Computer Vision Robotic Arm with 5-DOF

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December 13, 2023

Abstract

This project represents the development and implementation of a computer vision-guided robotic arm with five degrees of freedom (DoF), utilizing Arduino-based control and 3D-printed components. The primary objective of this project is to design an advanced robotic arm capable of performing efficient material sorting and placing tasks in industrial settings, empowered by computer vision techniques for intelligent object recognition and manipulation. The pivotal aspect of this project is the integration of computer vision technology. A camera module is mounted on the end effector of the robotic arm, allowing real-time acquisition of visual information from the environment. Advanced computer vision algorithms are employed to recognize and track materials, objects, or products in the workspace.

Acknowledgments

We express our sincere appreciation towards the respectable faculty and Team ORIC at SZABIST for recognizing our efforts and awarding us as the runners-up in the ZAB-EFEST FYP module. We would also like to extend our gratitude to the judges for their valuable feedback and evaluation. Additionally, we acknowledge and are thankful to our supervisor, Ms. Tanzila Younas for constructive feedback and showing patience towards us. It is because of her valuable trust and faith that kept us moving forward. Last but not the least our fellow classmates for their continuous guidance, support, and supervision throughout the project's fabrication. Their collective experience and assistance were instrumental in making this project a reality.

Contents

List of Figures

Nomenclature

Acronyms

CVR-5	Computer Vision Robotic Arm with 5 Degree of Freedom)
DoF	Degree of Freedom
UAV	Unmanned Aerial Vehicles
DIP	Digital image Processing

Chapter 1

Introduction

1.1 Overview

A computer vision robotic arm with five degrees of freedom (DoF) is a sophisticated robotic system. A computer vision robotic arm with five degrees of freedom (DoF) is a sophisticated robotic system designed to interact with the environment based on visual information. It combines the principles of computer vision and robotics to enable intelligent object recognition and manipulation, making it a versatile and powerful automation tool designed to interact with the environment based on visual information. It combines the principles of computer vision and robotics to enable intelligent object recognition and manipulation, making it a versatile and powerful automation tool. The robotic arm can be employed in manufacturing environments for tasks such as material handling, sorting, and assembling. Its ability to recognize and adapt to different objects makes it suitable for flexible production lines.

1.2 Background

Robotic arms, also known as robot manipulators, are mechanical devices designed to mimic the movements of a human arm. They consist of multiple joints and links, enabling them to perform a wide range of tasks with precision and repeatability. Robotic arms have a long history of development, starting from early mechanical manipulators to the advanced, intelligent systems we see today. The evolution of robotic arms has been driven by the need for automation, increased productivity, and the desire to perform tasks in environments hazardous or inaccessible to humans.

1.3 Integration of Sensors and Computer Vision 2010s

Robotic arms began to incorporate advanced sensors, such as force/torque sensors and tactile sensors, enabling them to interact with objects more delicately and adapt to changing conditions. Computer vision technology became a critical component of robotic arms, enhancing their ability to perceive and interact with the environment intelligently.

1.4 Motivation

In today's rapidly evolving technological landscape, the integration of computer vision and robotics has unlocked immense potential for transforming various industries. The development of a 5 Degree of Freedom (DoF) computer vision robotic arm is driven by the aspiration to create an intelligent, versatile, and efficient automation solution that can significantly enhance productivity and precision in real-world applications.

1.5 Current State of the Art

The state-of-the-art for robotic arms with computer vision was highly advanced. These robotic arms were equipped with sophisticated computer vision algorithms that enabled them to detect and recognize objects in their environment, perform visual serving for precise control, and utilize 3D perception for spatial understanding. They could plan and execute complex grasping and manipulation tasks, learn from human demonstrations, and collaborate safely with human operators.

Industries like manufacturing and logistics benefited from their pick-and-place automation capabilities, and their flexibility allowed them to handle diverse tasks with minimal reconfiguration. However, the field of robotics and computer vision is continually evolving, and newer advancements may have emerged since then.

1.6 Statement of the problem

To construct the computer vision robotic arm with 5 DoF to sort out the objects in the real time running on industrial conveyer belts based upon shape and color of the object.

1.6.1 Solution of the problem

Computer vision robotic arms solve various problems across industries through their advanced visual perception capabilities. These arms can identify, track, and manipulate objects with precision, leading to increased automation and efficiency in manufacturing and logistics. They improve quality control by detecting defects during production, reducing waste and ensuring product standards. In collaborative environments, they work safely alongside humans, enhancing productivity. Additionally, computer vision robotic arms assist people with disabilities, optimize precision agriculture, aid in medical procedures, and operate in hazardous environments, minimizing risks to human workers. These versatile systems continue to advance and hold promise for tackling even more complex challenges in the future.

The problem solution for this research report is

"Pick and place operations, Quality control and inspection, Hazardous

environments.”

1.7 Objectives

Following are listed as

1. Improved Quality Assurance: Robotic automation eliminates the risks of vigilance decrement by accurately producing and checking items meet the required standard without fail.

2. Increased Productivity: Due to continuous and stress less work the production will take place continuously and will boost the production.

1.8 Applications

A variety of applications includes:

1. Image Processing and Object Recognition: The robotic arm’s computer vision system captures images of the objects using one or more cameras. Advanced image processing algorithms analyze these images to identify and recognize the shapes and sizes of the objects in the field of view.

2. Object Localization and Tracking: Once the objects are recognized, the computer vision system determines their positions and trajectories in the camera’s frame of reference. This information is used to calculate the necessary robotic arm movements to reach and pick up each object.

3. Pick-and-Place Operations: The 5-DOF robotic arm, with its five degrees of freedom, offers sufficient flexibility to navigate in the 3D space and position

the end-effector accurately. The arm is programmed to grasp and lift objects based on their shape and size, making it capable of handling various items efficiently.

4. Sorting Mechanism: The robotic arm transfers the picked objects to the appropriate sorting location based on predefined sorting rules determined by their shapes and sizes. This process can involve placing items on designated conveyor belts, bins, or specific areas on a sorting table.

5. Iterative Sorting: The robotic arm, guided by the computer vision system, continues to pick up and sort objects in a continuous and iterative manner until the sorting task is complete

1.9 Sustainable Development Goals

SDG 9, or Sustainable Development Goal 9, is a goal of the United Nations (UN) related to Industry innovation and infrastructure.

1. In the context of sustainable industrialization, robotic arms bring automation and efficiency to production processes.

2. By optimizing manufacturing operations, they reduce waste and resource consumption, thus aligning with sustainability goals.

3. Innovation and technological upgrading, a significant aspect of SDG 9, are exemplified by the continuous advancements in robotic arm technology.

4. Integration of computer vision and artificial intelligence enables robotic arms to evolve and contribute to cutting-edge technologies.

5. Furthermore, robotic arms find application in research and development activities, supporting the quest for sustainable solutions in various industries.

6. Addressing inclusively in industrialization, a crucial concern of the SDG, involves thoughtful integration of robotic arms with human workers. Human-robot collaboration ensures that the benefits of automation are shared inclusively, empowering the workforce with more meaningful tasks.

7. Ensuring access to technology is also a key consideration. Making robotic arms accessible to a wide range of industries, including small and medium-sized enterprises, can bridge the technology gap and enable more sustainable and efficient production processes.

8. Moreover, capacity building and skills development are imperative as industries adopt robotic arms. Equipping the workforce with the necessary knowledge to operate, program, and maintain these advanced technologies fosters inclusive economic growth.

