Automated Visual Inspection and Rejection System

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***Abstract*—We believe that keeping product quality good is very important in today's factories. It helps make work faster cuts waste and makes customers happy. But the old way of checking products by hand takes a time can be uneven and relies on people. That is a problem on fast production lines. To solve this problem, propose the Automated Visual Inspection and Rejection System that uses a PLC for real-time checking of product quality. This system brings together an AI camera, industrial sensors, a PLC, a conveyor belt, and a machine that throws out items automatically. When the sensor sees the product and the camera takes the picture. Looks for problems such as missing parts, wrong size, scratches, wrong position or color changes. The PLC then tells the belt where to move and pushes the product into the reject bin. Lights warn workers about the status. I hope that this system will cut down checking reduce waste make checking more steady and help production run smoothly. It is a way to bring quality checking into small and medium factories just as Industry 4.0 says.**

***Index Terms*—PLC, machine vision, ESP32, AI vision Camera, conveyor automation, automatic rejection, servo motor, quality inspection**

I. INTRODUCTION

In modern manufacturing industries, maintaining exceptional product quality is vital to maximize operational efficiency, eliminate production losses, and boost customer satisfaction. Traditional manual inspection methods fall short because they are slow, inconsistent, and highly dependent on human judgement, making them impractical for modern, high speed assembly lines. To address these challenges, implementing a cost-effective, automated Vision Inspection System powered by a Programmable Logic Controller (PLC) offers and ideal solution for small and medium sized manufacturing enterprises. This smart setup integrates advanced AI-Driven vision technology with industrial automation to deliver rapid, highly accurate quality checks in real time.

The automated process begins on the production line when a sensor detects an AI vision camera to immediately capture its image. The system instantly analyzes the picture to identify diverse defects such as missing parts, incorrect dimensions, surface damage, miss alignment or color variations. Based on these inspection results, the PLC coordinates immediate actions by controlling the conveyor, activating warning Leads, and buzzers, and engaging a rejection mechanism to smoothly isolate defective products from the flawless ones. By adopting the intelligent industry 4.0-Compliant automation manufacturing industries can achieve continuous, reliable quality control, minimize costly downtime, drastically reduce material wastage and significantly lower operational expenses.

1.1 Problem Statement

Manual bottle inspection in manufacturing is slow, inconsistent and prone to human error, failing to reliably detects like water levels, missing labels, damaged caps, and deformed shapes. This comprises product quality and increases operational costs. To cost effective, automated inspection System combining AI vision PLC technology to accurately detect defects, automatically reject faulty items, and maximize production efficiency.

II. LITERATURE REVIEW

1. Machine-Vision-Based Plastic Bottle Inspection for Quality Assurance [1]

Majida Kazmi Basra Hafeez Hashim Raza Khan and Saad Ahmed Qazi 2022 suggested a machine vision-based plastic bottle inspection system in order to enhance quality control in the manufacturing industry this system applies image processing methods to identify typical defects such as wrong cap placement bottle dents and misaligned labels thus reducing the

requirements for manual inspection process the system they proposed reached an inspection accuracy of approximately 95 which means it is appropriate for use in small and medium-size industries nevertheless the system is based mainly on traditional image processing ,techniques and is only capable of detecting a limited number of defect types its performance could deteriorate when facing very lighting conditions different bottle shapes or colors and highspeed production lines further move the system is not integrated with industrial automation components such as PLCs which hinders its application in fully automated manufacturing environments in order to address these limitations the proposed project make use of PLC controlled conveyor automation to create a more intelligent and reliable inspection system AI algorithm enhance the accuracy of defect detection under different environmental conditions and are able to identify various kinds of bottle defects in real time the PLC controls the conveyor belt and automatically sorts out the defective bottles without any need for human intervention so that the system becomes faster more accurate more cost effective and suitable for continuous industrial production while at the same time improving the overall quality of the product and efficiency of manufacturing.

2. Maksymilian Maslanka, Daniel Jancarczyk and Jacek Rysinski – "Integration of Machine Vision and PLC-Based Control for Scalable Quality Inspection in Industry 4.0" (2025) [2]

Maksymilian Maslanka, Daniel Jancarczyk and Jacek Rysinski have proposed something for 2025. They want to use a machine vision system to check the quality of things in the industry. This system uses a camera a PLC and HMI. It is very good at checking things with over 95% accuracy. This means it does not often make mistakes when it finds defects. The problem with this technology is that it cost a lot of money. It needs equipment that is expensive it is also not very flexible. It is hard to add new things to it like a system that uses AI tools to find defects. The initial cost is very high. To overcome this limitations our project usus conveyor belt that is controlled by PLC the AI model that can find types of bottle issues such as missing caps, broken bottle labels that are not in right place and bottles that have wrong shape in different light situation the PLC controls the conveyor sends bad bottle away using a device that pushes with moving part the system also shows the results of the check on screen keeps the information about defects for checking quality this idea gives a correct and growing way to check bottles that works well for smaller and medium companies and also helps with the new way of making things using smart machines.

