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Automated material handling for inventory management system

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ABSTRACT
Industry 4.0 has improved productivity, facilitated work automation and simplified job augmentation. The rising deployment of robotic systems for warehouse automation is primarily responsible for the consistent growth of the Automated Material Handling Systems (AMHS) market. The emergence of Industry 4.0 has facilitated sustainability and ongoing technical breakthroughs. The design and constructionof a material-handling prototype robot and monitoring systemare described in this work. By reducing the need for humans, this system enables the effective transportation of commoditiesin the manufacturing area, inventory storage area, and warehouses. Robot mobility is the major emphasis of automated material handling systems, which combine mechanical and electrical components and link hardware and software. The adoption of this system is largely due to the ongoing developments in technologies like the Internet of Things (IoT), which allow for the easy integration of controllers with automated material handling equipment as well as the ability to control machines using a human-machineinterface (HMI) by using an application with the additional specification of visualizing the management system by the user, which will retrieve data from the machine using the thing speak platform. Furthermore, continuous automatic staking and unstacking can be achieved in a loop using queuing technology. According to the weight of the materials, using HMI one can select the appropriate slots and place it, which can able to withstand the strain of the rack for a long duration of time.

Section: RESEARCH PAPER

Keywords: Automated material handling; IoT; Industry 4.0; robotic automation

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1. INTRODUCTION

The term "Automated material handling" describes the control of material processing through the use of automated machinery and electrical and electronic types of equipment. Automated material handling lowers the need for people to perform all manual labor in addition to improving the productivity and speed of the production, shipping, storing, and handling of products. If heavy instruments are required to complete specific tasks or if human workers are physically incapable of performing the labor, this can greatly reduce expenses, human error or injury, and wasted hours [1].

During this Industrial Revolution, 4.0 has been developed Different types of robots can be divided into a number of categories, such as wheeled robots, crawlingrobots, and legged robots. In this area of automation, robots are proven to have enough intelligence to handle most tasks.Some of the extremely well-known methods used for robot navigation using mathematical modeling for transport system schedules can be achieved using wall-following,edge detection, and line-following. This system presents the design analysis of a robotic vehicle powered by the Internet of Things. In order to handle some specific jobs, such as sending the robotic vehicle to pick up and deliver the items to the godown, man would always like to follow safety precautions at work and even in his environment, as shown by this work. Typical robotic vehicles can navigate obstaclesand move through a variety of terrains.

The implementation of both designed hardware and software components is part of the design technique. To validate design parameters, a prototype of the IoT-controlled "AMHS" robotic vehicle was developed. This robotic vehicle system is strongly advised for industries, particularlyfor reasons of productivity and safety. According to this revolution, manufacturing industries created material handling systems for the inventory management process, while avoiding material movement in the warehouse by avoiding manual error when these material handling systemsare operated by humans [2]. One of the basic components ofany manufacturing system is its Material Handling System. We shall first study the different types of material handling systems that are currently in use. For example, let's take a nuclear fuel cycle facility, where they use glove boxes for storing mechanical containment to handle radiotoxic [3] andin the University Library and City Archives of Bergen, Norway they have re-organized entire library using this (AMHS) and published a paper [4] Material Handling refersto activities, equipment, and procedures related to the moving, storing, protecting, and controlling of materials in a system. In a typical factory, MH accounts for 24% of all employees, 55 % of the space, and 87 % of the production time. It accounts for between 15 % to 70 % of the cost of a product.

In the existing system, when a driver or human is controlling a simple robot with a remote, a guiding algorithmis implemented for robotic actions. Since the driver is present, humans can observe the barrier and guide the robot effectively. While this proposed method produces robots thatare respectable at fixing the issue, they are expensive, take alot of time to produce, and are not very customizable. In order to perform the predicted task, typical resolutions and practice models of the environment and robotics are required. These representations require precise verification of the robot's structure and the environment, requiring an overall effect onresources to maintain these models. consistently Sensors andsupercomputers needed to inform these models are the majorsources of these robots' expenses. The cost of the extra materials necessary to assemble the robots is not as remarkable, [5], [6].

