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Automated Storage and Retrieval System for Warehouse

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Abstract: Manual picking and retrieval of items from storage locations can be time-consuming, leading to delays in order fulfillment. This can negatively impact customer satisfaction and the overall responsiveness of the supply chain. In addition, manual data entry and tracking systems are prone to human errors, resulting in discrepancies between recorded and actual inventory levels. This can lead to stockouts, overstocking, and difficulties in maintaining accurate inventory records. Therefore, a fully automated storage and retrieval system is proposed to tackle this problem. The overall system consists of infrared sensor as presence of item stored, LEDs indicator, warehouse model with compartments and stepper motors act as actuator to pick and place the item. This project aims to automate the storage and retrieval system with the assist of monitoring system for accurate tracking of inventory and space savings. The use of Programmable Logic Controller (PLC) in this project is a good representation of integrated automation technology in automated storage system design. Furthermore, monitoring system connected to a web-based system will be used to remotely monitor and operate the facility. Implementing an Automated Storage and Retrieval System (ASRS) in the warehouse can address these challenges by automating the storage, retrieval, and tracking of inventory.

Keywords: Automation, PLC, storage system, visualization

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1. INTRODUCTION

In todays' scenario, ASRS are being widely used in the logistics industry [1]. An automated storage and retrieval system (ASRS) is a computer-controlled system that automatically stores and retrieves goods from predefined locations. It utilizes software applications to manage inventory, track storage locations, and optimize storage and retrieval processes. ASRS systems offer benefits such as improved inventory control, efficient use of time, space, and equipment. They consist of multi-tiered racks, stacker cranes, input/output stations, and a central supervisory computer, working together to ensure fast and accurate storage and retrieval operations [2]. The system typically consists of several key components: a storage rack, a retrieval mechanism (such as a crane or robot), and a computer control system. The storage rack is the physical structure that holds the materials being stored. This can be in the form of bins, shelves, or other types of storage compartments. The retrieval mechanism is responsible for moving the materials within the storage rack and bringing them to a pick-up location for the operator. This can be done through the use of a crane, robot, or other type of lifting device.

The computer control system is the brain of the ASRS, responsible for managing and coordinating the actions of the storage rack and retrieval mechanism. This system can be programmed to optimize storage density, improve inventory management, and reduce labor costs by automating the storage and retrieval process. The purpose of placing the goods has been stored in the database according to the goods being sorted. Data items that have been stored in the database are very helpful in the process of changing the warehouse system into a warehouse management system [3]. An ASRS is a computer-controlled system that automates the process of storing and retrieving materials in a warehouse. The storage retrieval equipment consists of a special mechanism responsible for transferring the products from input/output to a point in the shelves, a system for recording and arranging the products, a system for reading and executing an order, a system for locating and retrieving the products [4]. It can increase storage density, improve inventory management, and reduce labor costs by automating the storage and retrieval process, making it an essential tool in the modern warehouse and logistics industry.

This project utilizes a microcontroller as an automatic control on a computer numerical control (CNC) machine which aims to help simplify the programming of input files or data needed to move a CNC machine. The ball screw is used to convert the rotational motion generated from the stepper motor into a translational motion to move the working axis of the CNC machine [8]. Length of travel means the linear movement of stepper motors that control for X, Y and Z axes from point to another point [9]. The Arduino plotter machine uses Computer Numerical Control and is limited by the motion X, Y, and Z axes. The X-axis stepper motor controls left-right movement, the Y-

axis controls front-back movement, and the Z-axis controls pen up-down. The use of CNC to automate the movement of each linear actuator for each axes of X, Y and Z enable efficient movement for storing and retrieving of goods. This highlights the importance if CNC usage in warehouse system for better automatic movement.

Due to production volume, large-scale manufacturing relies on automation. Teams struggle to implement complex procedures with numerous controlled and tested parameters. Humans can also interfere. Programmable logical controllers (PLC) that act as a controlled system's "brain" solved this challenge. The controller evaluates and corrects all system factors to accomplish the prescribed mode. All automation systems are built. Processes vary. The PLC executes the process-specific program. System design involves correct software writing. Writing the program is possible in any convenient format: in the language of relay contact circuits, in the graphical language of functional block charts, and also with the help of high-level diagrams describing the stages and conditions of the transitions in the contemporary computer programming language [10]. In addition, the complex CODESYS makes it possible for you to see the program in operation, using the visualization editor. Visualization is possible without connecting the PLC.