3. Automated Defect Detection I Perfume Packaging Using Machine Vision Approach for Improved Quality Control. [3]

Ahmad Najmuddeen Ismail, Nur Aidawaty Rafan, Nor Affendy Norizan suggested a computer system that uses a camera to look for problems with perfume bottles. This system uses a computer program called a MatLab and a small computer board called Arduino uno it checks the bottle for defects by looking at pictures of them then uses a small motor to sort out the bad bottles this system is very good at finding defects. it gets it more than 95% of the time. This makes it set a good way to check the quality of bottles without spending a lot of money. The system looks at the bottle finds problems with them but it has some problems it does not work well if the light is not good or if the bottles are shapes or have different labels. It also uses Arduino which has not very good at doing complicated things with pictures and is not fast enough for big factory. So, we want to make a system a that is better. Our system uses a controller called PLC to move the bottles move on conveyor belt and good camera to look at the bottle in real life the computer program can find kinds of problem with the bottles like if the cap is missing or if the bottle is broken or if the label is not on right or if the bottles is not the right shape it can do this even if the light is not good or if the bottles are different the PLC sorts out the bottle and shows the result on a screen this makes this system fast accurate and good for big factories. It also does not cost a lot of money to set up the perfume bottles system is better because it uses a PLC and a good camera the system checks perfume bottles for problems and sorts out the ones.

2.1 Objectives

1. Create an artificial intelligence vision inspection system based on a PLC.
2. Detect bottle defects in real time.
3. Automatically reject defective bottles.
4. Improve both quality and production efficiency
5. Cut down on the needs for manual inspections and reduce production costs.

6. We should support smart industrial automation (Industry 4.0)
7. To classify various sorts of bottle defects by employing the trained AI vision camera.
8. To offer real-time analysis of the inspection results and the status of the system.
9. To enhance the quality and reliability of the process of inspecting the bottles.
10. The project aims to design a low-cost prototype for the small and medium scale industries.

2.2 Proposed System

The proposed system consists of a PLC, stepper motor and driver for conveyor movement, an IR sensor for product detection, an ESP32, AI vision camera for inspection, a servo motor for rejection, a servo home sensor, a 24 V DC power supply, LCD display, stack lights.

III. SYSTEM BLOCK DIAGRAM

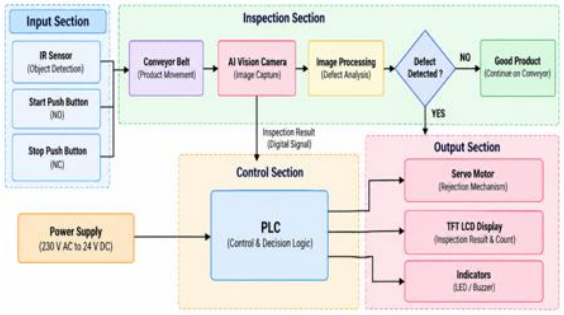


Fig. Block Diagram of Automated Visual Inspection & Rejection System

3.1 Working

1. Power ON the System:

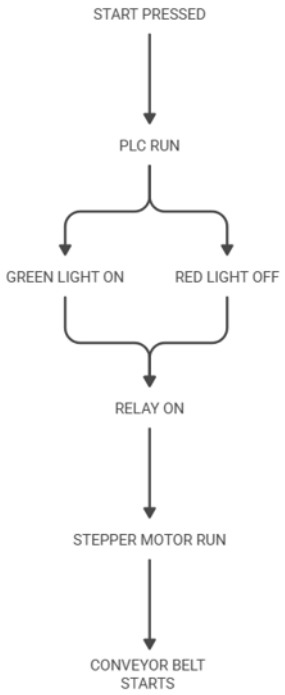
- The system is powered up by connecting it to 230 V AC mains.
- The SELEC RPS60-24-CU SMPS (SMPS) steps down the 230 V AC mains supply to 24 V DC.
- The 24 V DC supply feeds to the Delta DVP-12SA2 (PLC), Finder 24 V DC Relay (Relay), E18-D80NK (IR Sensor), TB6600 Stepper Motor Driver (Stepper Driver), Red Indicator LED (Red Light), Green Indicator LED (Green Light) and 24 V Buzzer (Buzzer).
- The XL4015 5A Step-Down Adjustable Power Supply (Buck Converter) provides the required lower voltage to the ESP32 (Controller), HUSKYLENS K210 (AI Camera) and 2.4" ILI9341 TFT LCD (TFT Display).
- The DS3225 (Servo Motor) is supplied from a suitable regulated supply.
- The PLC, ESP32, HUSKYLENS, TFT Display and servo are initialized.
- The servo moves to its HOME position.
- After powering on the system, it remains stopped until the START button is pressed
- The Red Light remains ON indicating that the process is STOPPED.
- The Green Light remains OFF.
- The Conveyor Belt remains OFF.
- The Buzzer remains OFF.

2. Press START Button and Start the System:

- The operator presses the START Push Button (Start Button).
- A 24 V DC signal is then sent to the appropriate PLC input.
- The Delta DVP-12SA2 (PLC) checks the STOP and Emergency Stop conditions.
- If all conditions are normal, the PLC will switch the system from the STOP condition to the RUN condition.
- The Green Light will turn ON indicating that the system/process has started.
- At the same time the Red Light will turn OFF indicating that the process is no longer stopped.
- The PLC activates the Finder 24 V DC Relay (Relay).
- The conveyor control circuit is activated.
- The TB6600 Stepper Motor Driver (Stepper Driver) drives the NEMA23 Stepper Motor (Stepper Motor).
- The stepper motor drives the drive roller.
- The Conveyor Belt starts moving.

