

IMPLEMENTATION OF IOT FOR SORTING AND PICKING A SPECIFIC PRODUCT IN AN INDUSTRIAL WAREHOUSE

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechatronics

By

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of VISHWESHWAR K (Reg. No. 40090037) and HARISH P S (Reg. No. 40090011) who carried out the project entitled **"IMPLEMENTATION OF IOT FOR SORTING AND PICKING A SPECIFIC PRODUCT IN AN INDUSTRIAL WAREHOUSE"** under our supervision from November 2023 to April 2024.

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We VISHWESHWAR K (Reg. No. 40090037) and HARISH P S (Reg. No. 40090011) hereby declare that the Project Report entitled "**IMPLEMENTATION OF IOT FOR SORTING AND PICKING A SPECIFIC PRODUCT IN AN INDUSTRIAL WAREHOUSE**" done by us under the guidance of **Dr. M. Sangeetha, M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.



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ABSTRACT

In the realm of industries and logistics, the manual handling of sorting, storage, and picking tasks has long been a dominant practice. However, this traditional approach incurs substantial labor costs, introduces error-prone processes, and impedes overall operational efficiency. The challenge of optimizing the sorting, storage, and picking of fast-moving components and products is two-fold. First, the heavy reliance on human labor in these processes results in escalating expenses. Second, manual methods often lead to inaccuracies and sluggish operations. This research project introduces a sophisticated IoT (Internet of Things) implemented warehouse management system designed to enhance the efficiency and accuracy of product handling and order fulfillment in a warehouse setting. Leveraging IoT techniques and visual assistance technologies such as "pick by light" and "pick by display," this system optimizes the processes of product input, sorting, storage, and output, ultimately improving overall warehouse operations.

The central components of this IoT-enabled system include input and output conveyors, a lift and shuttle system, and an extensive network of interconnected sensors and devices. These elements work in tandem to seamlessly manage product inventory, streamline product retrieval for order picking, and provide real-time visibility into warehouse capacity and product locations.

The project aims to advance the state of warehouse automation by significantly reducing order picking errors, improving the speed of order fulfillment, enhancing worker productivity, and optimizing warehouse space. By combining cutting-edge IoT technology with visual assistance mechanisms, it offers a comprehensive solution for the evolving demands of modern warehousing.

In conclusion, this research project showcases a novel approach to warehouse management that capitalizes on the potential of IoT and visual assistance technologies. It provides a blueprint for businesses seeking to modernize their warehousing operations, ultimately increasing efficiency and customer satisfaction while minimizing operational costs.

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LIST OF SYMBOLS AND ABBREVIATIONS

IOT	Internet of Things
3D	3 Dimensional
CAD	Computer Aided Drawing
CNC	Computer Numerical Control
QR	Quick Response
SKU	Stock Keeping Unit

CHAPTER 1

INTRODUCTION

The landscape of warehousing and supply chain management is undergoing a profound transformation in the wake of technological advancements and changing consumer expectations. As businesses strive for enhanced efficiency, accuracy, and responsiveness, the role of warehouses as hubs for the storage, sorting, and distribution of components and products has never been more critical. This report presents an innovative and ground-breaking approach to address the challenges of component sorting, storage, and retrieval within the modern warehouse.

In an era where precision and expediency have become paramount, this research proposes a unified warehouse system that amalgamates the power of automation, Internet of Things (IoT) technology, and visual assistance mechanisms. The aim is to optimize the handling of components with unmatched accuracy and efficiency, revolutionizing the way warehouses function. The implications of this revolutionary system extend beyond mere process optimization; they resonate with businesses' fundamental objectives to reduce operational costs, improve inventory management, and elevate customer satisfaction.

The foundation of this system is built upon a sophisticated network of automated conveyors, a camera module for QR code scanning, and an advanced lift and shuttle mechanism. These elements work harmoniously to orchestrate the orchestration of components within the warehouse environment, and the result is a level of precision that was previously unattainable.

Moreover, this system doesn't merely streamline processes; it provides a tangible, data-driven insight into the warehouse's inner workings. Through the implementation of IoT technology, real-time data regarding component locations, quantities, and movements are at your fingertips. The warehouse ceases to be a black box; it transforms into a smart, adaptive, and efficient hub for component management.

Throughout the report, we will delve into the intricacies of this innovative system. We will explore the key components, the methodologies, and the technology underpinning its functionality. We will dissect the benefits it brings, such as error reduction, real-time inventory monitoring, and enhanced order fulfillment, all of which contribute to improved customer satisfaction. Furthermore, we will discuss the broader implications and future directions, envisioning a world where warehousing systems align seamlessly with the demands of the modern marketplace.

1.1 Problems faced in industrial warehousing:

Industrial warehousing is a dynamic and indispensable facet of the supply chain, yet it is not devoid of formidable challenges. This section delves into the common issues and obstacles that warehouses grapple within their day-to-day operations. Acknowledging and effectively addressing these challenges is paramount for upholding operational efficiency, mitigating costs, and ensuring the fulfillment of customer expectations.

1.2 Inventory Management Issues:

Inventory management lies at the core of warehousing, and it presents its own set of complexities. Problems related to inventory management, such as inaccurate record-keeping, overstocking, and understocking, can severely impact warehouse operations. Inaccuracies often lead to operational inefficiencies, unnecessary storage expenses, and missed sales opportunities. Overstocking strains available space and working capital, while understocking jeopardizes order fulfillment and customer satisfaction.

1.3 Picking and Packing Errors:

Picking and packing are pivotal processes in warehousing, but they are prone to errors that can have cascading consequences. Errors may manifest as the selection of incorrect items, inaccurate quantities, or even the dispatch of damaged products. These issues bear direct consequences for customer satisfaction and return rates. Picking and packing errors result in increased labor costs for restocking, potential reputational damage, and inefficiencies within the warehouse that are often costly to rectify.

1.4 Inefficient Space Utilization:

Space utilization inefficiencies are another challenge that confronts warehouses. In some cases, warehouses fail to maximize their storage capacity or optimize their layouts effectively. The consequences of inefficient space utilization extend to underutilized storage space, necessitating costly expansions and impacting a warehouse's ability to accommodate growing inventories. These issues result in financial inefficiencies and missed opportunities for better space allocation.

1.5 Labor Productivity:

Labor productivity issues loom large in the warehousing landscape. High turnover rates, insufficient training, and employee fatigue are common challenges that hamper operational efficiency. High employee turnover incurs substantial recruitment and onboarding costs, while inadequate training exacerbates the risk of errors. Labor-related issues have further implications, affecting morale among workers and the overall atmosphere within the warehouse.

1.6 Technology Integration:

The integration of new technologies represents a double-edged challenge in warehousing. While technology can streamline operations, its incorporation introduces complexities and expenses. Warehouse management systems (WMS), the Internet of Things (IoT), and automation technologies necessitate comprehensive planning and financial investments. Challenges emerge in the form of downtime during implementation, data security risks, and the ongoing need for technical support, which can strain both efficiency and budgets.

1.7 SORTING METHODS IN INDUSTRIAL WAREHOUSING

Efficient sorting processes lie at the heart of industrial warehousing, ensuring that products are organized for streamlined storage and retrieval. This section delves into the essential sorting methods employed in warehousing and their significance in optimizing operations and enhancing customer satisfaction.

1.7.1 Manual Sorting:

Manual sorting represents a foundational approach to order and inventory management. In this method, human labor is pivotal in categorizing and organizing products based on various criteria. Warehouse workers use their knowledge of the products, such as SKU, size, or type, to manually arrange items in storage areas.

Manual sorting offers adaptability and is well-suited to environments with smaller inventory volumes. However, it is not without limitations. The process is labor-intensive and subject to human errors. In larger warehouses with substantial inventory turnover, manual sorting may struggle to meet the demands for rapid organization.

1.7.2 QR code and RFID Sorting:

QR code and Radio-Frequency Identification (RFID) sorting methods bring automation to the process. Products are affixed with QR codes or RFID tags, allowing for rapid and accurate sorting. Scanners and RFID readers are used to identify products and determine their destination within the warehouse.

These methods offer notable advantages, including enhanced accuracy, reduced sorting time, and the capability to handle larger volumes of inventory. They are particularly suitable for environments with high SKU counts and complex inventory requirements.

1.7.3 Batch Picking and Sorting:

Batch picking and sorting is a strategy that involves the simultaneous collection and sorting of multiple customer orders. Workers gather products for multiple orders at once,

and these items are subsequently sorted into their respective customer-specific containers.

This strategy offers several advantages, including reduced travel time, increased picking efficiency, and the ability to handle numerous orders concurrently. It is particularly beneficial in warehouses with high order volumes and frequent small-item orders.

1.7.4 Picking and Sorting:

Zone picking and sorting is a strategy that assigns specific warehouse zones to different workers or teams. Each worker is responsible for picking and sorting products within their designated zone. This approach is commonly used in larger warehouses with extensive inventory.