Pick and place using robots is a common application in industry. In a cyber-physical system, a smarter robot with vision sensing can decrease the uncertainty in decision-making for acquiring the position of objects in a scene [11]. Some systems in the industries embrace the efficiency which is a production line usually enabled in order to produce several different types of objects in turn. Based on these circumstances, pick and place robot was designed to have 9 laying position divided into 3 main groups, namely A, B, and C and 2 disposal positions included in group X for objects instead of main group. The sensors used for detecting and classifying objects are using an radio frequency identification system (RFID) because each RFID tag has a unique code and different from another [12]. The idea of putting RFID tag on each goods should be implemented in this project. With this, the goods stored in the storage can have its information extracted by the warehouse keeper for data management. Some of the additional information possible to be read such as the entry time, type of goods, weight of goods and shipping postcode. This is one of the ideas in improving the project further.

Creating a complete pick and place system, with a low price, able to reconfigure the entire mechatronic system by using an HMI interface through a minimal intervention on the adaptation of the z axis to the specific application. Thus, the system can be set up via the HMI interface to support a drawing, cutting, laser engraving or 3D printer [14]. In this case, the HMI interface plays a part in showing the full system process flow. The use of display for the storage and retrieval goods provide information to be stored. In this case, the boxes colored by green means the goods are stored. This provide easy goods management to the warehouse keeper instead of checking manually through observation if the storage rack are unreachable and not easily visible in a congested warehouse.

The use of CODESYS as the programming and controlling automation devices for PLC, the use of actual hardware PLC is not easily can be accessed unless being exposed directly to automation industry. The use of CODESYS provide the platform for getting to know automation control easily due to its user-friendly interface. The laboratory exercises are designed to provide students with practical aspects in the field of automatic control. The focus is on the basic concepts of a programmable logic controller (PLC) programming by implementing an IoT-compatible, student-oriented approach using the Raspberry Pi, the PiFace Digital 2 module, and the CODESYS environment. Students design a control program through developing a ladder diagram. The progressively gradually upgraded developed program, which is first tested in simulation, is finally implemented on an elevator laboratory device [16]. For this project, the use of personal computer is used to connect CODESYS with other peripherals.

In industries these advanced control schemes implemented through Distributed control system (DCS), programmable logic controller (PLC). For communication with different make controllers user can use various communication protocol such as Modbus TCP, Modbus RTU, Ethernet, Profibus, Profinet etc. In this experiment Modbus RTU, Modbus TCP communication protocol are used for communication and control of batch process from remote controllers [17]. Ethernet local area network operation is specified for selected speeds of operation from 1 Mb/s to 100 Gb/s using a common media access control (MAC) specification and management information base (MIB) [18]. Traditional Modbus/TCP server-side protocol includes in many inappropriate blocking I/O operations. These operations frequently lead to receiving thread blockage in the communication [19].

Based on the past research works, the importance of material or goods handling in storage system is highlighted from the previous paragraphs. A proper storage system is a system equipped with fully automated linear motion for each 3 axes for X, Y and Z as well as each compartment have its own coordinates and sensors to detect the goods such as proximity, RFID reader and weight sensor. In this project, the compartment are arranged in a 3 by 3 grid and each have its own coordinate being set in Arduino and IR sensor is used for detecting presence of goods inside the compartment. The movement of storing and retrieving are done by the linear actuator movement consists of stepper motors for automating movement.

2. METHODOLOGY

This project includes the design and build a prototype of an Automated Storage and Retrieval System. The development of this project is based on ASRS system that have been applied in most logistics facility and warehouses which can store items inside aisles or compartments. In designing an Automated Storage and Retrieval System (ASRS), there are two things that need to put onto consideration; physical design and control issues, to be addressed in the right way to fully take advantage of all its pros, such as controller, mechanical system, and communication [20]. Furthermore, the system can display

the presence of item inside the compartment. The box is containing nine compartments. When IR sensor detects, LED will light up as indicator for item being put inside the compartment.

Arduino Mega act as the brain of the system that control the operation for detecting item, pick and place item and serial communication between Arduino and CODESYS. AnyViz acts as the automation server to display Supervisory Control and Data Acquisition (SCADA) and Human Machine Interface (HMI) development. The overview design involves for this project as shown in Figure 1.