The proposed system will not require a remote control to operate the vehicle; instead, it will depend only on integrated operational installation in the robot to identify impedimentsand avoid these inside its track. In this paper, we construct arobotic vehicle, that avoids detection and barriers while alsopicking and placing the items in a specific location with helpof IoT.

By constructing a robotic vehicle, that avoids detection and barriers while also picking and placing the items in a specific location with help of IoT and HMI to enable seamless communication robotic vehicle and its environment.

The methodological framework is shown as a block diagram, with the development of the rover setup in Figure 1 serving as the first stage (the architecture of this system). The system should be built with a rover setup and an automated control system that integrates with the existing material handling in an inventory management system. This is a control system that uses an IR sensor as a feedback system, as derived in theAutomatic Guided Vehicle System (AGVS) [7]. Also, rovercan be designed based on the travel time, task completion time, and operational fleet sizing [8], [9]. For the movement ofY axis are used to calculate sets of mechanical movement byusing a ball screw to move all the axes since a ball screw will transform rotational motion into linear motion. Moreover, this system needs to combine two closed loops from two sensors as feedback and actuate motors based on the extended Markov chain model (EMCM) to rapidly and effectively analyse the performances of AMHS, [10]. For theZ-axis, employing another ball screw for motion, is the sameas for the Y-axis. The ball screw will be attached to a pistonand a vacuum gripper is attached to the end of the piston forhandling the device for suction purposes, which will act as material handling equipment (MHQ) [11], [12]. The updated inventory system can be connected to HMI for easier operation. By using IoT, the HMI will provide a user-friendly interface for operators to control the machine and monitor its progress. by, depending on the availability of racks, a virtual rack will be created and entering the material's details manually, which include the category name, ID, cost, weight, and places, it can choose the desiredslots based on the material's weight.

2. HARDWARE DESCRIPTION

In this system, the following mechanical and electrical elements. specifically, there are names like,

- Rover Setup
- Node MCU
- Motor driver
- IR Sensor
- Gear Motor
- Vacuum Pump
- Vacuum Gripper
- Ball Screw

Above mentioned components are interfaced for acomplete robotic vehicle. In different construction phases

- Designing rover setup with an object slot
- Ball screw and bearings interfacing with roversetup
- Gear Motors Interfacing with controller
- Vacuum Gripper interfacing Vacuum pump
- Controller Interfacing with rover setup

2.1. Designing Rover Setup With An Object Slot

Designing a framework for a rover setup can help to organize and streamline the development process, making it easier to build, test, and maintain the rover overtime. The Rover Set Up consists of three Modules. Suchas, IMS module, Rover module, Object slot module.

2.1.1 IMS Module

The Inventory Management System (IMS) Module is acritical component of a Rover Setup that provides a centralized view of

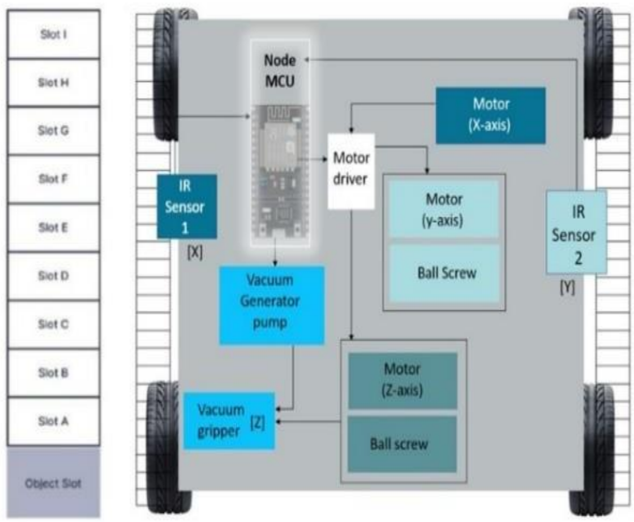

Figure 1. Architecture of the Proposed System.

