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GANTRY ROBOTIC CELL FOR AUTOMATIC STORAGE AND RETREIVAL SYSTEM

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Abstract:
The rapid advance in today's technology requires innovative solutions especially in the area of storage and retrieval processes. The objective of this project is to design and develop a gantry robotic cell for automatic storage and retrieval of products. The robot arm will be mounted on the top of the frame with the gripper facing downward. The products to be sorted and stored will approach using a conveyor belt. A light sensor is installed at the beginning of the conveyor belt in order to identify the object. A limit Switch is fixed at the stop station to inform that the object reached the pickup point. The gripper will move to pick the object and place it in a specific box based on the reading of the light sensor. These positions will be memorized for the retrieval process. A programmable Logic Controller (PLC) will be utilized to control the whole process. The prototype is developed and tested and the idea can be implemented practically to save time and money.

Key Words: Gantry, Robotic Cell, AS/RS, PLC, Conceptual Design

1. INTRODUCTION

A gantry robot is a stationary robot fixed at the top of a frame and typically contains a minimum of three degrees of freedom. The interior of the frame is referred to as working envelope (workspace) of the gantry robot. Gantry robots can move things anywhere within this envelope or perform some operations on an item within the envelope. They are known for their large workspace, filling an entire room if necessary and they have better positioning accuracy than their competitors. Positioning accuracy refers to how close the robot can place a part to the instructed location. This is why gantry robots are usually used for pick and place applications. In addition, they are easier to program since forward and inverse kinematics are equal. Typical application for gantry robots is the assembly of a device and pick and place operations.

Automatic Storage and Retrieval System, or AS/RS, is an automated robotic system that is used within a warehouse for sorting and retrieving items. Its main components are racks, machines (robots or cranes), aisles, I/O points and pick positions [1]. AS/RSs save warehouse floor space, improve inventory accuracy, reduce labor and product damage and can even save energy. They can also make processes more efficient [2].

Kusiak (1985) analyzed the design and operational decision problems for flexible manufacturing systems. He focused on Automated Guided Vehicle and AS/RS and discussed storing and batching policies. Sarker and Babu (1995) discussed extensively and in a comprehensive way some design aspects of AS/RS [4]. However, their paper concentrates only on travel time model [4]. Chincholker and Krishnaiah (1996) used Petri Nets and Tagushi method to simultaneously address the scheduling of jobs in flexible manufacturing systems.The AS/RS is both responsible for storing and retrieving loads and for transferring them between machines [5]. Manda and Pelakar (1997) discussed some papers considering the estimation of travel time for AS/RS and also the possible rates for batching policies [6]. Hwang et al. (2002) considered the design of mini load AS/RS in

combination with Automated guided Vehicle. Both a nonlinear model and heuristics have been proposed to determine the optimal number of loads to be transferred [7]. Inman (2003) studied the applications of AS/RS in the automotive industry. The function of AS/Rs is to restore the sequence in which jobs are handled at the various processes [8]. For more details of the different aspects of AS/RS, the reader is referred to the comprehensive literature review by Roodbergen and Vis in 2008.

The objective of this project is to design and develop a gantry robotic cell for automatic storage and retrieval system. The sorting element is a laser beam and each product will be stored in its correct place automatically. The object will be retrieved with the required number of units depending on the order given. The object will be delivered to the pickup position using a conveyor belt. The object's box will be marked by one, two or three square pieces of illuminated papers. When the object cuts the beam, it will be sorted by how many squares it interrupts. The gripper will pick the object and place it in the classified position. It will be stored in the memory based on this criterion for retrieval later on. A Programmable Logic Controller (PLC) is employed to control the whole system. The layout of the project is shown in Figure 1.

