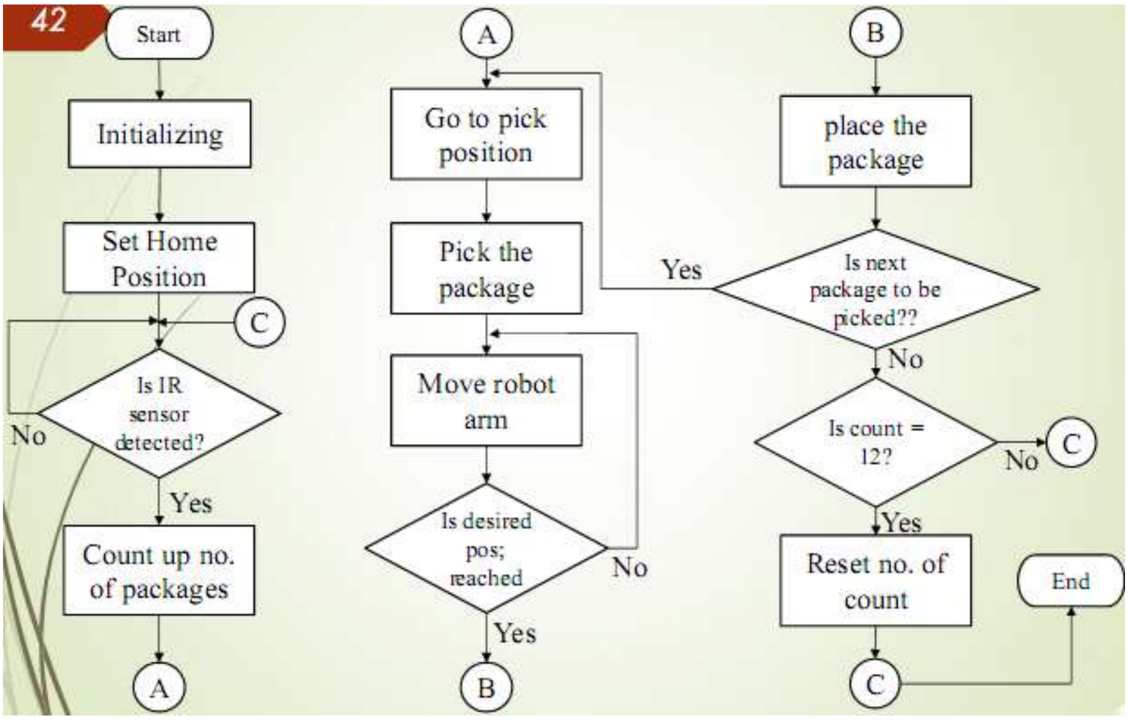


Figure: 4 Flow Chart of Robotic Arm

8. MECHANICAL COMPONENTS OF THE ARTICULATED ROBOT:

The design of the articulated robot arm consists of two rigid links, namely, vertical arm pitch and horizontal arm pitch. Horizontal arm pitch is fixed mechanism at 100° at the end of the arm. At the end of horizontal arm pitch, gripper is used as the end effector that can be rotated 90° at vertical axis, called wrist rotation. It can be rotated 180° at the base of the robot, namely base rotation which is 203 mm high from the ground. The following figure shows the manipulator & dimensions of workpiece.