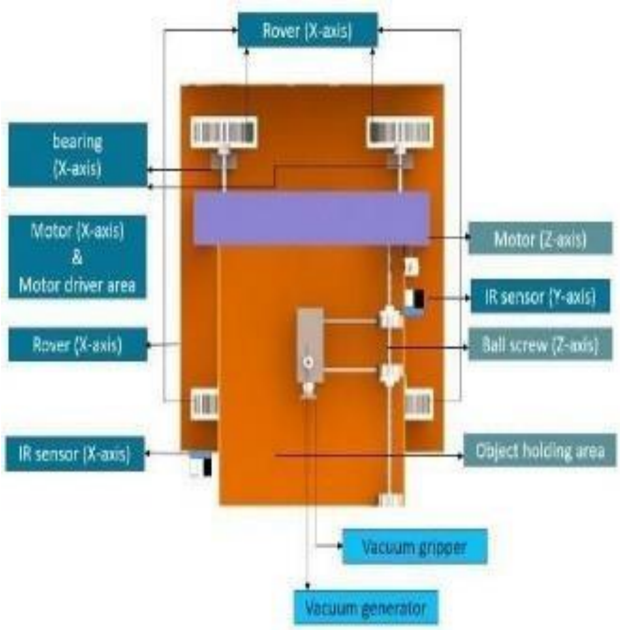

Figure 2. IMS Module.

item availability, enabling the Rover Module to select appropriate items located in the Object SlotModule in shown Figure 3.

2.1.2 Rover Module

Figure 4 describes the Rover Module, this module is the main controller of the Rover's activities and communicates with the Inventory Management System (IMS) Module and the Object Slot Module to manage inventory levels and ensure that the Rover has access to the necessary components for its tasks.

2.1.3 Object Slot Module

Figure 5 depicts the object slot Module, this module is a physical, space dedicated to supplying the necessary items for the Rover.

Its primary purpose is to provide quick and easy access to the items required for each task, minimizing downtime and ensuring that the Rover can complete its tasks efficiently.

2.2 Ball Screw Interfacing with Rover Setup

Ball screws are often used in rover setups to convert rotary motion from the motor to linear motion required for movement. Figure 2 depicts, interfacing a ball screw with a rover setup, connecting it to the motor and the rover's control system, and programming it to respond to commands from the controller.

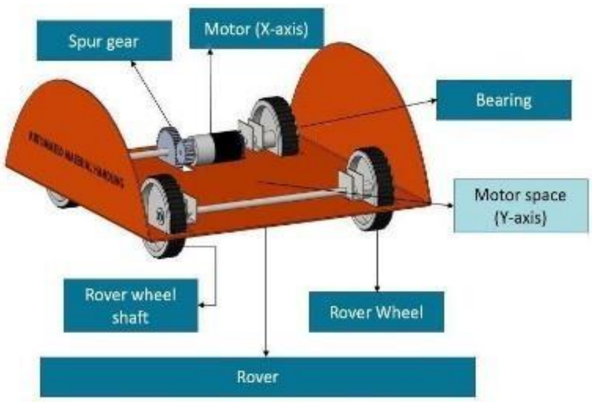

Figure 3. Rover Module.

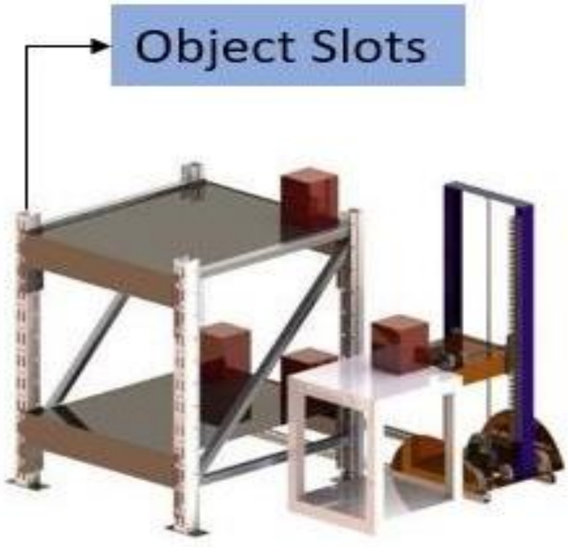

Figure 4. Object slot Module.

To connect the ball screw to the motor, a coupling mechanism is often used to transmit torque from the motor shaft to the ball screw. The ball screw can also be mounted on a bearing support to ensure that it rotates smoothly. To connect the ball screw to the rover's control system, an encoder is often used to measure the linear displacement of the ball screw. Once the ball screw is connected to the motor and the control system, it can be programmed to respond to commands from the controller. Overall, interfacing a ball screw with a rover setup is an important step in building a rover that can move with precision and accuracy.