9. Finally, the responsible and ethical deployment of robotic arms is essential to align their benefits with the broader objectives of the Sustainable Development Goals. By doing so, robotic arms can serve as a tool for sustainable and inclusive industrialization, innovation, and infrastructure building, contributing to the vision of SDG 9 and creating a more sustainable future

SDG 12, or Sustainable Development Goal 12, is a goal of the United Nations (UN) related to being responsible for consumption and production.

1. United Nations Sustainable Development Goal 12 (SDG 12) emphasizes the need for sustainable consumption and production patterns. While this goal

primarily focuses on human consumption and industrial processes, computer vision robotic arms play a vital role in contributing to its objectives.

2. These robotic arms optimize production processes by leveraging computer vision to identify and sort objects based on their characteristics. This level of precision reduces waste and minimizes the consumption of raw materials, aligning with the goal of resource efficiency.

3. Waste reduction is facilitated as computer vision-equipped robotic arms accurately recognize and handle objects during sorting and assembly tasks, minimizing the likelihood of defective products or materials being discarded as waste.

4. The integration of computer vision technology in robotic arms supports sustainable manufacturing practices. By enabling the production of high-quality goods with minimal defects, these arms contribute to responsible resource utilization.

5. Robotic arms with computer vision capabilities support the principles of the circular economy by facilitating the identification and retrieval of valuable components from discarded products, promoting recycling and reusing materials.

6. In terms of energy efficiency, computer vision robotic arms streamline production processes and reduce errors, leading to energy savings and aligning with SDG 12's objective of ensuring sustainable energy consumption.

7. The application of computer vision in robotic arms drives innovation and

research in automation and sustainable production. This ongoing advancement has the potential to influence various industries positively.

8. hese robotic arms contribute to sustainable supply chains by automating tasks such as quality control and inventory management, thereby enhancing supply chain efficiency and resilience.

SDG 9 and SDG 12 are amongst the 17 Sustainable Development Goals adopted by the UN in 2015 as part of the 2030 Agenda for Sustainable Development. The goals are designed to be a blueprint for a better and more sustainable future for all, and address a wide range of economic, social, and environmental issues.

1.10 Environmental, Social, Health, and Safety Impacts

Following highlights the benefits considering multiple factors:

1. **Environmental benefit:**
   Robotic arms equipped with computer vision are emerging as powerful allies in the pursuit of environmental sustainability. Through their precision, efficiency, and resource optimization, these machines contribute to reduced resource consumption, energy efficiency, and waste reduction. Moreover, their role in advancing recycling efforts and promoting circular economy practices fosters more sustainable consumption patterns. As they continue to revolutionize industries beyond manufacturing, including agriculture and environmental monitoring, robotic arms are poised to make even greater strides in safeguarding the environment and preserving natural ecosystems.

Embracing these cutting-edge technologies can pave the way for a greener and more sustainable future, aligning with global environmental goals and ensuring the wellbeing of both the planet and its inhabitants.

2. **Social benefits:**
   Robotic arms are more than just technological marvels; they are catalysts for positive social change. These advanced machines empower individuals with disabilities, enhance health care outcomes, and foster inclusion and accessibility. Embracing collaborative robotics encourages cooperation between humans and machines, leading to improved productivity and worker satisfaction. Additionally, the integration of robotic arms in various industries stimulates skill development and lifelong learning. As we continue to harness the potential of robotic arms, it is essential to strike a balance between technological advancements and human well-being, ensuring that these machines work hand-in-hand with humans to create a more inclusive, innovative, and prosperous society.

3. **Health and Safety benefits:**
   Robotic arms have revolutionized industries, providing numerous health and safety benefits to workers and society at large. They have improved occupational health, enhanced health care outcomes, and empowered individuals with disabilities. Collaborative robots have made shared workspaces safer, reducing the risk of accidents and injuries. However, it is essential to address challenges and risks associated with robotic arms, such as human error and ethical considerations. Proactive safety measures, comprehensive training, and ethical guidelines will play a pivotal role in maximizing the positive impacts and minimizing potential risks of robotic arms in society. Striking a

balance between harnessing the potential of robotic technology and ensuring the well-being of humans is key to creating a safer, more productive, and sustainable future for all.

Chapter 2

Literature Review

2.1 Overview

In the process to construct a robotic arm, we require proper design and simulation that is capable enough to perform tasks accurately and efficiently. For a 3 DOF robotic arm, we can see the design procedure and calculations presented in this paper as an example often found in medical biology laboratories where it's slightly similar to color sort objects such as test tubes. Through the mechanism in forward and inverse kinematics, the rotation angles of the end effectors assisted in determining position and orientation of the 3 DOF robotic arm. The former explains that in order to reach the desired position, the joint angles play an essential part. Also, the key elements like static torques, the most appropriate link cross sections, and the suitable workspace are needed in the inverse kinematics. [7]

The highlights shared in this paper for the designing and implementation of robot vision system operated through an interactive graphical user interface (GUI). As robotics becomes an increasingly integral part of the industrial complex, there is a need for automated systems that require minimal or no user training for operation. With this motivation in mind, the system designed so that even beginners can operate the device with little instruction. In this application, the user specifies the desired object, which is picked up by a robotic arm and placed at the target location. This application allows users to filter objects by color, shape, and size. Filtering along three parameters performed using a color recognition algorithm in Hue-Saturation-Value (HSV) mode, any shape recognition algorithm, and a sizing algorithm. Once the target object identified, a centroid detection algorithm used to determine the center coordinates of the object. Use an inverse kinematics algorithm to determine the joint positions of a robot arm to lift an object. The arm then cycles through series of preset positions to pick up and place the objects before returning the arm to its starting position. The joint coordinates passed to the microcontroller, which adjusts the arm's joint angles at each position. [10]

Patients require some assistance for their arm throughout training, which is a time-consuming and repeated task. The design and implementation for a low-cost and user-friendly interface for controlling a slave tolerated humanistic arm having 6 DOF. Six servo motors power the robot arm. If Gripper with 2 DOF is used to grasp items, force sensors are installed between the manipulator's joints to measure the amount with strain imposed on each joint. In order to analyze potential of man-machine interface, strict evaluation on the basis of numerous experiments had carried out as planned. The robot has a position precision of less than 0.5cm. [11]

The presenters wanted to bring light on an intelligent approach for inspecting and selecting objects in continuous flow in real time. Image processing has attracted the world and gained attention, as it could offered a wide range of application opportunities in many high-tech fields. The real challenge is to improve the existing classification system with new image processing capabilities in a modular processing system consisting of four integrated stations for identification, processing, selection and classification. Existing sorting methods use a variety of inductive, capacitive, and optical sensors to distinguish between the colors of objects. This article presents a mechatronic color sorting system solution using image processing. Image processing techniques detect objects in real-time images taken from webcams and identify colors and information from them. This information processed through image processing in the pick and place mechanism.