3. Bottle Moves to Inspection Station:

- The conveyor transports the bottle towards the inspection station.
- The E18-D80NK (IR Sensor) continuously monitors the inspection position.
- When a bottle reaches the inspection station, the IR Sensor detects it.
- The sensor sends the signal indicating the presence of the bottle to the PLC.



4. Bottle Detection and Conveyor Stop:

- The PLC receives the bottle detection signal.
- The PLC de-energizes the Finder Relay (Relay).
- The conveyor control circuit is stopped.
- The TB6600 Stepper Motor Driver stops the NEMA23 Stepper Motor.
- The Conveyor Belt stops.
- The bottle is positioned in front of the HUSKYLENS K210 (AI Camera).
- The Green Light can remain ON because the system is still in RUN/automatic mode.
- The TFT Display indicates that the bottle is ready for inspection.



5. AI Vision Inspection:

- The HUSKYLENS K210 (AI Camera) inspects the stationary bottle.
- The trained AI inspection system checks for the required bottle characteristics such as:
  - Cap condition
  - Label condition
  - Bottle shape
  - Bottle level
  - Other trained visible defects.
- The camera determines if the bottle is GOOD or DEFECT.

6. Inspection Result Processing:

- The HUSKYLENS sends the inspection result to the ESP32 (Controller).
- The ESP32 processes the result.
- The ESP32 sends the corresponding signal for the result to the PLC.
- The 2.4" ILI9341 TFT LCD (TFT Display) displays the inspection result
- If the bottle is defective, the TFT Display also displays the rejected reason.

7. GOOD Bottle:

If the inspection result is GOOD:

- The PLC receives the GOOD signal.
- The TOTAL counter is incremented by 1.
- The GOOD counter is incremented by 1.
- The Green Light stays ON.
- The Red Light stays OFF.
- The Buzzer stays OFF.
- The Finder Relay is energized.
- The conveyor is started again.
- The TB6600 drives the NEMA23 Stepper Motor.
- The good bottle continues moving along the conveyor.

8. DEFECTIVE Bottle:

If the inspection result is DEFECT:

- The PLC receives the DEFECT signal from the ESP32.
- The TOTAL counter is incremented by 1.
- The REJECT counter is incremented by 1.
- The Red Light turns ON indicating the defect/rejection condition.
- The Green Light turns OFF during the rejection operation.
- The 24 V Buzzer turns ON.
- The TFT Display displays the failed parameter and the reason for rejection.
- The conveyor moves the defective bottle to the reject position.

9. Automatic Defect Rejection:

- The defective bottle reaches the reject position.
- The PLC stops the conveyor.
- The ESP32 (Controller) activates the DS3225 (Servo Motor).
- The servo moves from its HOME position.
- The reject arm pushes the defective bottle into the reject bin.
- The servo moves back to its HOME position.
- The buzzer turns OFF after the rejection indication.
- The rejection cycle is complete.

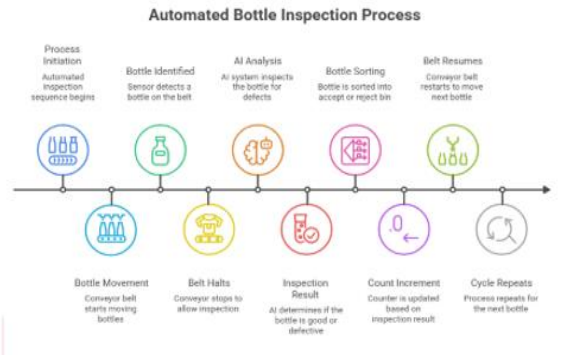


10. Conveyor Restarts:

- After either a GOOD or DEFECT operation has completed, the PLC clears the current inspection cycle.
- The Red Light turns OFF.
- The Green Light turns ON.
- The Finder Relay is energized.
- The TB6600 drives the NEMA23 Stepper Motor.
- The Conveyor Belt starts moving again.
- The next bottle moves towards the inspection station.

11. Continuous Automatic Operation:

The system continuously performs:



During normal automatic operation:

- Green Light = ON → System/process is running.
- Red Light = OFF → System is not stopped.
- Conveyor = ON when transporting a bottle.
- Conveyor = OFF temporarily during inspection.
- Red Light = ON during a defect/rejection indication.
- Buzzer = ON during the programmed defect/rejection indication.

12. STOP Button:

- When the operator presses the STOP Push Button (Stop Button), the PLC stops the automatic process.
- The Finder Relay is de-energized.
- The Conveyor Belt stops.
- The NEMA23 Stepper Motor stops.
- The Green Light turns OFF.
- The Red Light turns ON.
- The Red Light indicates that the process is STOPPED.
- The Buzzer turns OFF.
- The TFT Display shows:

The system stays stopped until the START is pressed again.

13. Emergency Stop:

- If an unsafe condition occurs, the operator presses the Emergency Stop Button (E-Stop).
- The conveyor and hazardous motion are stopped through the appropriate emergency/control circuit.
- The PLC detects the emergency condition.
- The Green Light turns OFF.
- The Red Light turns ON.
- The TFT Display shows:

EMERGENCY STOP

SYSTEM STOPPED

- The system stays stopped until the emergency condition has been safely cleared and the system has been reset.