2.3 Gear Motor Interfacing with Controller

Figure 7 describes Interfacing gear motors and motor driver modules with a rover setup that involves connecting the motors

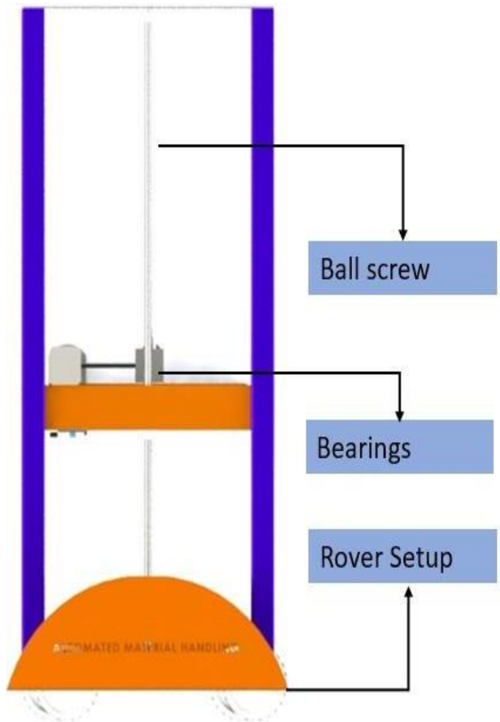

Figure 5. Ball Screw Interfacing with Rover Setup.

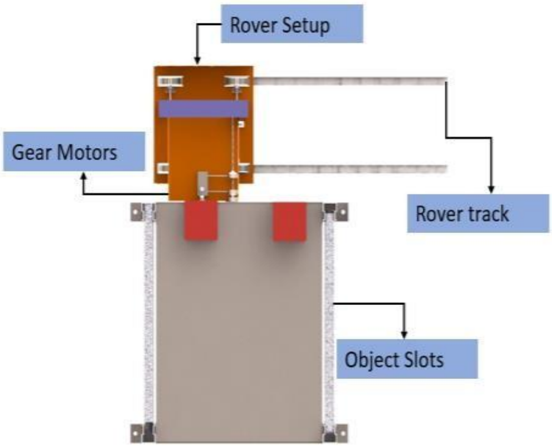

Figure 6. Gear Motors Interfacing with Rover Setup.

to the driver modules, connecting the driver modules to the control board, and programming the control board to send signals to the driver modules to control the motors. The driver modules act as an interface between the control board and the motors, allowing the control board to send signals to control the speed and direction of the motors. The driver modules can be connected to the control board via cables or wireless technology, depending on the setup. The control board is responsible for sending signals to the driver modules to control the motors, and the connections between the board and the driver modules must be secure to prevent any electrical interference. Once the motors and driver modules are connected, the control board can be programmed to send signals to the driver modules to control the speed and direction of the motors. after this, the rover can be controlled with precision and accuracy.

2.4 Vacuum Gripper Interfacing with Vacuum Pump

Vacuum grippers are often used in robotic systems, including rover setups, for picking up and manipulating objects. Figure 7 depicts, the vacuum pump creates a vacuum by removing air from the suction cups of the vacuum gripper, allowing it to hold onto objects. This vacuum pump can be connected to the gripper using hoses or tubing, and the connections must be secure to prevent any leaks. To program the vacuum gripper, the controller must be able to send commands to the vacuum pump to turn it on and off and adjust the suction level. This involves writing code to control the vacuum pump and monitor the gripper's sensors for feedback on object detection and gripping force. The controller can then send commands to the vacuum gripper to pick up and release objects as required.

2.5 Controller Interfacing with Rover Setup

Figure 8 describes the controller in a Rover Setup serves as the main interface between the operator and the Rover Module. It typically includes a user interface that allows the operator to interact with the Rover, select tasks, and manage inventory levels. To interface a controller with a rover setup, first, the controller needs to be connected to the rover. This requires connecting it to the rover's power supply, gear motor lines, vacuum pump and gripper systems, and various other components of the rover. Then, the controller needs to be programmed with instructions and commands pertinent to the rover's specific setup, and all communication between the controller and the rover components is successful. Finally, the controller can be tested with the rover and adjusted as necessary for successful navigation.