Zone picking and sorting enhances efficiency by reducing the need for workers to travel throughout the entire warehouse. It also improves accountability, as workers are responsible for their designated areas, resulting in faster sorting and fewer errors.

1.7.5 Wave Picking and Sorting:

Wave picking and sorting is a strategy that involves the batching of orders into waves. During each wave, workers pick products for a set of orders, and these products are then sorted and prepared for shipment. Multiple waves can be processed in a single shift.

The advantages of wave picking and sorting include better order consolidation and improved order fulfillment. By grouping orders into waves, warehouses can reduce the number of times a worker visits a storage location, resulting in time savings and increased sorting accuracy.

1.7.6 Automated Sorting Systems:

Automated sorting systems represent a modern strategy for streamlining sorting processes. These systems make use of conveyors, sensors, and software control to

automatically sort products into the correct storage locations or order fulfillment zones. Products are identified and routed without human intervention.

The benefits of automated sorting systems are efficiency and accuracy. These systems can handle high volumes of products quickly, reducing the risk of errors and improving order fulfillment speed. Automated sorting is essential in high-volume warehouses and distribution centers.

1.7.7 Just-in-Time Sorting:

Just-in-time (JIT) sorting is a strategy that prioritizes the sorting and organization of products immediately before they are needed. In this approach, products are sorted and positioned for rapid access in preparation for specific orders or production needs.

JIT sorting reduces the need for extensive storage and minimizes handling costs. It is particularly valuable in scenarios where quick access to specific products is essential, such as in manufacturing or assembly line operations.

1.8 PICKING METHODS IN INDUSTRIAL WAREHOUSING

Picking methods are pivotal in warehouse operations, influencing efficiency and accuracy. The project aims to optimize the picking process by exploring various techniques commonly employed in industrial settings.

1.8.1 Manual Picking:

Manual picking represents the traditional approach, relying on human labor to locate and retrieve items. Warehouse workers play a central role, utilizing knowledge and experience to complete orders. This method offers flexibility and simplicity, making it suitable for certain scenarios. However, it has inherent limitations, such as the potential for human errors and slower processing times.

1.8.2 Pick-to-Light (PTL) Systems:

Pick-to-Light (PTL) systems introduce visual displays to guide workers during the picking process. These displays illuminate the locations of items to be picked, minimizing errors and saving time. PTL systems are widely used in industries where precise order fulfillment is critical, such as electronics manufacturing and pharmaceuticals.

1.8.3 Pick-by-Voice Systems:

Pick-by-Voice systems employ voice commands to direct warehouse workers to pick locations. This hands-free approach enhances efficiency and reduces errors, as workers can focus on tasks rather than handling paperwork or devices. Industries such as cold storage and food distribution find this method particularly beneficial.

1.8.4 Pick-by-Display Systems:

The Pick-by-Display method utilizes visual displays to provide real-time information about pick locations. Warehouse workers receive immediate feedback on the quantities to be picked, improving order accuracy. This system is commonly applied in industries where real-time data and feedback are essential for efficient operations.

1.8.5 Automated Picking Systems:

Automated picking systems introduce robotics and conveyor systems to expedite the picking process. These systems offer high-speed, high-efficiency solutions that can operate around the clock. Industries like e-commerce and manufacturing increasingly rely on automation to meet demands for rapid order fulfillment.

1.9 Inventory Management Strategies in Industrial Warehousing

Effective inventory management is the linchpin of industrial warehousing, impacting operational efficiency and customer satisfaction. This section delves into advanced inventory management strategies and technologies employed in warehousing and their vital role in streamlining operations and enhancing customer experiences.

1.9.1 Warehouse Management Systems (WMS):

Warehouse Management Systems (WMS) are sophisticated software solutions designed to streamline inventory management. These systems provide end-to-end control over inventory, including tracking, monitoring, and optimization. They offer capabilities such as real-time stock level monitoring, order management, and inventory movement tracking.

WMS offers a multitude of advantages, including increased accuracy, reduced stockouts and overstocking, and the ability to provide real-time data for better decision-making. In larger, complex warehouses, WMS is indispensable for maintaining control over inventory, ensuring efficient order fulfillment, and enhancing overall operational efficiency.

1.9.2 QR code Technology:

QR code technology is a cornerstone of modern inventory management, bringing automation and accuracy to tracking and sorting inventory. Products are labeled with QR codes that contain essential data, such as SKU, location, and quantity. Scanners and readers are used to rapidly identify and manage inventory.

The benefits of QR code technology include error reduction, increased efficiency, and reduced human intervention in tracking and sorting. QR codes are fundamental for high SKU counts, fast-moving inventory, and complex storage arrangements.

1.9.3 IoT Integration:

Internet of Things (IoT) integration is a cutting-edge approach to inventory management that leverages connected sensors and devices. These IoT devices monitor and relay real-time data on inventory status, temperature, humidity, and other variables. This data is used to track and manage inventory accurately.

The advantages of IoT integration are vast, including precise environmental control, real-time tracking, and enhanced data analysis. IoT provides warehouses with the capability to make data-driven decisions, optimize supply chain operations, and ensure that products are stored under the ideal conditions.

1.9.4 Automated Replenishment Systems:

Automated replenishment systems represent a strategic approach to inventory management. These systems use real-time data to trigger automatic replenishment of inventory when stock levels fall below predetermined thresholds. Automation streamlines the restocking process, ensuring that products are always available when needed.

Automated replenishment systems offer enhanced efficiency by eliminating the need for manual restocking. These systems are particularly valuable for fast-moving items and industries where stockouts can have detrimental effects, such as retail and e-commerce.

CHAPTER 2

LITERATURE SURVEY

Rongjun Chen et al (2019) [1] discussed the model of two-dimensional QR code that can be identified with the help of Adaptive Binarization of QR Code Images. this process involves efficiently converting nonuniformly illuminated QR code images into binary form. The approach involves preprocessing and selecting block windows in an adaptive manner. To identify QR code(1-Dimensional) image is first scanned in four directions during the detection phase (horizontally, vertically, and in the direction of the diagonals (45 degrees). The edge pixels with vertical orientation are initially identified during the horizontal scan. The technique scans for pixels of the opposite polarity near each edge pixel. If there are several of such pixels in a particular region (as if they were a line segment), the area will be maintained Melinda Katona et al (2013) [2]. pivotal role of QR codes in enhancing the efficiency of various warehouse processes, including goods receipt, put away, order processing, outbound verification, loading, and stocktaking is studied by Nadya Amanda Istiqomah et al (2020) [3]

Ronald J. Mantel Peter Schuur and Sunderesh S. Hegaru (2007) [4] introduce us to the concept of Order Oriented Slotting (OOS), which aims to minimize the total travel time of order pickers for multi-item orders. It's different from traditional slotting strategies like COI (Cube per Order Index) that assume single-command transactions. heuristics for solving the OOS problem, including random allocation, popularity-based allocation, interaction frequency-based allocation, and a more complex quadratic assignment heuristic. This paper explores strategies for optimizing warehouse storage and order picking efficiency, with a focus on the OOS approach, which takes into account the order composition and routing strategies to minimize travel time.

Charles G. Petersen, Charles Siu and Daniel R. Heiser (2005) [5] perform the simulation experiment that explores different storage assignment strategies, including those that prioritize the placement of SKUs within the golden zone. The "Golden zone within-aisle (GZW)" and "Golden zone across-aisle (GZA)" focus on filling the golden zone first,

ensuring that high-demand items are easily accessible. The results of the simulation suggest that storing high-priority items in the golden zone can have a significant positive impact on order picking performance. While this may result in slightly longer travel distances within the warehouse, the time saved during picking operations outweighs the additional travel time.

Lorcan Murphy (2020) [6] examine the "Golden Zone" in slotting is the ideal location in a warehouse, typically between waist and chest level, where items are stored for easy and ergonomic picking. This zone is reserved for frequently picked and heavy items to reduce picker effort and increase efficiency. The golden zone in slotting refers to the optimal placement of items within a warehouse or storage facility. This zone is typically located between waist and chest level, chosen for ergonomic reasons. Placing frequently picked and heavy or bulky items in this zone is ideal to minimize picker effort and increase efficiency.

Andreas Baechler (2016) [7] Compares the various methods of order picking—human-based picker-to-parts systems (low-level and highlevel), automated parts-to-picker systems, and put systems—requires evaluating their advantages and disadvantages to determine the optimal method. The choice of the best method depends on specific warehouse characteristics, such as the type of products handled, order volume, order profiles, and available technology Ultimately, the optimal method should be selected after careful analysis of warehouse-specific factors, including order profiles, order volumes, available budget, and long-term goals for efficiency and cost savings.