14. Reset and Start Again:

- The operator safely clears the emergency/stop condition.
- The RESET Push Button (Reset Button) is pressed.
- The PLC clears the active sequence.
- The servo moves back to HOME.
- The system stays stopped.
- Red Light = ON.
- Green Light = OFF.
- When the operator presses START:
  - Green Light turns ON
  - Red Light turns OFF
  - Finder Relay gets energized
  - TB6600 Stepper Motor Driver starts the NEMA23 Stepper Motor
  - Conveyor Belt starts
  - The automatic inspection process starts again

IV. HARDWARE COMPONENTS

The main hardware components used in the proposed automated visual inspection and rejection system are listed below:

1. DVP14SS211T PLC: it is a PLC that is used to control the sensor and vision inspection system. It controls the conveyor, rejecter, indicators, and buzzer.
2. HUSKYLENS AI Vision Camera: it is an AI camera that classifies the visual appearance of the bottle. It has six categories of classification which are good bottle, without cap, level defect, label defect, empty, and shape defect.
3. E18-D80NK IR Sensor: it is an IR sensor that detects whether there is a bottle on a conveyor belt.
4. NEMA 23 Stepper Motor: it is a driver motor for the conveyor belt. It rotates the conveyor belt for inspection.
5. HY-DIV268N-5A Stepper Motor Driver: it is a stepper motor driver that receives input signals (pulses and direction) from the PLC and drives the NEMA 23 stepper motor.
6. DS3225 Digital Servo Motor: it is a servo motor that is used for the rejecter mechanism. It received a signal from the PLC for rejecting a defective bottle.
7. ESP32 Development Board: it is a development board that is used for managing the TFT LCD screen. It regulates and interprets display data from the vision inspection and control system.
8. TFT LCD Display: it is a display that presents the status of the system, detects the appearance of a bottle, its inspection status, defect status, and rejection status.
9. 24 V DC SMPS: it is a 24-volt switched-mode power supply that provides power to the PLC.
10. MCB: It is a miniature circuit breaker that protects the control panel circuit from short-circuiting or overloads.
11. Red and Green Indicators: they indicate the status of a product. Green indicates an accepted product while red indicates a defective product.
12. 24 V DC Buzzer: it warns when a defective product is detected and rejected.
13. Conveyor Belt: it conveys the product for inspection and rejection. It is 800 mm long and 140 mm wide, and it is made of a rubber strip.
14. PVC Conveyor Frame: it is a frame made of a plastic pipe that supports the conveyor belt.
15. Flexible Shaft Coupler: it couples the NEMA 23 stepper motor shaft and the drive roller shaft. It also allows some misalignment of the two shafts.

V. INPUT / OUTPUT CONFIGURATION

Table 1. Input / output Configuration

Address	Signal	Description
I0.0	Start Push Button	Starts the system.
I0.1	Stop Push Button	Stops the system.
I0.2	IR Sensor	Detects product.
I0.3	Camera OK Signal	Indicates good product.
I0.4	Camera NG Signal	Indicates defective product.
I0.5	Reject Position Sensor	Detects reject position.
I0.6	Servo Home Sensor	Confirms servo home position.
Q0.0	Stepper Run	Controls conveyor stepper run/pulse-enable.
Q0.1	Camera Trigger	Triggers camera inspection.
Q0.2	Servo Reject	Activates servo rejection.
Q0.3	Buzzer	Audible defective-product indication.
Q0.4	Green Light	Good-product indication.
Q0.5	Red Light	Reject/defective indication.
Q0.6	Yellow Light	Waiting/process indication.

VI. WORKING PRINCIPLE

The whole system will begin once the operator has pressed the START button. The IR sensor will then detect the presence of a bottle and will send a signal to the PLC. The PLC will then stop the conveyor at inspection position where the HUSKYLENS AI vision camera will be able to read and analyze the bottle. The camera will then classify the bottle as OK or NG according to the selected inspection categories.

If it is an OK category, the PLC will allow the conveyor to move and deliver the bottle to the next station. If it is an NG category, the PLC will deliver the bottle to the rejection position by utilizing the DS3225 servo motor to push the NG bottle to the reject bin. The status of the system will then be updated either by TFT display, indicators, and buzzer. And lastly, the NG bottle will have been rejected, and the servo motor will go back to its home position, and will be preparing for the next bottle to be inspected.

VII. PLC CONTROL LOGIC

The PLC program is created using ladder logic. The ladder sequence that is shown in the project includes start and stop latching, product detection stopping the stepper at the inspection position, camera triggering waiting for the camera result continuing the product moving the defective product to the reject position servo rejection, buzzer activation and reset.

1. System Start/Stop and Run Latch

- X0 – Start: Starts the system.
- X1 – Stop: Stops the system when pressed.
- X2 – Emergency Stop: Stops the system during an emergency.
- M0 – System Run: Holds the system in the ON state after the start button is released.

In simple words, this rung starts the system and keeps it running until stop or Emergency stop is activated.

2. Indicator Lights

- Y0 – Red Light: Turns ON when the system is stopped or an emergency stop is activated.
- Y1 – Green Light: Turns ON when the system is running.

These lights help the operator identify the current system status.

3. Conveyor Control

- M0: Confirms that the system is running.
- T0: Acts as the conveyor stop timer.
- Y2 – Conveyor Belt: Runs when the system is ON and the stop timer is not active.

When bottle is detected, the timer controls the conveyor stopping period so that the bottle can be inspected.

4. Bottle Sensor, Stop Timer and Counter

- X3 – IR Sensor: Detects the bottle on the conveyor.
- TMR T0 K70: Starts the conveyor stop timer when the sensor is activated.
- CNT C0 K9999: Counts bottle detections using the sensor's rising edge.