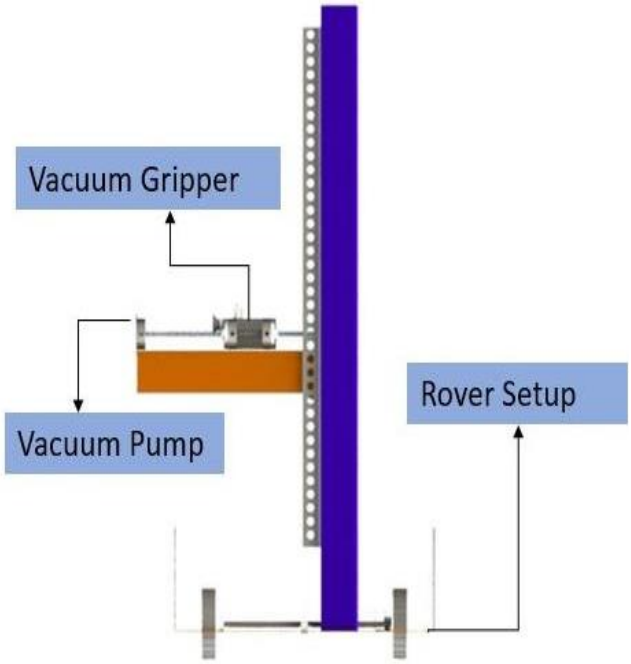

Figure 7. Vacuum gripper interfacing vacuum pump.

3. SOFTWARE DESCRIPTION

After the hardware design, coding needs to be done. The software used for coding and IoT Platform for cloud-based visualizations,

- Arduino IDE
- ThingSpeak
- Flutter
- HTML
- Queuing Technology.

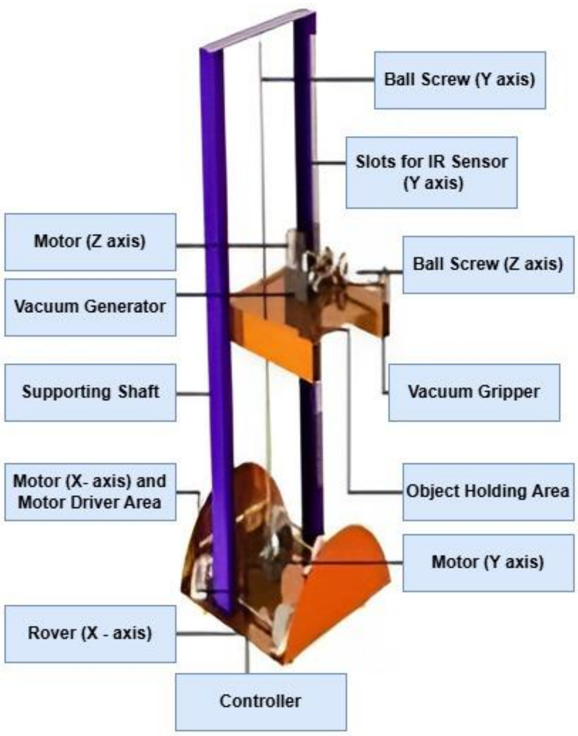

Figure 8. Controller interfacing with rover setup.

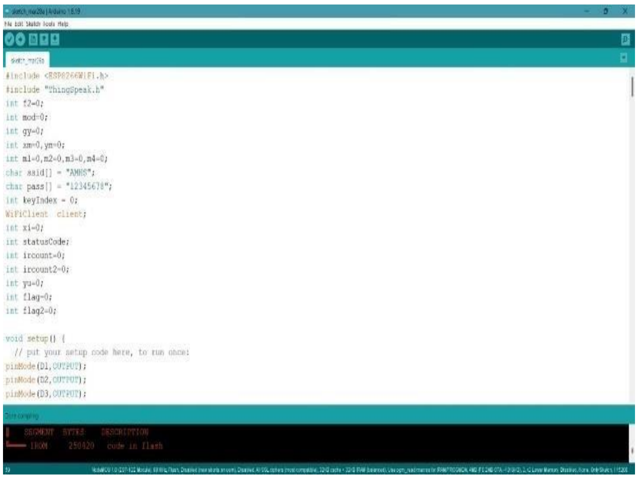

Figure 9. Arduino IDE Tool.