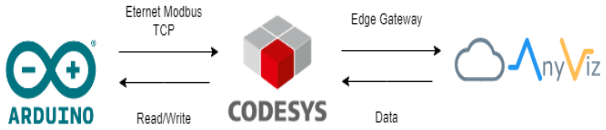

Figure 1. The overview of overall system implementation

2.1 Hardware Implementation

The implementation of hardware is including the construction of the circuit design which shows the interfacing between microcontroller with the devices and components. Figure 2 shows the early design of 9 compartments with input sensors and indicators.

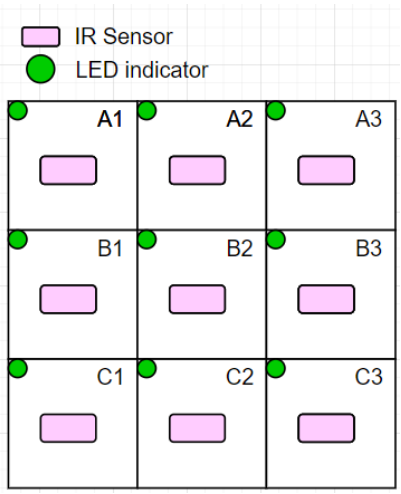

Figure 2. The box storage early design with 9 compartments equipped with IR sensors and LEDs as indicators

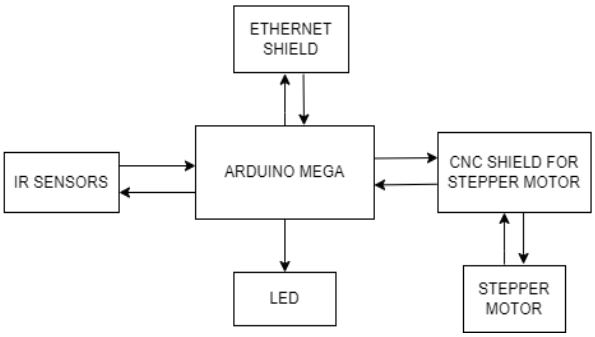

Figure 3. The hardware overview used in this project

From Figure 3, this ASRS system consists of IR sensors for detection of item inside the compartment. LED will light up upon detecting item and will stay light up when the item is still present. CNC shield is used as the driver for stepper motors and 3 stepper motors are used which will automate the pick and place process. Ethernet shield is used to send data of item presence to CODESYS through Ethernet Modbus TCP. Figure 4 shows the connection of Arduino Mega with IR sensors and LEDs for hardware implementation to indicate the presence inside each compartment.

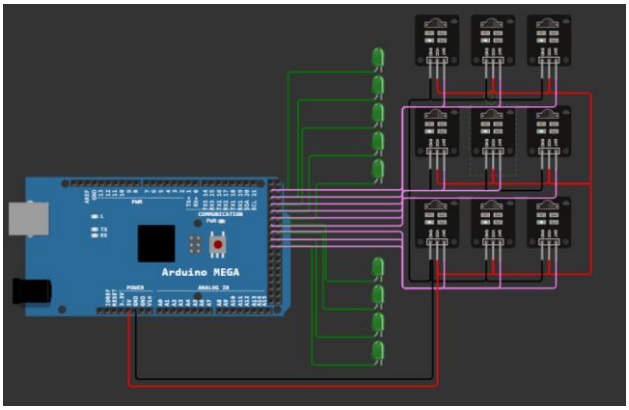

Figure 4. The connection of Arduino Mega with 9 LEDs and 9 IR sensors

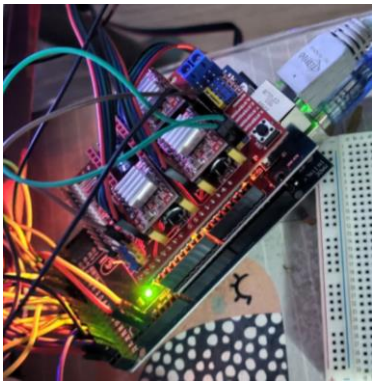

Figure 5. The connection of hardware for Arduino Mega, Ethernet shield and CNC shield

Figure 4 and 5 shows the overall connection of Arduino Mega, CNC shield and Ethernet shield for the hardware implementation. Figure 6 shows the overall setup of 3 stepper motors with aluminium profile base for the pick and place process. Figure 6 shows the 3-axes stepper motor actuator for X, Y and Z movement for pick and place item process. It consists of aluminium profile and stepper motors.