Ekren*, Z. Sari**, T. Lerher*** (2015) [8] The simulation model focuses on a warehouse equipped with racks, lifts, and shuttles. Shuttles are responsible for handling totes, both for storage and retrieval, while racks consist of bays for totes. The simulation specifically concentrates on a single aisle, with lifts located at the aisle's end, capable of carrying two totes independently. Transactions are scheduled based on a dual command (DC) rule, and each aisle includes an Input/Output (I/O) point. Key assumptions in the simulation model include arrivals following a Poisson process with equal rates for storage and

retrieval transactions. Loading and unloading times for totes onto/from shuttles and lifts are assumed to be 3 seconds each. Delays due to acceleration and deceleration of shuttles and lifts are considered at 2 m/sec^2 . In cases where the transaction is on the first tier, the lift is not utilized. Buffer positions exist at each tier for loading and unloading, and maximum speeds for shuttles and lifts are set at 2 m/sec .

Michael Eder (2019) [9] studies the design process of a Storage and Retrieval System (SBS/RS), understanding the performance of one aisle is crucial because it influences the design of other components, such as conveyors. This knowledge helps in creating an economically and ecologically efficient SBS/RS. The system being studied can have up to 50 tiers and up to 200 storage slots on each side of the aisle. These parameters were provided by a European material handling provider for SBS/RS. For validation, the results from an analytical model are compared to the results from a simulation model, which includes 30 independent replications. Each replication involves storing and retrieving 10,000 totes. 3.4.

Nils Boysen, Rene de Koster and Felix Weidinger (2018) [10] discuss two prominent warehousing policies, batching and zoning, which share the common objective of reducing unproductive walking by order pickers, particularly in traditional picker-to-parts warehouses. However, both policies necessitate a subsequent consolidation process. Batched orders must be separated, and orders picked in different zones during parallel zoning must be merged. It's important to note that progressive zoning, where orders visit zones sequentially, is a potential alternative that avoids the need for consolidation. In warehouses employing batching or zoning comprises three steps: Order picking, Intermediate storage and finally the consolidation area where the individual picking orders are assembled, packed into shipping cartons, and readied for transport to their respective destinations.

Kaveh Azadeh, René De Koster and Debjit Roy (2009) [11] examine the two approaches exist for modelling systems namely analytical and simulation-based. Simulation based models provide accurate representations of reality but are time consuming to develop.

Analytical models are preferred in the early stages to reduce the design search space and identify promising configurations. Analytical models are faster and can find optimal configurations directly or through quick enumeration of design parameters. The error in analytical models is usually acceptable for the conceptualization phase. It discusses decision variables and performance objectives in evaluating automated warehouses, including long-term and short-term decision making. It also presents a framework for different objectives and decision variables and suitable modelling approaches. In long-term planning, decisions focus on hardware design optimization, aiming to maximize throughput and storage capacity. Short-term planning involves operational control to minimize lead time, waiting time, and resource idleness.

P. Raghuram and Abhijeet Singh (2020) [12] SLAP deals with assigning incoming stock to storage locations, particularly relevant for automated storage/retrieval systems. Different policies, such as class-based storage, randomized storage, and dedicated storage, optimize product placement based on demand rates and accessibility. Class-based storage with proper routing methods can improve performance in terms of travel distance and order retrieval times. Data mining-based SLAP with associative rule mining has also been effective for fast-moving products. The paper covers the baseline scenario of the case warehouse, its current parameters, and the need for optimization. It delves into data analytics for optimizing the layout under various scenarios and presents results along with comparisons between current and modified scenarios.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

The aim of this project is to design, develop, and implement a unified warehouse management system that incorporates automation for sorting and storage, enabled by a comprehensive network of conveyors and cutting-edge technologies. This system is meticulously crafted to streamline component handling within a warehouse, with the overarching objectives as follows:

3.1.1 Enhanced Efficiency:

The primary aim is to significantly enhance the overall efficiency of warehouse operations. Through automation, precise sorting, and high-speed movement mechanisms, the system aims to reduce the time and labor traditionally required for these processes. The goal is to expedite component handling while minimizing operational downtime.

3.1.2 Accuracy and Error Reduction:

A fundamental objective of this project is to minimize errors in component sorting, storage, and retrieval. The system leverages technology such as QR code scanning and real-time data feedback to ensure the precise identification and allocation of components. By doing so, it mitigates the risk of human error, leading to higher accuracy in component management.

3.1.3 Real-time Inventory Monitoring:

The project aims to enable real-time inventory monitoring and data-driven decision-making. With the integration of IoT technology, the system provides continuous insights into component quantities, locations, and movements within the warehouse. This empowers warehouse managers to make informed decisions, optimizing inventory levels and reducing the likelihood of stockouts or overstocking.

3.1.4 Improved Order Fulfillment:

The pick-by-display/light approach is a central component of the project, with the aim of providing real-time guidance to warehouse workers during the order picking process. The objective is to enhance the efficiency of order fulfillment by providing workers with precise information on component locations and quantities, reducing picking errors, and speeding up the fulfillment process.

3.1.5 Cost Reduction:

By automating key warehousing processes and reducing errors, the project aims to contribute to operational cost reduction. This includes decreased labor costs, lower maintenance expenses, and more efficient space utilization within the warehouse.

3.1.6 Customer Satisfaction:

The project ultimately seeks to elevate customer satisfaction by ensuring timely, accurate, and error-free order fulfillment. Satisfied customers are more likely to become repeat customers and brand advocates, fostering long-term business success.

3.1.7 Adaptability and Scalability:

The system is designed with adaptability and scalability in mind. It can be customized to suit the unique needs of various warehouse environments, accommodating different types of products, sizes, and storage requirements. The aim is to create a flexible solution that can grow and evolve with the business.

3.2 SCOPE

The scope of the project encompasses a wide range of aspects, all focused on the design, development, and implementation of the unified warehouse management system that incorporates automation for sorting and storage. The project's scope includes, but is not limited to, the following key elements:

3.2.1 System Design:

This phase involves defining the architecture of the warehouse management system, including the layout of conveyors, placement of sensors, and the integration of the lift and shuttle mechanism. The scope encompasses decisions related to the hardware and software components, their specifications, and their interaction within the system.

3.2.2 Automation Integration:

The project aims to automate key warehousing processes, and as such, the scope includes the integration of automation technologies, such as conveyors, motors, and the lift and shuttle mechanism. It also covers the design and programming of control systems for these components.

3.2.3 IoT Implementation:

IoT technology is a core component of the project. The scope includes the selection and integration of IoT sensors and devices, as well as the development of software to collect, process, and visualize real-time data. Additionally, it involves setting up connectivity for data transmission and storage.

3.2.4 Visual Assistance Mechanisms:

The project incorporates visual assistance mechanisms such as the pick-by-display/light approach. The scope includes the design and installation of displays, the development of user interfaces, and the integration of these systems with the overall warehouse management system.

3.2.5 QR code Scanning and Recognition:

The camera module for QR code scanning is a critical component. The scope involves selecting the appropriate camera hardware, developing software for QR code recognition, and integrating this system with the larger warehouse management infrastructure.

3.2.6 Warehouse Layout and Configuration:

The physical layout of the warehouse, including the placement of conveyors, storage racks, and intermediate conveyors, is within the scope of the project. Decisions about the organization of warehouse space and the allocation of storage slots are part of this aspect.

3.2.7 Real-time Data Feedback:

The project aims to provide real-time data feedback to warehouse workers. This includes displaying information on component locations and quantities, as well as providing data on order lists and inventory levels. The scope involves developing the software and interfaces to make this data accessible to workers.

3.2.8 Testing and Validation:

Rigorous testing and validation of the system are essential. The scope includes conducting testing scenarios to ensure the system functions as intended, meeting efficiency, accuracy, and reliability benchmarks.

3.2.9 Customization and Scalability:

The project allows for customization and scalability. The scope includes considerations for adapting the system to different warehouse environments, accommodating variations in product types, sizes, and storage requirements.

3.2.10 Cost Analysis:

An important aspect of the project's scope is conducting a cost-benefit analysis. This includes assessing the initial investment required for the system's implementation and evaluating the expected cost savings and operational efficiencies it can deliver.

3.2.11 Documentation:

Comprehensive documentation is a fundamental aspect of the scope, covering system design, technical specifications, operating procedures, and maintenance guidelines.

3.2.12 Future Directions:

While not part of the immediate implementation, the project should outline future directions and potential enhancements, including the integration of additional technologies, like artificial intelligence or robotics, to further improve warehouse operations.

In conclusion, the scope of this project is comprehensive, encompassing the design, development, and implementation of a transformative warehouse management system. It is aimed at enhancing efficiency, accuracy, and adaptability within the warehouse while considering potential scalability and future growth.