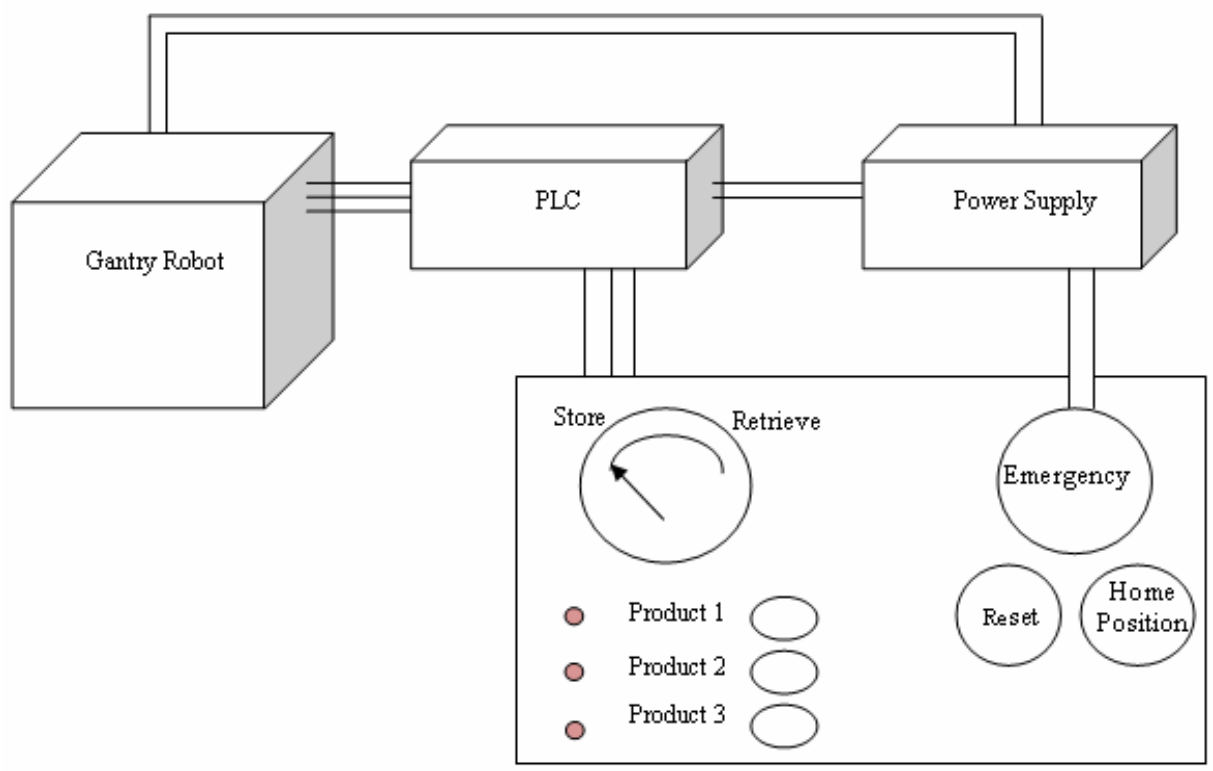

Figure 1: Layout of the gantry robotic cell.

2. CONCEPTUAL DESIGN

The project consists of a steel frame, a carriage that moves in the horizontal plane, a gripper that moves vertically, a conveyor belt to move the objects inside the workspace, sensing devices and a Programmable Logic Controller (PLC) as the brain for the whole project.

2.1 The carriage

The main function of the carriage is to move the gripper assembly in the horizontal plane (X-Y plane) to the selected position. It consists of two perpendicular power screws in the X and Y directions respectively as shown in Figure 2. Each power screw is connected to a DC motor with an optical encoder at one side and rolling wheels are attached to the slide plates

on the opposite side for a smooth movement. The signals from the two optical encoders will be sent to the PLC to control the carriage motion.

