

Design and Prototyping of Queuing Conveyor Belt System Based on Low-Cost Open-Source Microcontroller

1st Agus Putu Abiyasa

*Department of Electrical Engineering
Universitas Pendidikan Nasional
Denpasar, Indonesia
abiyasa@undiknas.ac.id*

2nd I Wayan Sugara Yasa

*Department of Electrical Engineering
Universitas Pendidikan Nasional
Denpasar, Indonesia
sugarayasa@undiknas.ac.id*

3rd I Made Asna

*Department of Electrical Engineering
Universitas Pendidikan Nasional
Denpasar, Indonesia
madeasna@undiknas.ac.id*

4th I Nyoman Gede Adrama

*Department of Electrical Engineering
Universitas Pendidikan Nasional
Denpasar, Indonesia
nyomanadrama@undiknas.ac.id*

Abstract—This study presents the design, implementation, and testing of a conveyor belt system aimed at queuing passenger luggage in airport terminals, with a focus on optimizing efficiency and passenger experience during pre-flight procedures. The system comprises three conveyors equipped with sensors and control mechanisms to automate luggage sorting and positioning. An Arduino Uno microcontroller and infrared sensors are utilized to prototype the model. Testing is conducted under various scenario conditions to assess the system's performance, including different passenger traffic volumes and environmental factors. Additionally, the system is designed to operate under normal and emergency conditions, with manual override functionality activated by an emergency button. Results demonstrate the system's ability to adapt to dynamic operational environments, enhancing operational efficiency and passenger satisfaction in airport terminals. Overall, this study contributes to the advancement of airport baggage handling technology, with potential applications for improving airport operations worldwide.

Index Terms—Conveyor Belt System, Airport Baggage Handling, Automation, Sensor Integration, Efficiency Optimization

I. INTRODUCTION

Efficient airport baggage handling systems are vital for ensuring seamless travel experiences and minimizing passenger inconvenience, particularly amidst the rapid growth of air travel. With this surge in demand, innovative solutions to streamline baggage handling operations have become imperative, leading to the emergence of conveyor belt systems tailored for airport terminals as promising avenues. These systems are designed to optimize efficiency and reduce waiting times before crucial pre-flight procedures, such as X-ray inspections [1] [2].

As airports grapple with escalating passenger volumes and operational complexities, the necessity of developing smart systems to enhance overall efficiency and passenger satisfac-

tion has become increasingly evident. Smart systems, integrating technologies like the Internet of Things (IoT), artificial intelligence (AI), and automation, offer innovative solutions to address these challenges by managing passenger flows, optimizing resource utilization, and improving service quality [3] [4] [5]. Airport smart systems play a pivotal role in transforming traditional airport operations into streamlined, responsive, and passenger-centric processes. By leveraging data-driven insights and real-time monitoring capabilities, these systems empower airports to proactively identify bottlenecks, anticipate passenger needs, and deliver personalized services tailored to individual preferences [6] [7]. Moreover, they facilitate seamless collaboration among various airport stakeholders, including airlines, ground handlers, and security agencies, ensuring smooth and coordinated operations throughout the passenger journey.

In response to these challenges, this study focuses on the design, implementation, and testing of a cutting-edge conveyor belt system specifically engineered for airport baggage handling applications. Equipped with advanced sensors and control mechanisms, the system automates the sorting and positioning of passenger luggage within airport terminals. By harnessing state-of-the-art technology, including Arduino Uno microcontrollers and infrared sensors, the system aims to revolutionize traditional baggage handling methods, offering a more streamlined and passenger-centric approach to luggage management [8] [9]. Additionally, this study aims to showcase the significant contribution of Internet of Things (IoT) technologies to the advancement of airport baggage handling systems, demonstrating the potential for enhanced efficiency, reliability, and adaptability in airport operations. Through seamless integration with existing airport infrastructure and intelligent automation of key processes, IoT-enabled conveyor

belt systems hold the promise of transforming baggage handling operations, ultimately leading to improved passenger experiences and operational efficiencies in airport terminals worldwide.

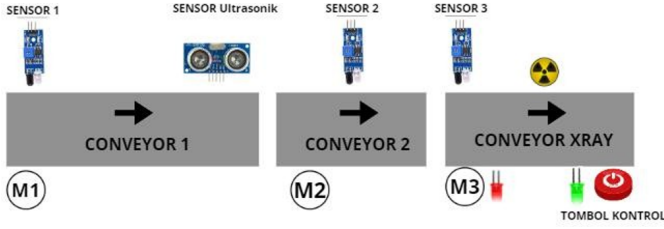


Fig. 1. Diagram of queuing conveyor prototype system design.