CHAPTER 4

MATERIALS AND EXPERIMENTAL METHOD

4.1 METHODOLOGY

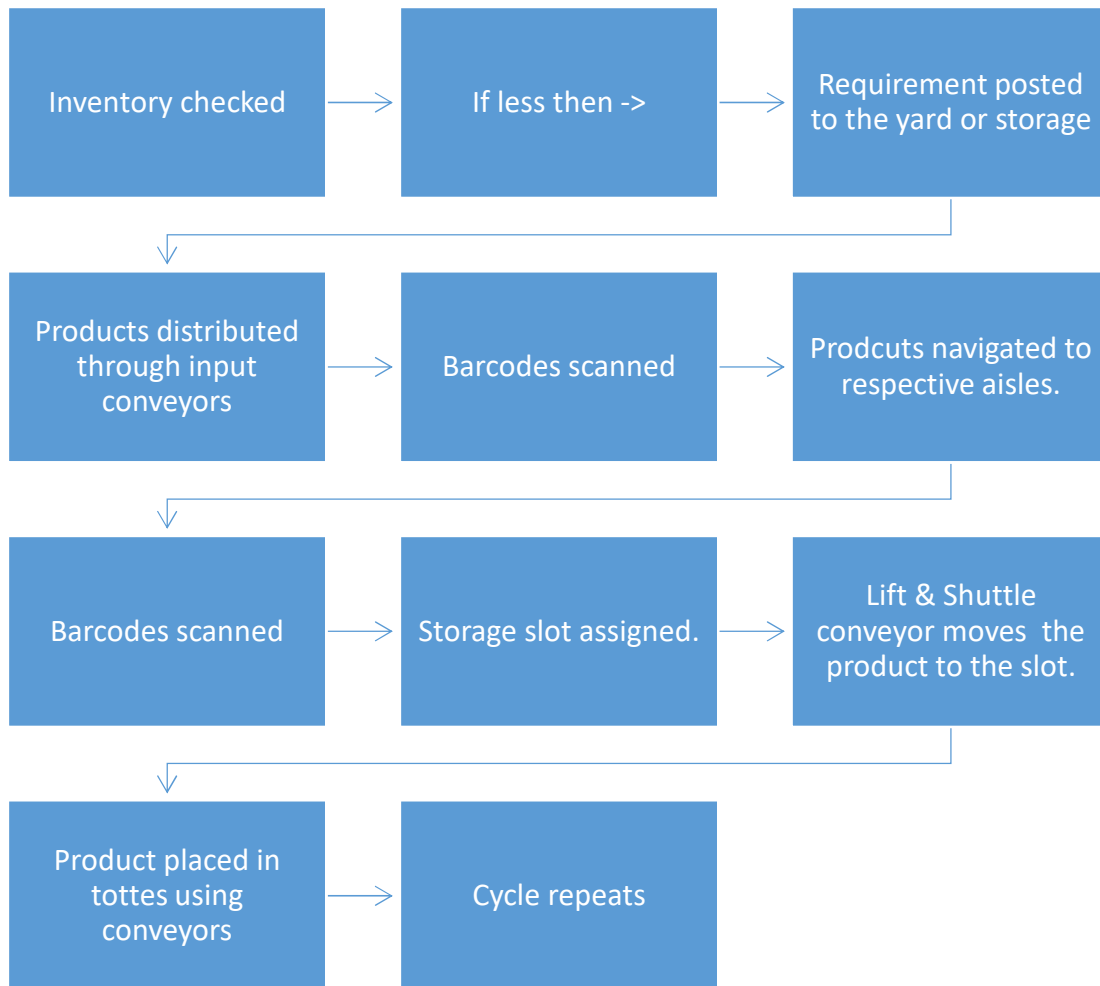


Fig:4.1 : Input of Products in Industrial Warehousing

The input of products in industrial warehousing represents a critical phase in the logistics and inventory management process (Fig:4.1). The methodology outlined here delineates the sequence of steps involved in sorting and storing products efficiently and accurately.

1. Requirement Verification:

At the initiation of the process, the first step involves a meticulous verification of the inventory requirements. Any instances of insufficient stock levels trigger an immediate response. In such cases, products are earmarked for dispatch to the yard or additional storage areas to ensure a seamless workflow.

2. Input Conveyors:

Products that meet the requisite inventory levels are channeled through the input conveyors. These conveyors act as the initial gateway into the warehousing system, facilitating the smooth entry of products into the warehouse.

3. QR code Scanning - Initial Verification:

Upon entry, each product is subjected to QR code scanning, an integral component of quality control. This initial verification ensures that the correct products are entering the warehouse, minimizing the risk of errors further down the line.

4. Navigation to Respective Aisles:

Following QR code verification, products are guided to their respective storage aisles. This step is critical in ensuring that products are directed to the correct section of the warehouse, streamlining the retrieval process.

5. QR code Scanning - Aisle Assignment:

As products enter their designated aisles, a second QR code scanning process takes place to confirm the accuracy of aisle assignment. This redundancy check enhances the precision of inventory management and minimizes the potential for errors.

6. Storage Slot Assignment:

Once products reach the designated aisles, the next step involves assigning specific storage slots. Storage slot assignment is based on predetermined criteria, optimizing the placement of products for ease of retrieval and efficient space utilization.

7. Lift & Shuttle Conveyor:

The lift and shuttle conveyor system plays a pivotal role in the warehousing process. This system is responsible for transporting products from the input conveyor area to their assigned storage slots. It does so swiftly and with precision, reducing the time required to store products.

8. Product Placement in Totes:

Upon reaching their respective storage slots, products are placed in totes. Totes are a convenient and efficient means of organizing and storing products within the warehouse. The conveyor system is employed to facilitate this process, ensuring products are neatly and securely placed in their designated totes.

9. Cycle Repeats:

The entire cycle repeats as new products enter the warehouse. Each new batch of products follows the same methodology, ensuring a consistent and structured approach to sorting and storing inventory.

This detailed methodology underlines the importance of a systematic approach to inputting products into industrial warehousing. By incorporating QR code scanning, automated conveyors, and strict quality control measures, warehouses can significantly enhance the accuracy and efficiency of their inventory management processes, ultimately leading to improved customer satisfaction and operational excellence.

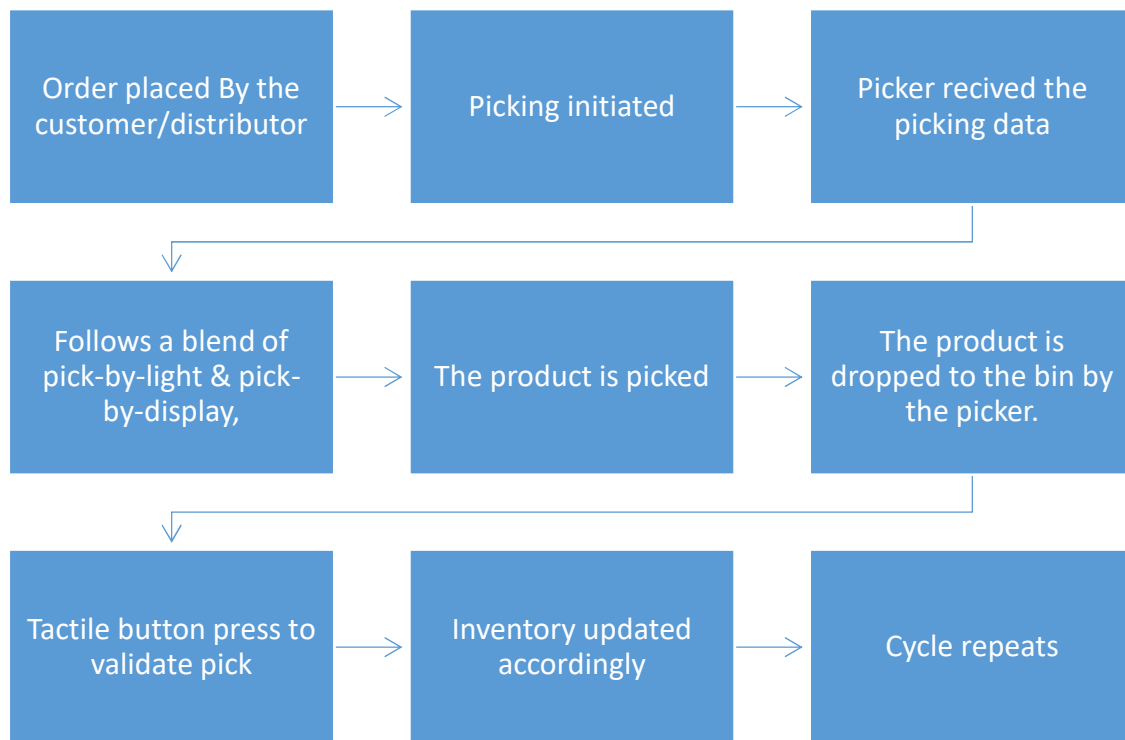


Fig:4.2 : Output Process with Assistive Picking and IoT Integration

Our warehousing system has been meticulously designed to ensure the smooth and efficient output process, all while harnessing the power of assistive technologies and IoT integration for heightened precision and order fulfillment speed (Fig:4.2).

1. Customer/Distributor Order Placement:

The journey begins when a customer or distributor places an order. This order serves as the catalyst for the subsequent phases of our advanced output process.

2. Initiation of Picking:

With the order in place, our system promptly initiates the picking process. This phase involves the methodical selection of products from our extensive inventory to meet the order's requirements.