This rung detects each bottle, initiates the stopping sequence, and maintains a bottle count.

5. Modbus Read – ESP32 Inspection Result (Register 0)

- M0: Allows communication when the system is running.
- M100: Enables the Modbus read command.
- MODRD K1 H0 K1: Reads one register from the ESP32 through Modbus.
- M101: Used as a communication completion or status flag.
- SET/RST M100: Controls the read-request flag.

This rung retrieves the inspection result from the ESP32 so that the PLC can decide whether the bottle is good or defective.

6. Compare Inspection Result and Mark Good/Defective Bottle

- CMP D100 K2 M20: Compare the inspection result stored in D100 with the value 2.
- M21 → SET M10: Sets the defective bottle flag when the corresponding comparison condition is satisfied.
- M24 → SET M11: Sets the good bottle flag when its comparison condition is satisfied.
- X3 → RST M11: Resets the good bottle flag according to the IR sensor input condition.

This rung uses the ESP32 inspection result to classify the bottle. The exact meaning of the comparison flags depends on the PLC's CMP instruction and the values assigned by the ESP32.

7. Reject Position Delay Timer (Defective Bottle)

- M10: Activates the timer when a defective bottle is identified.
- TMR T1 K200: Starts the rejection delay timer.

The delay allows the defective bottle to travel from the inspection point to the rejection position before the reject command is issued.

8. Modbus Write – Send Reject Command (Register 1)

- T1: Confirms that the rejection delay has elapsed.
- M12 and M30: Provide interlock conditions to prevent the command under specified conditions.
- MODWR K1 H1 K1: Writes one register value to the ESP32 through Modbus.

After the delay, the PLC sends the rejection command, provided the interlock conditions are satisfied.

9. Modbus Read – ESP32 Status (Register 2)

- M0 and M110: Enable the status-reading sequence when the system is running.
- MODRD K1 H2 K1: Reads one register from the ESP32.
- M111: Used to set the M110 request flag.
- RST M110: Resets the request flag.

This rung reads the ESP32 status to help the PLC monitor the rejection process and its completion.

10. Check Reject Completion and Reset

- CMP D102 k2 M26: Compares the status value stored
- M27 →

11. Fault Handling

- MODWR K1 H1 K1: Sends a Modbus command when M12 is active.
- M12 and X3: Control the defective bottle flag reset condition.
- RST M10: Clears the defective bottle flag when the rung conditions are met.
- RST M12: Resets the rejection-sequence flag.
- CMP D102 K3 M29: Compares the status register with the value 3.
- M30 → Y0: Turns ON the red indicator light when the fault condition is detected.
- M30 → RST M0: Stops the system when the fault flag is active.

This rung is intended to detect an abnormal status, activate the red light, and stop the system for safety.

VIII. AI VISION INSPECTION MODULE

We want to share how the vision module works. The vision module uses an ESP32 that we call the AI Vision Camera in this project. The AI Vision Camera is activated by the PLC. Once activated the AI Vision Camera gives one of two inspection outcomes: OK, which means the product is good or NG which means the product is defective. After the AI Vision Camera gives outcome, the PLC looks at that outcome. The PLC then decides which conveyor the product should go to next. The PLC also decides whether the product should be rejected.

- AI model used: HUSKYLENS Object Classification
- Training framework/software: HUSKYLENS built-in AI training interface
- Defect categories: Without cap, level defect, label defect, empty bottle, shape defect
- camera distance: 22.7 cm
- bottle spacing: 10 cm

IX. AI VISION CAMERA TRAINING AND DEFECT CLASSIFICATION

We trained the AI vision camera to classify bottles into categories based on each bottles visual condition. Six object classes were defined during the training process. ID1 was assigned to a bottle while ID2 to ID6 were assigned to different defective conditions, including missing cap, incorrect liquid level, label defect, empty bottle and abnormal bottle shape

I set the distance between the AI vision camera and the bottle to 22.7 cm during the training setup. I set the distance, between two bottles to approximately 10 cm to provide adequate separation during inspection.

We used these conditions to keep the inspection environment consistent and to reduce the chance that the AI vision camera would confuse bottles or see overlapping bottle detections.

Table 2. Ai Vision Camera Training and Defect Classification

Object ID	Classification	Description
ID1	Good Bottle	Bottle in acceptable condition
ID2	Without Cap	Bottle with missing cap
ID3	Level Defect	Incorrect liquid level
ID4	Label Defect	Missing, damaged, or incorrect label
ID5	Empty Bottle	Bottle without the required contents
ID6	Shape Defect	Bottle with abnormal or deformed shape

X. SIMULATION AND VIRTUAL TESTING

Prior to building the physical prototype, a simulation of the proposed automated inspection system is constructed. The objective of the simulation is to verify the operating sequence and control logic of the system. The focus of the simulation is on the interaction between the inspection unit, controller, conveyor, rejection mechanism, and display interface. A TFT display presents the status information that would be presented to an operator during system operation.

XI. SYSTEM INITIALIZATION

During system boot-up, the simulation starts by activating the controller. The controller then proceeds to initialize all modules and move the rejection mechanism to its home position. The TFT display shows the status of the components, such as the ESP32, TFT display, servo motor, camera, PLC and conveyor. The simulation waits until a bottle appears.

