AUTOMATIC WAREHOUSE MANAGEMENT USING COMPUTER VISION AND ROBOTICS

Main Project Report

Submitted by

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<u>DECLARATION</u>

I, **AJEEBA SHARAF M S**, hereby declare that the report of this project work,submitted to the Department of Computer Applications, Federal Institute of Science and Technology (**FISAT**), Angamaly in partial fulfilment of the award of the degree of Master of Computer Application is an authentic record of my original work.

The report has not been submitted for the award of any degree of this university or any other university.

Date

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DEPARTMENT OF COMPUTER APPLICATIONS

Focus on Excellence

CERTIFICATE

This is to certify that the project titled **"AUTOMATIC WAREHOUSE MANAGEMENT USING COMPUTER VISION AND ROBOTICS"** submitted by **AJEEBA SHARAF M S [Reg No: FIT21MCA-2007]** towards partial fulfilmentof the requirements for the award of the degree of Master of Computer Applications is a record of bonafide work carried out by her during the academic year 2022-2023.

Project Guide **Head of the Department**

Ms. Senu Abi **Dr. Deepa Mary Mathews**

Submitted for the viva-voce held on………………………at……………………….

Examiner :

ACKNOWLEDGEMENT

Gratitude is a feeling which is more eloquent than words, more silent than silence. To complete this project work I needed the direction, assistance and co-operation of various individuals, which is received in abundance with the grace of God.

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Finally, I wish to express a whole heart-ed thanks to my parents, friends and well-wishers who extended their help in one way or other in preparation of my project. Besides all, I thank God for everything.

ABSTRACT

Until recently, the warehouses of the largest industrial companies were perceived as a kind of secondary subsidiary segment. As a result of such attitude, the warehouses were ignored, even while the implementation of corporate-wide technical modernization projects. Meanwhile, a warehouse is one of the production sites for important stages in the preparation of the final product. Some technological processes are carried out in the warehouse, namely, the acquisition of goods, accounting of receipts, package and so on. Employers monitor the number of goods received, manually count the boxes, upload all the information to the database, move the boxes, distribute them throughout the warehouse, and also, from time to time, carry out the inventory of all products stored in the warehouse. all the above procedures are done by using our human resource. Although the human factor significantly affects the quality of these tasks, the main problem for the owner is the expenses of the warehouse managed exclusively by people. And only when the costs of delivery, storage, and processing of commodity flows reach half the cost price of the finished products, managers start thinking about the ways to modernize and automate their storage and logistic processes.The good news is that today there are quite comprehensive solutions designed to automate these processes. Through our project we are trying to design and develop a system to sort and keep track of our inventory in our warehouse with the help of Commuter Vision and Robotics.

CONTENTS

Chapter 1

INDRODUCTION

Automatic warehouse management using computer vision and robotics for parcel sorting is an innovative and efficient approach to handling the increasing volume of parcels in modern logistics and e-commerce industries. This system combines computer vision technology with robotic automation to streamline the sorting process and improve overall warehouse efficiency. Parcels arrive at the warehouse, either through manual loading or automated systems. Computer vision technology is employed to capture images of the parcels. Analyze these images to identify key characteristics, such as size, shape, barcode, or other unique identifiers. Based on the analysis, the computer vision system determines the optimal sorting destination for each parcel. This decision is typically based on factors like delivery location, size, weight, or specific handling requirements. The robots or robotic arms pick up each parcel and place it in the appropriate storage or sorting area based on the determined destination. This process may involve placing the parcels on conveyor belts, shelves, or designated bins. Throughout the sorting process, the system keeps track of the location of each parcel. Once the parcels are sorted and ready for dispatch, they can be loaded onto trucks or delivery vehicles for final transportation to their respective destinations. Benefits of this system include increased efficiency, reduced labour costs, improved accuracy in sorting, faster processing times, and enhanced tracking capabilities. It can handle a large volume of parcels with minimal human intervention, resulting in significant time and cost savings for warehouse operations.

1.1 SCOPE OF THE WORK

The scope of work for automatic warehouse management using computer vision and robotics for parcel sorting can be quite extensive. System Design and Integration it involves designing the overall architecture of the warehouse management system, including the integration of computer vision technology, robotics, conveyor systems, and other necessary components. It includes determining the hardware and software requirements and ensuring seamless integration of all system components. Developing computer vision and software that can accurately analyze parcel images, extract relevant information, and make sorting decisions based on predefined rules and criteria. Designing and developing robotic systems capable of autonomously navigating the warehouse, picking up parcels, and placing them in the appropriate sorting areas. This includes selecting or customizing robotic hardware, developing control systems , and implementing safety features to ensure efficient and safe operation. Designing and implementing the physical infrastructure required to support the automated sorting process. This includes installing conveyor belts, robotic arm, storage areas, bins, and other necessary equipment. The system should be designed to optimize parcel flow, minimize congestion, and facilitate seamless transfer between different areas within the warehouse.

Building the software that manages the overall warehouse management system, including parcel tracking, inventory management, sorting decision-making, and integration with other systems. This software should provide real-time monitoring and reporting capabilities to enable efficient warehouse operations and performance analysis. Ensuring smooth integration of the automated warehouse management system with existing software and systems used in the warehouse or logistics operations. Deploying the system in the warehouse environment and providing training to warehouse staff and operators on how to use and interact with the automated system. The scope of work may vary depending on the specific requirements, size of the warehouse, and the complexity of the sorting operations. It's essential to thoroughly analyze the project needs, define the scope, and allocate resources accordingly to ensure successful implementation.

1.2 RELEVANCE

Automated systems enable faster and more efficient parcel sorting compared to manual processes. Computer vision algorithms can quickly analyze parcels and make accurate sorting decisions, while robotics can handle multiple parcels simultaneously, resulting in higher throughput and reduced processing time. With the increasing volume of parcels in e-commerce and logistics operations, automation allows warehouses to scale their sorting capabilities without significantly increasing labour costs. The use of robotics and computer vision enables seamless handling of large quantities of parcels, accommodating the growing demands of the industry. Automating warehouse operations can reduce labour costs associated with manual sorting. By utilizing computer vision and robotics, warehouses can streamline their workforce, allocate resources more effectively, and achieve higher productivity with fewer personnel. This cost reduction becomes especially significant as parcel volumes continue to rise. Computer vision technology can accurately analyze parcel attributes such as size, shape, and barcode information, ensuring precise sorting decisions. This reduces the chances of human error, misplacement, or misrouting of parcels. Additionally, automated systems can perform quality control checks during sorting, identifying damaged or incorrectly labelled parcels and diverting them for manual inspection or resolution. Automatic warehouse management systems provide enhanced parcel tracking and traceability. Each parcel can be assigned a unique identifier, and its location can be continuously monitored throughout the sorting process. This real-time tracking enables better visibility, reduces the risk of lost parcels, and enhances customer satisfaction through accurate delivery status updates.

Automated systems reduce the physical strain on workers by taking over repetitive and physically demanding tasks. The relevance of this technology lies in its ability to address the challenges posed by the exponential growth of e-commerce and logistics, leading to improved customer satisfaction, reduced costs, and increased competitiveness in the market.

Chapter 2

PROOF OF CONCEPT

2.1 INTRODUCTION

In the case of a computer vision-based gesture-controlled wheelchair system, a proof of concept might involve building a small-scale prototype that demonstrates the basic functionality of the system

The core components include hardware setup, parcel recognition using computer vision algorithms, sorting decision-making based on extracted information, robotic control for parcel handling, seamless integration and communication among system components, comprehensive testing and evaluation, performance metric measurement, robust data management, implementation of safety measures, and thorough documentation of the system design and operational procedures. It will provide valuable insights into the viability and functionality of an automated warehouse management system. By showcasing the system's ability to accurately recognize parcels, make intelligent sorting decisions, and efficiently handle them using robotic arms, it will demonstrate the potential for substantial improvements in efficiency, accuracy, and scalability.