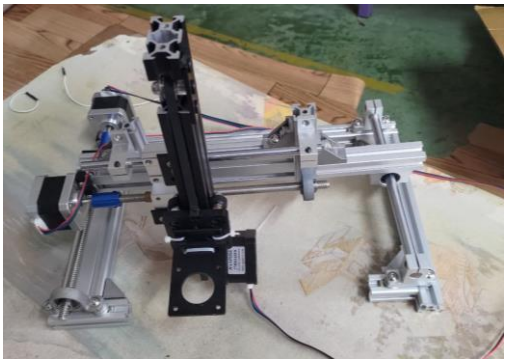

Figure 6. The 3 axes stepper motor setup for pick and place process

2.2 Software Implementation

The software part in this project Are about the full process from receiving data from Arduino IDE and then inputs from sensors which is then send to automation server which is AnyViz portal through CODESYS which act as the gateway.

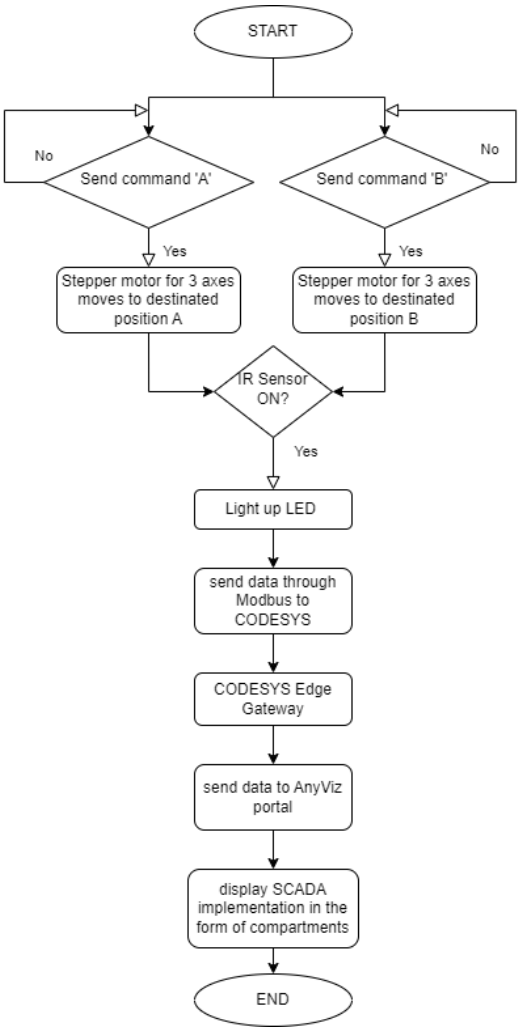

Figure 7. Flowchart for automated storage and retrieval system

Figure 7 shows the process of picking the item using the movement of stepper motors to move in the direction of X, Y and Z axes from the early stage to the end stage which is the display of item presence inside each compartment in the SCADA development.

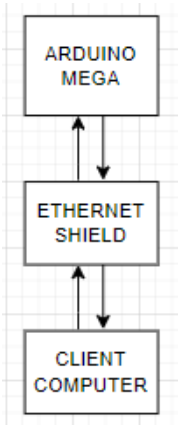

Figure 8. Arduino development for Modbus setup to computer client

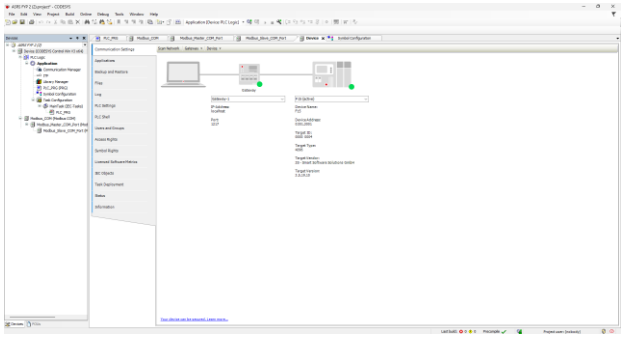

Figure 9. CODESYS development for PLC

Figure 8 shows the process in between Arduino Mega and Ethernet shield to the computer client. Figure 9 shows the CODESYS software interface which is configuring the gateway for local host connection to be connected to automation server which is AnyViz portal.