Figure 9 depicts, to use of Arduino IDE with automated material handling for inventory management, which is able to design programs to read and store sensor readings, control components and motors based on inventory levels, and storedata from individual steps of the handling process. This canbe done by writing sketches and/or integrating Arduino- compatible libraries available for material handling

Figure 10 shows as Integrating ThingSpeak with an automatedmaterial handling system in an inventory management system can help to improve data collection, analysis, and decision-making.

This developed application uses the data collected by the sensors and devices to make informeddecisions about inventory management, such as identifying trends in inventory levels, predicting future demand, and optimizing storage and retrieval processes.

Flutter can be an important tool for creating a user interface for an automated material handling system in an inventory management system shown in Figure 11. The interface can provide real-time control and monitoring of the transfer of items in and out of locations, which can help to optimize inventory management and improve productivity. By using Flutter, it can design an intuitive and user-friendly interface that allows operators to easily control and monitor the system. The interface can include features such as real-timetracking of inventory items,

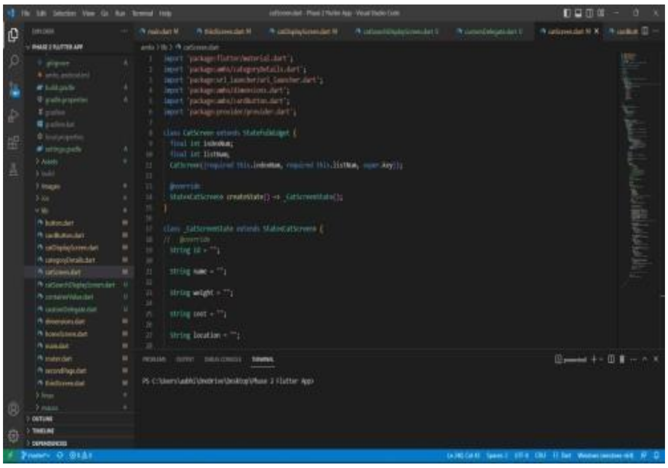

Figure 11. Flutter Interface Platform.

notifications for low stock levels, and automated updates to the inventory database to ensure accurate item counts.

When it comes to interfacing automated material handling in an inventory management system, HTML can be used to create the user interface that allows users to interact with the system is shown in Figure 12. This user interface can be accessed through a web browser, which makes it easy for users to access the inventory management system from anywhere with an internet connection. By creating this user interface, users can more easily interact with the system and make better decisions about inventory management.

4. RESULTS AND DISCUSSION

In the Figure 13 shows a developed, automated material handling system that uses a rover setup with an automated control system. The integration of this system with an existing material handling system in an inventory management system could offer benefits such as increased accuracy and speed of inventory tracking and order fulfilment, improved storage capacity, and easier recognition of inventory items. In this system Using an IR sensor as a feedback loop for the movement of the X and Y axes can help to ensure that the system moves precisely and accurately.

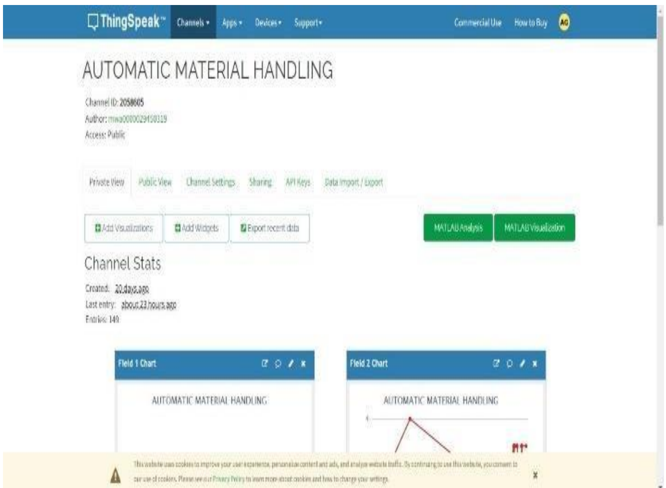

Figure 10. IoT-ThingSpeak Interface platform.