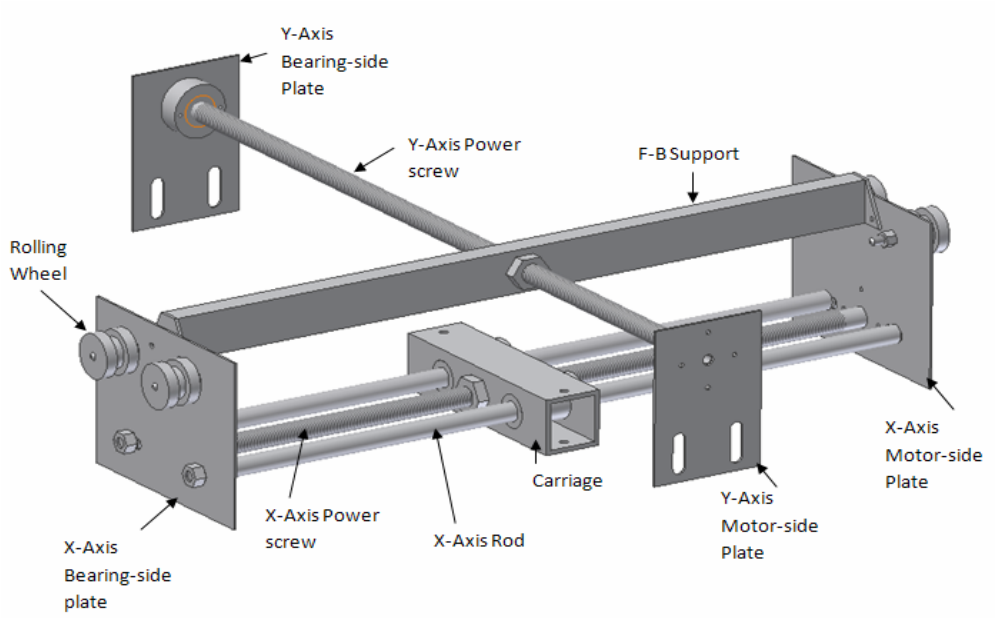

Figure 2: The carriage.

2.2 The vertical motion assembly

The vertical motion of the gripper is designed to provide smooth motion and to reduce vibration effect as well. The gripper is mounted at the end of power screw which is covered by a square tube moving with it. This square tube will be installed inside another fixed external tube for protection. The inner tube is coated with a wax film to reduce friction with the outside tube and make motion smoother. A 12V DC motor is utilized to drive the power screw (left or right) to move the gripper up or down in the Z axis direction.

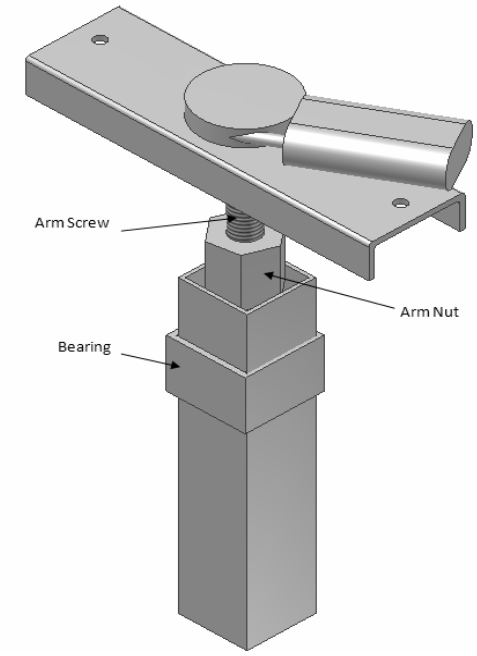

Figure 3: The vertical motion assembly.

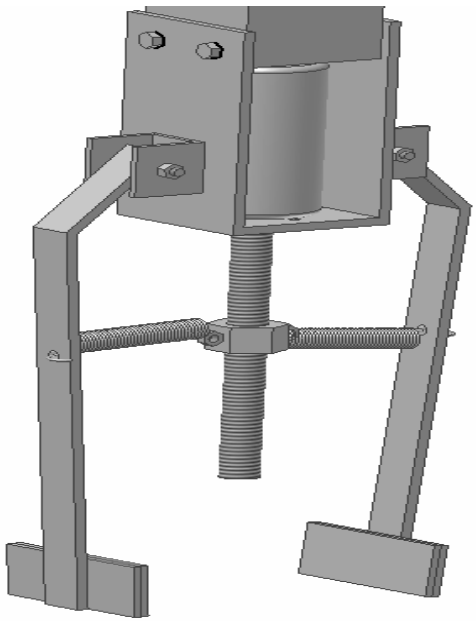

Figure 4: The Gripper.