The simulated system startup screen verifies that all major modules are initialized and ready before inspection starts.

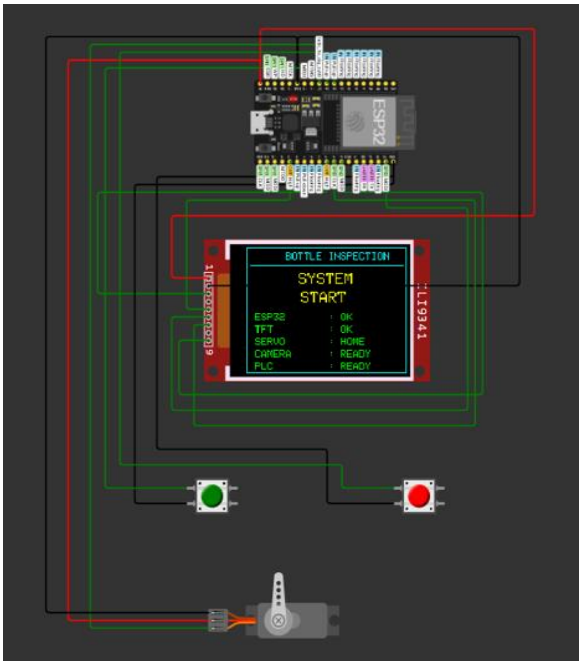


Fig. XI. Simulated system initialization and verification of connected modules.

XII. BOTTLE DETECTION

A sensor ensures that a bottle is present before visual inspection is initiated. When the bottle reaches the detection spot, the simulation recognizes the presence of the bottle. Initiates the inspection sequence. The TFT display changes from "WAITING FOR BOTTLE" to a bottle-detected/inspection status.
This approach prevents conducting image processing when there is no bottle present and ensures proper product synchronization.



Fig. XII. Simulated bottle detection using the IR sensor and initiation of the inspection process.

XIII. VISUAL INSPECTION PROCESS

Following successful detection of the bottle, the simulation activates the inspection process. The TFT display displays the inspection status for the bottle features, including:

- Cap condition
- Label condition
- Bottle shape
- Bottle level

During this phase, the TFT display displays "PROCESSING" or "INSPECTION ACTIVE" indicating that the bottle is being inspected.



Fig. XIII. Simulated visual inspection process for evaluating bottle quality parameters.

XIV. GOOD PRODUCT IDENTIFICATION

If all required inspection features are correct, the simulation marks the bottle as GOOD. The simulation highlights the cap, label, shape, and level as OK.
The TFT display displays: ACCEPTED → CONVEYOR ON → PLC: GOOD
The conveyor then continues to convey the accepted bottle along the production line.



Fig. XIV. Simulated identification and acceptance of a good product based on inspection results.

XV. DEFECTIVE PRODUCT IDENTIFICATION

When the simulation detects a defective bottle, the inspection status is updated to DEFECT. In this example, a missing cap results in rejection, while the other features remain correct.

The TFT display displays: DEFECT → REJECTING → SERVO ACTIVE

The PLC and controller logic then activates the rejection mechanism.

The servo moves from its home position to 90°, thus, pushing the defective bottle out of the main conveyor path.



Fig. XV. Simulated identification of a defective product based on inspection parameters.

XVI. REJECTION SEQUENCE

After the servo has pushed the bottle, the servo returns to its home position. The conveyor then continues to operate normally. The TFT display updates to "REJECTION COMPLETE". This indicates the reason why the bottle was rejected.

This sequence indicates that the rejection mechanism will only activate if a defective bottle is detected, minimizing the risk of rejecting a bottle.

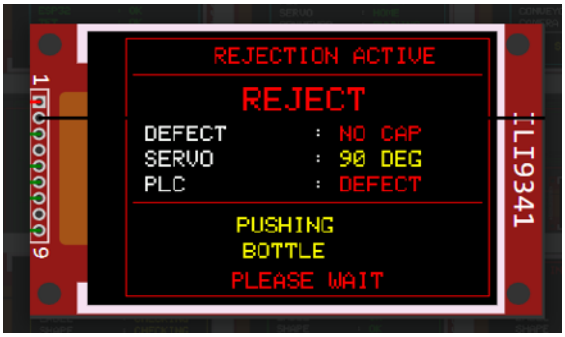


Fig. XVI. (a). Simulated activation of the servo-based rejection mechanism for removing the defective bottle.



Fig. XVI. (b). Simulated completion of the rejection operation and preparation for the next inspection cycle.

XVII. SIMULATION RESULTS

Table 3. Simulation Result

Simulation condition	Observed system response
System startup	Modules initialized and system ready
No bottle detected	Inspection sequence initiated
Bottle detected	Inspection sequence initiated
Inspection in progress	Cap, label, shape and level checked
bottle	Product accepted and conveyor continues
Defective bottle	Defect identified and rejection initiated
Rejection	Servo activated to remove defective bottle
Rejection completed	Servo returns to home position
Production counting	Total, good and rejected quantities displayed

In one simulated test the display shows three inspected products, two good and one rejected. This proves that the counting logic can keep counts for accepted and rejected bottles.

XVIII. SIMULATION OUTCOME

The simulation proves that the planned sequence of the inspection system works: bottle detection → inspection → classification → acceptance or rejection → counting → system ready for the bottle. The TFT interface also gives feedback on the current status and inspection result.