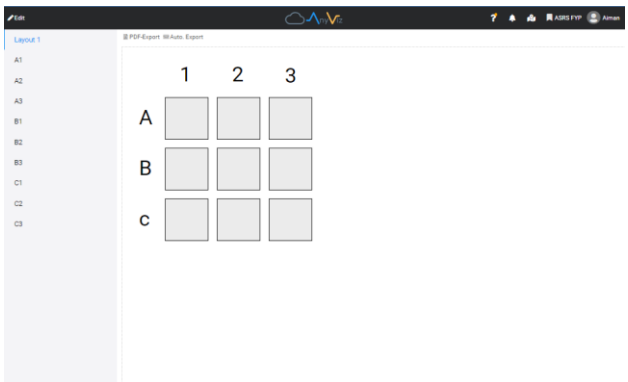

Figure 10. Automation server through AnyViz portal

Through the Anyviz portal like in Figure 10, users can configure automation tasks to be performed by the automation server. These tasks can range from simple repetitive actions to complex workflows involving multiple systems or applications. The automation server acts as the central component of the automation infrastructure. It receives instructions in the form of

Boolean data type from the Anyviz portal, which specify the tasks to be executed, their parameters, and the desired schedule. The server then carries out these tasks by interacting with the relevant systems or applications. The instruction sent to the CODESYS afterwards and will be updated inside the ladder diagram program which directly linked with the hardware. For this project, a simple representation of 9 identical arranged squares which will indicate the state of each compartment.

2.3 Sensor Selection

2.3.1 Arduino Mega

Arduino Mega is a microcontroller board that's part of the Arduino family of open-source hardware and software platforms. It's designed to provide more I/O pins, memory, and processing power compared to the standard Arduino boards, making it suitable for more complex projects and applications. The reason Arduino Mega was chosen as the microcontroller for this project because of its many I/O pins compared to other microcontrollers and it is also compatible to be use for shields such as CNC shield, Ethernet shield and WiFi shield.

Figure 11. Arduino Mega microcontroller

2.3.2 Infrared Sensor

An IR sensor, or an infrared sensor, is a key component used in projects to detect the presence of an item inside a compartment within a storage system. IR sensor is used compared to proximity sensor as described in the introduction because IR sensor is small and cheap for prototyping while proximity sensor is expensive and bigger then IR sensor in size so need to consider the sensor holder.

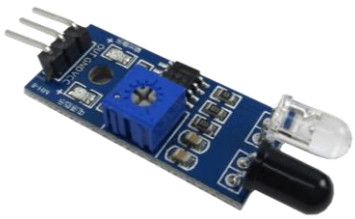

Figure 12. IR sensor

2.4 Hardware Design

The prototype was developed with nine compartments which are for receiving the items. For the movement of pick and place of items, 3 stepper motors are used for the 3-axes movement and the setup was built by using aluminium profiles as the base for the stepper motors as shown in Figure 6.

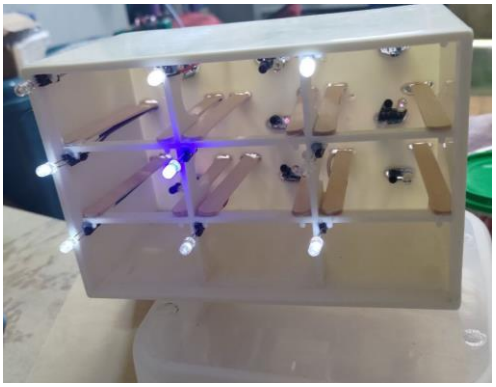

Figure 13. Prototype for box with 9 compartments for storage system

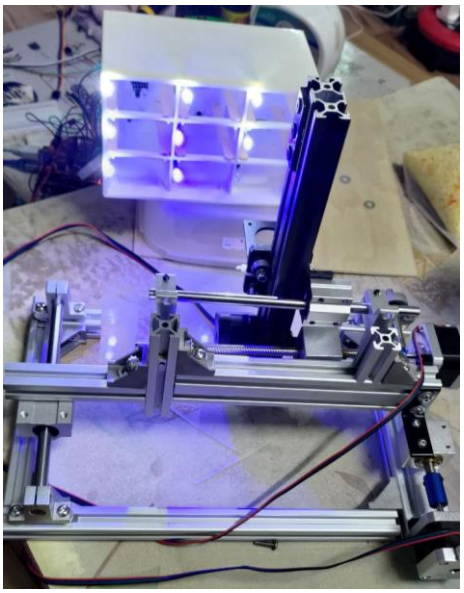

Figure 14. Overall full system of hardware involves with storage box and 3 axes stepper motor actuator

The measurement of the automated storage system box is 18cm*12cm*9cm. Figure 13 shows the overall prototype of automated storage and retrieval system. Based on Figure 14, the IR sensors and LEDs are position at each compartment.