2.2 REVIEW OF LITERATURE

“Warehouse robotics, the ultimate guide for 2022” by Abby Jenkins

Warehouse robotics refers to the use of robotic systems and automation technologies in warehouse operations to improve efficiency, accuracy, and productivity. These robotic systems are designed to handle various tasks traditionally performed by human workers, such as material handling, order fulfillment, inventory management, and picking and packing. The ultimate goal of warehouse robotics is to optimize warehouse operations by reducing labour costs, minimizing errors, increasing throughput, and improving overall operational efficiency. Warehouse robots are equipped with sensors, cameras, and other technologies to perceive and navigate through the warehouse environment, identify objects and locations, and execute tasks with precision.There are various types of warehouse robots Automated Guided Vehicles (AGVs), Autonomous Mobile Robots, Robotic Arms, Automated Storage and Retrieval Systems. Warehouse robotics systems are typically integrated with warehouse management systems (WMS) and other software platforms to streamline operations, monitor inventory, track orders, and optimize workflows. This integration enables seamless coordination and communication between human operators, robots, and other equipment in the warehouse. As technology continues to advance, warehouse robotics is expected to play an increasingly significant role in the optimization of warehouse operations, addressing challenges such as labour shortages, increasing order volumes, and the need for faster order fulfillment.

"Design, Analysis and Fabrication of Pick & Place Colour Sorting Robotic Arm" by Kunal N. Palasdeokar, Abhishek A. Chavan

This paper presents the design, analysis, and fabrication of a pick and place colour sorting robotic arm. The objective is to develop a versatile robotic system capable of accurately identifying and sorting objects based on their colours. The design process includes the selection of suitable hardware components, kinematic analysis, and control system integration. The fabricated robotic arm is evaluated for its performance in real-world colour sorting tasks. The results demonstrate the effectiveness and reliability of the developed robotic arm in achieving precise pick and place operations for colour-based sorting applications. It describes the design methodology employed for the development of the pick and place colour sorting robotic arm. It covers the selection of suitable mechanical components such as actuators, grippers, and sensors. The design considerations, including reachability, payload capacity, and accuracy, are discussed. The kinematic analysis is performed to ensure optimal arm geometry and motion planning. Various colour sorting tasks are conducted to assess its accuracy, speed, and reliability. The experimental setup, metrics for evaluation, and test scenarios are described. The results are analyzed and compared with predefined performance requirements. The conclusion summarizes the key findings of the study and highlights the contributions of the design, analysis, and fabrication of the pick and place colour sorting robotic arm. It emphasizes the effectiveness of the developed system in accurately sorting objects based on their colours and outlines future research directions in the field.

“The Rise of Automation and Robotics in Warehouse Management” by Amandeep Dhaliwal

In the past, material movement via manual methods in warehousing was a huge labor drain. But with the advent of modern technology, there has been a big change in the way the modern warehousing is carried out nowadays. In recent years, automated warehousing technologies and robotics have brought in huge transformation in order fulfillment and material handling work. Robotics as a technology plays a major role in this advancement. As these technologies become even more sophisticated, it would further help in making operations and simplifying logistics. The robotics solutions are also known as warehouse robotics and are of many different levels. Some of the most commonly used warehouse automation solutions in operations of businesses are the systems such as articulated robotic arms, automated guided vehicles (AGVs), automated storage and retrieval systems (AS/RS), automated guided carts (AGCs), autonomous mobile robots (AMRs), many of goods-to-person technology (G2P), and such machines**.**

A decade witnesses the dominance for data management and broader acceptance of artificial intelligence (AI). In particular, customer’s insight and business analytics with organizations beating insights improve and appreciate the customer behavior. Now, it’s time to locate that data to work in new techniques. Companies can develop into aggressive if the marketing data could be organized in reminiscent approaches such as recognizing the target market and following the efficient method for market development, as well as the expectation of consumer behavior, so as to congregate toward consumer appointment to improve their knowledge. Personalization with customers now is the key to achievement. Marketers will enhance investment in data management platforms (DMPs) that permit them to stock up, control, and inspect customer data from numerous sources and attach with spectators throughout the modified marketing movements. The marketer is observing technology to fetch the related applicable marketing knowledge to customers; incorporation of data for the fulfillment of approach is the main applicable feature. These incorporated data stage will enhance customer’s commitment. In disparity to the past years, nowadays getting data, channelizing, and processing it with an organized marketing information system (MKIS) instinctively during AI is a choice-making instrument to give a course to random and classify data and information.

"The transformation from manual to smart warehousing" by Joakim kembro, Andreas Norrman.

This paper presents an exploratory study conducted with retailers to investigate the transformation from manual to smart warehousing practices. The study aims to understand the motivations, challenges, and outcomes associated with adopting smart warehousing technologies and processes. Introduce the importance of warehousing in the retail industry and the increasing shift towards smart warehousing practices. Discuss the research objectives, methodology. Provide a comprehensive review of existing literature on smart warehousing, including the concepts, technologies, and benefits associated with the adoption of smart warehousing practices. Discuss relevant studies on the transformation from manual to smart warehousing. Present the observed impacts of adopting smart warehousing practices. Discuss improvements in operational efficiency, reduction in error rates, cost savings, inventory accuracy, and customer satisfaction. Explore how smart warehousing positively influenced overall supply chain performance.

2.3 LIMITATION OF EXISTING SYSTEMS

Implementing an automated warehouse management system with computer vision and robotics technologies can involve significant upfront costs. The cost of acquiring and integrating the necessary hardware, software, and infrastructure may pose a financial barrier for some organizations. Additionally, the complexity of system implementation and integration with existing warehouse processes and systems can be challenging, requiring specialized expertise and resources. The effectiveness of computer vision algorithms and robotics technology may have limitations in certain scenarios. Factors such as lighting conditions, parcel variability, and occlusions can affect the accuracy and reliability of the computer vision system's object recognition and sorting capabilities. Robotics technology may have limitations in terms of handling fragile or irregularly shaped parcels, requiring additional precautions or manual intervention. While scalability and adaptability are objectives, the existing system may have limitations in accommodating rapid changes or increasing parcel volumes. Scaling up the system to handle higher volumes of parcels may require significant adjustments to hardware, software, and infrastructure, potentially leading to disruptions in operations. Adapting the system to handle new parcel sizes, shapes, or sorting criteria may also require updates to the computer vision algorithms and robotic capabilities.

Automated systems require regular maintenance and monitoring to ensure their proper functioning. The complex nature of computer vision and robotics components may lead to potential system failures, requiring skilled technicians for maintenance and repairs. Reliability issues, such as breakdowns or malfunctions, can result in disruptions to warehouse operations and delays in parcel sorting. The existing system objectives may have limitations in terms of flexibility and adaptability to changing business requirements. Adapting the system to new warehouse layouts, incorporating new sorting criteria, or integrating with emerging technologies may require significant modifications or system replacements, which can be time-consuming and costly.

Chapter 3

SYSTEM ANALYSIS AND DESIGN

3.1 SYSTEM ANALYSIS

3.1.1 INTRODUCTION

System analysis is a critical step in the development of automatic warehouse management using computer vision and robotics for parcel sorting. It involves analyzing the requirements, features, and functionalities of the proposed system. Identify and document the functional and non-functional requirements of the automatic warehouse management system. This includes the ability to handle diverse parcel sizes and shapes, real-time tracking and monitoring capabilities, accurate object recognition and integration with existing warehouse management systems, scalability, and adaptability. Analyze the overall system architecture of the automatic warehouse management system. This involves understanding the interconnections between the computer vision subsystem, robotic components, control systems, and the warehouse environment. Evaluate the design choices made in terms of hardware, software, and communication protocols to ensure seamless integration and optimal performance. Examine the computer vision subsystem responsible for capturing and processing visual information.Analyze the image acquisition techniques, camera placement, and calibration methods employed to ensure accurate parcel identification and sorting. Evaluate the robotics subsystem that handles the physical manipulation and sorting of parcels. Assess the data integration capabilities of the system, including the seamless flow of information between the computer vision subsystem, robotics subsystem, and warehouse management systems.