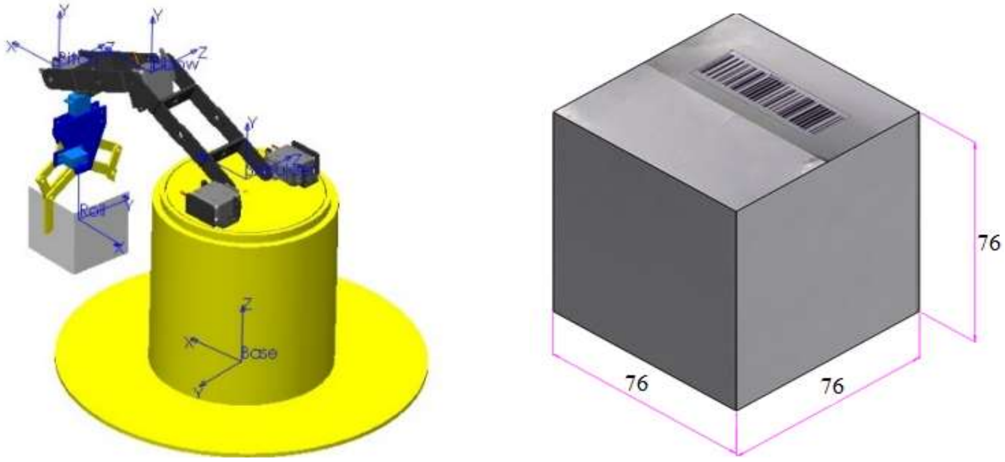


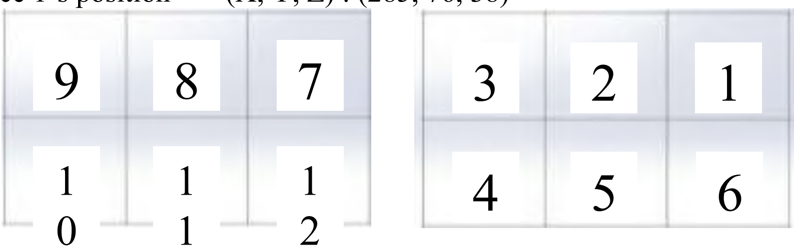
Figure:5 DOFs of the Manipulator & Dimensions of Workpiece

The physical constraints of robotic configuration are as follows:

- Degree of freedom = 5
- Joint offset of base, d_1 = 203 mm
- Joint limit of base, $\theta_1 = 0^\circ \sim 180^\circ$
- Link length of shoulder, a_2 = 210 mm
- Joint limit of shoulder, $\theta_2 = 0^\circ \sim 90^\circ$
- Link length of elbow, a_3 = 170 mm
- Joint limit of elbow, $\theta_3 = 0^\circ \sim 100^\circ$
- Joint limit of pitch, $\theta_4 = 0^\circ \sim 120^\circ$
- Length of gripper, a_5 = 177 mm
- Joint limit of roll, $\theta_5 = 0^\circ \sim 180^\circ$
- Horizontal maximum reach = 380 mm
- Horizontal minimum reach = 170 mm
- Vertical maximum each = 380 mm

9. PALLETIZING PATTERN:

Workpiece 1's position >> (X, Y, Z) : (285, 76, 38)



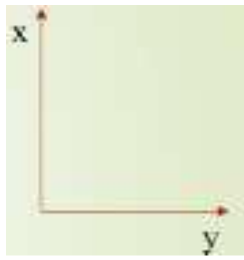


Table.1 Desired Work-Place Positions (coordinates) of Pieces

Workpiece No.	X	Y	Z	Workpiece No.	X	Y	Z
1	285	76	38	**7**	285	76	114
2	285	0	38	**8**	285	0	114
3	285	-76	38	**9**	285	-76	114
4	209	-76	38	**10**	209	-76	114
5	209	0	38	**11**	209	0	114
6	209	76	38	**12**	209	76	114

10. PALLETIZING PATTERN AND DESIRED WORK-PIECE'S COORDINATES:

Palletizing is a demanding application of stacking boxes, cases, bottles and cartons onto pallets as the last step in the assembly line before being loaded onto a shipping truck. A variety of software options allow the user to rapidly generate pallet patterns. Palletizing patterns can be selected by choosing the layout, configuring the pick and place positions and registering the dimensional data of the workpieces. Desired palletizing pattern is 2 rows, 3 columns and 2 layers like a rectangular prism. Dimensions of workpiece and desired palletizing pattern are shown. Desired workpiece place positions are described in Table.

11. MAIN COMPONENTS OF GRIPPER:

The components of gripper are as shown in Figure 6 and its components' design will be described.