The classification process based on a two-step operation are: A self-learning step where the device learns how to identify objects and an operational selection process where objects are detected, classified using a decision algorithm, and selected in real time. This project deals with automatic material handling systems. The objective is to sort the colored objects moving on the conveyor belt by color and size by selecting objects and placing them during their pre-programmed locations. Elimination of the monotony of human tasks and improves accuracy and speed. This project includes a sensor that detects the color and size of an object and sends a signal to a microcontroller. The microcontroller sends signals to circuits that drive various motors in the robot arm, which grabs objects and places them in designated locations. Based on the detection, the robot arm moves to the specified position, releases the object and returns to the original position. [13]

The researchers wanted to suggest ways that had an aim to leverage advances in information and communication technology (ICT) to improve waste management systems and lives. To maintain greenery, we consider Waste management and separation as a necessay task for environment safety and better (re)use resources. At a high rate density affected Bangladesh, people faced extensive challenges while dealing with excessive waste. The development of an Automatic waste separation system carried a series of light weighted experiments to evaluate the system, with a repetation 11 objects (waste) of different sizes and types. The results showed that the proposed system as reliable and achieved an accuracy of about 82 percent in classifying different types of waste. [5]

This authors describe one application that uses computer vision performed with Open CV equipped with microcontroller and a robotic arm to classify objects uses screening method as it's fast and does not require constant monitoring, facilitating industry growth leading to productivity and income. The image processing helped to attain results near approximation if robotics implementation is accurate. A lifecycle of every business faces major and minor obstacles, such as lack of time and labor, which leads to inefficient manufacturing. Various algorithms integrated into the microcontroller allow the robotic arm to classify objects based on defects such as missing drill holes, incorrect geometries, and other errors. [19]

The Author highlights development of an automatic fruit harvesting system that combines a low-cost stereo vision camera and a robotic arm placed on a grasping tool to estimate a fruit's the size, distance, and location. The harvesting stage requires calculation of the initial position of the fruit, the inverse kinematics of the robot arm to position the gripping tool in front of the fruit, and the final acquisition approach by iteratively adjusting the vertical and horizontal positions of the gripping tool in a closed visual loop. A stereo vision camera was attached to the gripping tool could be used for the robotic arm to pick up mechanically. Laboratory conditions controlling the process, a team of experts tested the system after completion with uniform illumination of the fruit, the cost-effective stereo vision system was tested under laboratory conditions at around ten different distances from the camera using small reference objects, an apple and a pear. It noticed that an average distance errors ranged from 4 to 5 percent, average diameter errors up to 30 percent for small objects, and 2 to 6 percent for pears and apples. Many Speculation were made about this system to be tested and refined under conventional outdoor conditions. [9]

The author's aim was to bring in a new dynamic fruit planning system designed to coordinate the four arms throughout the harvesting process. The requirements of horticulture labor became more demanding, automated solutions with an approach to maintain productivity and quality. This article describes the design and performance evaluation of a new multi-arm kiwi harvesting robot designed for autonomous operation in a pergola orchard. This harvester consists of four robotic arms specially developed for kiwifruit harvesting, each equipped with a new end effector safely harvest kiwifruit. This vision system leverages recent advances in deep neural networks and stereo matched reliably detect and localize kiwifruit under real-world lighting conditions. Uncertainity in performance meassure of the harvester through comprehensive and realistic field tests in a commercial orchard environment. The results show that the presented harvester can successfully harvest 51.0 percent of the total kiwi fruit in the orchard with an average cycle time of 5.5 seconds/fruit. [20]

In many situations, autonomous robots always provide an effective solutions for laborious tasks. The AT89S52 microcontroller is the heart of the circuit that controls all functions. Its desirable to create an autonomous robot that identified an object on a conveyor belt and managed the placement of objects that met the criteria. Handling large numbers of objects wasn't simple task, but such an application for this type of robot made things easy. The low costs and design complexity in robot built around a platform and uses several different robots. Sensors that collect information about the robot's environment so that the robot can react accordingly. This article is about the problem I'm trying to solve. The goal is to create an autonomous robot that can identify objects placed on a conveyor belt based on color recognition and classify the objects by moving to a specific location. A gripper arm used to pick up each object from the conveyor belt using a controlled motor and place it according to color recognition. Microcontroller (AT89S52) allows dynamic and fast control. A liquid crystal display (LCD) makes the system easy to use. [17]

This work presents a process for automatically classifying parts of different colors. This paper highlights the result of an in-depth interdisciplinary study in industrial automation, specifically focused on robotics, computer science or the control of flexible manufacturing systems. The hardware and software system consists of a robot arm with color sensor along a conveyor belt, over an ejection cubic storage system, and a robot arm transport system. The author intends to use a robotic arm to pick up cubes from a tray and move them on a conveyor belt. The cubes are identified based on color, and once the pieces reach the end of the conveyor belt, they are picked up by a robotic arm and sorted by color. The applied motivation created a platform that provided students, researchers, and engineers with the opportunity to track operational control systems for classifying various objects manipulated by robotic arms and real-time monitoring of industrial processes. You can . This research incorporates knowledge from mechanical, electrical, and computer science (mechanical and electrical drives, sensors and transducers, structures and flexible systems design, electronic devices and circuits), and this research clearly aims to develop a system that automates the classification of parts by size. Colors expressed without external human intervention to the experimental model realization attempts to apply various automation knowledge to an industrial process on a laboratory platform to study events related to the control and monitoring of a flexible color sorting line. [16]

Factors discussed in this paper describes that Robotic automation is preferred because the human eye cannot always distinguish colors, ultimately reduces work efficiency. A system proposed and implemented using a robotic arm to classify objects based on shape and color. This system captures real-time images from webcams and preprocesses them through RGB to HSV conversion and denoising using a median filter. An object with color recognition system based on its lower and upper HSV values. Next, the system performs shape recognition of the object using contour recognition technology. In this method, contours identified utilizing a modified boundary fill approach, and then shapes are recognized based on the contours using the Douglas-Peucker algorithm. The robotic arm that was designated to classify objects based on their identified shapes and colors. Also, tested on three object shapes: square, triangle, and rectangle. [8]

Based on inverse kinematics, the author indicates that Robotic arms have automatic motion that can successfully navigate the Industry 4.0 revolution among manufacturing companies utilized to evolve into a technology. An ability to behave like a human means that the robotic arm must use peripherals. The aim of this research was to develop a design that can use the Kinect sensor as a peripheral to enable the human ability to see objects. From a case study, we conducted a color-based object classification simulation, where the experimental tests showed that the average error percentages of the end effector position in X, Y, and Z coordinates were 5.83 percent, 5.89 percent, and 8.59 percent, respectively, Such result means that a robot arm with a Kinect sensor can specifically classify and move objects based on color. Robotic arms might have good chance to interact with humans and solve problems, had become an authentic research topic. [3]

The main focus of this work is the design and development of a system of two robotic arms for classifying and sorting objects based on shape and size using machine vision. The system uses a low-cost, high-performance hierarchical control system includes one master and two slaves. Each slave is a microcontroller-based robot controller that receives commands from the master independently control the robot arm. The master is an embedded computer for image processing, kinematic calculations and communication. A simple and efficient image processing algorithm was to proposed that can be applied in real time, helping to reduce the time of the sorting process. The proposed method uses a series of algorithms indicated to contour finding, boundary extraction, centroid algorithm, and shape thresholding for object recognition and noise elimination. 3D coordinates of objects are estimated only by solving a system of linear equations. The movements of the robot joints planned to follow a trapezoidal profile with an acceleration/deceleration phase, helping the robots move smoothly and reducing vibration. Experimental evaluation reveals the efficiency and accuracy of the robotic vision system in the sorting process. The system can be used in an industrial process to reduce the time required to achieve a production line task, leading to improved production line performance. [4]

Industry 4.0, or the Fourth Industrial Revolution, refers to the next stage in the digitization of the manufacturing sector. There, the Internet of Things (IoT) is likely to play a major role, potentially providing information and creating value for manufacturing. Achieve low-volume, high-quality production in a cost-effective manner. This also includes managing and organizing the entire value chain process in manufacturing. Various organizations are advocating the concepts of the Industrial Internet of Things and Industry 4.0 to create smarter things. Industry

4.0 is a new area where the internet of things alongside cyberphysical systems interconnect in a way where the combination of software, sensor, processor and communication technology plays a huge role for making 'things' to have the potential to feed information into it and eventually adds value to manufacturing process. [15]