3.1.2 PROPOSED SYSTEM OBJECTIVES

The primary objective of the proposed system is to enhance the efficiency of warehouse operations. By leveraging computer vision and robotics technologies, the system aims to automate the parcel sorting process, reducing manual labour and minimizing the time required for sorting tasks. This objective includes optimizing the overall throughput, reducing order processing times, and improving the overall productivity of the warehouse. Another crucial objective is to enhance the accuracy of parcel sorting. The system aims to achieve precise identification and classification of parcels using computer vision. By eliminating human errors and inconsistencies, the system can ensure accurate sorting based on predefined criteria such as destination of product. This objective contributes to minimizing order errors, improving customer satisfaction, and reducing the need for manual interventions. The proposed system aims to enable real-time tracking and monitoring of parcels throughout the sorting process. By utilizing computer vision techniques, the system can track the location and movement of each parcel, providing visibility and transparency to warehouse managers and customers. Real-time tracking facilitates better inventory management, enables timely order updates, and enhances the overall supply chain visibility. The system objectives include optimizing resource utilization within the warehouse. By utilizing robotics technology, the system aims to streamline material handling, reducing unnecessary movements and minimizing idle time. This objective contributes to efficient use of warehouse space, equipment, and human resources, ultimately reducing operational costs and increasing overall productivity. he proposed system should be designed with adaptability and scalability in mind. The objective is to create a flexible system that can accommodate changing warehouse requirements, such as varying parcel sizes, shapes, or sorting criteria. The system should be capable of integrating with existing warehouse management systems and easily scalable to handle increased parcel volumes as the business grows. Safety is a critical objective in the design of the proposed system. The integration of robotics should adhere to strict safety standards to prevent accidents or injuries to workers. The system should include safety features such as collision detection, emergency stop mechanisms, and clear separation of human and robotic workspaces. Ensuring a safe working environment for both employees and robots is paramount. The proposed system should seamlessly integrate with existing warehouse management systems (WMS). By aligning with these proposed system objectives, an automatic warehouse management system using computer vision and robotics for parcel sorting can significantly enhance operational efficiency, accuracy, and customer satisfaction in warehouse operations.

3.1.3 HARDWARE AND SOFTWARE SPECIFICATIONS

Hardware specifications are:

The hardware requirements for the proposed automatic warehouse management using computer vision and robotics include a ATmega328 microcontroller, DC motor driver L293D , Servo Motor, IR Sensor, Camera Unit.

- **ATmega328 microcontroller**

The ATmega328 is a microcontroller chip commonly used in various electronic projects and devices. It is part of the Atmel AVR family of microcontrollers and is widely known for its versatility and ease of use. The ATmega328 is based on the Harvard architecture, which separates program and data memory. It features a 8-bit RISC (Reduced Instruction Set Computer) CPU, offering a good balance between performance and power consumption. The ATmega328 typically operates at a clock speed of 16 MHz, providing fast execution of instructions and data processing capabilities. It has a total of 32KB of flash memory for program storage, which allows you to write and store your code. Additionally, it offers 2KB of SRAM (Static Random-Access Memory) for temporary data storage during program execution. The ATmega328 has a range of digital and analog I/O pins that can be used to connect and control external devices. It features a total of 23 GPIO (General-Purpose Input/Output) pins, with 14 of them capable of digital input/output and 6 of them supporting analog input. The chip includes various built-in peripherals, such as UART (Universal Asynchronous Receiver/Transmitter), SPI (Serial Peripheral Interface), and I2C (Inter-Integrated Circuit) interfaces. These peripherals enable communication with other devices and support various protocols. The ATmega328 is commonly programmed using the Arduino development environment, which provides a beginner-friendly platform with a simplified programming language and extensive libraries. However, it can also be programmed using other IDEs (Integrated Development Environments) and languages, such as C or C++

Figure 3.1 ATmega328 microcontroller

- **DC motor L293D**

The L293D is a popular motor driver integrated circuit (IC) commonly used in robotics and other electronic projects to control DC motors and stepper motors. It provides an easy and efficient way to drive motors with a microcontroller or other digital logic circuits. The L293D is capable of driving two DC motors or one stepper motor. It provides bidirectional control, allowing the motors to rotate in both forward and reverse directions. The motor speed can be varied by controlling the voltage applied to the motor. The L293D motor driver uses an H-bridge configuration to control the direction and speed of the motors. It consists of four integrated power transistors arranged in two sets of H-bridges. Each H-bridge can control the polarity of one motor, enabling it to rotate in both directions. The L293D has a high current capacity, with each output channel capable of driving up to 600 mA of continuous current and 1.2 A of peak current. This allows it to drive a wide range of motors, including small DC motors and stepper motor. The L293D incorporates various protection features to safeguard the motor driver and connected components. It includes internal diodes to protect against back electromotive force (EMF) generated by the motors during deceleration or when power is removed. It also has built-in thermal shutdown protection to prevent overheating. The L293D is compatible with a wide range of microcontrollers and digital logic circuits. It can be controlled using standard digital logic signals, such as TTL (Transistor-Transistor Logic) or CMOS (Complementary Metal-Oxide-Semiconductor) levels. The L293D is available in different package options, including DIP (Dual In-Line Package) and SOIC (Small Outline Integrated Circuit) packages. These packages provide flexibility in terms of circuit board design and ease of soldering. When using the L293D motor driver, it is important to refer to the datasheet and follow the recommended guidelines for proper wiring, power supply requirements, and motor connections. Understanding the pin configurations and electrical characteristics of the L293D is crucial for successful motor control and preventing any potential damage to the IC or connected components

Figure 3.2 L293D Motor Driver

- **Servo motor**

A servo motor is a type of rotary actuator that provides precise control of angular position. It is widely used in various applications, including robotics, automation systems, remote control vehicles, and industrial machinery.

The main characteristic of a servo motor is its ability to maintain a specific position accurately. It achieves this through a feedback mechanism that continuously compares the desired position with the actual position and adjusts the motor's rotation accordingly. A typical servo motor consists of a small DC motor, a gear train, a control circuit, and a potentiometer or an encoder for feedback. Servo motors are controlled by sending a series of pulses to the control circuit. The duration of each pulse determines the desired position. The most common signal is the Pulse Width Modulation (PWM), where the width of the pulse corresponds to the angle or position. Servo motors have built-in feedback devices such as potentiometers or encoders. These devices provide information about the motor's actual position to the control circuit, enabling it to make adjustments and maintain precise positioning. Servo motors can deliver high torque even at low speeds, making them suitable for applications requiring precise control and movement. Servo motors can rotate at high speeds while maintaining accurate positioning. They offer excellent dynamic response and can quickly change their speed and direction. A servo control system typically consists of a controller, servo amplifier, and servo motor. The controller generates the control signals based on user inputs or feedback, the servo amplifier amplifies the control signals, and the servo motor executes the desired motion. Servo motors come in various types, including AC servo motors and DC servo motors. AC servo motors are more common in industrial applications, while DC servo motors are often used in smaller, low-power systems. It's important to note that there are different types and models of servo motors available, each with specific specifications and capabilities. When choosing a servo motor for a particular application, factors such as torque requirements, speed range, power supply, and communication interface should be considered.

Figure 3.3 Servo motor

- **IR Sensor**

An IR (Infrared) sensor, also known as an IR detector or IR receiver, is a device that detects and responds to infrared radiation. It is commonly used in a variety of applications, including remote controls, security systems, proximity sensors, and automation systems. IR sensors operate by detecting the infrared light emitted by objects or sources and converting it into an electrical signal. Infrared radiation refers to the electromagnetic waves with wavelengths longer than those of visible light. IR sensors are designed to detect this radiation, which is emitted by objects based on their temperature. IR sensors typically consist of an IR receiver, which is a photodiode or a phototransistor. When exposed to infrared radiation, these devices generate an electrical signal proportional to the intensity of the received IR light. The detection range of an IR sensor depends on various factors, including the sensitivity of the receiver and the power of the IR source. Typically, the range can vary from a few centimeters to several meters. IR sensors can be used to detect the presence or absence of an object within their detection range. When an object comes into the sensor's field of view and reflects or emits infrared radiation, the sensor detects the change in received IR light and triggers a response. IR sensors can also be used for proximity sensing, where they detect the distance between the sensor and an object. By measuring the intensity of reflected infrared light or using time-of-flight techniques, they can estimate the distance to the object. IR sensors are commonly used in obstacle detection systems, such as in robotics or automated machinery. By emitting infrared light and measuring the reflected light, they can detect the presence of obstacles and trigger appropriate actions. IR sensors are widely used in communication systems, such as infrared remote controls. They receive modulated infrared signals from a remote control unit and convert them into electrical signals that can be interpreted by the receiving device. IR sensors often incorporate filters to minimize the influence of ambient light and focus on the desired infrared wavelength range. Signal processing techniques are also employed to improve the reliability and accuracy of the sensor's output. IR sensors provide a cost-effective and reliable solution for various sensing and control applications. Their versatility, ease of use, and compatibility with a wide range of electronic systems make them popular in many industries.