The virtual testing confirmed the control sequence before building hardware. It also helped spot timing and coordination problems, between bottle detection,

inspection, conveyor movement and the servo-based rejection mechanism.

XIX. PLC PROGRAMMING & CONTROL LOGIC

Ladder Program for controlled Automated Visual Quality Inspection & Rejection system.

1.Start: The Start Push Button will be pressed by the operator. This will start the ladder program and activate the Internal Memory Bit (M0) (RUN mode).

2.System Status: The LEDs will show what state the system is in. There will be 2 LED's the red and green. These will be connected to Output Y0 & Y1.

3.Conveyor Belt: Output Y2 will turn on the Conveyor belt. The T0 Timer will turn off the conveyor belt.

4.Bottle Detection: We will be using the IR Sensor (E18-D80NK) to determine if there is a bottle present. We will be using Input X3. A Counter will be used to count how many bottles there are (Counter C0).

5.Inspection Results: The PLC will communicate to the ESP32 using Modbus. The results will be read from the inspection and stored into Register H0. The results will then be stored into D100.

6.Bottle Classification: The Inspection value will be compared to values that have been created inside the PLC. If the bottle is faulty then the Internal Memory Bits will be turned on (M10 & M11).

7.Delay: If the bottle is broken or faulty timer T1.

8.Send Rejection: Once the delay has been completed all the conditions will be met and the PLC will send a rejection command. This will be sent to Register H1 on the Modbus.

9.Status: PLC will read the status from the Modbus Register H2 and store it into D102.

10.Fault Detection: The status will be compared to the set value. If the system is in a fault state, then the Red Light will light up by going into stop mode. This will also reset the Memory Bit (M0).

11.Control Logic: This Control Logic ensures the inspection has finished and is ready for the next bottle to be inspected.

The Ladder Program can detect if there are bottles in, control the conveyor belt, detect the results of the inspection, send out rejection commands and detect faults. This has automated the quality inspection with little human interaction.

XX. EXPERIMENTAL METHODOLOGY

The intended prototype was tested by letting the bottles pass through the conveyor belt until the IR sensor was able to detect its presence. First, the E18-D80NK IR sensor had to read the presence of the bottle and initiate the inspection process. Meanwhile, the PLC had to operate the conveyor belt in order to properly position the product in front of the HUSKYLENS AI Vision camera. Next, the camera had to identify the product according to the trained classifications. Finally, the Good/NG indication had to be read by the PLC in order to operate the conveyor belt or the rejection cylinders accordingly.

The test products included 6 bottles, 1 Good product, and 5 defective products. The vision system was trained to detect and classify the different categories of the tested product which were good bottle, missing cap, level defect, label defect, empty bottle, and shape defect. During the test setup, the distance between the camera and the product was around 22.7 cm while the lighting was controlled to allow the camera to capture good quality images of the tested product. At the same time, the spacing between the different bottles was kept at approximately 10 cm for the training setup.

The experiment procedure consisted of inspection process, conveyor belt positioning and product rejection. Firstly, the IR sensor had to detect the presence of the bottle. Then, the conveyor belt had to stop at the inspection station in front of the camera while the inspection process was initiated. Ultimately, the PLC had to read the inspection result and activate the conveyor belt or the rejections cylinders accordingly. In case of good products, the conveyor belt had to continue moving in order to deliver the product to the next station. Meanwhile, in case of defective products, the conveyor belt had to redirect the product to the rejection station where the DS3225 Servo Motor had to open the rejection gate. After the

rejection process, the servo motor had to return to its initial position in order for the inspection system to be ready for the next inspection cycle.

Experimental parameters:

- Number of total test products: 6
- Number of Good test products: 1
- Number of Defective test products: 5

Lighting Controlled/constant lighting:

- Distance between camera and product Approximately: 22.7 cm
- Bottle to bottle spacing Approximately: 10 cm
- Conveyor speed (in inspection): Not measured
- Average inspection time: Not measured
- Average cycle time: Not measured

XXI. PERFORMANCE EVALUATION

The performance of the proposed system needs to be checked using classification accuracy and physical rejection performance. The following results are intentionally left empty because they have to be gathered through experiments, with the prototype.

Table 4. Performance Evaluation

Performance Parameter	Measured Result
Total products tested	6
Correct Good classifications	1
Correct Defective classifications	5
Vision classification accuracy	100%

XXII. RESULTS AND DISCUSSION

The model shows that the product detection, inspection, classification, conveyor movement and automatic rejection all work as planned. The specific numbers that show how well the system works need to be found out by doing tests.

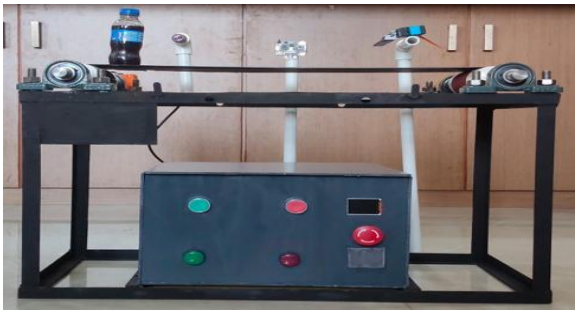


Fig. Real image of automated visual inspection and rejection system

Observed vision accuracy: 100%
Observed rejection accuracy:
Observed average inspection time:
Observed throughput:
Best operating lighting condition: Controlled and constant lighting
Main observed failure condition: Variation in lighting, camera position, or bottle orientation

The systems last performance needs to be talked about using both vision classification and physical automation. An AI or vision classification is not enough if the PLC timing or servo system does not work to remove the bad product. So, classification accuracy and complete rejection accuracy must be shown on their own.

