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Segregation of Quality Products on the Production Line

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Abstract: **In the highly competitive manufacturing industry, producing high-quality products is crucial for success and reputation. The issue of segregating quality products on the production line has emerged as a critical concern, necessitating effective strategies to tackle that problem. This project aims to design a quality control unit using controllers, sensors, and a robotic arm to segregate products based on height, substance amount, and cap presence. Ensuring product quality enhances customer satisfaction, improves production efficiency, optimizes resources, and boosts profitability through waste reduction and brand preservation. Workforce training will focus on quality standards and defect identification**.

Keywords: Production line, industry, robotic arm.

I. INTRODUCTION

Over the last few years, many discussions have been done on segregation and its importance [1-4]. Segregation has many uses and is essential in many spheres of life. We will also talk about the practices employed in segregation.

Segregation: Segregation is a process in which we separate required quality and faulty products before packaging in the production line.

Importance of Segregation: Segregation in industry refers to separating different components, materials, or processes within a manufacturing or industrial setting. It has several important implications and benefits:

- **Safety:** By limiting the blending of processes or materials that could cause accidents, fires, explosions, or chemical reactions, segregation helps ensure safety. Accidents and injuries can be prevented by segregating dangerous materials, lowering the chance of cross-contamination, and putting in place appropriate storage and handling procedures [5-9].
- **Quality Control:** Segregation is essential for maintaining product integrity and preventing contamination, according to quality control. The risk of cross-contamination is decreased by keeping various materials or processes apart, improving quality control and product consistency. This is especially crucial in food processing, pharmaceuticals, and electronics production sectors [10-15].
- **Regulatory Compliance:** To maintain worker safety and environmental protection, several industries are subject to strict norms and requirements regulating segregation. Compliance with these standards is crucial to prevent legal repercussions, penalties, and reputational harm.
- **Productivity:** By arranging materials, equipment, and processes logically and methodically, proper segregation can increase workflow productivity. It makes things simpler to access, clears up confusion, and makes things run more smoothly, which boosts output and cuts down on downtime.
- **Waste management:** Effective waste management depends on segregation. It is simpler to handle and properly dispose of waste when separated at the source, such as recyclables, hazardous items, and general debris. This aids recycling and trash reduction programs and promotes environmental sustainability [16-19].

Methods of Segregation

In the following topic, we will delve into the methods of segregation.

Automated Visual Inspection Systems: Systems for automated visual inspection are essential for separating high-quality products from others in production lines. To find flaws and irregularities, they employ cutting-edge cameras and image processing. Studies demonstrate their usefulness in providing real-time feedback and averting the release of substandard goods onto the market. These technologies have benefits, particularly in high-volume manufacturing lines, including accelerated inspection speed, decreased human error, and enhanced consistency. Integration with data analytics and machine learning makes continuous improvement in the inspection process possible.

Sensor-Based Inspection Techniques: Because of their adaptability and precision, sensor-based inspection systems have gained popularity. Product qualities like size, material composition, and colour consistency are evaluated using a variety of sensors, including infrared, ultrasonic, and colour sensors. Including many sensors enables thorough product evaluation, guaranteeing that only those that fulfill quality standards continue in manufacturing. The inspection procedure is started when infrared sensors identify the presence of an object on conveyor belts. For the evaluation of dimensions, ultrasonic sensors offer non-contact distance measurements. Colour sensors confirm consistent bottle cap location and colour, which helps with overall quality control [20-25].

Machine Learning and Artificial Intelligence: Machine learning and AI have changed Production line quality control. Liang et al. (2020) demonstrate how these algorithms assess sensor and historical data for intelligent product segregation [26-28].

Continuous learning makes it possible to adapt to shifting qualities and high expectations. Integration improves performance by managing complicated decisions, spotting subtle patterns, and instantly changing segregation criteria. Growing data enables machine learning-based systems to identify defects more effectively and accurately, ensuring high-quality products.