II. METHODOLOGY

The design of the conveyor belt system depicted in Fig. 1 comprises three individual conveyors intended for queueing passenger luggage within airport terminals. With the aim of minimizing waiting times before X-ray inspections, the system is equipped with sensors and control mechanisms to efficiently arrange passenger luggage inside the airplane. To bring this concept into reality, the prototype model will leverage an Arduino Uno microcontroller and infrared sensors. The infrared sensors are strategically placed along the conveyor belts to detect the presence of luggage items, enabling the system to initiate timely actions for sorting and positioning. Through the integration of Arduino Uno and infrared sensors, the system can automate the process of organizing luggage, ensuring swift and orderly transportation through the airport terminal. This design not only enhances operational efficiency but also contributes to a smoother and more streamlined passenger experience during the pre-flight inspection process.

A. Hardware Design

The system utilizes an Arduino Uno microcontroller alongside a combination of sensors and motors to create an efficient conveyor system as depicted in Fig. 2. Three IR proximity sensors are strategically positioned along the conveyor's path to detect the presence of objects or baggage. These sensors serve as the system's eyes, triggering actions based on the detected objects. Additionally, an HC-SR04 ultrasonic sensor is employed to measure the distance between objects, ensuring smooth and precise movement along the conveyor. The Arduino Uno processes the input from these sensors and orchestrates the operation of three DC motors responsible for driving the conveyor belt. Through careful programming, the Arduino controls the speed and direction of the motors, facilitating the seamless transport of baggage along the conveyor. This integrated system offers reliability, precision, and automation, making it an ideal solution for baggage handling applications in various settings, such as airports or logistics centers.

B. Software Design

In the Arduino IDE, the programming language used is a simplified version of C/C++. The software controls the input

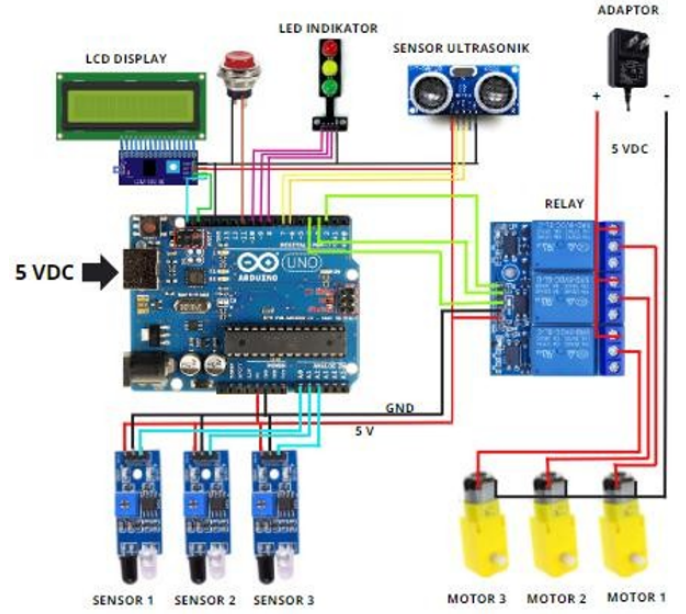


Fig. 2. Wiring diagram of queuing conveyor system.

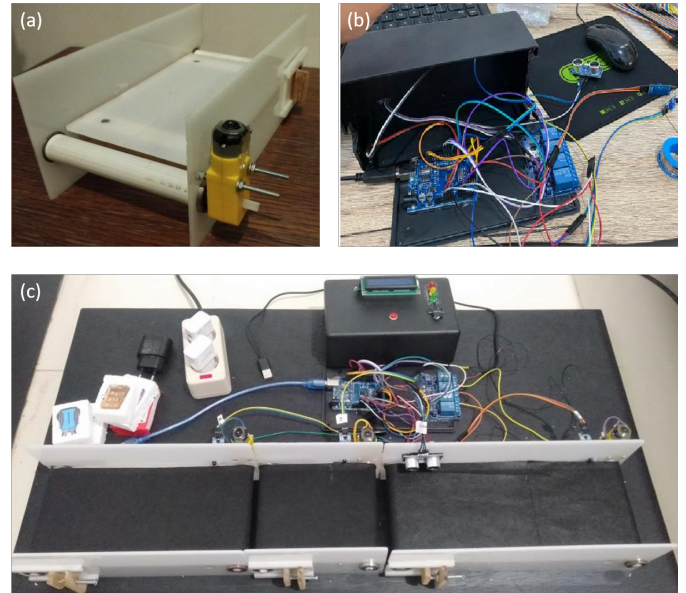


Fig. 3. Hardware assembly, (a) Conveyor (b) Electronic (c) System prototype.