Object speculations could based on it's shape properties, centroid algorithms, and edge extraction from what the writers proposed a robot vision system that identifies an object's color and their positional coordinates and sorts objects (products) by color on a right-branching belt conveyor in real time. The pointers shared and discussed in the paper about object detection and contour coordinate extraction and implementation using a number of image processing technique, object's color gets detected, the microcontroller starts the robot's movement. Not all systems can have based on HVS mode algorith for classifying products by color. Also, a classified set of objects based on color characteristics was an objective achieved from a collection of objects. Moreover, the system could update shape detection of the object, determine its position, pick up the object shape, and place it on the correct branching conveyor belt. Specific sort of robots had movements like (opening and closing of the gripper, up and down, left and right movements of the arm) are controlled by a microcontroller that controls the right-side movement to the branch conveyor belt. The results authencity based on the approach developed in this paper was 92 percent for object shape classification and 97 percent for color classification. [1]

All pointers mentioned in article about mechanical design and kinematic analysis, simulation studies, and practical applications to discuss comprehensive control of its performance describes remote vision-based manual motion control of a five-degree-of-freedom (DoF) articulated industrial robot arm for remote operation. When focused to study the positioning of the robot manipulator that was suppose to be determined by the operator, while robotic system had considered as a fixed-base that went on with various development for an equipped and ensured to remotely manage tasks that were operational in order to improve workplace safety and facilitate the work of professionals. Also, a human operator operates the robot arm using a controller according to the received camera images. The Authors instict proposed a system with features like a modular mechanical structure to simplify operation and maximize the performance of the robotic arm. In order to maintain standard communication, a technology known as IEEE 802.11 used as a three-way communication path. A live camera recorder had a suitable wide-angle to capture image, and then sent to base station along with the data bits. A Computer-aided design performed before any developed system transferred to the real world, and then remotely controlled robotic arms used to handle heavy and hazardous loaded material and explore uninhabitable spaces. The kinematic model validation was suppose to done by observing the output response obtained from the simulation study. Similarly, a kinematic design of a five-degree-of-freedom robotic arm was in development process, a sophisticated model that reflects real-world motion. [6]

This article presents a project to develop a robust robotic arm capable of performing multifunctional tasks. The manipulator's control was dependent on an Arduino Mega 2560 microcontroller, with the purpose of this project is to focus all the axes of the manipulator to lift, carry, and lower an object at the desired location. It requires precise drive motion control, including an electric motor as the drive system. Further experiments performed to implement his camera-based 3D vision system integrated with computer vision algorithms to detect object deformations with a spatial adjustments and control deviations from the original training. The 3D visualization system can recognize the distance between the object and the end effector and send a signal to the drive system. Image processing systems require separate computer hardware that could've handle complex image processing algorithms. A Raspberry Pi microcontroller used to process the vision data. That allowed the vision system to recognize specified objects according to program commands. [14]

Industry 4.0 ultimately aims to construct an open, smart manufacturing platform for industrial networked information applications.Our 4th Industrial Revolution will be based on cyberphysical systems, the Internet of Things and Internet of Service. More companies and nations are joining the movement with different approach so as to be competitive in order to benefit from the productivity and economic gains at provides. Although industry 4.0 covers a very wide application area in the manufacturing industry, the trend is quickly materialized with the new emergence of new robotic and automation product innovation that is tailored for industrial revolution. [12]

This paper highlights the importance of subsets for Robotic arms, defined as electromechanical machines controlled by electronic or computer programming. To ensure safety, implementation of multiple methods that can avoid any extremely dangerous or impossible for humans, such as digging, spraying, heavy lifting, welding, and rescue operations. This article presents an RF-controlled pick-and-place method for designing and manufacturing robotic vehicles. The components in manufacturing are RF transceiver modules, encoder and decoder ICs, microcontrollers, voltage regulators, servo motors, motor drivers, batteries, and other electronic components and materials. The completed prototype weighed approximately 1.35 kg and had length, width, and height dimensions of 25.5 cm, 20.5 cm, and 45.0 cm. Vehicle controlled from a maximum distances. The RF remote control can reach a range of 100m and perform the desired operation (lifting and placing small objects) smoothly. [2]

Demand for industrial robots is increasing in many areas, from spraying and welding to transportation, handling, assembly and material processing. When implementing new software, the requirements become more complex and precise, placing greater demands on robots and controllers. The need to develop robot controllers with new software and communication technologies is growing, especially in India, as a proper robot controller design can significantly improve performance. Since PLCs are the most commonly used controllers in industrial processes in all fields, the economic condition faced very high, their maintenance and programmer required huge. To rsolve economic factor, a 6-axis industrial robot with simple equipment and low cost control base developed. The same factor will demonstrate PLC functionality using Python programming and web development control using a Raspberry Pi. [18]

Throughout this paper, in order to inspect and select any object based on a real time smart approach in continuous flow then it depends on the color size. That will be sorted and sensed while flowing on conveyor.For this, camera used as input sensor, The camera will take a snap and it will feed to PC for color processing. In PC Matlab is used for processing on color., depending on this signal will be given to micro controller AT mega 328. The micro controller in turn will control the servomotors by PWN signals. These servomotors will control the movement of robotic arm by controlling their angular movement. Fully functional sorter machine can be implemented by using a structure of parallel and independent channels in order to increase the overall through put which results with a forecasters performance.

The project can work successfully and separate different objects using sensors. The sensor handling systes which drive the pick and place robot to pick up the object and place it into its designated places can work if accurately designed. There are 2 main steps in sensing part, objects detection and recognition. The system can successfully perform handling station task, namely pick and place mechanism with the help of sensor. Thus, a cost effective Mechatronic System can be designed using the simplest concepts and effective result can be observed. High efficiency: the working speed can be high.

Keeping in mind the high scale precision of encountering errors and making sure to reduce them to a greater extent. Various kinds of vegetables can be detected based on PLC control of different colors that are selectively suitable for fruits like pears, orange and others. Any highly efficient machine can control good quality and low failure rate with degree of intelligence machine which has a realizable operation and maintenance.

The robotic arm has been created with a dimension SST 1200es 3D rapid prototyping printer in ABS (FullCure720) plastic material which includes 6 low-cost DC gear motors controlled by a cortex. M4F ARM STM32F407VGT6 micro controller that provides velocity and speed control and different connectivity options. On initial fruit detection stage was specifically tested with 2 segmentation algorithms in the case of using reddish pears as fruit targets. The time-performance of the complete harvesting prototype also tested, requiring an average time of 16 sec to detect and pick up a pear, whereas the limitations found in mechanical side were 95 percent originated and imposed to the robotic arm.

The design and development of a 5-DOF robotic arm for feeding the elderly or those with special needs. The operator determines the positioning of the robot's arms using robotic kinematics concepts and MATLAB. The main heart of this project are its components, that connects with the graphical user interface, motors, and sensors. The simulation tool MATLAB has been employed to confirm the exactness of the kinematics algorithm. A recovery program and machine is being developed. This wearable robot arm works well with both users' arms. Each joint has a range of rotation from -90 to 90 degrees, allowing it to encompass all human arm motions.