3. Picker Receives Picking Data:

Our dedicated picker, entrusted with the task of order fulfillment, promptly receives the essential picking data. This data includes comprehensive information about the specific items and quantities needed to complete the order.

4. Seamlessly Blending Pick-by-Light & Pick-by-Display Systems:

Our picker leverages the dynamic combination of our Pick-by-Light and Pick-by-Display systems to receive invaluable guidance. These cutting-edge technologies illuminate the way, directing our picker to the precise locations of the products that need to be selected. The visual cues, such as illuminated displays or indicators, provide clear instructions, while the Pick-by-Display system offers real-time insights into product quantities at each location.

5. Precise Product Picking:

Our highly skilled picker follows the guidance of our integrated Pick-by-Light and Pick-by-Display systems to perform a meticulously precise product selection. These technologies significantly reduce the likelihood of errors and expedite the entire picking process.

6. Secure Product Placement in the Bin:

Once the selected products are in hand, our picker securely places them within a designated bin. This bin serves as a convenient staging area for the collected items, streamlining the subsequent steps of packing and quality control.

7. Validation via Tactile Button:

To ensure the utmost accuracy, our picker employs a tactile button to validate the correctness of the pick. This final confirmation acts as a fail-safe, assuring that the right items have been accurately selected.

8. Real-time Inventory Updates with IoT Integration:

Our system, integrated with IoT technology, springs into action to provide real-time updates to our inventory records. These updates reflect the successful completion of the order and maintain accurate stock levels by deducting the picked items.

9. The Ongoing Cycle:

This meticulously designed process has been meticulously crafted to be seamlessly repeatable for each order we receive. With each new order, our system springs into action once more, consistently ensuring the precision and efficiency of our order fulfillment.

Our advanced output process is a testament to our commitment to enhancing order fulfillment through state-of-the-art technology and precision-driven methodology. The implementation of Pick-by-Light, Pick-by-Display, and IoT integration guarantees not only heightened customer satisfaction but also operational excellence.

4.2 MATERIALS USED

4.2.1 *Arduino Mega*

The Arduino Mega with WiFi (Fig:4.3) combines the functionality of the Arduino Mega board with integrated WiFi capabilities, usually achieved through a separate WiFi module. Here's a summary and some specifications (Table 4.1):

The Arduino Mega with WiFi is a powerful microcontroller board that provides extensive I/O capabilities and wireless connectivity for IoT (Internet of Things) projects, robotics, automation, and more. It merges the features of the Arduino Mega, offering a large number of digital and analog pins, with the convenience of onboard WiFi connectivity, enabling seamless communication with other devices and the internet.

Table 4.1 : Arduino Mega Specifications

Specifications:
1. Microcontroller: ATmega2560 (same as Arduino Mega)
2. Operating Voltage: 5V
3. Input Voltage (recommended): 7-12V
4. Digital I/O Pins: 54 (of which 15 provide PWM output)
5. Analog Input Pins: 16
6. Flash Memory: 256 KB (8 KB used for the bootloader)
7. SRAM: 8 KB
8. EEPROM: 4 KB

9. Clock Speed: 16 MHz
10. WiFi Module: Integrated or compatible with external WiFi modules such as ESP8266 or ESP32
11. WiFi Connectivity: Typically supports 802.11b/g/n protocols
12. Operating Voltage (WiFi Module): Usually 3.3V

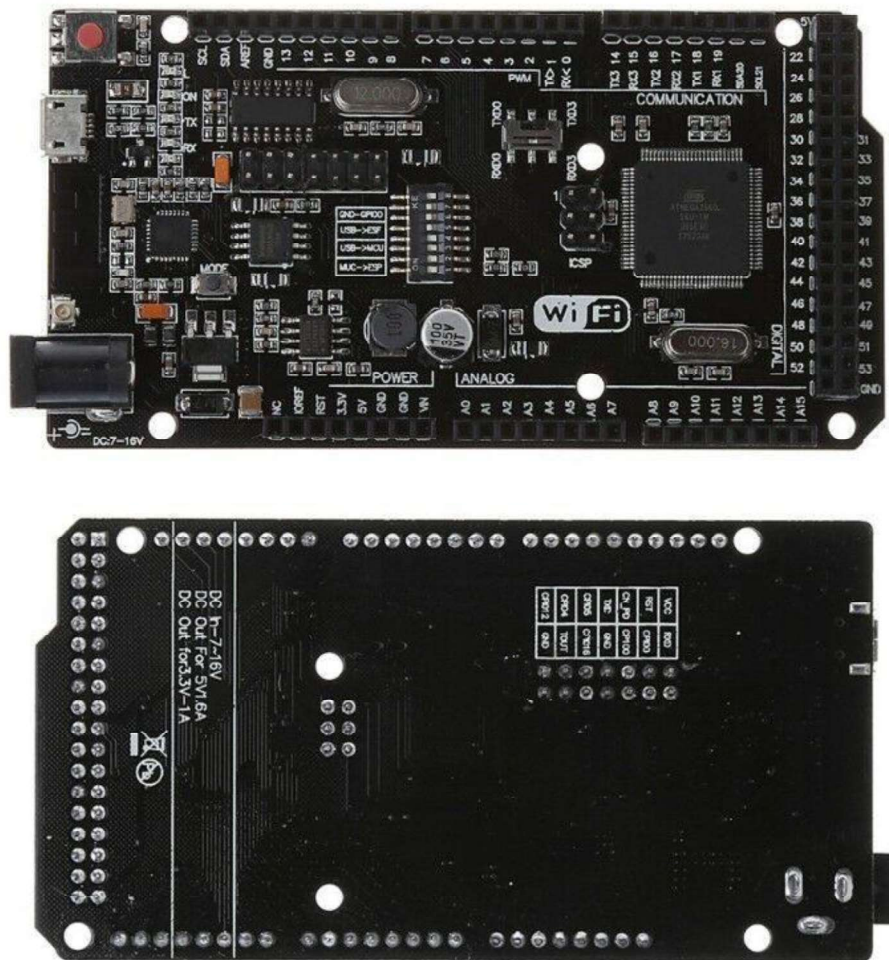


Fig:4.3 : Arduino Mega

4.2.2 Arduino CNC Shield

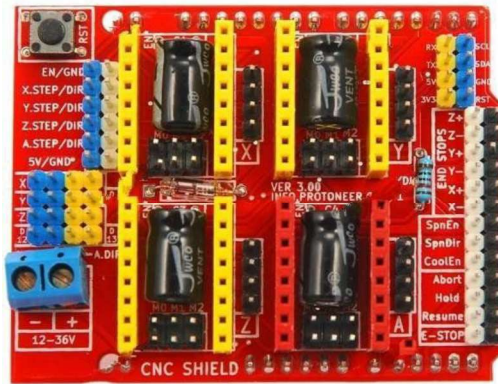


Fig:4.4 : Arduino CNC Shield

The Arduino CNC Shield (Fig:4.4) is a circuit board that mounts onto an Arduino Uno or compatible board, expanding its capabilities to control stepper motors and other components in CNC machines, such as 3D printers, laser cutters, engravers, and more. It provides convenient connectivity for stepper motor drivers, limit switches, and other accessories commonly used in CNC systems (Table 4.2).

Table 4.2 : Arduino CNC Specifications

Specifications:
1. Compatible with Arduino Uno and compatible boards
2. Stepper Motor Driver Compatibility: Typically supports A4988, DRV8825, and other commonly used stepper motor drivers
3. Power Supply Input: Usually accepts 12V to 36V DC power supply
4. Expansion Ports: Includes headers for connecting stepper motor drivers, limit switches, spindle control, and other peripherals
5. Microstepping Support: Often provides microstepping support for smoother motor control
6. Dimensions: Fits the form factor of an Arduino Uno board

4.2.3 Esp32 camera module

The ESP32 CAM WiFi Module Bluetooth with OV2640 Camera Module 2MP For Face Recognition (Fig:4.5) has a very competitive small-size camera module that can operate independently as a minimum system with a footprint of only 40 x 27 mm; a deep sleep current of up to 6mA and is widely used in various IoT applications.

It is suitable for home smart devices, industrial wireless control, wireless monitoring, and other IoT applications.

This module adopts a DIP package and can be directly inserted into the backplane to realize rapid production of products, providing customers with high-reliability connection mode, which is convenient for application in various IoT hardware terminals.

ESP integrates WiFi, traditional Bluetooth, and BLE Beacon, with 2 high-performance 32-bit LX6 CPUs, 7-stage pipeline architecture. It has the main frequency adjustment range of 80MHz to 240MHz, on-chip sensor, Hall sensor, temperature sensor, etc.