Robotic Arm-Based Segregation: By leveraging sensor data to perform precise pick-and-place actions, robotic arms automate segregation. Their adaptability and accuracy enable effective handling of a variety of products. Integration simplifies the procedure and makes physical separation possible. They handle delicate objects and complex shapes because they are programmed for precise movements. Robotic arms maintain quality segregation throughout manufacturing in a steady, unflappable manner.

Integration of IoT and Cloud Computing: By linking sensors and inspection equipment to handle real-time data on a bigger scale, IoT and cloud integration improve quality segregation systems [3]. They provide better processing, data storage, and scalability for handling massive data volumes. Through seamless data sharing and collaboration among stakeholders, cloud computing offers insightful production data. Real-time data collecting made possible by IoT provides proactive problem-solving and increased production effectiveness.

Quality Management Software: Quality management software (QMS) is required for effective product segregation. It enables establishing inspection processes, defining and enforcing quality criteria, and monitoring performance across time. A consolidated platform for managing quality-related data is provided by QMS, allowing for data-driven decision-making and real-time monitoring of parameters. Thorough reports and analytics ensure product uniformity, compliance, and ongoing production process improvement.

II. LITERATURE SURVEY

Introduction: Seating quality products on a production line is critical to manufacturing processes. Identifying and separating defective or sub-standard items from high-quality products ensures that only acceptable items reach the market, reducing waste and maintaining product quality. This literature survey explores multi-sensor integration and a robotic arm in segregating medicine pill-filled bottles based on various quality parameters.

Multi-sensor Integration for Quality Inspection: Integrating multiple sensors is vital in automating quality inspection tasks in production lines. We use various sensors, including IR sensors, ultrasonic sensors, colour sensors, and laser sensors, to ensure comprehensive quality assessment.

Infrared (IR) Sensor: A device that detects infrared radiation in its immediate environment is an infrared (IR) sensor, commonly referred to as an IR detector or IR receiver. Between visible light and microwaves on the electromagnetic spectrum, infrared radiation has wavelengths that are longer than visible light but shorter than radio waves (see Fig. 1).

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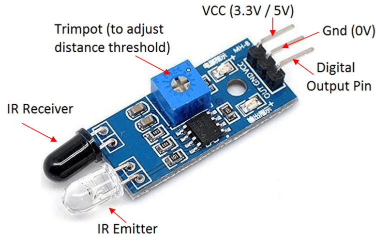

Figure 1. IR Sensor [1]

They comprise an emitter that radiates infrared energy and a receiver that picks up and examines infrared signals that are reflected or emitted. By measuring the reflection or emission of infrared light, these sensors determine if an object is present or absent within a given range. They are frequently employed in proximity switches, obstacle detection systems, and automatic faucets (see Fig. 2).

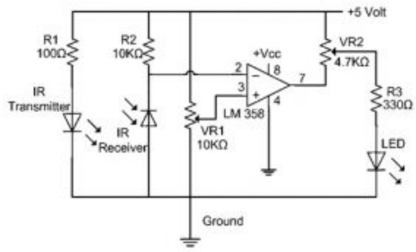

Figure 2. Circuit Diagram of IR Sensor [2]

Colour sensor: A colour sensor, commonly referred to as a colour detector or colorimeter, is a tool that can recognize and distinguish between various hues. To determine the colour of an object or surface, it detects and measures light intensity over a range of wavelengths (see Fig. 3).

Figure 3. Color Sensor [3]

Colour sensors use various technologies, such as RGB (Red, Green, and Blue) sensors, colour filters, or spectral analysis, to detect colours (see Fig. 4).

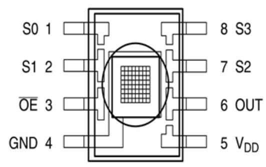

Figure 4: Schematic Diagram of Color Sensor [4]

Three separate sensors, each sensitive to red, green, or blue light, make up RGB color sensors. Each sensor generates an electrical signal in response to light exposure that is proportionate to the intensity of the observed color. The colour sensor can ascertain the object's color composition by integrating and analyzing the outputs of these sensors.