2.3 The gripper

The main function of the gripper is to pick and place the sorted objects. A gripper with two fingers is designed and fixed at the end of the vertical motion assembly as shown in Figure 4. A metal nut connected with two side springs is attached to the two fingers. A 12V DC motor turns the middle power screw down causing the fingers to open. When the motor turns in the opposite direction, the nut moves upward and with the help of the two springs it can hold the object or close based on the required task.

2.4 Laser sensor

We used a simple idea of laser transmission and reception which is used in many systems such as security system. The idea is when the laser beam is cut, the receiver gives a zero signal otherwise gives one, it can be considered a normally close switch from the controller point of view. The main function of this sensor is to identify the object coming on the conveyor in order to put it in its storage place. At the objects side one, two or three reflector(s) are fixed at the object's side facing the laser beam. When the reflector cuts the laser beam, it reflects it to the receiver at the same side of the transmitter, and so a signal is transmitted to the controller. It should be noted that the transmitter and receiver are fixed with accurate angles and that the object is at a constant distance from the transmitter (3 cm.). The transmitter angle from the horizontal line is 120° and the receiver angle is about 75º as shown in Figure 5.

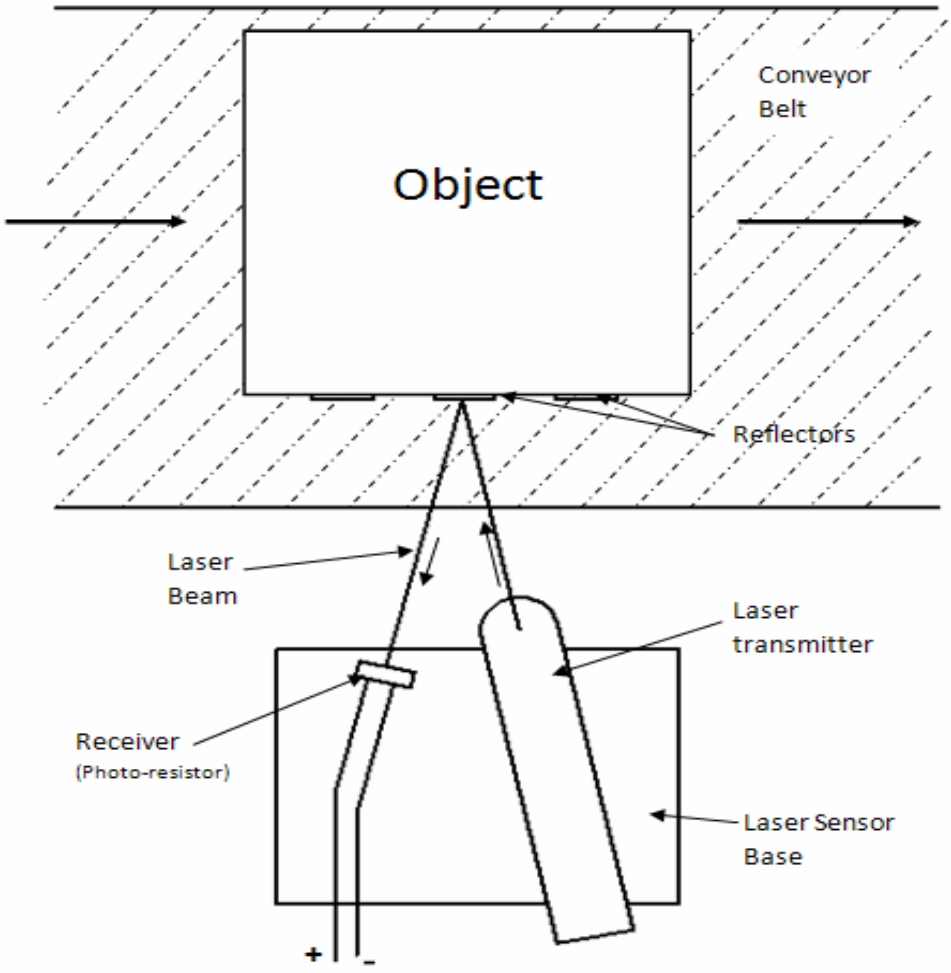

Figure 5: The laser sensor theory of action.

