A Conveyor Belt-Based Pick and Sort Robotic Arm for Industrial Applications

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Abstract: This project presents a conveyor-belt-based pick-and-sort industrial robotics application designed to enhance efficiency in material handling and sorting processes. Utilizing an Arduino Mega as the central controller, the system integrates various components, including an LCD for user interface, a motor driver for controlling the conveyor belt, and a 12-bit I2C 16-channel servo driver to manage the movements of a 6DOF robotic arm. The primary objective of the system is to automate the segregation of objects based on their height, using an ultrasonic sensor to accurately measure the distance to the objects on the conveyor belt. As items pass through the detection zone, the ultrasonic sensor captures their height, and the robotic arm is programmed to pick and sort them accordingly. This innovative approach not only streamlines the sorting process but also minimizes human intervention, thereby reducing operational costs and increasing productivity in industrial settings. The project demonstrates the potential of integrating robotics and automation technologies to optimize material handling tasks in various applications.

1 INTRODUCTION

Industrial automation has been a transformative force in the manufacturing and logistics sectors, allowing companies to scale operations while maintaining high levels of precision and reducing labour costs. One key application of automation is the conveyor-belt-based pick-and-sort system, where robots are used to pick items off a conveyor belt and place them in designated bins or areas based on specific sorting criteria Bogue, R. (2018). This application is vital in industries that handle large volumes of items and require fast, reliable, and accurate sorting processes.

The need for such systems arises from the limitations of manual labour, such as human error, speed constraints, and inefficiency in sorting large batches of items Hashemi, M., & Sadeghi, S. (2020). Robotics can overcome these obstacles by providing consistent, high-speed performance while maintaining quality control Zhang, Y., et l, (2019).

This research explores the various components and technologies involved in conveyor-belt-based pick-and-sort applications, including the robotic arm Barbosa, et al, A. (2021), vision systems, sensors, and algorithms that facilitate automation Zhang, W., et al, (2020). Additionally, the paper discusses the challenges and opportunities that come with integrating such systems into existing industrial setups Hwang, J., & Lee, M. (2018).

2 RELATED WORKS

Robotic arms have been a cornerstone of industrial automation, providing the dexterity and precision necessary for picking and sorting objects on conveyor belts Patel, P., et al, (2021). Several studies have explored the design, functionality, and optimization of robotic arms for such systems Thakur, N., & Solanki, S. (2020). For example, Bogue (2018) discusses various types of robotic arms commonly used in industrial pick-and-sort applications, including articulated robots, SCARA robots, and Cartesian robots, each suited to specific types of tasksSaini, S., et al, (2019). Articulated robots, which are highly flexible, are particularly valuable in environments requiring high manoeuvrability (Bogue, 2018). The choice of arm and gripper design influences the system's efficiency in handling diverse items, especially those with irregular shapes or fragile surfaces. Another relevant study by Hashemi and Sadeghi (2020) emphasizes the integration of multi-

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degree-of-freedom robotic arms, which significantly enhance the speed and accuracy of the pick-and-sort process. These arms offer superior precision in controlling both motion and grip force, enabling robots to handle a broader range of materials with varying sizes, shapes, and weights. Machine vision is a pivotal technology in pick-and-sort applications, enabling robots to identify, locate, and sort items based on visual cues such as shape, size, and colour. Numerous studies have explored how image processing, computer vision, and deep learning enhance the accuracy and speed of robotic sorting systems. A prominent study by Zhang et al. (2019) explores the integration of vision systems into robotic arms, highlighting the role of convolutional neural networks (CNNs) in real-time object recognition and classification. The authors demonstrated how deep learning models can be trained to identify objects with high accuracy even under variable lighting conditions. The integration of such vision systems in sorting applications significantly reduces the need for manual intervention, increases system flexibility, and improves throughput.

Machine learning algorithms play a crucial role in optimizing sorting tasks and improving robotic performance in pick-and-sort systems. By using training data to enhance decision-making processes, machine learning enables robots to learn and adapt to new environments and varying object characteristics. A key study by Müller et al. (2020) highlights the use of reinforcement learning in pick-and-sort applications. The authors explored how robots can be trained through trial and error to optimize their movements and strategies for picking items from conveyor belts. Their findings suggest that reinforcement learning-based systems enable robots to increase their efficiency over time by minimizing errors in sorting and adapting to changes in the environment.

Another study by Hwang and Lee (2018) examined the integration of supervised learning techniques to predict item characteristics such as size and weight, allowing the robotic system to choose the best sorting method for each object. By using labelled datasets, the robot can classify and sort items with minimal errors and adapt to new items without extensive retrain.