from the IR proximity sensors and the HC-SR04 ultrasonic sensor to trigger the motor responsible for running the conveyor belt. The program starts by initializing the sensors and motor pins, setting them as inputs or outputs accordingly. It then enters a loop where it continuously checks the sensor inputs. For the IR proximity sensors, the program monitors the digital outputs of each sensor. Different scenarios are defined based on the conditions of these sensors. For example, if all three IR sensors detect baggage, indicating a continuous flow of luggage, the motor runs at a steady speed to transport the baggage along the conveyor belt. If only one or two sensors

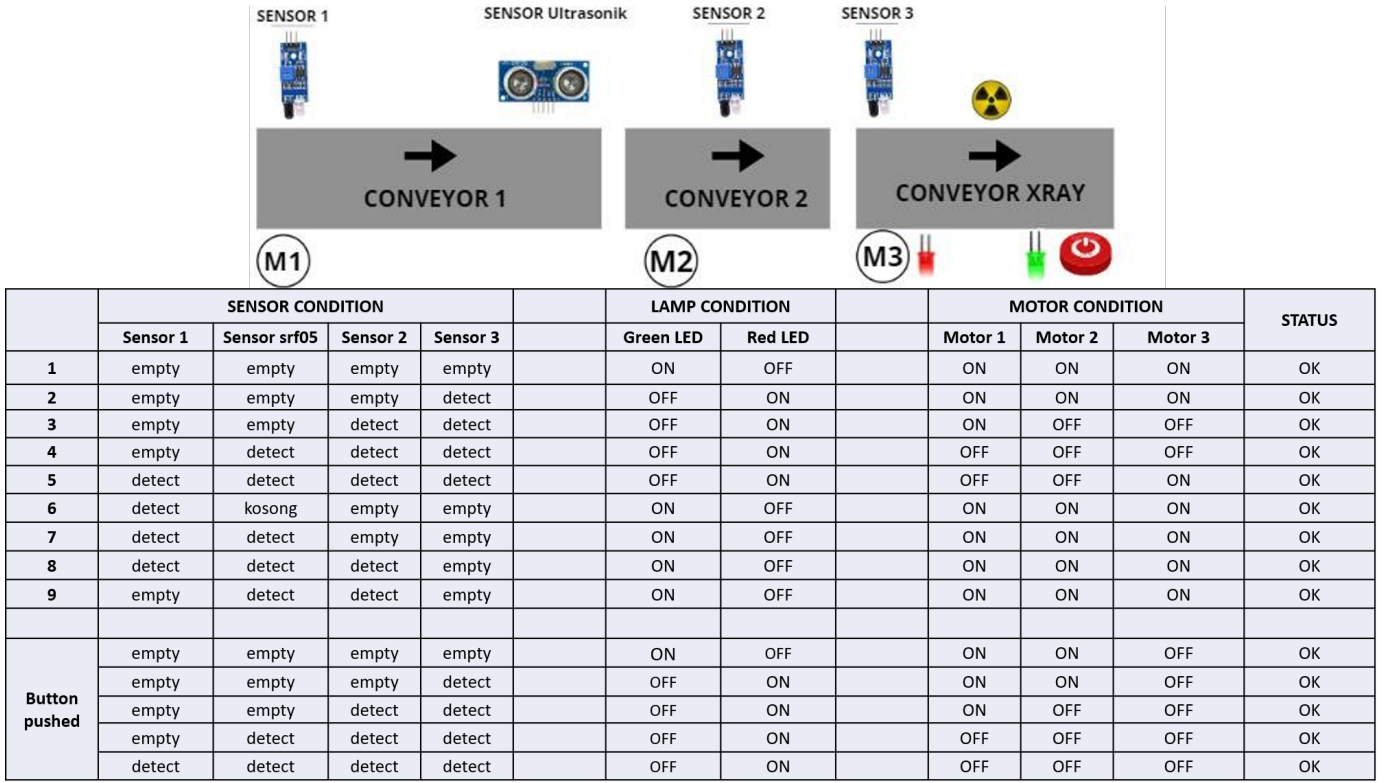


Fig. 4. All condition system testing.