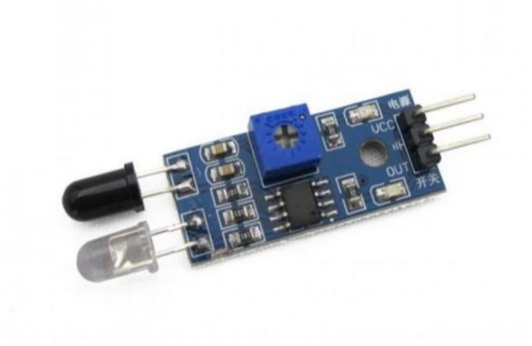

Figure 3.4 IR Sensor

- **Camera Unit**

To implement automatic warehouse management using computer vision and robotics for parcel sorting, a suitable webcam system can be utilized. Choose a webcam with a high-resolution sensor to capture detailed images of parcels. A minimum resolution of 1080p (Full HD) is recommended, but higher resolutions like 4K can provide even better image quality. a webcam with a high frame rate capability to ensure smooth and real-time video capture. Automatic focus and exposure adjustment are essential features for adapting to different lighting conditions and maintaining optimal image quality throughout the sorting process. : Ensure that the webcam is compatible with your chosen computer vision and robotics system. Check for compatibility with the operating system and software libraries used for image processing. USB connectivity is common and provides easy integration with computers and robotic systems. Verify that the webcam can be easily integrated with the computer vision and robotics systems you plan to use. Compatibility with popular frameworks or APIs for computer vision processing, such as OpenCV, can simplify the development process.

Figure 3.5 Webcam

Software specifications are:

The software requirements include a programming language such as Python, OpenCV library for image processing, PyCharm IDE for coding, and Arduino IDE for the programming of microcontrollers. Python is a high-level, interpreted programming language that provides a large number of libraries for image processing. OpenCV is an open-source library for computer vision that can be used to process images and videos. PyCharm is an integrated development environment that is used for coding, debugging, and testing of Python applications. It provides features such as code completion, syntax highlighting, and debugging tools. Arduino IDE is used to program the microcontrollers that are used to control the motors and other peripherals of conveyor. It provides a simple interface for programming the microcontrollers and uploading the code to them.

- **Arduino IDE**

Arduino IDE (Integrated Development Environment) is a software application that is used to write, upload, and debug the code on the Arduino microcontroller boards. The Arduino IDE (Integrated Development Environment) can be used in conjunction with the ATmega328 microcontroller for developing the control system of an automatic warehouse management system using computer vision and robotics for parcel sorting. The ATmega328 is a popular microcontroller used in Arduino boards like the Arduino Uno. Connect the ATmega328 microcontroller to computer using a USB-to-serial adapter or an Arduino board that has the ATmega328 chip, such as Arduino Uno. The IDE provides a simple and intuitive interface for writing and debugging code using the Arduino programming language, which is based on C/C++. The Arduino IDE also provides access to a large library of pre-written code snippets and functions that can be used to implement various features and functionalities. The Arduino IDE is used to program the ATmega328 microcontroller board and interface it with other components such as the camera module, IR Sensor, Servo motor, and L293D motor driver. The IDE helps to create a seamless integration between the hardware and software components.

- **PyCharm IDE**

PyCharm is an Integrated Development Environment (IDE) specifically designed for Python development. It provides a comprehensive set of tools and features to help developers write, debug, and maintain Python code efficiently. PyCharm offers advanced code editing features, including intelligent code completion, code analysis, and error detection. It helps developers write code faster and with fewer errors. Additionally, the IDE provides powerful navigation capabilities, allowing developers to easily navigate through code files, classes, functions, and symbols. PyCharm offers a wide range of integrated tools and plugins that enhance the development experience. It includes support for version control systems, project management tools, code quality analysis, and testing frameworks. These tools help streamline the development workflow and improve productivity.

In the context of a, PyCharm IDE can be used to develop and test the software that runs on the computer vision module. automatic warehouse management using computer vision and robotics for parcel sorting, This software is responsible for processing the video feed from the camera and identifying the parcels and corresponding destinations. PyCharm can be used to write and test the code that performs this parcel recognition, as well as the code that sends commands to the microcontroller based on the recognized QR code. PyCharm also provides a user-friendly interface for debugging the code, allowing developers to identify and fix errors in their software.

- **OpenCV**

OpenCV is an open-source computer vision and machine learning software library that is used in many computer vision applications. In the context of implement automatic warehouse management using computer vision and robotics, OpenCV can be used to detect and recognize the packets.

The process of using OpenCV for packet recognition typically involves several steps. First, an image or video stream is captured using a camera. The image is then processed to identify the destination. Once the packet has been identified, the QR code Scanned And find the corresponding destination. Finally, these informations will send to the microcontroller. OpenCV provides a wide range of tools and functions that make it easy to perform these steps. For example, it includes functions for image processing, feature extraction, and machine learning. Additionally, it provides support for a wide range of programming languages, including Python, C++, and Java, making it easy to integrate with other software components.

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3.2 SYSTEM DESIGN

3.2.1 INTRODUCTION

The system design of a automatic warehouse management using computer vision and robotics for parcel sorting consists of several components, including a camera, microcontroller, motor driver, DC motor, IR Sensor, Servo motor. The camera is used to capture the QR code of packet, which is then processed by the microcontroller using the OpenCV library. The microcontroller processes the image and get a corresponding destination, which is sent to the motor driver. The motor driver controls the DC motors that move the conveyor and the servo motor turn to the desired direction. The IR sensor detect the packet and stop the conveyor for Scan the QR code. The software requirements for the system include the Arduino IDE, PyCharm IDE, OpenCV library, and Python programming language. The hardware requirements for the system include these components , By integrating these components, the system can accurately recognize the packet and move to corresponding location and control the movement of conveyor accordingly.

3.2.2 MODULE DESCRIPTION

This project includes mainly 3 modules. They are

Robotics Arm for pick and place

Building a robotic arm for pick and place operations in an automatic warehouse management system, utilizing servo motors and integrating it with computer vision and IoT, can enhance efficiency and enable real-time monitoring and control. Design and construct a robotic arm with multiple degrees of freedom (DOF) using servo motors. Connect servo motors to the robotic arm joints, enabling precise and controlled movements. Utilize appropriate motor drivers or microcontrollers to interface with the servo motors and send control signals to adjust their positions. Coordinate with the conveyor system to synchronize the arm's actions with the movement of the parcels.

Here, 2 Servo motors have used for constructing Robotic Arm. One motor used to open the hand to pick the parcel. Second Servo motor to reach connection tower and conveyor. For smooth movement of Robotic Arm an additional wheel added. The Arm created using halogen sheet.

Conveyor movement

After picking the packet using Robotic Arm to conveyor, the conveyor going to rotate. Rotation is done by the DC motor that controlled by L293D motor driver . when the packet moving along the conveyor , the IR Sensor detect the packet .The camera on the top of the IR sensor scan the QR code of packet. The QR code information is Decoded and get the destination id. This information going to the microcontroller . When the destination identified the 3^{rd} servo motor turn in to the corresponding direction.

Packet sorting

After get the destination details, the conveyor again rotated. At the end of the conveyor the packet again detect by second IR Sensor. Then the packet will fall into the corresponding direction .There are two destination set for packet sorting are kochi and Kottayam..

3.2.3 SYSTEM ARCHITECTURE

The diagram of the automatic warehouse management using computer vision and robotics mainly consists of three modules: the input module, the processing module, and the output module. The input module includes a camera that captures the QR code of the packet. The processing module consists of the ATmega328, which processes the signals received from the components. The output module includes a servo motor rotate the corresponding location in appropriate angle.