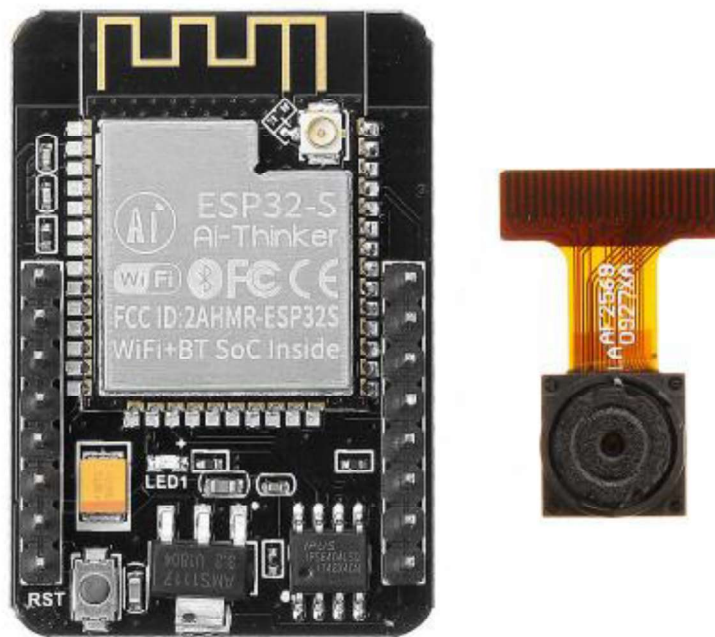


Fig:4.5 : ESP32 Camera Module

4.2.4 NEMA 17 stepper motor

The NEMA 17 stepper motor (Fig:4.6) is a commonly used component in various precision motion control applications. With a compact size and high torque output, it offers reliable performance for a wide range of projects.

Featuring a step angle of 1.8 degrees per step, or 200 steps per revolution, the NEMA 17 stepper motor provides precise control over rotational movement, making it suitable for applications requiring accurate positioning.

Typically operating at 2.8 to 3.5 volts per phase, the NEMA 17 stepper motor offers a balance between power consumption and performance. With a current rating typically ranging from 1.2A to 1.5A per phase, it can deliver sufficient torque for most applications. The motor's holding torque, usually around 0.4 Nm (57 oz-in), ensures that it can maintain its position even under load. This makes it suitable for tasks such as driving linear actuators, moving robotic arms, or controlling 3D printer axes.

Available in both four-wire and six-wire configurations, the NEMA 17 stepper motor allows for bipolar or unipolar operation, providing flexibility in wiring and control options. Its standardized NEMA 17 faceplate size of 42x42mm with M3 or M4 mounting holes makes it easy to integrate into various mechanical setups, ensuring compatibility with existing designs and systems.



Fig:4.6 : NEMA 17 Stepper Motor

4.2.5 16×2 LCD display

The 16x2 LCD display (Fig:4.7) is a commonly used alphanumeric display module that consists of 16 columns and 2 rows, allowing it to display up to 16 characters per line and 2 lines of text. Here's an overview of its features and specifications (Table 4.3):

Table 4.3 : 16×2 LCD Display Specifications

1. Display Size: 16 characters per line, 2 lines
2. Character Set: Typically supports ASCII characters and some custom characters
3. Interface: Commonly uses a parallel interface (e.g., HD44780 compatible) or an I2C/SPI interface with an external backpack module
4. Backlight: Often includes a backlight feature for improved visibility in low-light conditions
5. Operating Voltage: Typically operates at 5V DC, although some modules may support a wider voltage range
6. Contrast Adjustment: Allows for manual adjustment of contrast for optimal readability
7. Dimensions: Compact and suitable for integration into various projects



Fig:4.7 : 16×2 LCD Display Module

The 16x2 LCD display is widely used in projects that require a simple and cost-effective way to display information, such as temperature readings, sensor data, messages, menus, and more. Its compatibility with various microcontrollers and ease of use makes it a popular choice among hobbyists, students, and professionals for adding a visual output to their electronic creations.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 PROTOTYPE DESIGN