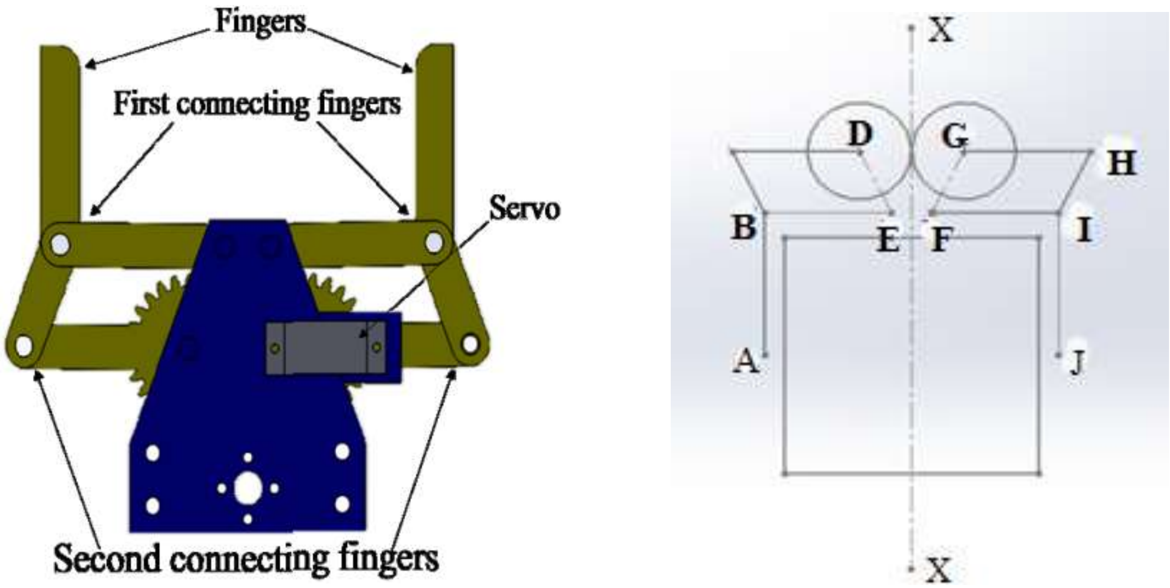


Figure:6 Components of Gripper

12. GRIPPING FORCE:

Impactive grippers of the form shown in Figure 8, retain the object solely by frictional forces F_R. The gripping force F_G applied to the workpiece is given for a slow vertical motion (neglecting safety margins) by:

$$F_G = \frac{mg}{\mu n}$$

where, F_G = Gripping force
m = mass of the workpiece
g = acceleration due to gravity
n = number of fingers and jaws
μ = friction coefficient between the gripper jaw and theworkpiece