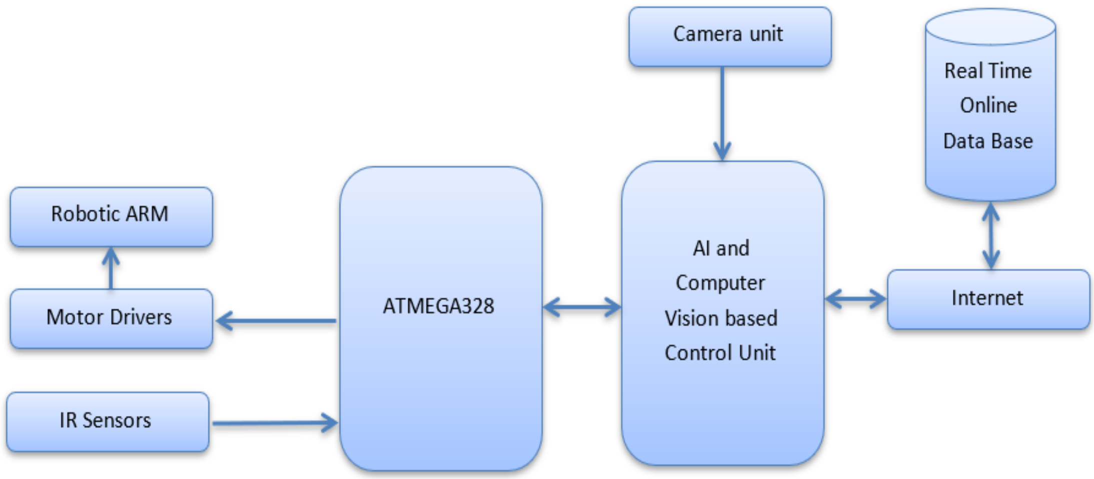

Figure 3.2.1 block Diagram

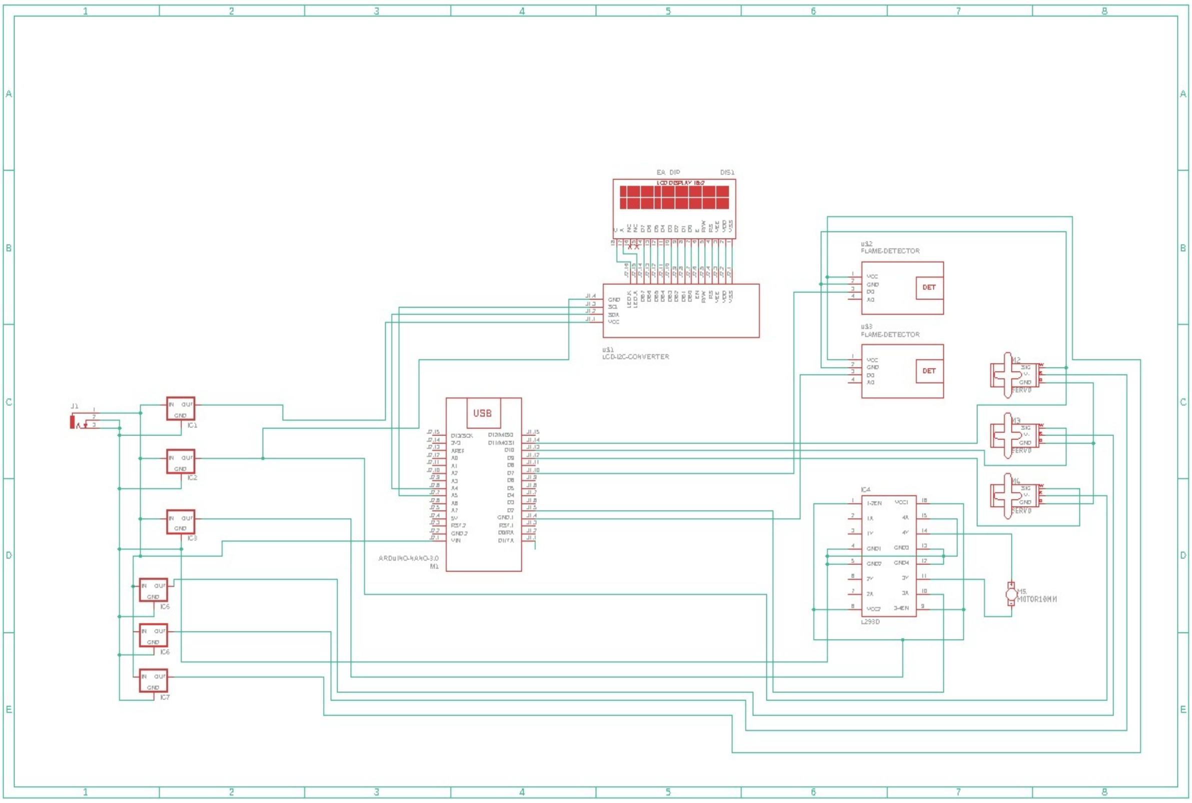

Figure 3.2 .2 Circuit Diagram

3.3 RESULTS AND DISCUSSIONS

3.3.1 INTRODUCTION

The proposed automatic warehouse management using computer vision and robotics was tested using packets and the results were found to be promising. The accuracy of the packet recognition system was found to be around 90%, which is a good accuracy for a real-time application. The system was able to recognize various hand gestures and generate corresponding commands for the wheelchair movement, such as forward, reverse, left, right, and stop. The output module of the system was able to control the movement of the wheelchair based on the recognized gestures. The wheelchair was able to move in the desired direction, as commanded by the gestures. The LCD display module was also able to display the labels of the recognized gestures, which helped in understanding the system behavior.

3.3 PERFORMANCE EVALUATION

Measure the accuracy of the computer vision system in identifying and locating parcels within the warehouse. Evaluate the system's ability to recognize different parcel, barcodes, or QR codes correctly. Connect servo motors to the robotic arm joints, enabling precise and controlled movements. Utilize appropriate motor drivers or microcontrollers to interface with the servo motors and send control signals to adjust their positions. Integrate computer vision technology to enable object detection, recognition, and localization. Use cameras or sensors to capture images of the parcels in the warehouse environment. Establish an IoT infrastructure to connect the robotic arm, computer vision system, and other components of the warehouse management system. Process the image data obtained from the computer vision system in real-time to detect and locate parcels accurately. Integrate the robotic arm with the conveyor system to facilitate pick and place operation.

Coordinate with the conveyor system to synchronize the arm's actions with the movement of the parcels. By combining servo motors, computer vision, and IoT connectivity, this project can deliver a comprehensive solution for automating pick and place operations in an automatic warehouse management system

Chapter 4

SUMMARY

In conclusion, implementing automatic warehouse management systems using computer vision and robotics for parcel sorting offers numerous benefits and advancements in the logistics industry. By combining these technologies, companies can optimize their operations, increase efficiency, and improve customer satisfaction. firstly, computer vision plays a vital role in automating the parcel sorting process .computer vision systems can accurately identify, classify, and track parcels as they move through the warehouse. This eliminates the need for manual intervention, reducing errors and increasing sorting speed. Secondly, robotics provides the physical capabilities required to handle parcels efficiently. Robotic systems, can pick up parcels from one location and transport them to the appropriate destination., avoiding obstacles and optimizing the route for maximum efficiency. Implementing automatic warehouse management using computer vision and robotics also offers scalability and flexibility. Furthermore, automation reduces the reliance on human labour for repetitive and physically demanding tasks. This not only minimizes the risk of human errors but also frees up the workforce to focus on more complex and value-added activities. Overall, the integration of computer vision and robotics in automatic warehouse management for parcel sorting revolutionizes the logistics industry. It streamlines operations, improves efficiency, reduces costs, and enhances the customer experience. As technology continues to advance, we can expect further innovations in this field, leading to even more sophisticated and efficient warehouse management systems.

4.2 FUTURE ENHANCEMENTS

The future of automatic warehouse management using computer vision and robotics for parcel sorting holds exciting possibilities for further enhancements and advancements. Continued research and development in artificial intelligence can lead to more sophisticated algorithms for computer vision systems. These algorithms can improve object recognition, handling complex scenarios such as damaged or irregularly shaped parcels, and enhance the overall accuracy and speed of parcel sorting. Collaboration between humans and robots, known as cobots, can be explored to further optimize warehouse operations. Cobots can work alongside human workers, assisting them in parcel sorting tasks, and leveraging the strengths of both humans and robots. This collaborative approach can lead to increased efficiency, flexibility, and safety in warehouse management. Swarm robotics involves coordinating a large number of small, autonomous robots to perform tasks collectively. Implementing swarm robotics in warehouse environments could enable a highly scalable and adaptable system for parcel sorting. These robots can work collaboratively to sort parcels, dynamically adjusting their routes and optimizing the overall process.

