DESIGN AND PROTOTYPING OF CONTROLLING AN AUTOMATED STORAGE AND RETRIEVAL SYSTEM

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ABSTRACT This research aimed to design and prototype of controlling an automated storage and retrieval system (AS/RS). The prototype will be used for demonstrating the automation system and training students to control the system. Nowadays, the AS/RS is widely used in industry especially in the warehouse because of using a few labor and high accuracy in inventory management. Unfortunately, the equipment of AS/RS are very expensive even for the laboratory scale, which school cannot provide enough equipment for training students in AS/RS. Therefore, the school desired to design and prototyping by using technology, for example, PLC (Programmable Logic Controller) and LabVIEW NI Vision Module. In this study, LabVIEW was developed to control mechanisms of the AS/RS with in format the Fixed Location System, FIFO (FIRST-IN-FIRST-OUT) and barcode data record. The AS/RS system has three station consists i.e. Scanning station, Pick up station and Loading station run up automatically. The system's procedure start by scanning the bar code on the object and recording the data. After that, the pick up station will pick the object from Scanning station and move to the home position of loading station. Finally, the loading station will place the object in the shelf on the determined position. Whereas the retrieval process, the loading station will retrieval the object from shelf and move to home position. The later, Pick up station will pick the object on loading station and move to initial position. Due to path of motion in the storage and retrieval are the same path, when the storage command object is active the retrieve command must don't active. The results show that the prototype can control store and retrieval efficiently. Moreover, it can train the students by understanding the automated storage and retrieval system.

1. INTRODUCTION

Currently, the automated storage and retrieval systems are widely used in industry. The Automated storage and retrieval systems were first introduced in the 1950s to eliminate the walking that accounted for 70 % of manual retrieval time (Sagar R. et al., 2014). This system is a part of a production system using a Computer Integrated Manufacturing (CIM). The automatic storage and retrieval system (AS/RS) is automatically stores and retrieves materials from storage without worker (Vasili et al., 2008). Which is expensive and high cost. In order to an AS/RS to satisfy the needs of the domestic market, it should be low cost and using the existing software of storage of each company and should be flexible so that it is adapted to the size and the flow of the products and it can function with the minimal possible interventions in the existing system of storage (Dimitrios et al., 2009). Thus reducing the cost of warehouse management systems of an automated storage and retrieval system with motion control by Programmable Logic Controller (PLC) and data collection by machine vision. Which has ability to see and high precision. It was developed as a prototype of the AS/RS system with low cost and used in teaching. Ideal for inventory control as storage and retrieval characteristics in a small volume, the Fixed Location System and FIFO (FIRST-IN-FIRST-OUT) are used in the AS/RS system. It can identify the exact location of storage and reduce the deterioration of the product and enhancing the control and product tracking.

2. THEORY METHODOLOGY

2.1 Governing Equations

This system considers the stability of the system, which assumes control of the storage and retrieval the object at any position by PLC and checking position to reach by sensor encoder. This is shown in the figure 1. This kind of controller is a closed-loop controller or feedback controller.

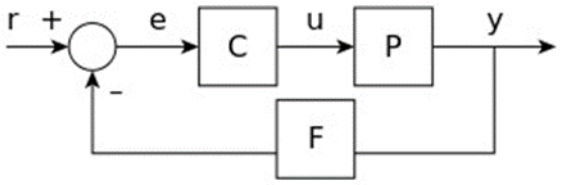

Figure 1. Closed-loop transfer function.

If assume the controller PLC is C, the position of storage and retrieval is P, and the sensor encoder is F are linear and time-invariant (i.e., elements of their transfer function C(s), P(s), and F(s) do not depend on time), the systems above can be analyzed using the Laplace transform on the variables. This gives the following relations:

$$Y(s) = P(s).U(s) \quad (1)$$
$$U(s) = C(s).E(s) \quad (2)$$
$$E(s) = R(s) - F(s).Y(s) \quad (3)$$

Equation (1), (2), (3) Solving for Y(s) in terms of R(s) gives:

$$Y(s) = \left(\frac{P(s).C(s)}{1+F(s).P(s).C(s)}\right).R(s)$$

$$Y(s) = H(s).R(s)$$

The expression H(s) is referred to the closed-loop transfer function of the system. The numerator is the forward (open-loop) gain from r to y, and the denominator is one plus the gain in the feedback loop. If $|P(s).C(s)| \geq 1$, i.e., it has a large norm with each value of s, and if $|F(s)| \approx 1$, then Y(s) is approximately equal to R(s) and the output closely tracks the reference input.

2.2 The movement of Pick up station and Loading station

The movement of Pick up station and Loading station were using an encoder to get position and move to the desired location by PLC control. The Incremental Position Encoder (IPE) used in prototype consist of disc or straight-line sheet. When the hole on a straight- line on the path of the moving mechanism will measure the distance from lighting survive periodically. The position of the motor will give signal pulse output time to time while the motor is running. The rotation angle or distance will be known. This information will be used through counter to obtain parallel information in PLC.