2.5 Conveyor belt

The conveyor belt is considered as one of the most common object transfer in industrial automation. It is intended to transfer objects, products and row material between terminals. The conveyor belt has two main objectives in our project to transfer boxes from the production line to be stored in the storage area and to retrieve the desired product in the opposite direction. The boxes will be delivered manually to the conveyor belt to be sorted at the home position based on reflected laser signal from the illuminated portion assigned to each box. An Artiloon pulley is attached at each side of the conveyor belt where the proximal one is connected to a unidirectional 12v dc motor for smooth movement

3. CONTROL STRATEGY

The controller has a very important rule and guarantees the smooth motion of the mechanical parts of the gantry robotic system. We have already divided the tasks into two main tasks: Storage and Retrieval. We designed the control strategy based on these two tasks. After the robot finishes any of these tasks, it has to go back to its home position to be ready for the next order. In general, when the system is powered on, no procedure can be accessed except the home position procedure (reset mode). If there is a failure or power shut down, the first thing that will happen automatically when the power is back on is the last order given to the system. When an object is brought to the home position by the conveyor belt, it will be sorted at the beginning of the conveyor using the laser beam sensor. The object will stop at the pick and place position using a limit switch and the gripper will move down, open, pick up the object, and place it in its classified position. Four corners are designed for an object with one, tow, three or no reflectors or defected objects as shown in Figure 6. All locations will be memorized inside the controller for every object for the retrieval process to be carried out later on. As soon as the storage task finishes, the carriage will bring the gripper back to the home position. For the retrieval process, the carriage will move the gripper to the specified corner based on the signal from the PLC and the conveyor belt will be on hold waiting for the object. The gripper will pick up the object and drop it on the conveyor belt at the home position. A signal will be sent from the PLC for the conveyor to start moving the object to be picked up. Figure 7 shows a photo of the project and the flowchart representing the operation sequence is shown in Figure 8.