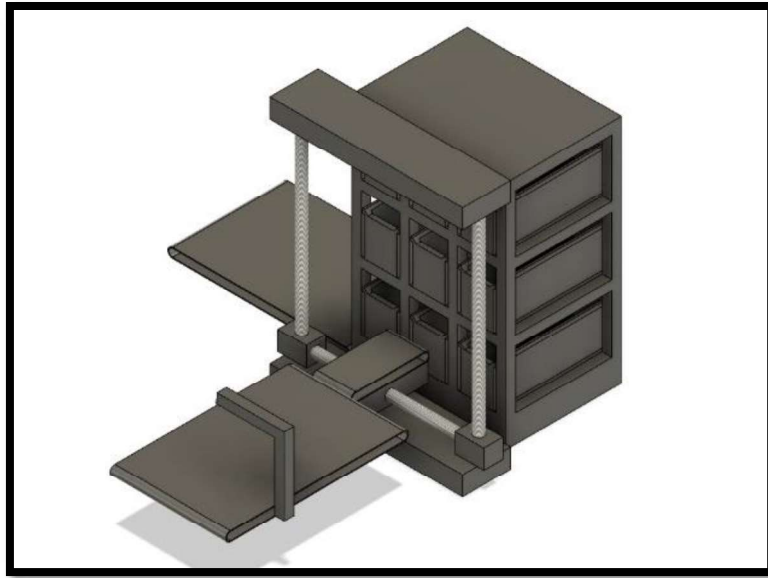


Fig:5.1 : Isometric View Back

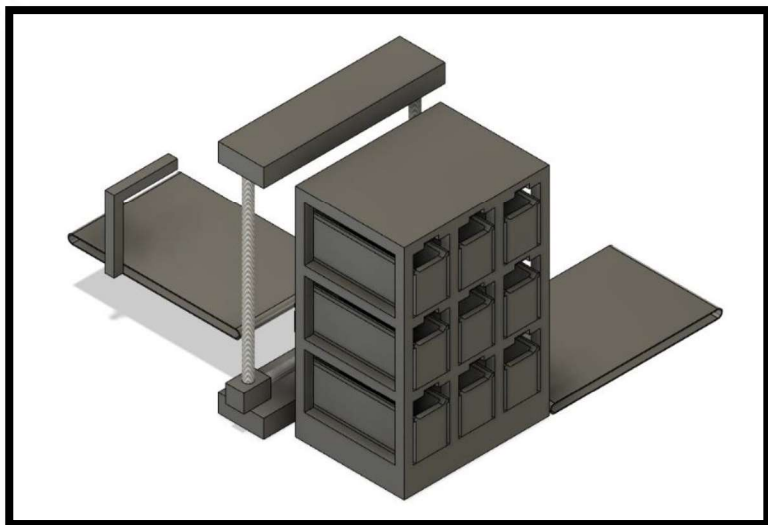


Fig:5.2 : Isometric View Front

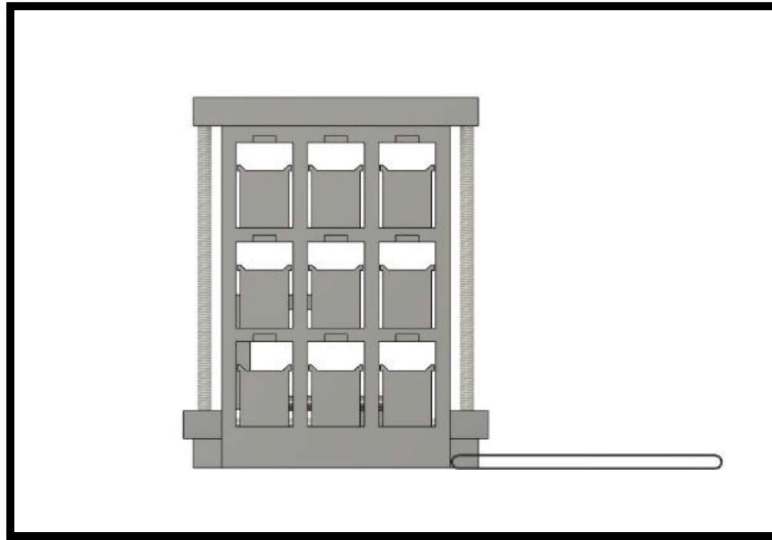


Fig:5.3 : Front View

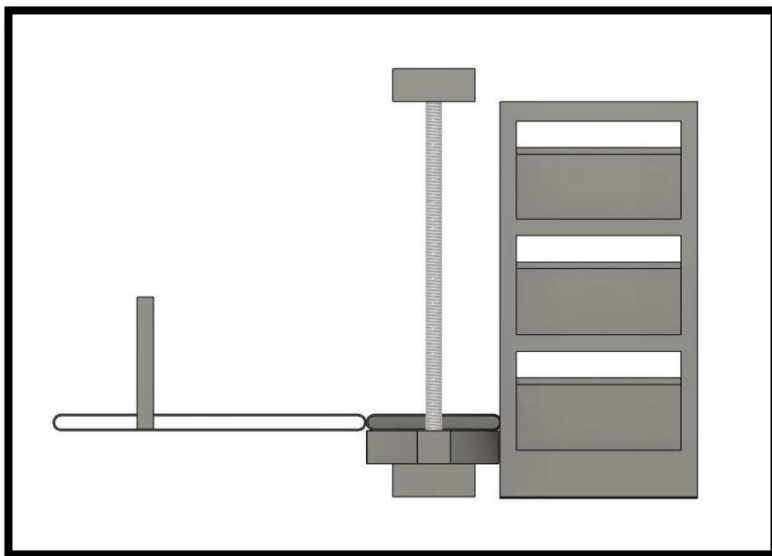


Fig:5.4 : Side View

5.2 FABRICATION

The fabrication of our IoT-based warehouse was an intricate process that required meticulous planning, thoughtful selection of materials, and precise execution. We commenced by choosing 10mm thick wood (Fig:5.5.1) as the primary construction material for its robustness and structural integrity, ensuring that our warehouse could withstand the rigors of daily operations while providing a stable framework for the entire system. One of the critical elements in our warehouse design was the implementation of lead screws for the movement mechanisms. These lead screws played a pivotal role in ensuring precise and controlled movements of both the lift and shuttle systems. By incorporating lead screws, we could achieve the necessary accuracy and reliability required for seamless warehouse operations. To reinforce the structure and provide additional support, we strategically integrated 8mm MS steel rods (Fig:5.5.2) throughout the warehouse. These steel rods not only added strength but also contributed to the overall load-bearing capacity of the warehouse, making it capable of handling varying loads with ease. In terms of mechanical components, we meticulously selected ball bearings, linear bearings, and 8mm lead screw nuts (Fig:5.6). These components were strategically placed and utilized across the project, ensuring smooth and efficient operations while minimizing friction and wear on moving parts.

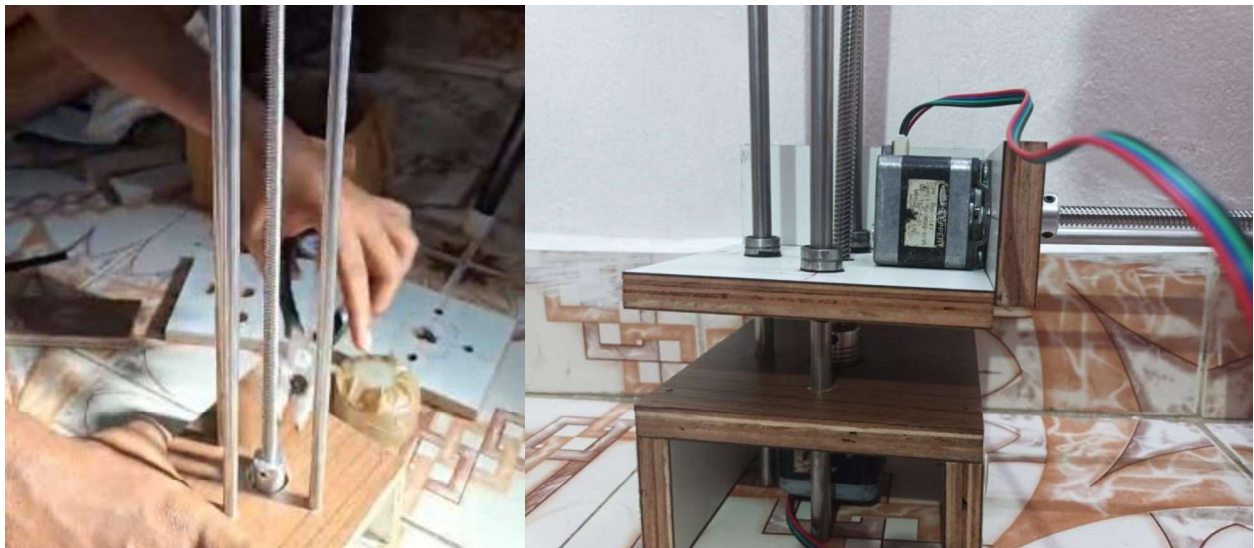


Fig:5.5.1 : Fabrication Images

Our electronic setup was carefully crafted to meet the demands of modern warehouse management. We incorporated an Arduino Mega paired with a CNC shield to control and coordinate the various functions of the warehouse. A 16×2 LCD display (Fig:5.7) was integrated for user interaction, providing real-time updates and status information. Additionally, we leveraged an ESP32 CAM for QR scanning capabilities (Fig:5.8), enhancing inventory tracking and management within the warehouse.

Powering the essential lift and shuttle operations were two stepper motors, which we supplied with a dedicated 12V power supply. This ensured consistent and reliable performance, enabling swift and precise movements as required by the warehouse workflow. To ensure longevity and optimal performance, we implemented a comprehensive lubrication system. This system was designed to lubricate critical moving parts, reducing friction, preventing wear and tear, and ultimately contributing to smoother and more efficient operations of the warehouse.