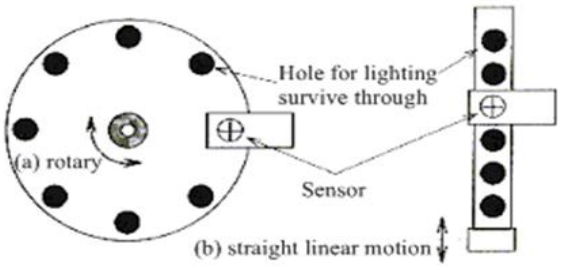

Figure 2. Optical Encoder Increment of (a) rotary and (b) a straight linear motion.

3. EXPERIMENT

The main purposed of this study is to design and prototyping of mechanisms that are able to pick object and transfer to a storage shelf. Program LABVIEW used to read barcodes and record the location for storage and retrieval purposes into the database prior to pick. For manual system if user command the system to storage the objects, the AS/RS system must successfully storage the objects and placed to a storage shelf. Whereas, the user command the system to retrieve the objects, the AS/RS system must successfully retrieve the objects and placed back to the user. In the first stage of the design is to repair the system and add devices for complete design. Figure 3 and Figure 4 show the AS/RS system in repair to before-after and additional devices in the system. In the proposed prototype compose of three workstations are Scanning station, Pick up station and Loading station. The electrical system consists of power supply, PLC, electronic modules, sensors and actuators. The scanning station consists of Camera for scan barcode on the object. For pick up station is Cylindrical robot consists of pneumatic handling device for pick up objects with Y-axis at counterclockwise motor position and move objects clockwise to unloading station at home. For loading station is Cartesian robot consists of unloading pneumatic to move object at storage shelf in with coordinate X-Y. Shelf it is the location for the unloading pneumatic to neatly arrange the object in multi-store rack. In this prototype development, there are 28 slots (4 x 7 dimensions) for storing the object. Thus Logic controller and data management system is carefully planned to ensure the system can fulfill the task given.

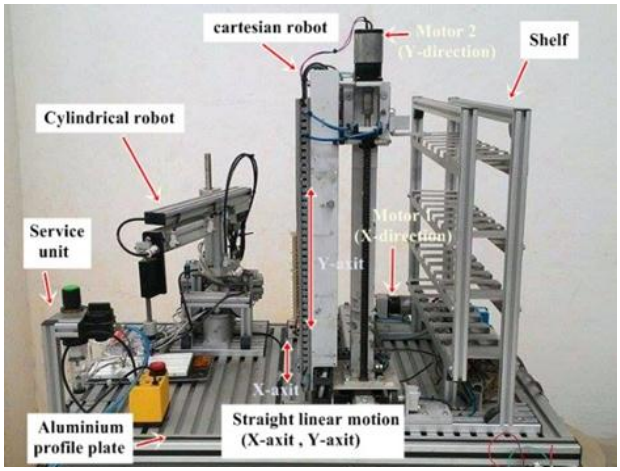

Figure 3. Shown the AS/RS system before repair.

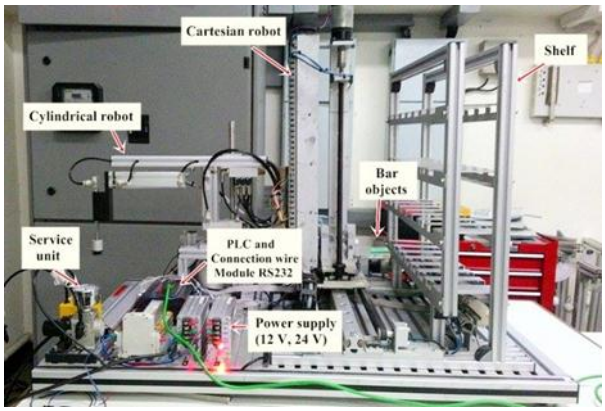

Figure 4. Shown the AS/RS system after repair.

3.1 Technical Data for each station

The AS/RS has base size 800 × 500 mm, consist of 1 handling device with Y-axis and automatic storage and retrieval system (AS/RS) comprising of each a vertical and horizontal axis with shelf unit. The camera used scan barcode has a resolution of 16 million pixel with CMOS. It can scan barcode clearly and zoom in-zoom out but must control environment of light and scanning. For pick up station has base size 200 × 200 mm, consist of sensor as 4 cylinder end switches and encoder of the motor. The actuators has 1 DC-motor 12 V and 2 motor relays connect with voltage source 24 V in the form H-Bridge. It can drive the DC- motor to rotate counterclockwise and clockwise. For PLC-requirements is 5 digital PLC-inputs and 5 digital PLC-outputs. The loading station has base size 550 × 400 × 30 mm consist of belt 680 × 50 mm, 2 barrier light sensor and 1 dark sensor. There are also 8 sensors micro switches for stopping the motors when moving up and down the vertical and horizontal axis. Which PLC-requirements in to control has is 13 digital PLC-inputs, 5 digital PLC-outputs and service unit size 3/2-way hand valve and Shelf consist of 28 slots for storing the object.