XXIII. ADVANTAGES OF THE PROPOSED SYSTEM

- Automatic inspection.
- Accurate detection of Good and NG products based on the performance of the vision model used.
- Automatic rejection of products.
- PLC-based sequence control for operation.
- Low-cost prototype built using ESP32-CAM.
- Need for continuous manual inspection.
- Status indication using yellow and red stack lights.
- Audible alert for products via buzzer.
- Consistent inspection and rejection process.
- Potential to scale as an automation prototype.

XXIV. LIMITATIONS

- I notice that the number and type of defects are limited to those that are built into the vision model and this may affect the inspection accuracy.
- I see that vision performance may depend on camera position and lighting conditions careful setup is needed.
- I observe that the ESP32-CAM has computational resources than industrial vision computers, which limits the processing speed.
- I understand that the current system is a prototype and the current system production-scale performance has not yet been established, so scaling remains uncertain.
- I realize that the maximum reliable conveyor speed and throughput are not yet experimentally established, meaning throughput limits are unknown.

- I note that size and diversity of training/ test dataset are not yet specified, which could impact model generalization.

XXV. FUTURE SCOPE

- I will increase training dataset by adding data and include more defect categories to cover a wider range of issues.
- I will improve robustness to changes in lighting, angle and placement.
- If the application demands it I will deploy an advanced edge-AI model to boost performance.
- I will increase speed while keeping inspection reliable.
- I will add production data logging. Set up statistical quality monitoring to track performance over time.
- I will integrate extra HMI features, for defect counts and production reports.
- I will evaluate the system with a variety of industrial products to ensure broad applicability.
- I will investigate communication and higher-level Industry 4.0 integration.

XXVI. CONCLUSION

This paper shows a system that uses a PLC for vision inspection and automatic rejection. The system uses an ESP32-CAM AI vision camera IR product detection, a stepper motor for the conveyor and a servo for rejecting products. The PLC controls the process: finding the product stopping at the right spot taking a picture deciding if it is good or not moving to the right bin rejecting the bad ones showing the status and getting ready for the next product. The design is meant to offer checking, correct identification, automatic rejection, better quality and lower costs. After doing tests we need to add numbers, about how accurate it's how well it rejects bad products how fast it works and how many it can handle.

REFERENCES

[1]. Kazmi, M., B. Hafeez, H. R. Khan, and S. A. Qazi, “Machine-vision-based plastic bottle inspection for quality assurance,” in Proc. 7th Int. Electrical Engineering Conference (IEEC), Karachi, Pakistan, 2022, doi: 10.3390/engproc2022020009.

[2]. M. Maślanka, D. Jancarczyk, and J. Rysinski, “Integration of machine vision and PLC-based control for scalable quality inspection in Industry 4.0,” Sensors, vol. 25, no. 20, Art. no. 6383, 2025, doi: 10.3390/s25206383.

[3]. J. Yang, S. Li, Z. Wang, H. Dong, J. Wang, and S. Tang, “Using deep learning to detect defects in manufacturing: A comprehensive survey and current challenges,” Materials, vol. 13, no. 24, Art. no. 5755, 2020, doi: 10.3390/ma13245755.

[4]. X. Zheng, S. Zheng, Y. Kong, and J. Chen, “Recent advances in surface defect inspection of industrial products using deep learning techniques,” Int. J. Adv. Manuf. Technol., vol. 113, pp. 35–58, 2021, doi: 10.1007/s00170-021-06592-8.

[5]. S. H. Huang and Y. C. Pan, “Automated visual inspection in the semiconductor industry: A survey,” Comput. Ind., vol. 66, pp. 1–10, 2015, doi: 10.1016/j.compind.2014.10.006.

[6]. N. Hütten, M. Alves Gomes, F. Hölken, K. Andricevic, R. Meyes, and T. Meisen, “Deep learning for automated visual inspection in manufacturing and maintenance: A survey of open-access papers,” Appl. Syst. Innov., vol. 7, no. 1, Art. no. 11, 2024, doi: 10.3390/asi7010011.

[7]. D. Y. Patrashko and V. Gurau, “Machine learning-powered vision for robotic inspection in manufacturing: A review,” Sensors, vol. 26, no. 3, Art. no. 788, 2026.

[8]. Y. Ma, J. Yin, F. Huang, and Q. Li, “Surface defect inspection of industrial products with object detection deep networks: A systematic review,” Artif. Intell. Rev., vol. 57, Art. no. 333, 2024.

[9]. Z. Li, Y. Yan, X. Wang, Y. Ge, and L. Meng, “A survey of deep learning for industrial visual anomaly detection,” Artif. Intell. Rev., vol. 58, Art. no. 279, 2025.

[10]. S. B. Jha and R. F. Babiceanu, “Deep CNN-based visual defect detection: Survey of current literature,” Comput. Ind., vol. 148, Art. no. 103911, 2023.

[11]. M. Babic, M. A. Farahani, and T. Wuest, “Image based quality inspection in smart manufacturing systems: A literature review,” Procedia CIRP, vol. 103, pp. 262–267, 2021.