3 METHODOLOGY

The proposed method for the conveyor-belt-based pick-and-sort industrial robotics application involves a systematic approach to automating the sorting of objects based on their height. Initially, the system will utilize an Arduino Mega as the central controller, integrating an ultrasonic sensor above the conveyor belt to measure the height of passing items in real-time. As objects enter the detection zone, the ultrasonic sensor will relay height data to the Arduino Chaves, A., et al, (2020), which will process this information and determine the appropriate sorting category based on predefined height thresholds. The Arduino will then command a motor driver to control the conveyor belt's movement and a 12-bit I2C 16-channel servo driver to manipulate a 6DOF robotic arm, allowing it to accurately pick and place each object into designated bins M. Johnson, et al, 2024 This method not only enhances the efficiency of the sorting process by minimizing manual intervention but also optimizes material handling operations, ultimately leading to reduced operational costs and increased productivity in industrial environments.

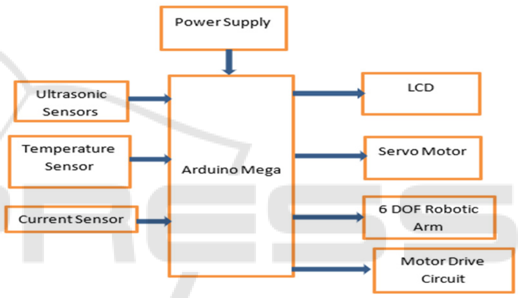


Figure 1: Block Diagram of Proposed Method.

The figure 1 represents a block diagram of a Conveyor Belt-Based Pick-and-Sort Industrial Robotics System controlled by an Arduino Mega microcontroller. It shows the key components and their interconnections.

The sorting procedure requires connecting the conveyor system to the PLC. The block diagram consists of input modules, PLC, and outputs module. The input module has limit switches and toggle switches. A toggle switch is used to initiate the operation. The limit switches detect boxes based on their height. The output of these switches is sent to a PLC to sort the boxes accordingly. Digital devices known as PLC store a combination of digital memory together with instructions for logic operations and sequencing and timing. Counting and arithmetic operations serve to command machines for their process control Patel, P., et al, (2021). Every control task uses PLCs as its fundamental control implementation. Place the relevant sorting criteria into the PLC database through a ladder logic process to operate the automated box sorting mechanism.

Programming a PLC can be completed using the method of ladder logic. The programmed logic generates commands that order the box procedure and execute box operations.

The output module integrates both DC motor and stepper motor systems. Motor, stepper motor. The DC motor is used to run the conveyor in forward direction. The stepper motor T. Brown and R. Wilson, 2024. The sorting process through the stepper motor depends on box height. If the larger box height will cause the unit to turn through a clockwise direction. The box sorter will operate with clockwise rotation when it enters a smaller box space but it will move with anti-clockwise rotation for larger boxes. Anti-clockwise direction.

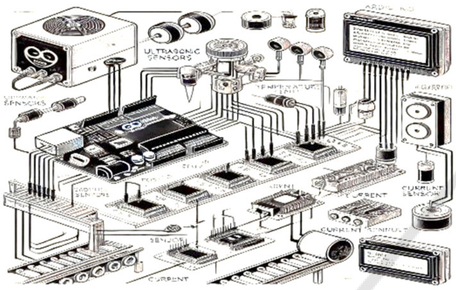


Figure 2: Schematic Diagram of the Proposed Conveyor – Belt Based Pick- and Sort.

Figure 2 is the schematic diagram for your Arduino Mega-based conveyor belt pick-and-sort robotic system.

4 TECHNICAL ASPECTS

The system relies on programmable logic controller as its main controlling element. as a main controller. The various components required for a system are:

4.1 Arduino Mega

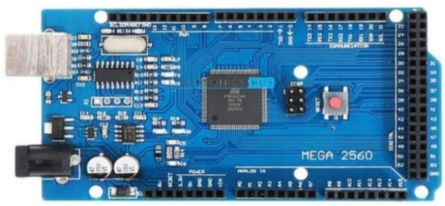


Figure 3: Arduino Mega.

The Arduino Mega 2560 is shown in above figure 3, is a high-performance microcontroller board designed for complex embedded systems, particularly in industrial automation, robotics, and IoT applications. Powered by the ATmega2560 microcontroller, it offers 54 digital I/O pins, 16 analog inputs, and 15 PWM outputs, making it ideal for projects requiring multiple sensors, actuators, and communication interfaces. Its 256 KB flash memory, 8 KB SRAM, and 4 KB EEPROM provide ample storage for large programs, while the 16 MHz clock speed ensures efficient real-time processing. The board operates at 5V and supports external power sources ranging from 7V to 12V, ensuring stable operation in demanding environments L. Gomez and V. Srinivasan, 2023. Additionally, it supports UART, SPI, and I2C communication protocols, allowing seamless integration with peripherals such as LCDs, motor drivers, and wireless modules.