A 6 DOF manipulator developed to benefit in Ideal for extraterrestrial environments and space exploration. The robot contructed from advanced composite materials with features Light wieghted with high precision. There are two types of arm tips that enable the effectors adaptive use of both symmetrical and asymmetrical objects expensive. This arm is configurable can perform a variety of tasks that have space applications can efficiently use a single platform. A 5 degree-of-freedom robot arm manipulator that controls direction and uses a Cortex ARM M3 LPC1768 microcontroller. The servo Each joint has a motor that positions each connection. A rotary encoder can be adjusted to each angle using position control and measured. The bad news is that it also works at high temperatures and pressures. An environment unsuitable for humans. The functionality of the designed robot arm would have been verified by attaching it to the wearable robot body and conducting various experiments. The arm controlled by his 8052 MCU in an Atmel arrangement. The authors presented the following experimental results. You can organize the system of two robot arms have developed a binocular vision and payload retention. This survey is Signal transmission complete, speed and crisp control completed PC into double automatic arm frame.

The kinematics method is the movement geometry of the robot manipulator from a reference position to a desired position that creates force or other factors affecting the robot's movement. In kinematics he has two main classes: forward kinematics and inverse kinematics. Use forward kinematics to transfer joint variables and determine the end effector position. On the other hand, inverse kinematics applied to determine the joints variables from the end effector position.

With the development of industrial automation, robotic arms efficiently used to replace human on production floors increasingly to perform high-risk and repetitive tasks. Compared with traditional robot arms, four-axis robot arms are gradually came in industrial production scenarios due to their structural stability, ease of maintenance, and scalability. In recent years, research has mainly focused on path planning algorithms to improve the intelligence of robot arms, innovations in the software and hardware systems of robot arms to reduce cost and power consumption, and the best utilization of robots. I'm guessing. The arm system has improved the application scenario, leading to improvements in the development of robotic arm systems. However, as robotic arms gradually become used in various industries, industrial automation places higher requirements on the intelligence and portability of robotic arms.

A study of project-based learning developed knowledge of computer vision and robot control to complete tasks that detects small objects randomly placed on a target surface and controls an educational robot arm to pick them up and move them to a predefined target. Robot arm systems determined an extensive use of computer vision and robot arm control theory, but the degree of automation is low. They were unable to analyze autonomously perform precise grasping. From earlier researches found an image segmentation algorithm with a dynamic programming algorithm and an occlusion algorithm to improve the success rate of picking the harvester. An image segmentation algorithm (based on SVM pixel classifier, watershed transformation, and point cloud registration) is responsible for the detection and localization of eggplants. Experimental results show that the robot arm can harvest 91.67 percent of the numerous eggplants in the proposed collaborative scenario. This system uses computer image processing algorithms rather than deep learning algorithms to detect targets, resulting in lower accuracy. A massive announcement about control system for intelligent manipulators created waves in industry. The target object is recognized by the vision system and displayed to the user in a video. By analyzing the acquired brainwave signals, a brain-computer interface that infers the exact object was much needed. These results are sent to a unique control system, allowing precise object manipulation with visual servo technology. By coordinating task motion and ego-motion method (CTS), the robot has autonomous obstacle avoidance capability, the intelligence of the joint control systems improved. Such system contained a basic color separation algorithm for the target detection algorithm, and complex colored objects cannot be detected independently.

To enable mobile robots to complete complex tasks such as explosive ordnance disposal with two dexterous hands, Sun etal. We developed a control approach. Operations involved to make faster R-CNN is used to determine the grasp range for robot operation through object detection and learning. Finally, the explosive ordnance disposal scene aims to justify its effectiveness and good performance. This robot arm was good movement effective, neither it's portable, nor applicable on a large scale.

The arm robot is controlled via a Raspberry Pi with an endoscopic camera sensor. The inverse kinematics method applicable to the arm robot. Computer vision technology and shape recognition techniques are applied to camera sensors to identify the shape of moving objects. As a result of the shape recognition study, two errors occurred for the triangular shape in around 15 tests. The inverse kinematics method for arm robots has an error of 0.6cm to 5.3cm. The camera sensor performs well at a light intensity of 59 lux, with hue, saturation, and value segmentation (HSV) values ranging from low HSV (0,103,120) to high HSV (180,255,255). Based on these issues and previous research, the authors developed a task of detecting objects based on the color and shape of grouped objects using a CV image processor and moving object from one position to another. We developed a four-degree-of-freedom (DOF) arm robot that can be executed. Each joint driven by a servo motor controlled by an Arduino Uno and a camera sensor that acts as a color-based object detection tool. The working principle of this system is that the input takes the form of red, yellow and green cubes and placed on a working surface of 15 cm x 30 cm. Things are left carelessly in the work area. During the process, colors recorded along with shapes, the camera carried out in the open CV program. The results of the image processing program are the coordinates of the X and Z axes and the color of the object. The data is then sent to the Arduino Uno via serial communication, coordinates processed using inverse kinematics techniques to obtain the angles of the joint roots, shoulders, elbows, wrists, and grippers. The angle value is sent to each servo of the articulated robot, so that the end effector robot driven can be the target point and the robot arm's gripper can reach the desired object and place objects into the container according to the detected color with a camera.

Three-dimensional recognition is one of the authentic technologies for robots. A 3D view of the robot's environment is essential for fully autonomously performing navigation and manipulation tasks in an imperfectly known environment. Furthermore, remote control of robots requires human-readable visualization of the environment, which is authentic for an intuitive user interface. Therefore, vision systems for robot guidance generally need to acquire 3D information. For a given point in the scene, the corresponding point in the image determined using a mathematical model. That's the immediate problem. This process was known as camera calibration, since a set of parameters distuinguish that describes the association between her 3D points in the world coordinate system and his 2D image coordinates. The perspective projection coordinated onto an image rarely modeled using a graphical representation, the pinhole camera model. Using this model, an image of his 3D point P formed by rays passing through the optical center and intersecting the image plane. The result is a point P‘ in the image plane, located a distance f (focal length) behind the optical center.

Chapter 3

Experimentation

3.1 Experimental Framework

The experimental framework follows functions mentioned below, that are to be done stepwise manner:

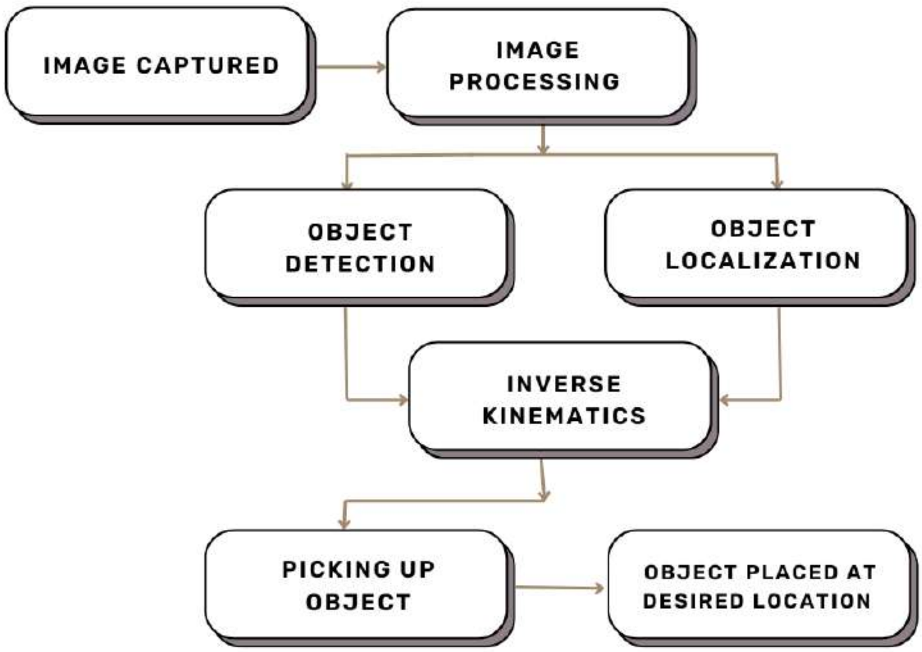

Figure 3.1: Experimental Framework

Step 1. Define Object Sorting Requirements:

Identify the specific objects to be sorted based on their shape and size.Determine the desired sorting locations or bins.