detect baggage, signaling a decrease in the flow, the motor speed might be adjusted accordingly to maintain an optimal pace for sorting. Similarly, the HC-SR04 ultrasonic sensor continuously measures the distance between objects on the conveyor belt. If it detects an obstruction or a significant gap between objects, the program adjusts the motor speed or stops it temporarily to prevent collisions or jams. Through careful programming and scenario-based logic, the Arduino IDE effectively controls the conveyor belt system, optimizing baggage sorting efficiency while reducing the need for manual intervention. This automation streamlines the baggage handling process, ensuring smoother operations and minimizing delays in passenger luggage sorting.

III. RESULT AND DISCUSSION

A. Hardware Assembly

The hardware assembly of the conveyor system encompasses three main components: the conveyor model itself, the installation of electronic components, and the overall system assembly as shown in Fig. 3. Firstly, the conveyor model is constructed using acrylic material, providing durability and transparency for monitoring purposes. Each section of the conveyor is equipped with a DC motor, allowing precise control over the movement of baggage or objects.

Secondly, electronic components such as microcontrollers and sensors are installed onto the conveyor model using jumper wires based on a meticulously crafted wiring diagram. These components include Arduino Uno microcontrollers,

IR proximity sensors, HC-SR04 ultrasonic sensors, and DC motors. The wiring is organized to ensure efficient signal transmission and power distribution throughout the system.

Finally, all components are integrated into the overall system assembly, culminating in the prototype model. The microcontrollers receive input from the sensors, process the data, and regulate the motor speed accordingly to optimize baggage handling operations. The entire assembly is powered by a 5V DC power supply, providing stable and reliable power to drive the conveyor system. Overall, the hardware assembly results in a functional and robust conveyor system prototype, ready for testing and further refinement in baggage handling applications.

B. System Testing under Different Condition

The testing of the system under different scenario conditions, as outlined in Fig. 4, involves subjecting the conveyor belt system to various simulated situations to evaluate its performance and robustness. These scenarios may include different passenger traffic volumes, variations in luggage sizes and shapes, and changes in environmental conditions such as lighting or temperature. Additionally, the system may be tested under scenarios mimicking real-world airport operations, such as peak travel times or unexpected delays. During testing, the functionality of the system's sensors, control mechanisms, and conveyor belts is assessed to ensure that they respond effectively to different scenarios. The system's ability to adapt to dynamic conditions, maintain optimal throughput, and

minimize waiting times for luggage before X-ray inspections is thoroughly evaluated. By conducting comprehensive testing under diverse scenario conditions, any potential weaknesses or inefficiencies in the system can be identified and addressed, ultimately leading to the development of a reliable and efficient conveyor belt system for airport baggage handling operations.

In discussing the operation of the conveyor belt system, it's important to consider two distinct operating conditions: normal and emergency. Under normal conditions, all sensors operate according to the predefined plan, efficiently detecting and sorting passenger luggage along the conveyor belts. During normal operation, the light indicators on the system display green, signaling that operations are proceeding as expected. However, in the event of an emergency, such as a system malfunction or unexpected circumstance, an emergency button can be pressed to activate manual control. In this mode, the system operates under manual control, bypassing the automated processes. The light indicators on the system turn red during emergency mode, providing a visual indication of the altered operating condition. This discussion underscores the importance of incorporating safety measures and contingency plans into the design of automated systems, ensuring effective operation under both routine and emergency situations.

IV. CONCLUSION

In conclusion, the development and testing of the conveyor belt system for queuing passenger luggage in airport terminals have demonstrated its potential to significantly improve efficiency and passenger experience during pre-flight procedures. By integrating Arduino Uno microcontrollers and infrared sensors, the system effectively automates luggage sorting and positioning, minimizing waiting times before X-ray inspections. The thorough testing under various scenario conditions has validated the system's performance and robustness, highlighting its ability to adapt to dynamic operational environments. Overall, the successful implementation of this conveyor belt system represents a promising advancement in airport baggage handling technology, paving the way for enhanced operational efficiency and passenger satisfaction in airport terminals worldwide.

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