Fig:5.5.2 : Fabrication Images

5.3 FINAL PROTOTYPE

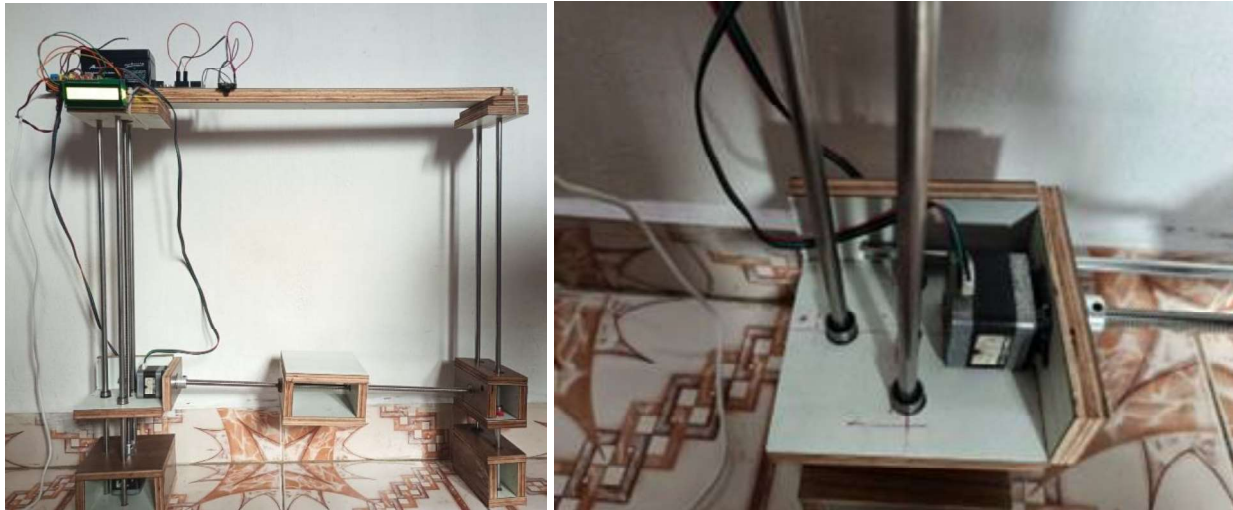


Fig:5.6 : Frame

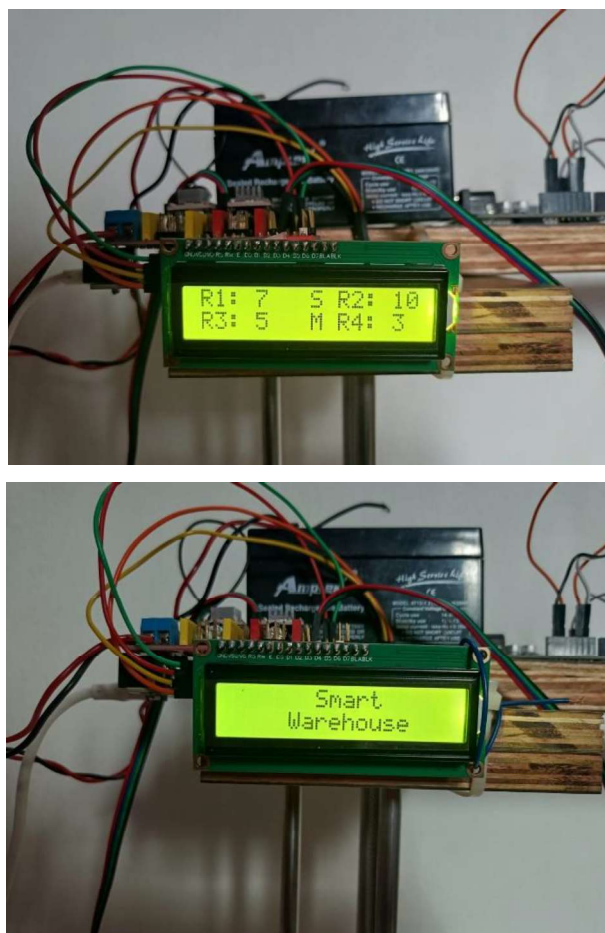


Fig:5.7 : Display

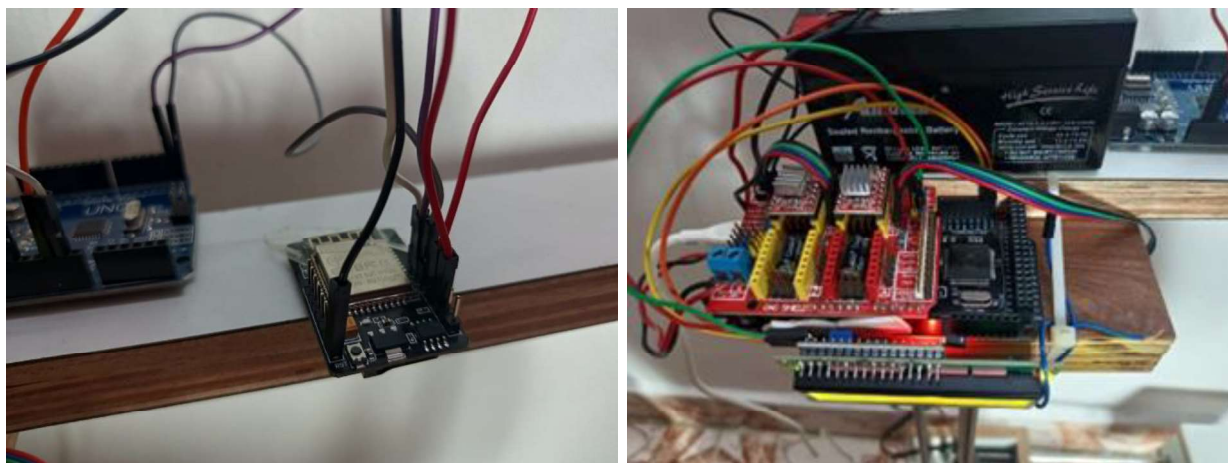


Fig:5.8 : Electronic Components

5.4 FINDINGS

5.4.1 Pick-by-Display Integration:

The selection of Pick-by-Light and Pick-by-Display technologies for our warehousing system reflects a well-considered choice. These systems offer real-time, visual guidance to our warehouse workers, improving the accuracy of product selection and the speed of order fulfillment. By utilizing these technologies, we enhance picker productivity and reduce the potential for errors, ultimately enhancing customer satisfaction. The decision to opt for Pick-by-Light and Pick-by-Display systems was driven by their proven track record in achieving these objectives.

5.4.2 QR code Scanning vs. Bar Code:

The choice of QR code scanning over barcode in our project is rooted in compatibility and simplicity. QR codes are widely recognized and can be easily integrated into existing systems and workflows. This familiarity streamlines implementation and reduces potential obstacles. While QR codes offer advantages in terms of storage capacity and data density, QR codes align more closely with the practicality of existing systems, facilitating seamless integration and lessening the learning curve for warehouse staff.

5.4.3 Lift & Shuttle Conveyor vs. Robotic Arms:

The selection of the Lift & Shuttle Conveyor system over robotic arms for product transportation is based on a combination of cost-effectiveness and adaptability. Lift & Shuttle systems provide a reliable and flexible solution for moving products within the warehouse. They offer a balance between speed, accuracy, and cost efficiency. While robotic arms are advanced and capable of complex tasks, they often require higher upfront investments and may be better suited for specialized applications. For our project's goals, the Lift & Shuttle Conveyor system aligns with our need for efficiency and cost-effectiveness.

5.4.4 Future Scalability and Adaptation:

Throughout the ongoing progress of the project, we maintain a steadfast focus on future scalability and adaptability. The decisions made in terms of technology and methodology are not only about meeting current needs but also ensuring that our solution can grow and evolve with the changing demands of the warehousing industry. The project's ongoing progress allows us to remain agile and responsive to emerging technologies and logistical challenges.

5.4.5 IoT Integration:

In addition to the above findings, we have developed a Blynk IoT platform (Fig:5.9) specifically for managing movements and product placement within the warehouse. This platform leverages IoT capabilities to enhance real-time monitoring, control, and optimization of warehouse operations. The integration of the Blynk IoT platform adds a layer of intelligence and automation, further improving efficiency and adaptability in our warehousing system.

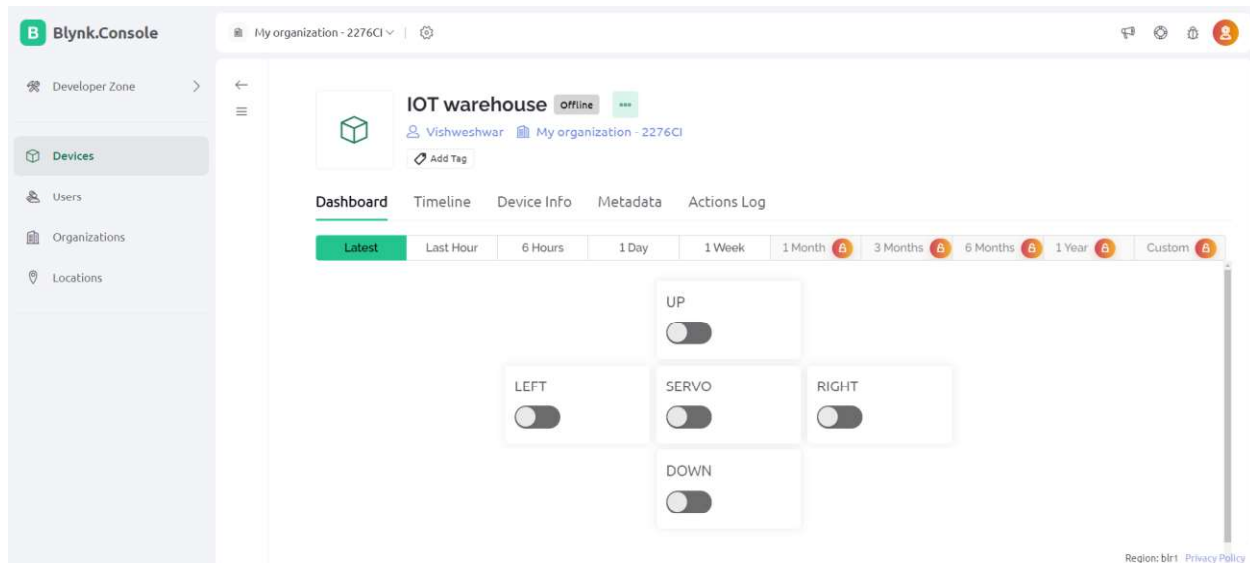


Fig:5.9 : Blynk IoT platform

5.4.6 Limitations:

From our perspective, the limitations of the IoT-based warehouse project are evident, particularly in terms of accuracy and connectivity. The existing setup, while functional, poses challenges regarding precise movements of the lift and shuttle systems due to factors like mechanical wear and calibration issues. This inherently limits the level of accuracy we can achieve without significant upgrades or improvements to the motion control systems.

Similarly, connectivity and data handling present ongoing challenges. While we have implemented IoT devices like the ESP32 CAM for QR scanning and data acquisition, ensuring seamless connectivity, reliable data transmission, and effective integration with the warehouse management system (WMS) remain areas of concern. These limitations highlight the need for robust network stability, optimized data processing, and efficient real-time monitoring capabilities, all of which are crucial for maximizing the project's effectiveness within the current constraints.

CHAPTER 6

CONCLUSION

In conclusion, this project represents a monumental stride forward in the landscape of industrial warehousing, offering not only a visionary solution but also a practical roadmap for transformative change. The integration of advanced technologies such as Pick-by-Light, Pick-by-Display systems, automated sortation, and camera-based QR code scanning, fortified by image recognition, has revolutionized the order fulfillment process, setting new standards for efficiency and precision in the industry. However, the utility of this project extends far beyond its immediate impact. It offers a forward-looking perspective on the future of warehousing. By adopting innovative sorting and inventory management strategies, including real-time IoT integration, automated replenishment systems, and demand forecasting, the project positions itself as a harbinger of optimization in inventory operations. The introduction of a camera based QR code scanner, underpinned by image recognition, underscores our unwavering commitment to real-time, accurate product identification and storage.

The practicality of the system we've developed is a testament to its usefulness. In an industry where order fulfillment accuracy and efficiency are paramount, our solution ensures precise and timely deliveries, elevating customer satisfaction. Additionally, the reduction in operational errors, cost savings, and streamlined inventory management hold the potential for substantial financial advantages for warehousing operations. Furthermore, the scalability and adaptability embedded in our project ensure its usefulness is not confined to the present. As industry demands evolve, our system's flexibility allows for seamless growth, making it adaptable to future challenges and opportunities. Ultimately, the project serves as a practical model for warehousing solutions, offering a blend of cutting-edge technologies and methodological innovations. Its usefulness is not just in the here and now but also in ushering in an era where industrial warehousing can operate at peak efficiency while keeping customer satisfaction at the forefront. In doing so, it propels the industry towards a future of optimized operations and elevated excellence.

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APPENDIX

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