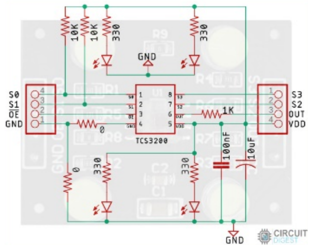

Figure 5: Circuit Diagram of Color Sensor [5]

Eight pins make up the TCS3200 Color Sensor module: VCC, OUT, S3, S2, S1, S0, OUT, 0E, and GND. Except for VCC and Ground, every pin on this sensor module is digital (see Fig. 5 and Fig. 6).

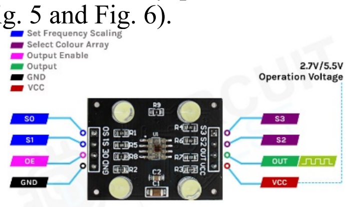

Figure 6: Pin out Configuration of Color Sensor [5]

Numerous industries, including manufacturing, automation, printing, robotics, and quality control, use color sensors.

Ultrasonic sensor: An ultrasonic sensor is a tool used to detect and quantify item existence, closeness, and distance using sound waves at frequencies higher than the top audible limit of human hearing (usually above 20 kHz). The idea behind how it operates is the reflection of sound waves (see Fig. 7).

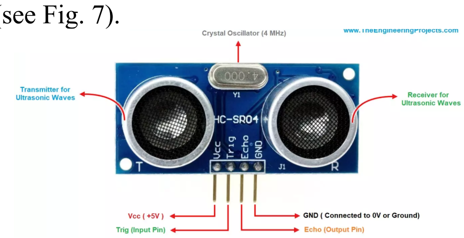

Figure 7: Ultrasonic Sensor [6]

The main features of this ultrasonic sensor (see Table 1).

Parameter	**Value**
Main Parts	Transmitter & Receiver
Technology Used	Non-Contact Technology
Operating Voltage	5 V
Operating Frequency	4 MHz
Detection Range	2cm to 400cm
Measuring Angle	30º
Resolution	3mm
Operating Current	<15mA
Sensor Dimensions	45mm x 20mm x 15mm

Table 1: Specifications of Ultra Sonic Sensor [6]

The sound waves bounce off an object's surface as they come into contact with it in their course. Ultrasonic sensors can determine whether any objects are within their detection range by setting a threshold distance. They are advantageous for proximity sensing, object detection, and obstacle avoidance applications (see Fig. 8).

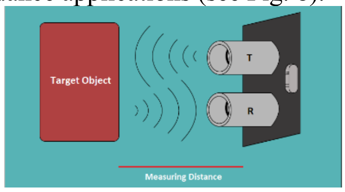

Figure 8: Obstacle Detection [6]

The Table 2 shows the HC-SR04 Pinout & Description.

No.	**Pin Name**	**Pin Description**
1	VCC	The power supply pin of the sensor that mainly operates at 5V DC.
2	Trig Pin	It plays a vital role to initialize measurement for sending ultrasonic waves. It should be kept high for 10us for triggering the measurement.
3	Echo Pin	This pin remains high for short period based on the time taken by the ultrasonic waves to bounce back to the receiving end.
4	Ground	This pin is connected to ground.

Table 2. Pinout Configuration of Ultra Sonic Sensor [6]

Numerous industries use ultrasonic sensors, including robotics, industrial automation, security systems, parking sensors, level monitoring, liquid level measurement, and others.

Laser sensor: Powerful new technologies for precise quality monitoring of nonfracturing operations include laser sensors. These sensors use laser beams to measure various product attributes, such as proximity, size, and surface qualities (see Table 3).

Operating Voltage	5V
Output Power	5mW
Wavelength	650nm
Operating Current	< 40mA
Working Temperature	-10°C ~ 40°C [14°F to 104°F]
Board Dimensions	18.5mm x 15mm [0.728in x 0.591in]

Table 3: Specifications of Laser Sensor [7]

Basically, the transmitter and receiver modules make up a laser sensor. The laser receiver module is made up of a separate non-modulating laser tube sensor that serves as a laser beam sensor. The laser transmitter module comprises a laser diode that transmits the beam (see Fig. 9 and Fig. 10).