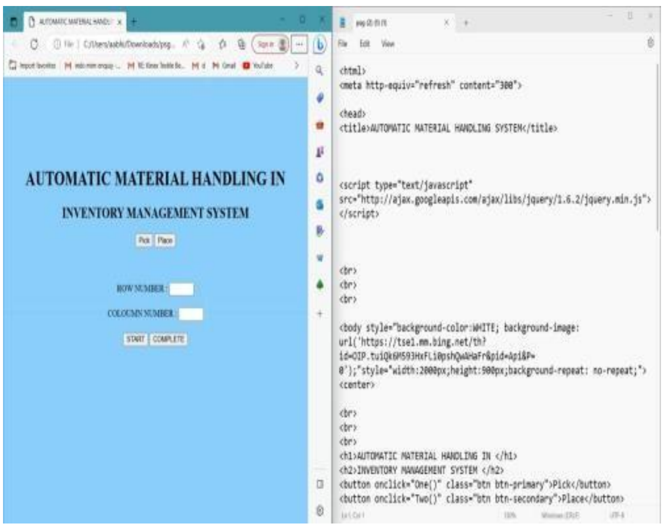

Figure 12. HTML Interface Platform.

Figure 13. AMH in the inventory management system.

The X-axis typically refers to horizontal movement along a straight line, usually from left to right or right to left. In an AMHS, the ball screw can be used to control the horizontal movement of robotic arms or conveyors. Figure 14 shown, movement can be used to pick up or place items on a conveyor, move an item from one location to another, or position a robotic arm for further processing.

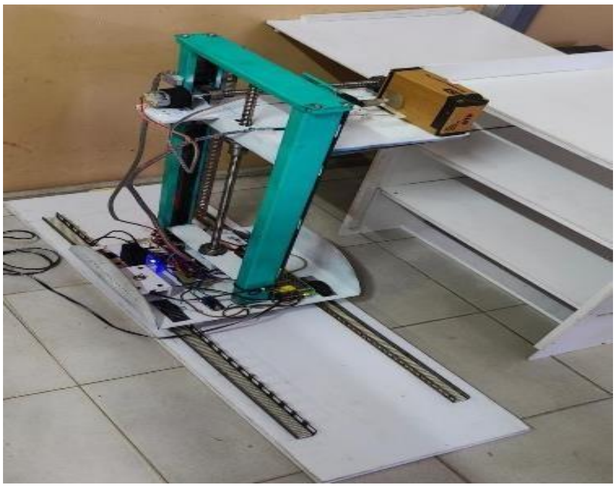

Figure 14. Movement of the X-axis of this system.

Figure 15. Movement of the Y-axis of this system.

Figure 16. Movement of the Z-axis this system.

Figure 15 shows, the Y axis typically refers to vertical movement, usually up or down. The ball screw can also be used to control this movement, which can be used to lift items from one object slot to another object slot. The Y axis is also used to position robotic vehicles.

Figure 16 shows, the Z axis refers to depth or distance, usually moving forward or backward. The ball screw can be used to control this movement, which is commonly used to move items from one location to another, such as moving items from a loading dock to a storage area. The Z-axis can also be used to position the robotic vehicles for further processing. Based on this movement, By calculating sets of mechanical and electrical movements using a ball screw, the system can transform rotational motion into linear motion and move all axes smoothly and consistently. Additionally, a vacuum gripper attached to the end of the piston can provide a secure way to handle the device using suction. Connecting the updated inventory system to an HMI (Human Machine Interface) can offer easier operation and monitoring of the automated material handling system. This could enable operators to quickly and easily access information about inventory levels, order status, and system performance, helping to improve overall efficiency and productivity.

Integrating IoT (Internet of Things) technology into the automated material handling system can provide a range of benefits. By creating an HMI (Human Machine Interface) that is user-friendly, operators can easily control the machine and monitor its progress in shows Figure 17. The HMI can be designed to display real-time data about the system's

Figure 17. UI of AMH in the inventory management system.