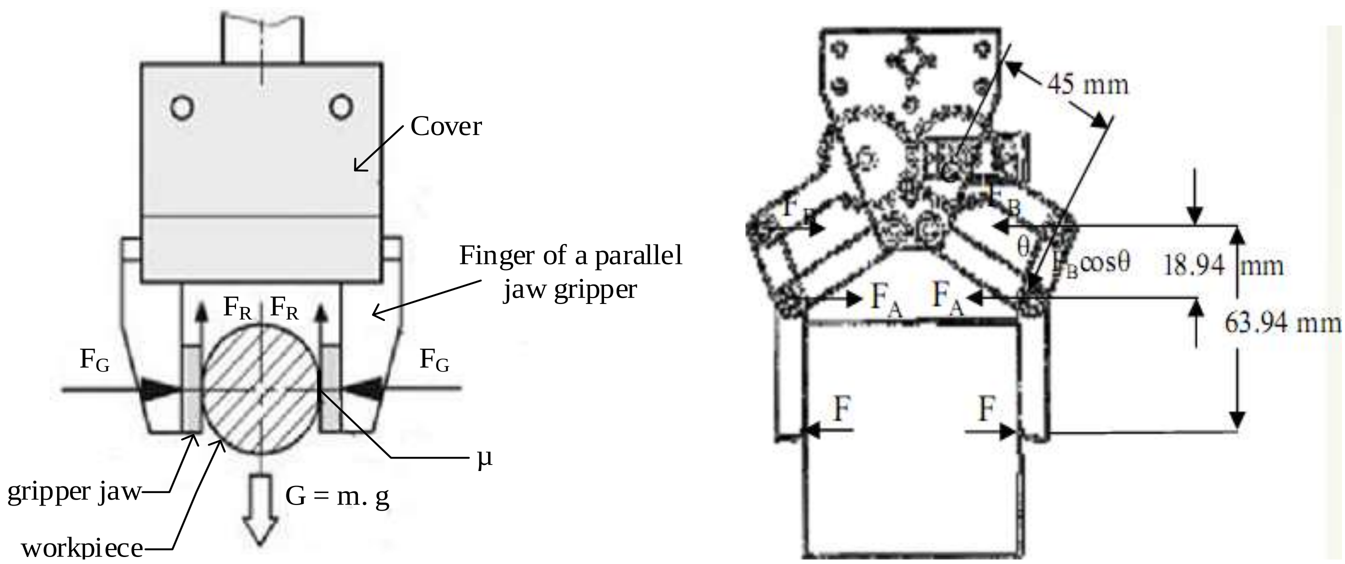


Figure:7 Force acting on an Object Held at Rest, and During Motion

Table.2 Results of Calculation for Links & Motor Selection

Description	Arm Link	Wrist Link	Horizontal Arm	Base Link	Vertical Arm
Volume (V)	2.639 cm^3	5.013 cm^3	25.051 cm^3	56.762 cm^3	33.224 cm^3
Weight (W)	0.03 N	0.059 N	0.294 N	0.657 N	0.385 N
Thickness (t)	3 mm	3 mm	3 mm	6 mm	6 mm
Torque (T)	0.005 Nm	1.021 Nm	1.021 Nm	0.058 Nm	1.942 Nm
Motor	MG 90S Servo Motor	MG 996R Servo Motor	MG 996R Servo Motor	Stepper Motor	PDI 6221MG Servo Motor

13.SIMULATION IN ROBOANALYZER:

In this software, a desired robot can be simulated with the help of CAD software, and passed through the calculations of the centers of the links and their inertias. Below the Figure:8 shows the position of 1st package and the other 11-package positions are also analyzed.