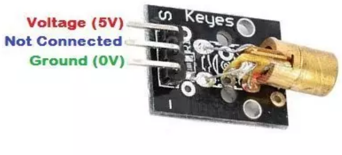

Figure 9: Transmitter of Laser Sensor [8]

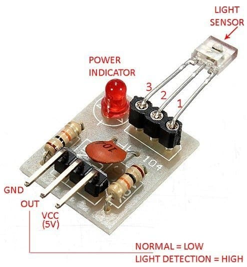

Figure 10: Receiver of Laser Sensor [9]

A complete and effective quality segregation system is produced by combining laser sensors with other sensor technologies, automated visual inspection systems, robotic arms, machine learning, IoT, and cloud computing.

III. Experimental Work

The main purpose of our experimental work is to demonstrate the project and its working. We have shown that this technique can be done cost-effectively. Our main objective is to make the technique of segregation way simpler than before. We have to suggest a strategy that, for a particular industry, it is easier to maintain good quality products on a production line as it is thought that it takes work to perform.

Conveyor Belt: We first have the conveyor belt in our project's construction. We use a conveyor belt to carry the products from one end of the conveyor to the other. It is a very simple and efficient way to carry products from one end to the other of the production line.

Importance of Conveyor Belt: The wide application of belt conveyors in the market is due to their performance advantages, which create more value for users:

- **Reliable Operation:** Because belt conveyors provide continuous movement, they are frequently used in major industrial units where the loss of a machine would be enormous [10].
- **Low Power Consumption:** The conveyor belt minimizes the running resistance, productivity, and wear and tear on the cargo, which helps lower the production cost [10].
- **Effective Customization:** The belt conveyor's transmission line is versatile and flexible. The demands dictate the line's maximum length, which might be more than 10 kilometres [10].
- **Flexible Feeding:** The belt conveyor can accept materials from a single point or numerous locations, and it can also discharge goods to some points or sections [10].

Figure 11: Types of Conveyor Belts [10]

Flat Belt Conveyor Belt: Our project uses a flat belt conveyor belt. Rubber, fabric, or synthetic materials like polyvinyl chloride (PVC) or polyurethane (PU) are frequently used to create flat conveyor belts. The type of cargo being transported, its weight, the environment, and any special needs like resistance to abrasion or chemicals all have a role in the choice of belt material (see Fig. 11 and Fig. 12).

Figure 12: PVC [10]

Flat belts often have a flat, smooth surface and are wide. They can feature a laced or mechanical fastening mechanism for simple installation and replacement, or they can be endless belts with the ends linked to make a continuous loop. Depending on the needs, any length can be recommended.

In a flat belt conveyor, two rollers are attached—one at one end and the other at the other. One roller is controlled with the help of a dc gear motor. The other roller is an idler roller that guides the belt and helps maintain tension. One roller is controlled with the help of a dc gear motor. Its movement and speed are controlled through it (see Fig. 13).

Figure 13: Motor Pulley [11]

DC Gear Motor: The DC motor is the main part of a DC gear motor. It produces mechanical rotating motion by converting electrical energy from a direct current power source. It comprises several shafts and gears that are organized in a particular way. It also includes a gearbox with parts like gear wheels, bearings, and shafts. The gearbox, connected to the DC motor's shaft, lowers the motor's speed while boosting its torque output. The toothed parts transporting power between the motor and the output shaft are gear wheels, often known as gears or pinions. The part that extends from the gearbox and transmits rotational motion to the external load or system is known as the output shaft. The motor shaft, output shaft, and gears are all supported and made to rotate smoothly with the aid of bearings.

They facilitate effective power transmission by reducing friction. The electrical connections to the power supply are made via terminals or connectors on DC gear motors. Positive and negative terminals for the DC power source could be included in these connections (see Fig. 14).