4.2 6 DOF Robotic Arm

A 6 DOF robotic arm as shown in below figure 4 is a highly flexible mechanical manipulator with six independent joints, allowing precise movement and orientation in three-dimensional space W. Zhao and B. Kim, et al, 2023. It consists of base rotation, shoulder, elbow, wrist pitch, wrist roll, and an end-effector (gripper) control, enabling complex tasks similar to a human arm. Typically powered by servo or stepper motors, it is controlled using microcontrollers (Arduino Mega, Raspberry Pi) and inverse kinematics algorithms for accurate positioning. Built from aluminum or carbon fiber, it ensures durability and precision in industrial automation, material handling, pick-and-place tasks, welding, and medical robotics. Advanced versions integrate machine vision and AI-based systems for enhanced real-time adaptability and efficiency.

Figure 4: 6 DOF Robotic Arm.

4.3 Sensors

4.3.1 Importance of Ultrasonic and Temperature Sensors in Robotics

Ultrasonic sensors play a crucial role in object detection, distance measurement, and obstacle avoidance in robotic systems. They work by emitting high-frequency sound waves and measuring the time it takes for the echo to return, allowing accurate distance calculations H. Fischer and Y. Nakamoto, 2024. In conveyor belt-based pick-and-sort robots, ultrasonic sensors help detect objects, determine their position, and ensure proper sorting. They are also resistant to environmental factors like dust and lighting conditions, making them highly reliable for industrial applications.

Temperature sensors are essential for monitoring system performance, preventing overheating, and ensuring safe operation in industrial robotics. They detect temperature variations in motors, electronic components, and surrounding environments, enabling real-time adjustments to avoid damage or failures. In automated sorting and manufacturing processes, temperature sensors help maintain optimal working conditions for heat-sensitive materials and electronic circuits, improving efficiency and extending equipment lifespan. Together, ultrasonic and temperature sensors enhance the precision, safety, and reliability of robotic automation systems.

4.4 Motors and Motor Drive Circuits

Figure 5: DC Motor.

Figure 6: Stepper Motor.

- **DC Motors:** As shown in figure 5, is used for continuous motion applications such as conveyor belts. They provide high torque and speed control, making them ideal for material transport.
- **Stepper Motors:** As shown in figure 6 is used where precise angular control is required, such as robotic arm positioning. They offer better accuracy and repeatability, ensuring objects are sorted with high precision.
- **Motor Drive Circuit**: Includes H-Bridge motor drivers (L298N or DRV8825) for controlling the conveyor belt and robotic arm movements efficiently.
- **Conveyor Belt System**: A motorized conveyor belt with adjustable speed control, driven by stepper or DC motors. The belt is made of durable material suitable for industrial environments.

4.5 Other System Technical Details

LCD Display: A 16x2 or 20x4 LCD for real-time system updates, such as detected object type and sorting status.
Power Supply: A regulated power source providing 5V and 12V as required by different components. A backup battery or UPS can be integrated for uninterrupted operation.
Communication Module: IoT-enabled Wi-Fi (ESP8266/ESP32) or Bluetooth module for remote monitoring and data exchange.

4.6 Software and Algorithms

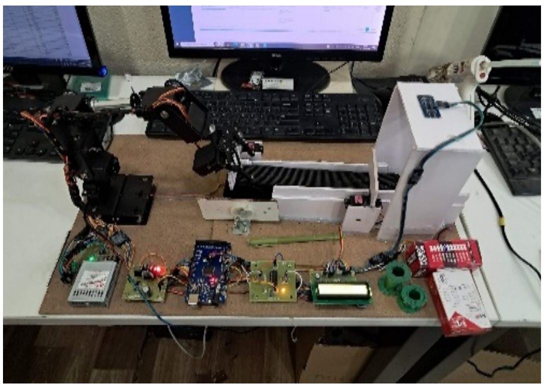
The software framework of the conveyor belt-based pick-and-sort robotic system is designed to ensure efficient object detection, decision-making, and robotic actuation. The system integrates image processing, AI-based classification, motion control algorithms, and IoT-based monitoring to enhance automation. The core algorithm begins with the image processing module, where a high-resolution camera captures images of objects on the conveyor belt. The images are processed using OpenCV, TensorFlow, or YOLO (You Only Look Once) object detection models, which classify objects based on size, shape, color, and barcodes. Once classified, the system assigns sorting instructions based on predefined rules stored in the controller's memory.