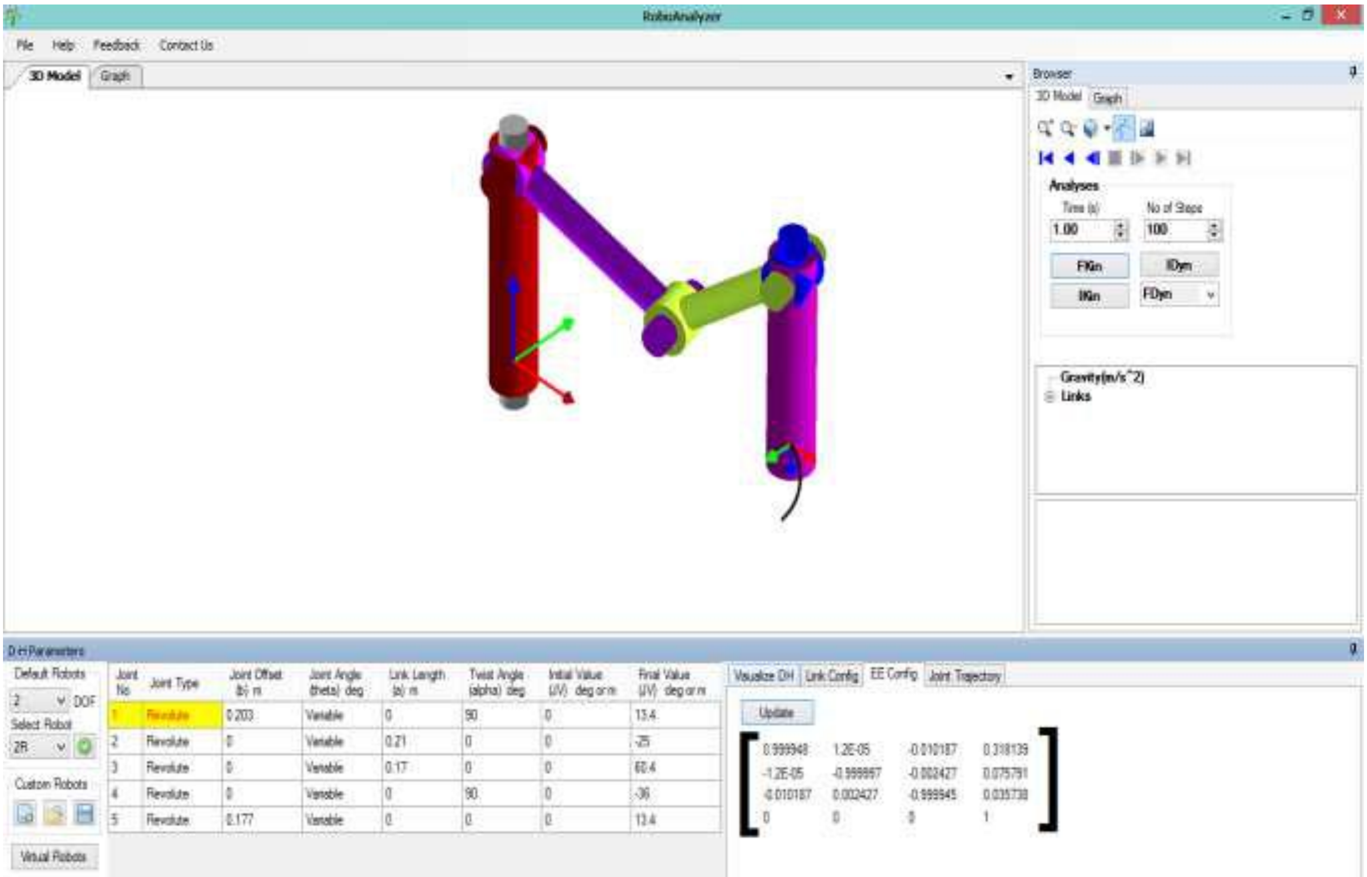


Figure:8 Simulation in RoboAnalyzer 7.1

Table.3 Theoretical Result of Position and Orientation

Package No.	Position			Orientation				
	X	Y	Z	θ_1	θ_2	θ_3	θ_4	θ_5
1	318.1	75.8	35.7	13.4	-25	60.4	-36	13.4
2	319.2	0	37.6	0	-27	66	-39	0
3	318.1	-75.8	35.7	-13.4	-25	60.4	-36	-13.4
4	243.0	-75.7	36.4	-17.3	-39	96	-57.4	-17.3
5	244.3	0	38.4	0	-40.3	101	-60.4	0
6	243.0	75.7	36.4	17.3	-39	96	-57.4	17.3
7	317.7	75.7	111.3	13.4	-9	53	-45	13.4
8	319.9	0	112.3	0	-11	59	-48	0

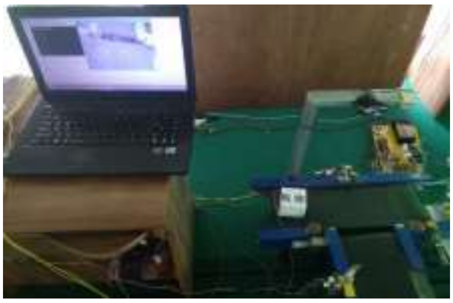
9	317.7	-75.7	111.3	-13.4	-9	53	-45	-13.4
10	243.9	-75.9	113.9	-17.3	-20	90	-70	-17.3
11	242.9	0	114.2	0	-21	95	-74	0
12	243.9	75.9	113.9	17.3	-20	90	-70	17.3