Connecting robotic systems, computer vision cameras, and other devices in the warehouse to the Internet of Things (IoT) can provide real-time data on various aspects of the sorting process. This data can be leveraged through advanced big data analytics techniques to gain insights, identify patterns, and make data-driven decisions for further optimization and efficiency improvements. AR can enhance the efficiency and accuracy of parcel sorting by providing workers with real-time visual information and instructions. Wearable devices, such as smart glasses or augmented reality headsets, can overlay virtual labels or route instructions onto physical parcels, guiding workers during the sorting process and reducing errors. The use of autonomous mobile robots can be expanded beyond simple transportation tasks to include more complex sorting activities. AMRs equipped with computer vision systems can navigate the warehouse, identify parcels, and sort them into appropriate destinations autonomously, reducing the need for fixed infrastructure or conveyor systems. Implementing systems that can continuously learn from data and optimize their processes over time can lead to ongoing improvements in warehouse management. Machine learning techniques can be employed to analyze historical data, identify inefficiencies, and dynamically adjust sorting strategies to maximize efficiency and accuracy. With a growing emphasis on sustainability, future enhancements could focus on reducing energy consumption, optimizing route planning to minimize fuel usage, and incorporating eco-friendly materials in warehouse infrastructure and robotics systems. This can contribute to more environmentally friendly and sustainable warehouse management practices. These potential future enhancements indicate the continuous evolution and refinement of automatic warehouse management using computer vision and robotics for parcel sorting. By leveraging emerging technologies and innovative approaches, the logistics industry can further optimize its operations, improve customer satisfaction, and meet the demands of a rapidly evolving market.

SAMPLE CODE

Hardware code

```
# include <Servo.h>
   # define IRE 7 // IR at end point
   # define SA  6 // Servo a
   # define SB  5 // Servo b
   # define SC  9 // Servo b
   # define IN1 4 // Motor pin LOW to stop
   # define MS  3 // Motor speed control PWM pin
   # define IRC 2 // IR at camera point
   # define kochi 45
   # define Kottayam 100

 /*=====================================*/

   Servo servoA;
   Servo servoB;
   Servo servoC;

/*======================================*/

   int val=0;
   int i=0;//Motor a pos hand
```

```
    int j=180;//Motor b pos aRM
    int start =1;
    int box = 0;

/*========================================*/

    void Serial_test();
    void open_hand();
    void close_hand();
    void arm_to_convair();
    void arm_to_collection_tower();
    void move_convair();
    void stop_convair();
    void pick_box();

/*========================================*/

    void setup()
    {
      Serial.begin(9600);
      Serial.println("Automated parcel sorting");
      pinMode(IN1,OUTPUT);
      pinMode(IRC,INPUT);
      pinMode(IRE,INPUT);
      pinMode(MS,OUTPUT);
      analogWrite(MS, 0);
      digitalWrite(IN1,LOW);
      servoA.attach(SA);
      servoB.attach(SB);
      servoC.attach(SC);
```

```
    servoA.write(j);
    servoB.write(i);
    servoC.write(kochi);
  }

/*=======================================*/

  void loop()
  {
    Serial_test();
    if(start ==1)
    {
      if(digitalRead(IRE)==0 && box ==0)
      {
        box =1;
        delay(800);
        stop_convair();
        pick_box();
        while(digitalRead(IRC) == 1)
          {
            move_convair();
            delay(50);
          }
          stop_convair();
      }
    }
  }

/*==================================*/
```

```
void Serial_test()
{
 char x;
 if(Serial.available())
 {
    x=Serial.read();
    if(x=='a')
    {
     start =1;
     pick_box();
     while(digitalRead(IRC) == 1)
     {
        move_convair();
        delay(50);
     }
     stop_convair();
    }
    if(x=='b')
    {
     stop_convair();
    }
    if(x=='c')
    {
     pick_box();
    }
    if(x=='d')
    {
     move_convair();
    }
    if(x=='m')
```

```
        {
          servoC.write(Kottayam);
          delay(150);
          box=0;
        }
        if(x=='n')
        {
          servoC.write(kochi);
          delay(150);
          box=0;
        }
        if(x=='s')
        {
          start =0;
          box=0;
          stop_convair();
        }

    }
  }

/*==============================*/

  void open_hand()
  {
    if(i<20)
    {
      Serial.println("Hand Already opened");
    }
    else
```

```
      {
        Serial.println("hand opening");
        for(i=150;i>=0;i--)
        {
          servoB.write(i);
          delay(8);
        }
      }
    }

/*====================================*/

    void close_hand()
    {
      if(i>140)
      {
        Serial.println("Hand Already Closed");
      }
      else
      {
        Serial.println("hand closing");
        for(i=0;i<=150;i++)
        {
          servoB.write(i);
          delay(8);
        }
      }
    }

/*=============================*/
```

```
void arm_to_convair()
{
  if(j>140)
  {
    Serial.println("Hand Already At convair");
  }
  else
  {
     Serial.println("Moving to convair");
     for(j=90;j<=180;j++)
     {
       servoA.write(j);
       delay(8);
     }
  }
}

/*================================*/

void arm_to_collection_tower()
{
  if(j<100)
  {
    Serial.println("Hand Already At Collection tower");
  }
  else
  {
     Serial.println("Moving to Collection tower");
     for(j=180;j>=90;j--)
```

```
        {
          servoA.write(j);
          delay(8);
        }
      }
    }

/*=================================*/

    void pick_box()
    {
      box=1;
          open_hand();
          delay(1000);
          arm_to_collection_tower();
          delay(1000);
          close_hand();
          delay(1000);
          arm_to_convair();
          delay(1000);
          open_hand();
    }

/*================================*/

    void move_convair()
    {
          Serial.println("Moving Convair");
          analogWrite(MS, 255);
          digitalWrite(IN1,HIGH);
```

```
  }

/*================================*/

  void stop_convair()
  {
        Serial.println("Stop Convair");
        analogWrite(MS, 255);
        digitalWrite(IN1,LOW);
  }
```

Test3.py

```
import serial
import time
import qrcode
import cv2

kochi = ['1004', '1005']
kottayam = ['1006', '1007']




serialPort = serial.Serial(
    port="COM6", baudrate=9600, bytesize=8, timeout=2, stopbits=serial.STOPBITS_ONE
)


d = cv2.QRCodeDetector()
cap = cv2.VideoCapture(0)
font = cv2.FONT_HERSHEY_PLAIN



def get_destination(id):
    dest = "unknown"
    id = int(id)
    for i in kottayam:
        if int(i) == id:
            dest = "Kottayam"
            return dest


    for i in kochi:
        if int(i) == id:
            dest = "Cochin"
            return dest
    return dest
```

```
x = input("press 1 to begin")
msg_dest = "unknown"
while True:
    if x == '1':
        serialPort.write(b"a\r\n")
        x = 0
    _, frame = cap.read()
    val, points, straight_qrcode = d.detectAndDecode(frame)
    if val:
        msg_disp = get_destination(val)
        msg_dest = msg_disp
        if int(val) == 1008:
            print ("please restart again")
            serialPort.write(b"sss\r\n")
            break
        val = " ID = " + val
        msg_disp = " Destination = " + msg_disp
        print(val)
        cv2.putText(frame, str(val), (50, 50), font, 2,
                    (255, 0, 0), 2)
        cv2.putText(frame, str(msg_disp), (50, 130), font, 2,
                    (0, 0, 255), 2)

        print(msg_disp)
    cv2.imshow('Frame', frame)

    if msg_dest == "Kottayam":
        cv2.imshow('Frame', frame)
        serialPort.write(b"m\r\n")
        print("Setting dest to Kottayam")
        time.sleep(3)
        serialPort.write(b"d\r\n")
        time.sleep(2)
        print("stop")
        #serialPort.write(b"b\r\n")
        msg_dest = "unknown"

    if msg_dest == "Cochin":
        cv2.imshow('Frame', frame)
        print("Setting dest to Cochin")
        serialPort.write(b"n\r\n")
        time.sleep(3)
        serialPort.write(b"d\r\n")
        time.sleep(2)
        print("stop")
```

```
        #serialPort.write(b"b\r\n")
        msg_dest = "unknown"
    if cv2.waitKey(25) & 0xFF == ord('q'):
        break
```