3. RESULTS AND DISCUSSION

Tests and experiments were run on the system to test the functionality of the system. Three tests were run and the data was collected and analyzed which are testing the functionality of infrared sensor through serial monitor in Arduino IDE which is then send to CODESYS through Modbus which is identified by ladder diagram program. Second test is the indicators of LEDs to see the presence of items. Third test is the test to see the visualizations of indicating the presence of items inside the compartments through visual Human Machine interface or user interface

which can be understand easily through graphically representations.

3.1 Detection of Sensors

Detection of IR sensors can be identified by referring to serial monitor in Arduino IDE apart from knowing it through indicator lights. A command is constantly being produced to actively checking the state of each IR sensors and a display command in serial monitor is generated to indicate the status of IR sensor state.

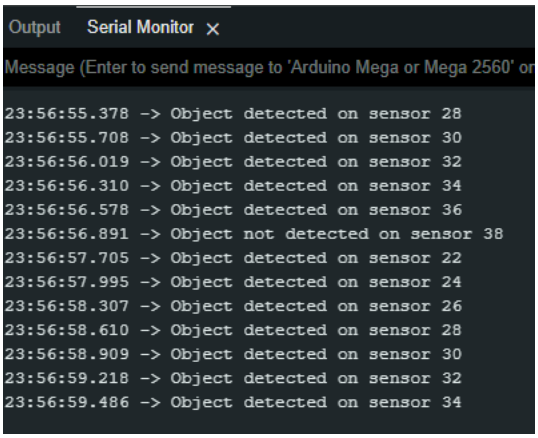

Figure 15. IR sensor status detection

Figure 15 shows the state of IR sensors for 9 compartments. If no detention then a display message of "No object on Sensor XX" is shown in the serial monitor.

3.2 Simulation of Control System

AnyViz portal user interface gave an overview of the system through the graphical representation towards storage system. The default display for this will be gray for 9 compartments. If the sensors detect item entering LED indicator are all available for each compartment to indicate the presence of item.

Figure 16. LED are not lighting up when no detection of pallet inside the compartment

Figure 17. LED are lighting up when detecting pallet inside the compartment

Figure 16 and 17 are the results of detecting pallet inside the compartment. The LED indicator represent the presence of pallet if present the LED will light up for that compartment.

3.3 Visualization through AnyViz Portal

AnyViz portal user interface gave an overview of the system through the graphical representation towards storage system. The default display for this will be gray for 9 compartments. If the sensors detect item entering the compartment, then the consequent box will be turn to green colour. If row A column 1 in hardware box (Figure 2) detects item inside that compartment, then the graphical representation inside AnyViz portal will turn to green indicating the presence of item.

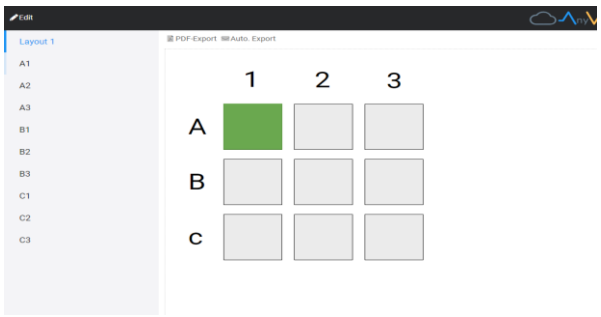

Figure 18. Detection of pallet inside the compartment

Figure 18 shows the result of items being placed inside the compartment and being displayed in real-time through indication of colour change inside the SCADA graphical user interface. Based on Figure 18, Row A Column 1 is containing an item.

4. CONCLUSION

This experiment integrates mechanical and electrical understanding. Mechanical elements help the ASRS do its robotics role, while electrical elements govern object movement. Finally, warehouse and distribution management efficiency need automated storage and retrieval systems ASRS. These advanced systems boost operating efficiency, precision, and supply chain performance. Automation, robotics, and advanced control

systems optimise ASRS storage and retrieval. They maximise space use for more product in a smaller area. This is valuable in metropolitan areas with limited and expensive space. ASRS systems automate storage and retrieval, improving order accuracy and customer satisfaction. They can manage huge inventories effectively and correctly, reducing processing time and throughput.

Real-time inventory tracking and monitoring improves demand forecasts, inventory management, and optimisation. ASRS systems create massive amounts of data that can be used with analytics tools to optimise processes and make decisions. ASRS systems have transformed warehouse operations by speeding storage and retrieval, reducing expenses, and improving customer satisfaction. Modern supply chain management gives organisations an edge in today's fast-paced and demanding industry.

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