Figure 14: DC Gear Motor [12]

Construction of the Conveyor Belt: We need to build the stand first to construct the conveyor belt. After designing the stand, we required a 12V DC Gear Motor and fix its shaft with the motor roller or motor pulley at one end of the stand and fix another roller or pulley at the other end of the stand. After that place the belt on the stand (see Fig. 15).

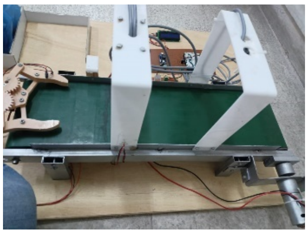

Figure 15:. Conveyor Belt

Circuit Building: In the following topic, we discuss about how we build the circuit of our projects by dividing them into smaller circuits.

Power Supply: We're referring to a power adapter for converting electrical power from 220V to 12V. It is easy and simple to convert a 220V AC power supply to a 12V DC power supply. 220V AC serve as the input voltage. This is the AC-to-DC converter. Connect a switch and a fuse after the AC wire plug at the input. The transformer is the foundation of the circuit by step-down the AC voltages from 220V to 12V. As is common, we require a rectifier circuit whenever we convert from AC to DC. The output is rectified using diodes is 12V DC [13].

12V to 5V Regulator Supply: A 12V to 5V regulator can be used to change a 12V DC to a 5V DC output. Although many different types of regulators exist, a voltage regulator module or a DC-DC buck converter is a popular option. We must clearly define the current and voltage ratings as well as the power specs in order for the regulator to function. We must choose a suitable regulator module that guarantees a 12V input range and offers a regulated output of 5V. The use of FETs allows for the conversion of 12V to 5V. The IC 7805 FET, which is mostly used for voltage regulation, is the FET that we employ in the regulator circuit (see Table 4).

S.no	Component	Value	Qty
1.	Voltage Regulator IC	LM7805	1
2.	Electrolyte Capacitor	10uF, 1uF	1
3.	Power Source	12V	1
4.	Heatsink	1	1

Table 4. Components of Regulator Circuit [15]

Motor Driver FET: Motor Driver Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs), commonly referred to as FETs, are a form of motor driver circuit that employs MOSFETs to control the functioning of a motor. Due to their quick switching times, low power consumption, and great efficiency, MOSFETs are frequently employed in motor driver circuits.

The main FET commonly used in the driver is 75NF75, which helps to drive the motion of the motor in Fig. 16.

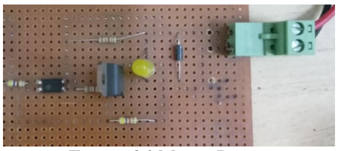

Figure 16 Motor Driver

To control the motor speed, a Pulse Width Modulation (PWM) signal is applied to the input of the motor driver. The PWM signal switches the MOSFETs on and off rapidly, effectively regulating the average voltage applied to the motor. By varying the duty cycle of the PWM signal, the motor speed can be adjusted. MOSFETs require a gate driver circuit to provide the voltage and current to rapidly switch the MOSFETs on and off.

Arduino Uno: A well-liked microcontroller board is the Arduino Uno. A set of digital and analog pins on the Arduino Uno are available for input and output. There are six analog input pins with the letter "A" and 14 digital I/O pins with the letter "D." Using the relevant routines in the Arduino IDE, these pins can be set up to read analog voltages or digital signals (HIGH or LOW). A USB connection or an external power source can power an Arduino Uno. While independent projects can use an external power source, programming and powering the board during development is often accomplished via a USB connection. The Arduino Uno is best used with voltages between 7 and 12 volts.

The Arduino IDE, a user-friendly development environment based on the C++ programming language, is where you write code to program the Arduino Uno. The Arduino Uno can connect to various electronic devices, including sensors, actuators, displays, LEDs, buttons, and communication modules. You can interact and control your applications' peripherals using the I/O pins and the proper libraries.