14. PERFORMANCE TEST OF SORTATION SYSTEM WITH PICK & PLACED ROBOTIC ARM

System Design of Sortation & Packaging

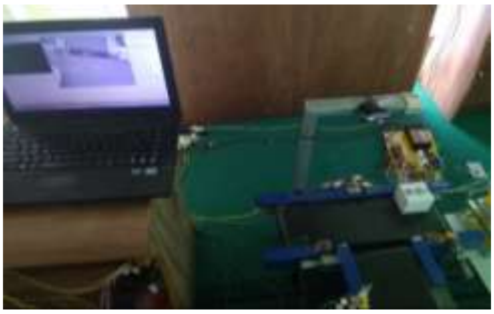
Initial State of the System

Standard Package,
UTYCC Barcode is Inspected



"UTYCC" Barcode is Moved to the Left

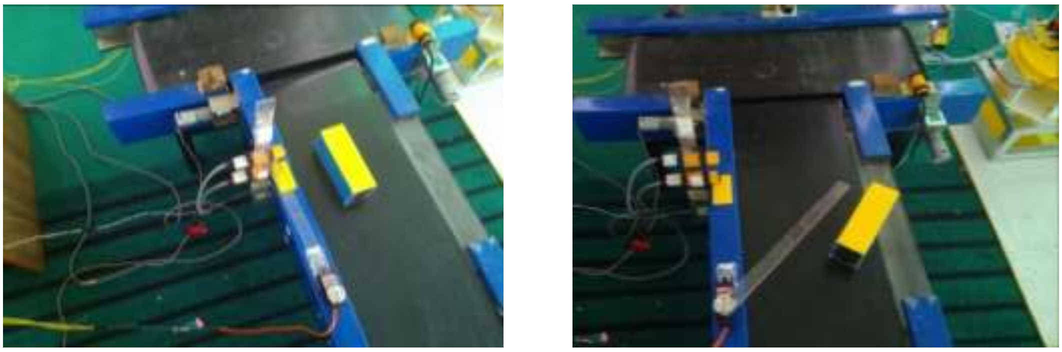
Standard Package, UTYCCPRE
Barcode is Inspected