SCREENSHOTS

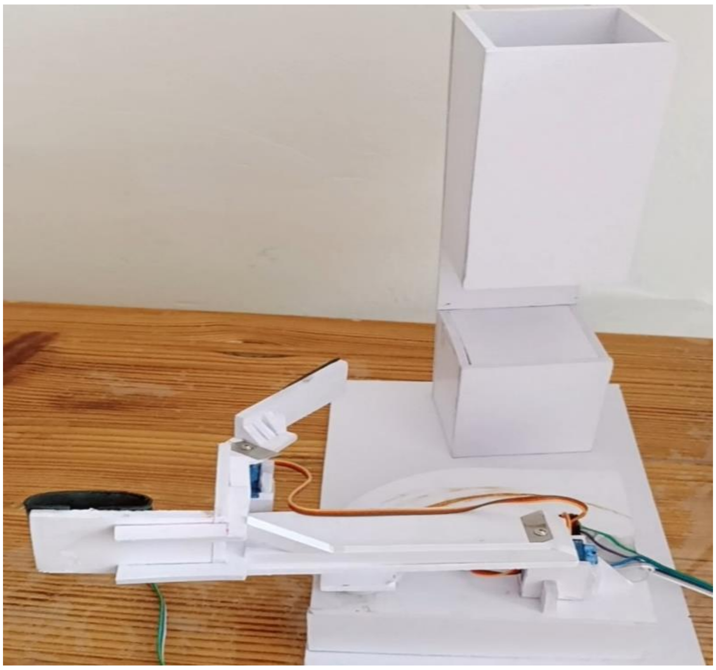

Figure 1. Robotic Arm Using 2 servo Motor

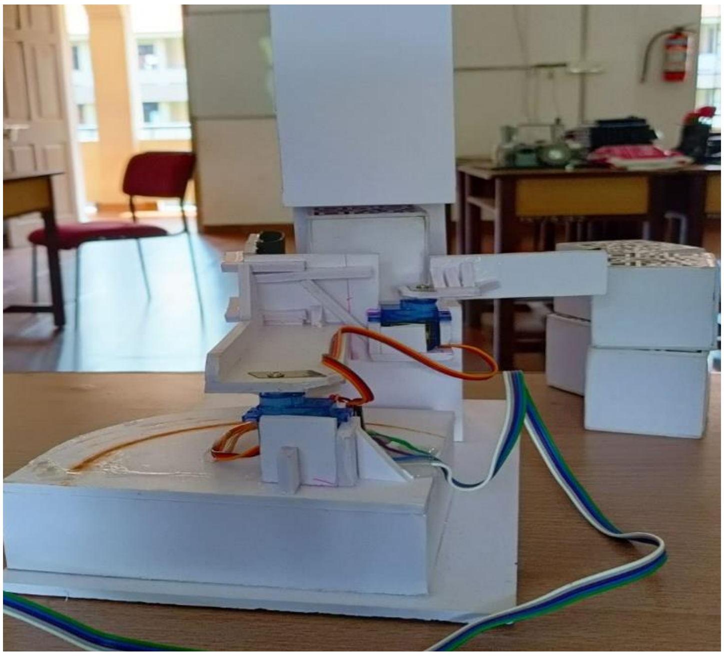

Figure 2. packet picking from connection tower

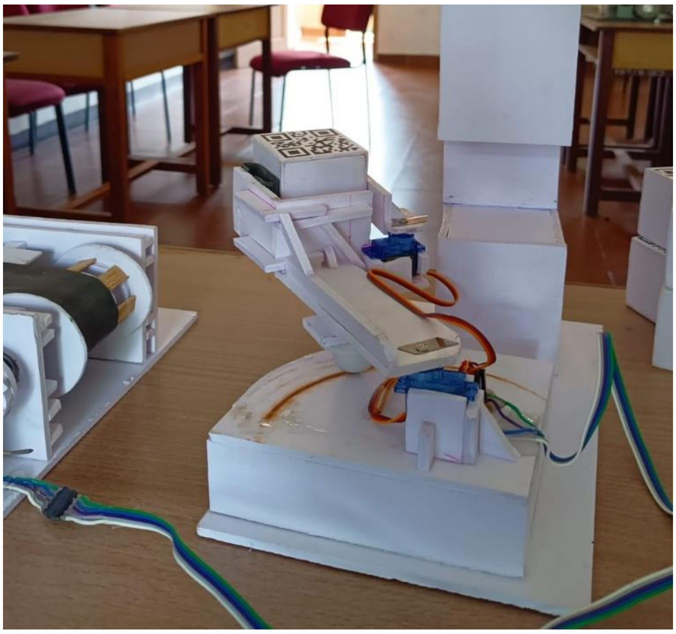

Figure 3. packet picking from connection tower

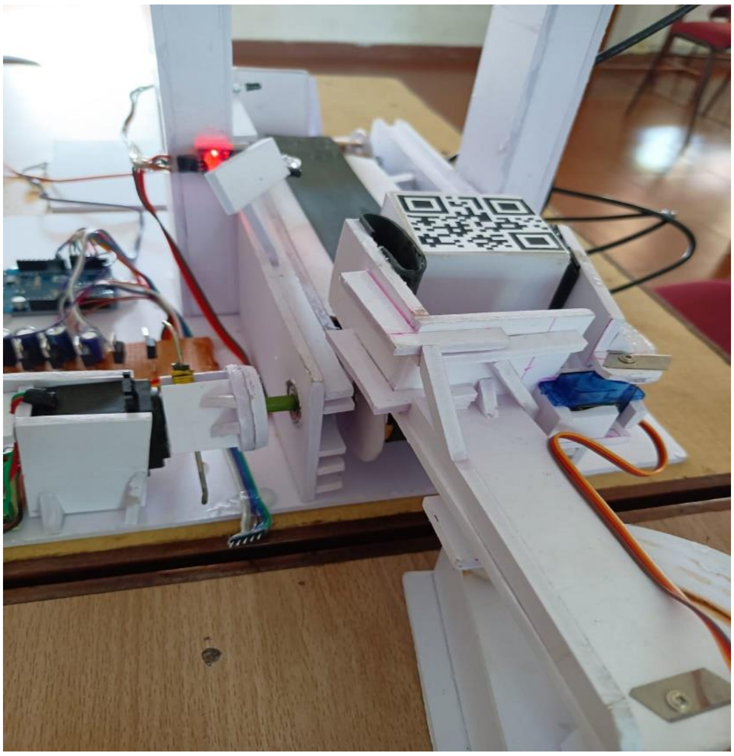

Figure 4. place the packet on the conveyor

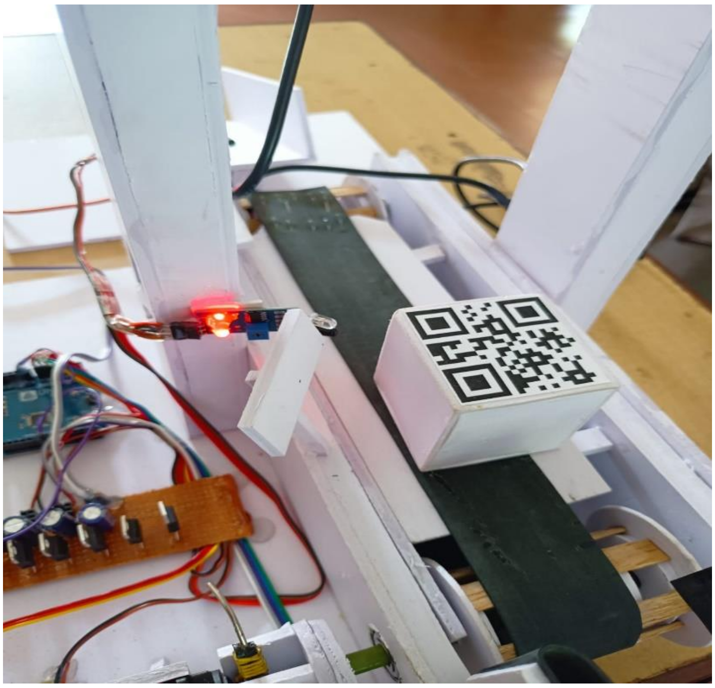

Figure 5. packet detect by the first IR sensor

Figure 6. QR code of packet scanned by Webcam