Robotic Arm: A robotic arm controlled by servo motors operates using a combination of mechanical linkages, position feedback, and control signals. The servo motor is connected to the joint of the robotic arm through mechanical linkages, such as gears. These linkages transmit the motion from the servo motor to the arm joint, allowing it to rotate or move in a controlled manner in Fig 17.

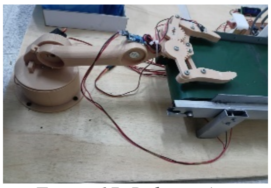

Figure 17. Robotic Arm

Servo Motor: A servo motor is a kind of motor that has extremely precise rotational capabilities. Servo motors can rotate precisely because they often have a control circuit that provides feedback on the motor shaft's current position. You use a servo motor when you want to spin an object at a specific angle or distance. It is merely a motor that a servo system is controlling. A motor is called a DC servo motor if a DC power source drives it, and an AC power supply powers an AC servo motor. Based on the type of gear arrangement and operational characteristics, there are numerous other servo motor types. A servo motor often has a gear configuration that enables us to produce a very high torque servo motor in tiny, light designs. These characteristics have led to its employment in various applications, including toy cars, RC helicopters and planes, and robotics.

Construction of Servo Motor

The Servo motor is a DC motor which has 5 following parts:

1. Stator Winding: This winding is wrapped around the motor's stationary portion. It is sometimes called the motor's field winding [19].

2. Rotor Winding: This winding is wrapped around the motor's rotating component. It is sometimes called the motor's armature winding [19].

3. **Bearing:** Two types of bearings are used to move shafts, front bearing and back bearing [19].

4. Shaft: The motor's shaft comprises the armature winding attached to an iron rod [19].

5. Encoder: It has a rough sensor that calculates the motor's rotational speed and revolutions per minute [19].

Working of Servo Motor: The pulse length transmitted to a servo motor's Control PIN, which operates on the PWM (Pulse width modulation) principle, controls the motor's rotation angle. A servo motor is a DC motor managed by certain gears and a variable resistor (potentiometer). A DC motor's high-speed force is converted into torque by gears. Work = Force x Distance. A servo has a high force and a low distance, unlike a DC motor with a low force and a high distance (speed). The potentiometer is connected to the servo's output shaft to calculate the angle and stop the DC motor at the proper angle [9].

Robotic Arm Building

For the construction of the robotic arm, we used PLA material. PLA material is widely used for 3D printing.

We controlled the movement of our robotic arm with the help of 3 servo motors.

- One servo motor is placed at the base. This servo motor rotates from 0 to 180 degrees from left to right and right to left.
- The second servo motor is for the controlling of motion and position of the arm. It will rotate the arm according to the control signals given.
- The third servo motor is for the jaw of the robotic arm. It will help in opening and closing the jaw which will ultimately help us in opening and closing the jaw and this will help us in picking and dropping the products in the desired location.

Working: In this project, we first have a flat belt conveyor belt where the products move as in a production line. Multiple sensors detect the bottle and provide valuable information regarding the product. This information/data is then sent to the Arduino. Then it compares it with the required specifications, i.e., checks the quality and whether it suits a particular industry. The products satisfying all the specifications would proceed further, and the rest will be pulled out of the conveyor belt production line. We preferred the robotic arm, which works tirelessly without fatigue and is way more efficient than human work in Fig. 18.

IR sensor: At first, the information from IR sensor is sent to Arduino that the bottle is detected so that the Arduino begins to work.

- One IR sensor is at the start, and the other is at the end. The IR sensor detects the bottle at the start, and the system begins to work, i.e., the conveyor belt begins to run.
- The one at the end detects and counts how many quality products meet our required specifications.

Ultrasonic sensor

- The ultrasonic sensor will check the height of the product to determine whether it suits our specifications.
- The dimensions of the bottles are recorded through this sensor and displayed on the LCD.

Color sensor

- After that color sensors tell whether the color which is required is met or not.
- This color sensor will also check whether the bottle has its cap placed on it.

Laser sensor

- When the bottle is passed from the laser sensor, if the number of pills is at a standardized level, then the laser beam it cut to meet our standard will pass.
- When the laser is not cut down, it will segregate from the production line.