Step2. Robotic Arm Design and Assembly:

Design the 5-DOF robotic arm with NEMA 23 and 17 actuators to meet the payload and reach requirements for the objects to be sorted. Assemble the robotic arm, ensuring proper calibration and alignment of the joints.

Step 3. Camera System Setup:

Mount a high-resolution camera on the robotic arm or in the workspace to capture images of the objects for object detection. Connect the camera to the Arduino Mega using appropriate communication interfaces (e.g., USB or SPI).

Step 4. Image Preprocessing and Object Detection Algorithm:

Implement image preprocessing techniques (e.g., noise reduction, image enhancement) in Arduino Mega to optimize image quality. Develop an object detection algorithm using OpenCV library or custom image processing code to identify the shape and size of each object.

Step 5. Calibration and Testing:

Calibrate the robotic arm and camera system to ensure accurate positioning and alignment. Test the object detection algorithm to verify its accuracy in recognizing the objects based on their shape and size.

Step 6. Sorting Logic Implementation:

Design and implement the sorting logic in Arduino Mega based on the output of the object detection algorithm. Define the rules and decision-making process for sorting objects to their appropriate locations or bins.

Step7 Control System Integration:

Integrate the robotic arm, camera system, and object detection algorithm into the Arduino Mega as a unified control system. Develop the code to coordinate the movements of the robotic arm and the operation of the camera and image processing.

Step 8 User Interface and Interactivity:
Create a user interface using a display module (e.g., TFT LCD) or serial communication to interact with the robotic arm system. Allow users to input sorting parameters and monitor the sorting process through the interface. Allow users to input sorting parameters and monitor the sorting process through the interface.

3.2 Experimental Setup

This whole physical setup is 3D printed at our very own company named as 3D verse under the supervision of this group members, our robot body printed in different parts then we assembled in whole using components like brass inserts, nut bolt, timing pulleys, and belts.

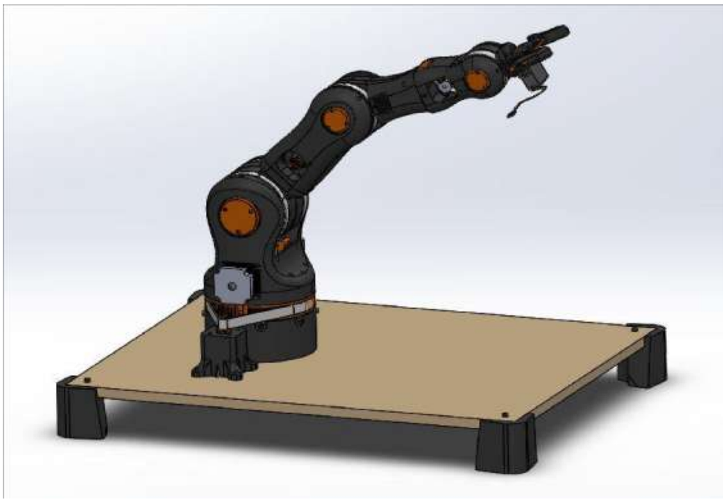

Figure 3.2: CVR-5 CAD MODEL

The robotic arm has five joints (DOF). Links 1, 2, and 3 have pure rotational joints (i) along the z-axis, while links 4 and 5 have prismatic joints (di) along the z-axis. The twist angles (i) for links 4 and 5 can be non-zero if the joints are not perpendicular to each other.
Here is a table with DH Parameters:

link	ai (link length)	di (link offset)	Tetai (joint angle)	a (twist angle)
1	1.1	0	teta 1	0
2	1.2	0	teta 2	0
3	1.3	0	teta 3	0
4	0	D4	teta 4	4
5	0	D5	teta 5	5

The actual values of these DH parameters (L1, L2, L3, d4, d5, 4, 5) depend on the specific geometry and configuration of the robotic arm. These values are determined based on the physical design and kinematics of the arm and are typically provided in the arm's specifications or documentation.

3.3 Image Processing

Image processing in a robotic arm for computer vision involves using Python and various image processing techniques to detect objects of different shapes and sizes in images captured by a camera system. The process typically includes the following steps:

A. Image Acquisition:

The camera system captures images of the workspace, containing objects to be detected and sorted by the robotic arm.

B. Preprocessing:

The acquired images may contain noise, variations in lighting, or other artifacts that could affect object detection. Preprocessing techniques, such as noise reduction, contrast enhancement, and image normalization, are applied to improve the quality and standardize the images.

C. Object Detection Algorithm:

A computer vision algorithm is developed in Python using libraries like OpenCV. This algorithm processes the preprocessed images to identify objects of interest. Various techniques, such as edge detection, contour analysis, and feature extraction, are used to detect object boundaries and characteristics.

D. Shape and Size Classification:

The detected objects' contours and features are analyzed to classify their shapes and sizes. The algorithm can use shape descriptors (e.g., Hu moments, Fourier descriptors) to identify shapes like circles, rectangles, triangles, etc. Additionally, the dimensions of the detected objects can be measured to determine their sizes.

E. Decision-Making and Sorting:

Based on the shape and size classification results, the Python program makes decisions regarding the sorting destinations for each object. The robotic arm's control system is communicated with these decisions to perform the sorting process accurately

3.4 Inverse Kinematics

Inverse Kinematics (IK) is a computational process used to determine the joint angles or joint positions of a robot's manipulator (e.g., robotic arm) to achieve a desired end-effector position and orientation in the workspace. For a robot with 5 degrees of freedom (DOF), the IK problem involves finding the joint angles , , , , and that result in a specific end-effector position (x, y, z) and orientation (roll, pitch, yaw). The IK process for a 5-DOF robot involves the following steps:

A. Forward Kinematics:

   To begin the IK process, it is essential to have a well-defined forward kinematics model for the robot. The forward kinematics model relates the joint angles to the position and orientation of the end-effector in the workspace. It is usually represented by a set of transformation matrices that define the relationship between each joint and the end-effector.

B. Desired End-Effector Pose:

   The user or the control system specifies the desired position (x, y, z) and orientation (roll, pitch, yaw) of the robot's end-effector in the workspace.

C. Solving for Joint Angles:

   The IK algorithm aims to find the joint angles (, , , ,) that satisfy the desired end-effector pose. This is achieved by solving a system of equations derived from the robot's forward kinematics equations.

D. Analytical Methods:

   For some robot configurations, there might be analytical solutions to the IK problem, allowing for direct computation of joint angles. However, for more complex robot geometries, analytical solutions may not exist, and numerical methods like the iterative NewtonRaphson method or the Jacobian-based methods are used to iteratively approximate the joint angles that achieve the desired pose.

E. Joint Constraints:
While solving the IK problem, joint constraints must be considered to ensure that the joint angles fall within the physical limitations of the robot's actuators and mechanical structure. Joint limits, velocity limits, and singularity avoidance are some of the constraints that need to be taken into account.

F. Multiple Solutions:
In some cases, a 5-DOF robot may have multiple solutions for a given end-effector pose. In such situations, the IK algorithm may need to select the most appropriate solution based on specific criteria or constraints.

G. Real-Time Implementation:
For real-time control of the robot, the IK algorithm needs to be efficient and computationally feasible, ensuring that the robot can adjust its joint angles and reach the desired pose accurately and quickly.