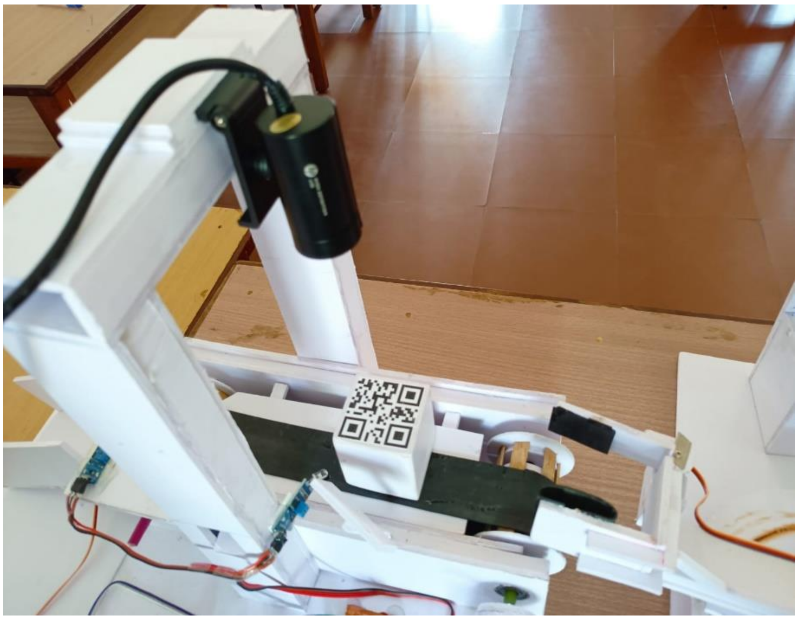

Figure 7. Get the destination id from QR code

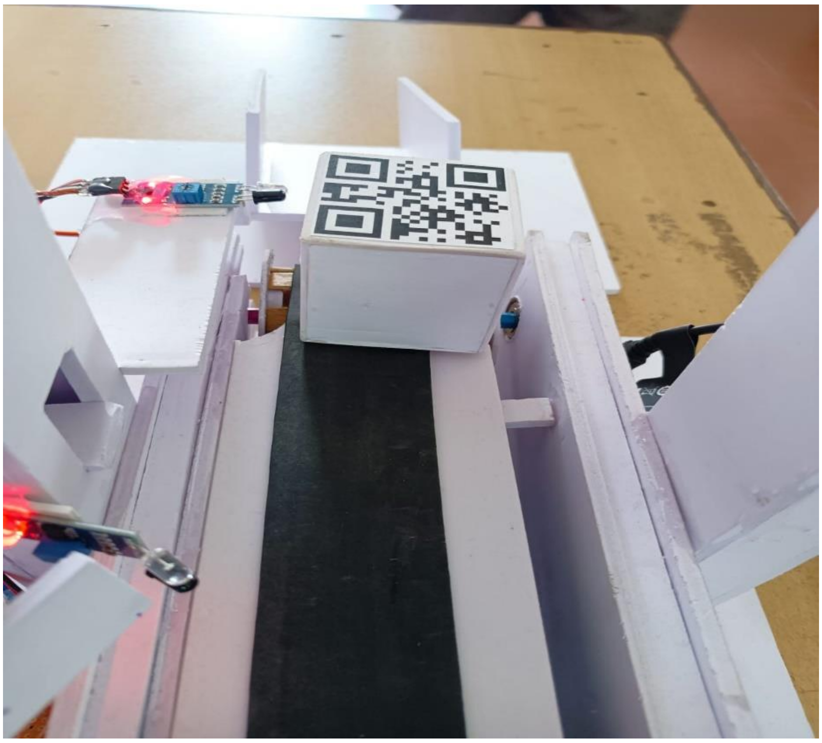

Figure 7. packet again detected by second IR sensor at the end of conveyor

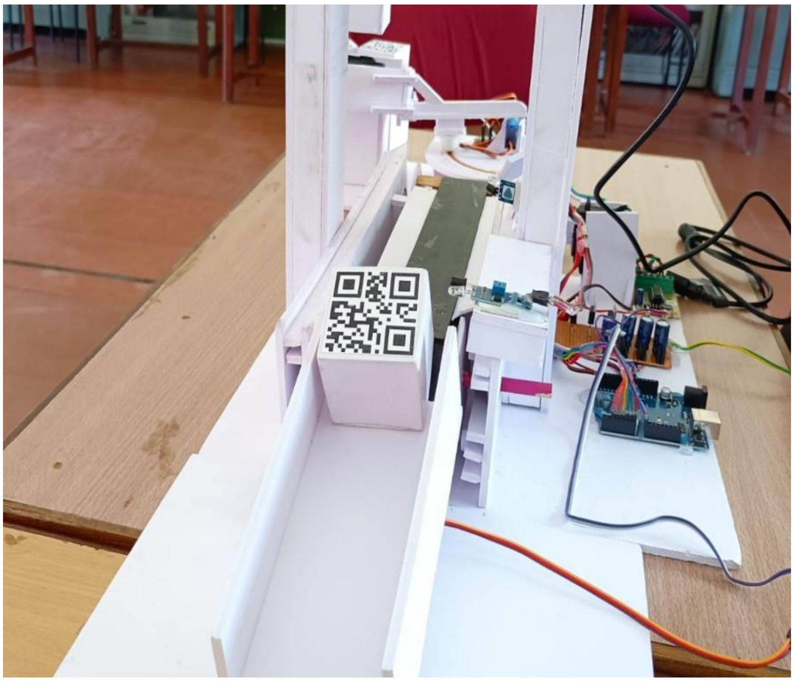

Figure 8..Motor Turn 45 degree angle for destination Kochi

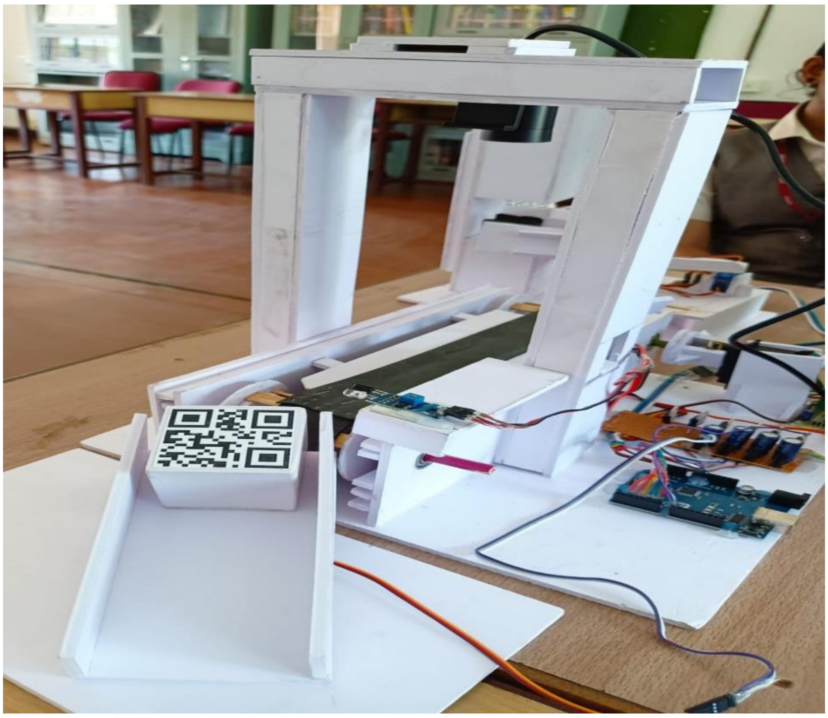

Figure 9.Motor Turn 100 degree angle for destination Kottayam

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