Arduino

- All of the above information given by the sensors is sent to the Arduino, and then the Arduino decides whether it is the desired quality product or not.
- After assessing Arduino, it sends a message to the robotic arm to perform segregation.

Robotic Arm

- The product will be sent to the packaging line through the arm if it meets our standards.
- The product will segregate from the production line if it does not meet our standards in Fig. 19 and Fig. 20.

Block Diagram

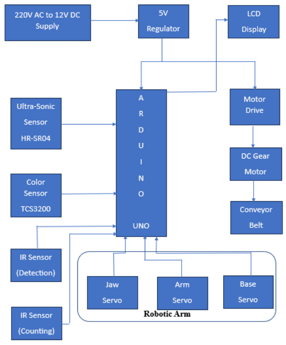

Figure 18: Block Diagram

Hardware Implementation

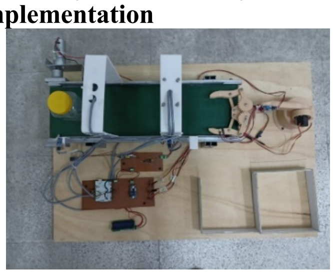

Figure 19: Top View

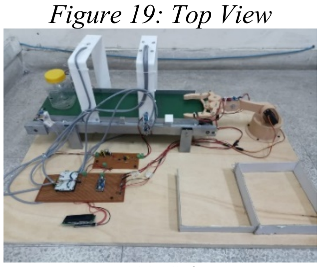

Figure 20: Side View

IV. RESULTS AND DISCUSSION

A test is run on a variety of items. Our experiment was successful, and the outcome was of exceptionally high quality in Table 5. The project still has room for development to increase its effectiveness.

Bott le	IR Sens	Ultraso nic	Color Sensor	Laser Senso	Segregat ion

No	or	Sensor		r	Status
B1	Prese nt	Within Toleranc e	Standardi zed	Passed	Good Quality
B2	Prese nt	Within Toleranc e	Non-Standard	Reject ed	Defective
B3	Abse nt	N/A	N/A	N/A	N/A
B4	Prese nt	Out of Toleranc e	Standardi zed	Reject ed	Defective
B5	Prese nt	Within Toleranc e	Standardi zed	Passed	Good Quality

Table 5. Results

Total Bottles	Good Quality	Defective
10	7	3

Table 6. Statistics of the Results

Discussion: Table 5 presents the outcomes of the quality inspection process. Each bottle has a specific identification number, and data from the various sensors (IR, ultrasonic, colour, and laser) used to inspect it are recorded. Each bottle's "Segregation Status" column indicates whether it is "Good Quality" and has met inspection requirements or "Defective" and has been removed from the production line.

According to Table 6, out of the ten bottles processed during the experiment, seven (70%) were deemed "Good Quality," passing all of the quality criteria and the inspection process. In comparison, three bottles (30%) were deemed "Defective" and removed from the production line because they did not meet the necessary quality standards and were rejected to stay off the market.

V. CONCLUSION AND FUTURE WORK

In this FYP, we successfully carried out the production line segregation. The sensors have collected the data needed for segregation, and Arduino will use this data to determine whether the product is damaged. Then, using a robotic arm, it is positioned in the required area by the control signal information. This tactic is carried out easily and economically. The circuitry, or wiring and connections, are all quite straightforward to understand because they are readily available in markets. Additionally, it took less time to produce and can assist us in resolving various challenging issues of factories and other industrial settings.

Future Work: Future research in this area may concentrate on creating more complex AI algorithms, enhancing the integration of various inspection technologies, and improving real-time data analysis capabilities to optimize the segregation process in manufacturing industries further as technology develops. It is anticipated that the constant evolution and use of these cutting-edge technologies would increase production line efficiency, decrease waste, and improve product quality. Therefore, additional research on this subject is needed from engineers, scientists, and other professionals to create highly effective machines and algorithms that can handle these challenging tasks in the near future.

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