Inverse Kinematics is an essential aspect of robotic control and enables the robot to perform tasks in a specified position and orientation in the workspace. Solving the IK problem for a 5DOF robot requires a combination of mathematical analysis, numerical methods, and considerations of joint constraints to achieve accurate and reliable motion planning

Chapter 4

Implementation

4.1 Hardware

The hardware part of the project is the body of robotic arm which is 3D printed and the actuators which are NEMA 23 and NEMA 17 that will be integrated with micro controller and move according to the CV program.

4.2 Equipment

4.2.1 Tools

A. NEMA 23

1. Size:
   NEMA 23 motors have a standard flange size of 2.1 inches (53.1 mm) square. This refers to the mounting face dimensions, which allow for compatibility with corresponding mounting brackets and couplings.

2. Step Angle:
   Stepper motors are known for their precise movements achieved through step angles. NEMA 23 motors typically have a step angle of 1.8 degrees per step. This means that the motor rotates 1.8 degrees with each electrical pulse received.

3. Holding Torque:
   NEMA 23 motors offer considerable holding torque, which is the maximum torque the motor can apply to hold its position when energized. The holding torque depends on the specific motor design and can vary between different manufacturers and models.

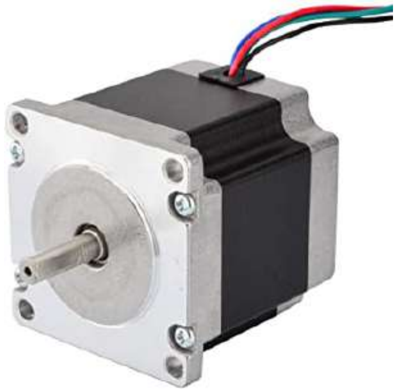

Figure 4.1: NEMA 23

4. Operating Voltage and Current:
   The electrical specifications of NEMA 23 motors may vary depending on the winding configuration. They generally operate on a voltage range from a few volts to several tens of volts. The current rating can also vary, ranging from a few hundred milliamperes to several amperes.

5. Coil Resistance and Inductance:
   Stepper motors have coils with specific resistances and inductances. The resistance and inductance values determine the motor's electrical characteristics, such as its response to voltage and speed profiles.

6. Rotor Inertia:
   The rotor inertia is an important parameter for stepper motors, especially in applications requiring quick acceleration and deceleration. A lower rotor inertia allows for faster response times.

7. Operating Temperature:
   NEMA 23 motors are designed to operate within specific temperature ranges, ensuring reliable performance under normal operating conditions.

8. Shaft Options:
   Stepper motors typically offer different shaft options, such as single or doubleended shafts, with various shaft lengths and diameters to accommodate different coupling and attachment methods.

9. Environmental Protection:
   Depending on the application, NEMA 23 motors may come with different levels of environmental protection, such as IP ratings for dust and water ingress

B. NEMA 17

A. Size:
   NEMA 17 motors have a standard flange size of 1.7 inches (43.2 mm) square. This refers to the mounting face dimensions, which allow for compatibility with corresponding mounting brackets and couplings.

B. Step Angle:
   NEMA 17 motors typically have a step angle of 1.8 degrees per step. This means that the motor rotates 1.8 degrees with each electrical pulse received.

C. Holding Torque:
   NEMA 17 motors offer a range of holding torque options, depending on the specific motor design and construction. The holding torque can vary between different manufacturers and models, but it is generally lower than larger NEMA sizes.

D. Operating Voltage and Current:
   The electrical specifications of NEMA 17 motors may vary based on the

winding configuration and the specific motor's intended use. They generally operate on voltages ranging from a few volts to around 24 volts. The current rating can vary from a few hundred milliamperes to a few amperes.

E. Coil Resistance and Inductance:

NEMA 17 stepper motors have coils with specific resistances and inductances. These electrical characteristics influence the motor's response to voltage and speed profiles.

F. Rotor Inertia:

Rotor inertia is an important parameter for stepper motors, affecting their ability to accelerate and decelerate quickly. NEMA 17 motors typically have lower rotor inertia compared to larger stepper motor sizes.

G. Operating Temperature:

NEMA 17 motors are designed to operate within specific temperature ranges to ensure reliable performance under normal operating conditions.

H. Shaft Options:

NEMA 17 stepper motors come with various shaft options, such as single or double-ended shafts, with different shaft lengths and diameters to accommodate different coupling and attachment methods.

I Environmental Protection:

Depending on the application, NEMA 17 motors may come with different levels of environmental protection, such as IP ratings for dust and water ingress.

J. Applications:

NEMA 17 motors find applications in a wide range of industries, including 3D printers, CNC machines, robotics, camera automation systems, and other precision motion control applications

4.2.2 Working Principle

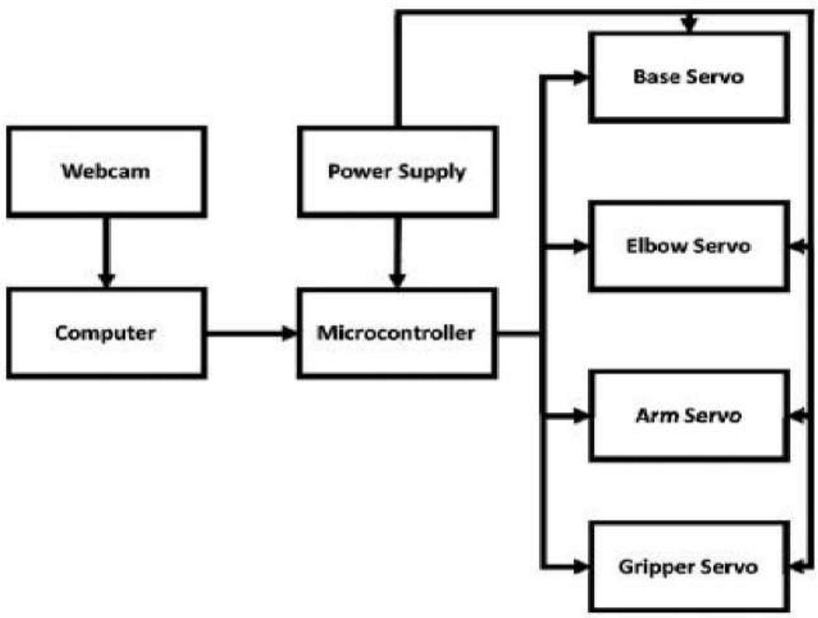

Figure 4.2: Working

A. Camera Setup and Object Detection:
   Mount a camera (e.g., webcam or Raspberry Pi camera) above the conveyor belt to capture live video feed of the objects moving on it. Utilize OpenCV libraries in Python to process the video stream and perform object detection. OpenCV provides various pre-trained deep learning models like YOLO (You Only Look Once) or SSD (Single Shot Multibox Detector) that are capable of detecting objects in real-time.

B. Communication with Arduino: Establish communication between the Python script running OpenCV on the computer and the Arduino Mega microcontroller using a serial communication protocol (e.g., USB or Bluetooth).

C. Arduino Control Logic: Develop the control logic on the Arduino Mega to receive commands from the Python script and control the movements of the robotic arm. Implement code to read data from the Python script, such as the detected object's coordinates, shape, and size.

D. Robotic Arm Kinematics: We Define the kinematics of the 5-DOF robotic arm. This involves calculating the joint angles required to position the end effector (gripper) at a specific point in 3D space based on the detected object's position.

E. Actuation Using NEMA 21 and NEMA 17: Map the joint angles calculated in the kinematics step to the appropriate steps or rotations required for each NEMA 21 and NEMA 17 motor to achieve the desired arm configuration. Send control signals to the stepper motor drivers that are connected to the NEMA 21 and NEMA 17 motors, ensuring precise and controlled movements.