"UTYCCPRE" Barcode is Moved to the Right

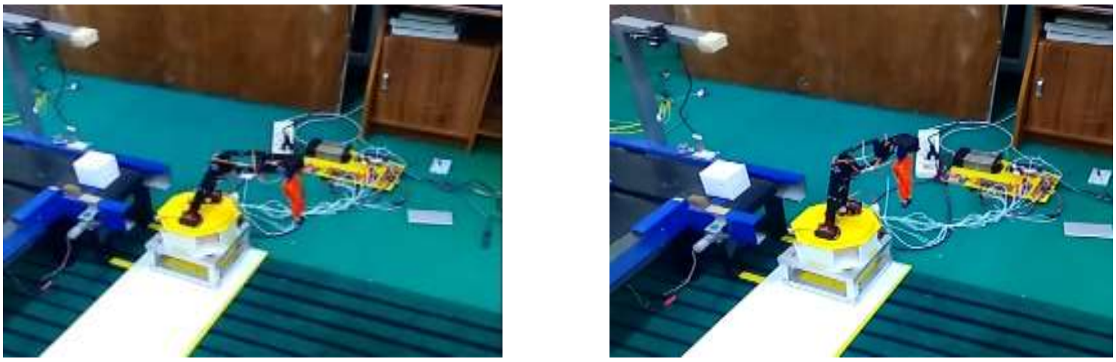
"UTYCC" Barcode

"UTYCCPRE" Barcode

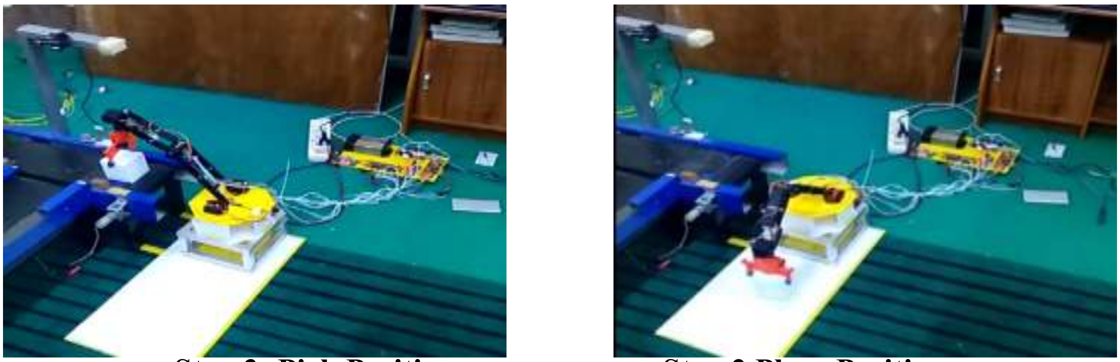


Nonstandard Package is Inspected **Nonstandard Package is Rejected**

Figure:9 Barcode based Sortation Process



Step 1- Home Position **Step 2 – Hold Position**



Step 3- Pick Position **Step 2 Place Position**

Figure:10 Pick and Place Process with Articulated Robotic Arm

15. EXPERIMENTAL RESULTS FOR POINTS:

In this section, the 12 sorting points are described. The resulted data between the input position and output position are lightly missed. But, the resulted data can pose the robotic arm completely perpendicular to the pallet. According to the performance test, the desired position and actual output position is described in Table.

Table.4 Resulted Data Description

Package No.	Desired Position	Experimental Result
1	318.1,75.8,35.7	310, 110, 40
2	319.2, 0, 37.6	310, 37, 41
3	318.1, -75.8, 35.7	310, -37, 39
4	243.0, -75.7, 36.4	266, -53, 40
5	244.3, 0, 38.4	263, 23, 42
6	243.0, 75.7, 36.4	249, 98, 40
7	317.7, 75.7, 111.3	307,110, 118
8	319.9, 0, 112.3	310, 43, 120
9	317.7, -75.7, 111.3	311, -21, 122

10	243.9, -75.9, 113.9	268, -35, 120
11	242.9, 0, 114.2	253, 32, 124
12	243.9, 75.9, 113.9	246, 103, 122

16. BENEFITS:

This research allow for much faster and efficient manufacturing in factory automation, as well as better research in medical and scientific labs. It can reduce the man power and improve in production capacity, quality and economic cost in total manufacturing processes.

17. CONCLUSION:

The hardware and software implementation of barcode-based package sorting system are described. The desired programming software is used in C Programming for Arduino Mega 2560. The system is for sorting specified packages based on barcodes and picking and placing 12 packages in 2 rows, 3 columns and 2 layers in good accuracy. The system can be operated several hours in industries and is low power required for it. This system is very suitable for logistics automation in warehouse automation. In this system, palletizing robot is designed with 5 DOF (Degree of Freedom) with base, shoulder, elbow, pitch and roll. The design specifications of the robot arm are fully defined. By using static equilibrium and torque equations, the torque required to drive this robot is obtained. The torques at base, shoulder, elbow, pitch and roll are 9.76 Nmm, 0.82 Nmm, 447.57 Nmm, 1334.1Nmm and 1345.9 Nmm respectively. The end effector of the robot arm is four bar linkage gripper. Its design is also calculated. The torque required to rotate gripper is 32.18 Nmm. Since belt conveyor is used in this system, its design parameters are also calculated. The suitable motor for the system can be chosen based on the torque that developed by packages carrying on conveyor (98.1Nmm).

18. RECOMMENDATIONS:

In designing for robot components, design calculation of each links, gripper and actuator are all under satisfied level but test should be carried out by using software for more accurate result. By changing the aluminium alloy to plastic, the design is more economical. With more DOF, the robot can approach the object with greater approach angles. And the robot can get minimum floor space and the target with less time. Moreover, the robot is more mobility and the motion of the robot is more stable by restricting its joint losses.

The system can be enhanced by including feedback encoder to drive the servo motor to reach the desired position for getting accurate position. Moreover, the vision system is more popular in modern day that can be more enhanced in precision accuracy by including vision system to grasp the object. This system can be controlled via not only remote control but also voice base command.

According to practical result, there is a considerable position deviation. To increase performance accuracy, this deviation is needed to eliminate. This deviation occurs because of joint angle losses of robotic arm. Joint angle losses are caused by serial robot linkage design. Robot's DOF joints cannot withstand high payload at the end effector. Therefore, other links are needed to support this joint to reduce joint angle loses. Moreover, joint angle losses can be eliminated by using robotic servomotors, stepper motors having greater stall torque. Rather than using actuators at joints, hydraulic and pneumatic cylinders can be used as a hoist to rotate DOFs of robot. Alternatively, joint angle losses can be tolerated by using feedback encoders and PID control methods.

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