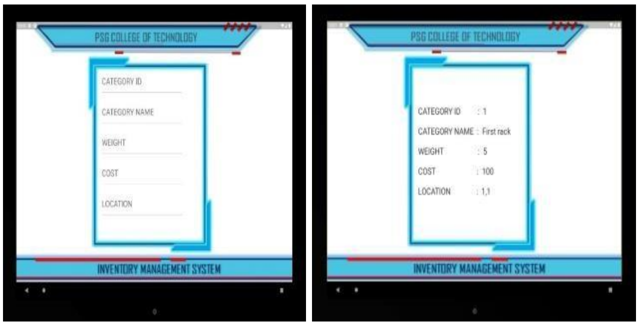

Figure 18. Materials Description.

performance, such as inventory levels, order status, and system performance.

Figure 18 describes, manually entering the material's details can certainly help to ensure inventory management by entering information such as category name, ID, cost, weight, and storage locations, the system can track the movement of inventory items and make informed decisions about how to manage them. In this system can use this information to determine which items are selling quickly and which are not, allowing businesses to adjust their inventory levels accordingly. It can also help to identify items that are taking up too much space in the warehouse and suggest ways to optimize storage.[13].

One way to improve the accuracy and efficiency of the system is by creating a virtual rack that mirrors the physical racks in the inventory management system in shown Figure 19 and

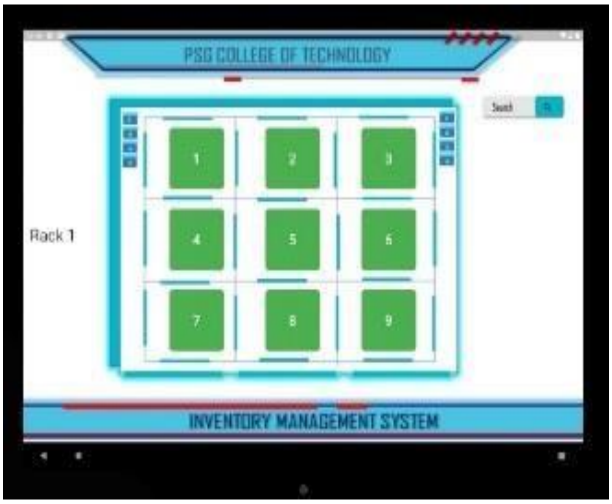

Figure 19. Virtual view of the rack.

Figure 20. Availability of the material (Red Grid).

Figure 20. This can help to ensure that the automated material handling system is always aware of the available slots and can choose the most appropriate ones based on the material's weight [14]. Existing Material handling systems are manual methods of moving and storing inventory, while automated material handling systems are computerized systems that use robotics, sensors, and other technologies to automate the process. Both systems are used in inventory management systems, but automated material handling systems provide more accuracy, efficiency, and cost savings than manual ones. Automated material handling systems also require less physical labor, which can help to reduce overall operating costs and improve workplace safety.

5. CONCLUSION

Automated material handling in inventory management systems can offer several benefits, including increased efficiency, accuracy, and safety. By using technologies such as automated guided vehicles (AGVs), conveyor systems, and robotic systems, businesses can streamline their inventory processes, reduce the risk of human error, and increase their overall productivity. By designing and assembling the components and sub-components to form the final material handling system, businesses can streamline their operations and reduce the risk of human error. The use of a microcontroller to automate the system further enhances its efficiency, ensuring that the material handling and engraving operation can be completed in a fixed time for the user. This eliminates the need for workers to perform difficult and tedious tasks, freeing them up to focus on more valuable tasks that require human expertise. Additionally, the integration of automated material handling systems with inventory management software can provide real-time inventory tracking and management, enabling businesses to make data-driven decisions that can improve their operations and reduce costs. Overall, the implementation of automated material handling in inventory management systems can lead to significant improvements in productivity, accuracy, and safety, making it a valuable investment for businesses of all sizes. The future scope for automated material handling in inventory management systems is quite promising. With the advancements in technology such as artificial intelligence (AI), machine learning (ML), and the internet of things (IoT), there are numerous opportunities to enhance and optimize the automated material handling system. According to this technology, the installation of a camera module in an automated material handling system for inventory management can offer several benefits and is a promising area for future development. By leveraging machine vision technology and digital image processing, businesses can improve the accuracy, efficiency, and safety of their inventory management processes, making it a valuable investment for the future.

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