F. Object Pickup and Placement: Based on the object's position and size detected by OpenCV, use the robotic arm to move the end effector (gripper) to the object's location and pick it up.

G. Relocate the object to a specified location on the conveyor belt or to another location as required

H. Feedback and Iteration: Implement feedback mechanisms to ensure accurate object detection and proper arm movements. For example, Continuously optimize and fine-tune the system by collecting data from the conveyor belt and adjusting the robotic arm's parameters accordingly.

4.3 Software

A. ARDUINO IDE

B. MATLAB FOR ROBOTICS

C. PYTHON FOR DIP

D. SOLIDWORKS FOR CAD MODEL

4.4 Tools and Platform

The main tool of our project is the conveyer belt, we will use conveyer belt at the automation lab at campus 154. We will perform various detection of objects while compiling the code for image processing and machine learning based upon the size or shape of the object.

4.5 Assumption

Implement feedback mechanisms to ensure accurate object detection and proper arm movements. For example, Continuously optimize and fine-tune the system by collecting data from the conveyor belt and adjusting the robotic arm's parameters accordingly until our robot learned to detect the specific shape or size object from the running conveyer belt in the real time.

Chapter 5

Observation and Analysis

5.1 Observation

Table 5.1: Comparison of Hardwares

Name	**Sensor**	**Conveyor belt**	**No of Joints**	**Way of Connection**
CVR-5	Camera	Yes	5	USB
RVS	Camera	Yes	4	USB
VCR	Camera	No	4	USB
IRS	TCS3200	No	4	none
CBGS	TCS3200	No	4	Web based

Chapter 6

Results and Discussions

6.1 Results

The selection of a computer vision robotic arm with 5 degrees of freedom (DOF) represents an optimal choice for various applications due to its versatility, precision, and adaptability. The 5-DOF configuration allows the robotic arm to navigate through a broader range of spatial orientations, facilitating intricate movements and precise positioning. This flexibility is particularly advantageous in industries where tasks demand a dynamic range of motion.

The integration of computer vision further enhances its capabilities. By incorporating vision systems, such as cameras and depth sensors, the robotic arm gains the ability to perceive and interact with its environment intelligently. This facilitates object recognition, enabling the arm to respond to diverse shapes and sizes efficiently.

Such a robotic arm is well-suited for tasks in manufacturing, assembly, and logistics, where the ability to handle varied objects and adapt to changing conditions is crucial. The computer vision element ensures adaptability and responsiveness to the surrounding environment, enhancing the arm's autonomy.

In conclusion, a computer vision robotic arm with 5 DOF is an ideal choice for industries seeking a balance of flexibility, precision, and adaptability. It represents a technological solution that aligns with the demands of modern manufacturing and automation processes.

Chapter 7

Conclusion and Recommendations

7.1 Conclusion

Our thesis aims to bring forth a design that may provide leverages in industry with a functionality of a sorting machine having a structure comprising parallel and independent channels. Our Robotic Arm can enhace the overall operational efficiency that have crucial task of segregating diverse objects. From other researches, we understood facts that sensor-handling systems play a pivotal role in guiding pick-and-place robots in accurately lifting and depositing objects at their designated locations. The detection process involves two key steps: object detection and subsequent handling.

A successful project is based on the following factors: precision of its design, ensuring that the sensor-driven mechanisms perform seamlessly. Through image processing, it's not easy to sort out machine essentially functions as a handling station, employing a pick-and-place mechanism facilitated by sensors. As a Mechatronic Engineer, we are here to implement ways with a straightforward yet effective design underscores the potential for achieving optimal results and can benefit our society mechatronic systems . Our project demonstrates a well fabricated system that can lead to a cost-effective mechatronic solution with efficient sorting capabilities and will enhance performance.

7.2 Recommendations

After a getting a hold onto various researches, we came up with the following recommendations that can definitely be considered for future:

a. Machinery optimization:
   It would definitely turn out to be an effective tool to optimize machinery by automating and improving various processes. Task repetition can be performed accurately by reducing human error and increasing efficiency. Our robotic arms can collect real-time data, contribute to predictive maintenance, and minimize downtime. Its flexibility allows you to adapt to different machine configurations and optimize your production line for various tasks. These arms integrated with machinery to streamline workflow, shorten production cycles, and improve product quality. Ultimately, robotic arms in industry will lead to machine optimization by achieving high precision level, speed, and reliability, thereby increasing overall productivity and cost efficiency.

b. Scaling up production:
   Based on exceptional exposure, this 5-degree-of-freedom (DOF) computer vision robotic arm with unique operating system greatly help improve productivity. It would optimize coordination and increase the efficiency of the robotic arm in completing various tasks. Easy object detection will allow people in quickly adapting different production scenarios. The 5-DOF design allows for versatile motion and facilitates complex operations required in manufacturing processes. The unique

operating system ensures seamless integration with other production systems and streamlines your workflow. Overall, this intelligent robotic arm increases precision, speed, and adaptability.

c. Quality Assurance:

Mechatronics blends robotics and Artificial Intelligience, ensuring optimal functionality within Quality assurance of robotic arms in industrial environments. Rigorous testing based on the fulfilment of kinematic accuracy, feedback systems, and control algorithms ensures arm accuracy in dynamic environments. The quality assurance process extends to the end effector, testing its grip strength, haptic feedback, and adjustment. Advanced sensors such as accelerometers and encoders play a vital role in real-time data collection for performance monitoring. Continuous calibration and adaptive control mechanisms combined with closed-loop control ensure arm reliability across any operating conditions. Robust error detection algorithms integrated into the mechatronics framework provide preventive measures and minimize downtime. Comprehensive testing methods according to ISO standards verify that the robotic arm complies with strict quality standards, ensuring its effectiveness in modern industrial workflows.

Appendices

Appendix A: List of components & price list

Table A.1: List of components & price list

Components	Quantity	Price (PKR)
3D printed robotic arm	7	49,000
Stepper motor NEMA 23	2	5,000
Stepper motor NEMA 23 - driver	3	6,500
Stepper Motor NEMA 17	3	3600
Stepper Motor NEMA 17 - driver TB6600	5	7,500
Arduino mega 2560	1	4,200
Miscellaneous	..	6,000
Total		84,750

Appendix B: Gantt Chart

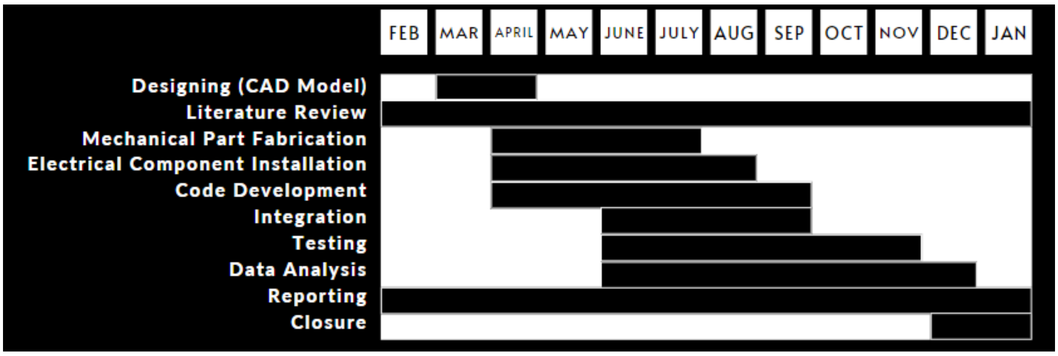

Figure 7.1: Gantt Chart

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