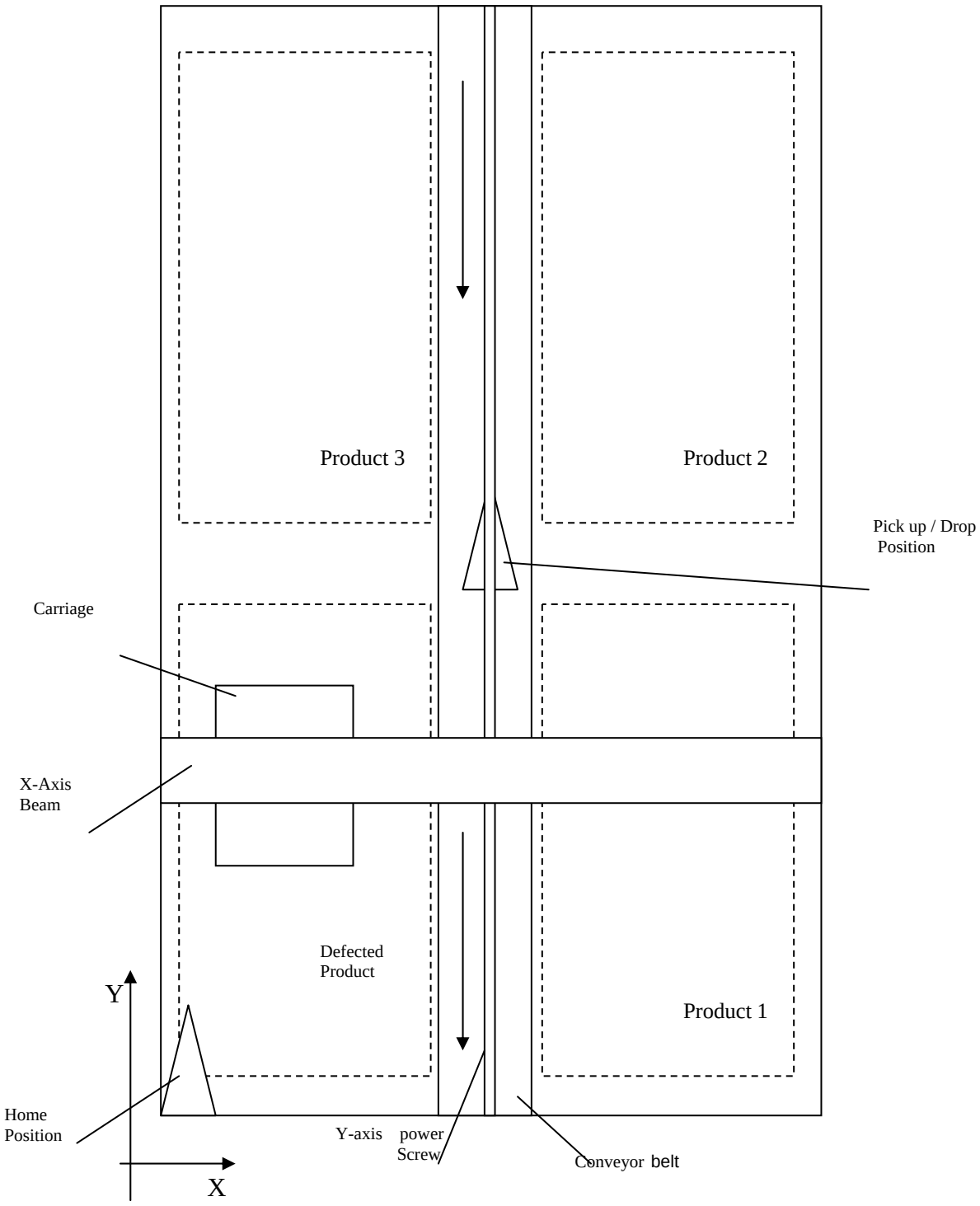

Figure 6: Top view of the gantry robotic cell.

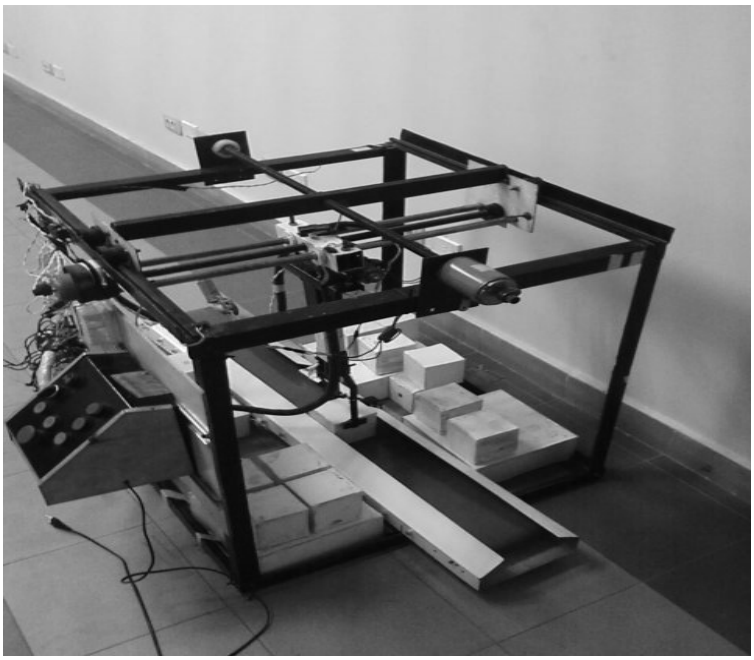

Figure 7: Photo of the prototype of the gantry robotic cell.