4. RESALT AND DISCUSTION

4.1 Scanning station

For scanning station will start when barcode on the object scanned by the camera and code is recorded in the database.

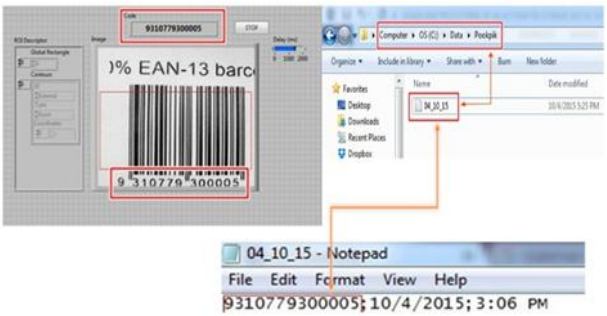

Figure 5. Shown front panel of scan barcode and database from scan barcode.

Figure 5 showed scanning barcode and data collection of the object. The record data use for selecting an object to storage and retrieval. On the front panel showed barcode Ean-13 Type as the image match code panel display. In file database will record number barcode, Day, Month, Year and Time are all referenced in the store on Shelf.

This article discusses the principles of storage and retrieval system that has been designed to operate according to the principles Fixed Location System and FIFO (FIRST-IN-FIRST-OUT). When the command for storage, the system is moving to a position of command that has already been saved. While retrieval system, by locating the storage and retrieval, according to the Figure 6.

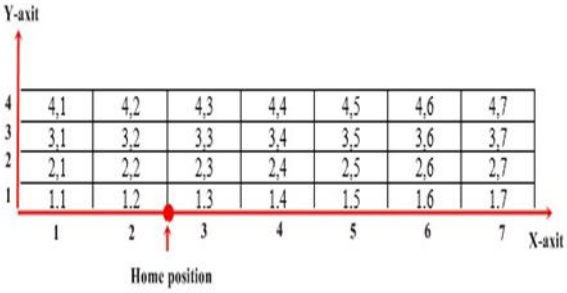

Figure 6. Coordinate for storage.

Figure 6 showed coordinate for storage of 28 slot. The Y axis showed the row number and the X axis showed the column number. Red point between the coordinate (1, 2) and (1, 3) indicates the position corresponding to the home of Loading station. When loading station move to the home position, it will match the red point on the coordinate.

4.2 The system works

In the working system, PLC used for control the movement. This is the ladder diagrams and simulation of the ladder diagram using the KV Studio Ver.4.

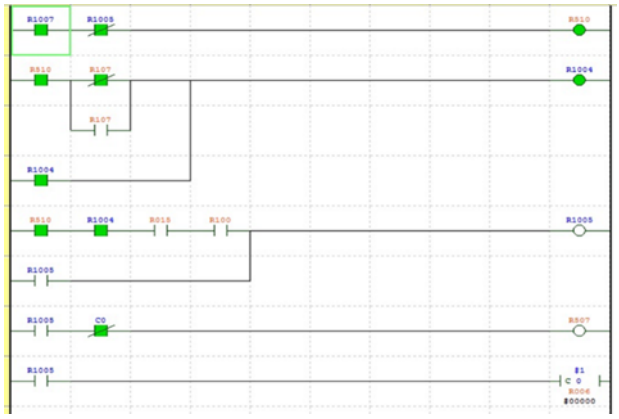

Figure 7. Loading station move an object to shelf,

coordinate (1, 1).

For Figure 7 show loading station move an object to shelf at coordinate (1, 1). When Cartesian robot in direction X has move to home position before loading an object on shelf. Cartesian robot at direction Y has move to home position. Thus when Cartesian robot direction Y encounter with limit switch stopping motor (M2) CCW at address (015, 100) will operating and place an object on shelf.

The first thing to consider is motion control of system make a smooth transition. When loading station has storage or retrieve objects completed already moving to home every times to calibrate with reference point make for ensure accuracy. For pick up station, the movement of an object will rotate clockwise to home position of loading station, When it place objects on the bar objects, the pick up station rotate counterclockwise to initial position again. To prevent the both workstation crashes, the system has the cons, which is the power supply outage or a separate line output even for a short while or when interference occurs. For the scan barcode and data collection the object, the record data to select an object storage and retrieval on shelf. The control environment of light and scanning obtain the data collection based format designed.

CONCLUSION

This research is designed to a prototype for the training in laboratory. It has integrating both mechanical elements and electrical elements knowledge iuncluding the knowledge in warehouse management with automation. Moreover it can access the system simplily and AS/RS system can be developed in different forms and also can store and retrieval efficiently.

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NOMENCLATURE

e : The error e (difference) between the reference and the output to change the inputs u to the system under control P.
u : Input from controller.
r : The reference value.
y : The output of the system.

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