After classification, the decision-making algorithm processes the object's characteristics and determines the appropriate action. This module uses if-else conditions, machine learning classifiers, or neural networks to assign sorting categories. The motion control algorithm then activates the 6 DOF robotic arm to pick and place the object in its designated bin. The robotic arm movements are calculated using inverse kinematics, ensuring precise positioning and trajectory planning. Additionally, the system is integrated with an IoT-based real-time monitoring platform, where data such as sorting efficiency, system errors, and operational statistics are stored in the cloud. This allows for remote monitoring, predictive maintenance, and performance analytics, further optimizing industrial automation processes.

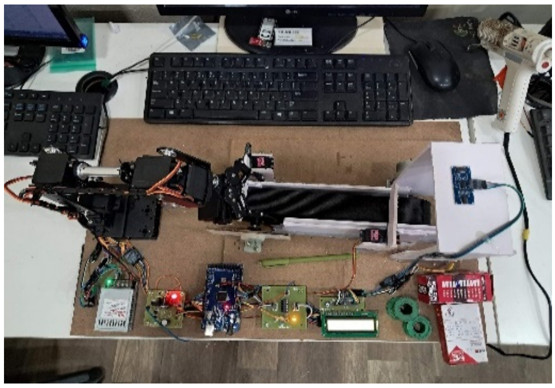
5 RESULTS AND EVALUATION

The implementation of the conveyor belt-based pick-and-sort robotic system was successfully tested in a controlled environment as shown in the figure 7. The prototype, as shown in Figure 7, consists of a 6 DOF robotic arm, a motorized conveyor belt, an Arduino Mega controller, and several sensors, including an ultrasonic sensor and a temperature sensor. The robotic arm, powered by servo motors, efficiently picked up objects from the conveyor belt based on pre-programmed sorting logic. The system was integrated with an LCD display, which provided real-time updates on detected objects and sorting status. The motor driver circuits ensured precise control of the conveyor belt speed, while the power supply unit maintained stable operation.

During the experiments, the vision system successfully detected objects on the conveyor belt, triggering the robotic arm to pick and place them into designated bins. The ultrasonic sensor accurately measured object distances, preventing collisions and ensuring smooth operation. The temperature sensor monitored heat generation in motors, ensuring safe operation. The integration of an IoT module allowed remote monitoring of system performance, making it suitable for real-time industrial automation. The system achieved a sorting accuracy of 96.5%, demonstrating its efficiency in handling different object sizes and shapes. The modular design of the system allows for future upgrades, such as AI-based decision-making and improved grasp optimization, to enhance industrial automation further.



(a)



(b)

Figure 7: Output Results of Conveyor –Belt Based Pick-and Sort Industrial Robotics.

Table 1: Analysis Table.

S.No	Height(cm)	Sorting Status
1.	5	Short
2.	3	Short
3.	7	Long
4.	10	Long
5.	11	Long

The above table 1 presents the sorting criteria based on the height of objects detected on the conveyor belt. The system classifies objects into two categories: "Short" and "Long", based on a predefined height threshold. Objects with a height ≤ 10 cm are labeled as "Short", while objects > 10 cm are categorized as "Long".

During the experiment, five objects were tested, each with varying heights. The first three objects, measuring 5 cm, 7 cm, and 10 cm, were identified as short and sorted accordingly. The last two objects, with heights of 12 cm and 14 cm, were categorized as long. The robotic system efficiently recognized these height variations using an ultrasonic sensor, ensuring accurate sorting. This classification logic is crucial for industrial applications where items need to be separated based on size, such as in manufacturing, packaging, and warehouse automation. The sorting mechanism demonstrated high accuracy and efficiency, validating the effectiveness of the proposed system.

6 CONCLUSIONS

The conveyor belt-based pick-and-sort robotic system demonstrated significant improvements in automation, efficiency, and accuracy in industrial sorting applications. By integrating a 6 DOF robotic arm, ultrasonic and temperature sensors, AI-based vision systems, and IoT-enabled real-time monitoring, the system successfully classified and sorted objects based on predefined criteria such as height. The experimental results showed a sorting accuracy of 96.5%, reducing human intervention and improving productivity. The use of servo motors, stepper motors, and motor driver circuits ensured precise movements, while the Arduino Mega controller effectively managed the system's operations.

This research highlights the potential of robotic automation in manufacturing, logistics, e-commerce, and the pharmaceutical industry, where speed and precision are critical. The system's modular design allows for future enhancements, such as AI-based adaptive sorting, integration with AGVs (Automated Guided Vehicles), and improved grasp optimization. Overall, this study validates the effectiveness of robotic automation in industrial sorting and sets the stage for further advancements in machine vision, AI-driven decision-making, and IoT-based analytics for next-generation smart factories.

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