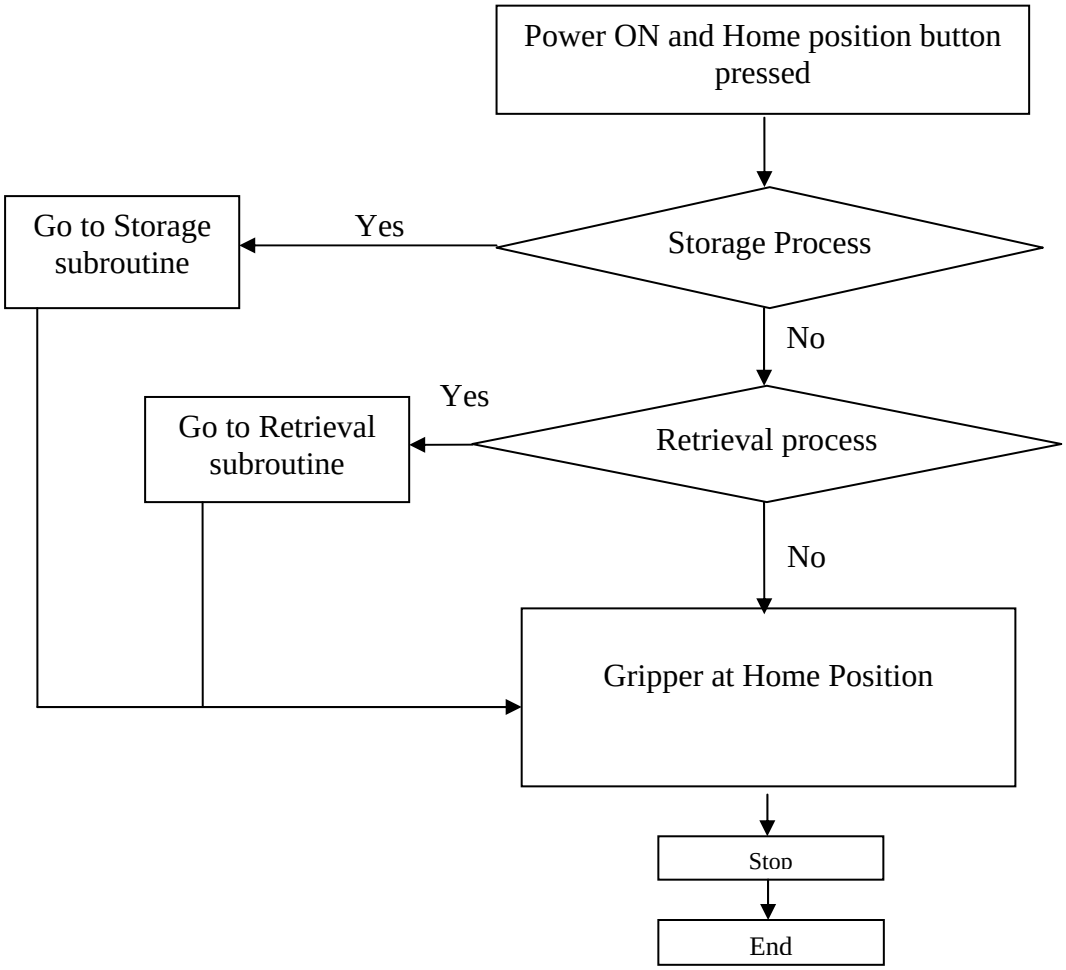

Figure 8: Flowchart of the control algorithm.

4. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

A gantry robotic cell for automatic storage and retrieval system has been designed and developed. The cell consists of a 3 DOF robotic arm with a gripper attached at the end of the vertical motion assembly. A conveyor belt is developed to move the objects either in the storage and retrieval modes. A programmable Logic Controller is utilized to control successfully the whole process.

In the next development of the project, a barcode system may be utilized for sorting of objects. The signal from the barcode reader must be adopted to suit the controller. For classifying a large number of objects with different sizes, a camera may be used with built-in images for comparison with the objects running at the conveyor belt. The signal from the camera will be sent to the controller for further action. It is also recommended to use linear motors instead of the DC rotary motors and power screws. The main motivation for the DC motors is the low cost since linear motors are very expensive. There is also a room for modifying the gripper by using suction cup that can handle many objects.

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