

THE UNIVERSITY OF DANANG
UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING



CAPSTONE PROJECT

MAJOR: Mechatronics Engineering

THESIS TOPIC:

**DESIGN OF OPTICAL INSPECTION
MACHINE FOR DEFECTS DETECTION ON
CASTED PARTS**

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Class : **20CDTCLC1**

DaNang, 06/2025

ABSTRACT

This thesis designs and develops an optical inspection system to detect defects in casted parts, organized into five key chapters:

Chapter 1: Overview

- Research and review of existing optical inspection machines on the market.
- Analysis of the advantages and disadvantages of current systems.
- Discussion of real-world applications and development trends of visual inspection technology for casted parts.

Chapter 2: System Design and Technical Calculations

- Definition of system requirements.
- Proposal of a complete design solution.
- Design mechanical components using SolidWorks and AutoCAD.
- Selection of devices such as sensors, cameras, processors, and actuators.

Chapter 3: System Implementation

- Construction of the hardware, including motion systems, fixtures, and gripping mechanisms.
- Designed and implemented the monitoring interface using Qt Designer and Python.

Chapter 4: Implementation Results

- Presentation of mechanical and electrical assembly results.
- Functionality of the monitoring interface and image processing system.
- Evaluation of the system's defect detection and classification capabilities.

Chapter 5: Conclusion and Future Development

- Summary of achievements compared to initial objectives.
- Recommendations for future improvement, including increased processing speed, AI-based defect detection, and enhanced defect classification.

GRADUATION PROJECT ASSIGNMENT

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1. Thesis topic:

Design of optical inspection machine for defects detection on casted parts.

2. Intellectual Property Agreement: An intellectual property agreement is signed regarding the project results

3. Initial data and information:

- Number of parts inspected per cycle: 4 parts per cycle
- Surfaces to be inspected: 2 sides (top and side views)
- Types of defects to be detected: cracks, burrs, and deformations
- Required inspection speed: 500 parts/hour

4. Contents of explanation and calculations:

No	Student's name	Contents
1	Nguyen Tang Duc	Write a report
2	Phan Thanh Hai	Select materials and components Operate and test the machine Assemble and test the machine Image processing

5. Drawings and diagrams

No	Student's name	Contents
1	Nguyen Tang Duc	Kinematic Diagram of the Machine (A0) Algorithm Flowchart (A0) Electrical Diagram (A3)
2	Phan Thanh Hai	General Assembly Drawing (A0) Detailed Structural Drawing (A0) Subassembly Drawing (A0) Assembly Drawing (A0)

6. Supervisor: PhD. Do The Can

Co - Supervisor: Le Huu Dung

7. Assignment Date: March 12, 2025

8. Due Date: June 12, 2025

DaNang, March 2025

Head of department: Ph.D Vo Nhu Thanh

Supervisor

PREFACE

In industrial manufacturing, quality inspection of casted parts plays a crucial role in detecting defects such as cracks, air pockets, or shape deviations at an early stage, thereby ensuring product quality and production efficiency. Optical inspection using image processing technology is increasingly being adopted due to its high accuracy and automation capabilities.

From this practical need, our team carried out the project titled “Design of Optical Inspection Machine for Defects Detection on Casted Parts”, aiming to design and build a prototype that utilizes industrial cameras combined with image processing algorithms. The system is capable of detecting surface defects and automatically classifying the parts, thereby enhancing the efficiency of production monitoring.

We would like to express our sincere gratitude to Ph.D Do The Can for his dedicated guidance and support throughout the implementation of this project.

Our appreciation also goes to all lecturers of the Faculty of Mechanical Engineering – University of Science and Technology, The University of Danang, for their teaching and valuable support during our studies and research.

We are also thankful to Danapi Company and the reference sources that provided valuable information and practical support, contributing to the successful completion of our project.

Sincerely,
The Project Team

ASSURE

Dear faculty of mechanical engineering – University of Science and Technology –
The university of DaNang

We, the student group undertaking this project, hereby affirm that our work fully complies with all academic integrity regulations, as detailed below:

- No form of dishonesty was used during the implementation or presentation of academic results.
- All information provided is truthful, verifiable, and properly cited in accordance with academic standards.
- No fabricated or falsified data was used in any surveys, experiments, practical work, internships, or other academic activities.
- We did not plagiarize or present the words, translations, expressions, or ideas of others as our own without proper citation.
- We did not engage in self-plagiarism, reuse previously published research without citation, or fragment our research results for multiple publications.

We take full responsibility for the honesty and transparency of the project's content and are committed to upholding the academic standards of the University.

The Student Group

Nguyen Tang Duc

Phan Thanh Hai

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol/Abbreviation	Meaning
PLC	Programmable Logic Controller
PC	Personal Computer
V	Volt
M	Met
Cm	Centimeter
Mm	Millimeter
Kg	Kilogram
Hz	Hertz
I/O	Input/Output
G	Gam
H	Hour
Nm	Newton-meter
DC	Direct Current
AC	Alternating Current

INTRODUCTION

1. Purpose of the Project

The project aims to enhance the efficiency and accuracy of visual inspection for post-casting products by replacing traditional manual inspection methods, which are labor-intensive and prone to human error. Its main purpose is to promptly and accurately detect surface defects such as porosity, cracks, burrs, deformation, and dimensional deviations, thereby ensuring the quality of the final products. Additionally, the project focuses on developing an automatic inspection system utilizing image processing technology to optimize the production process, reduce labor costs, and improve product quality monitoring capabilities.

2. Project Objectives

- To design and fabricate a prototype machine for automatic visual inspection of post-casting products.
- To apply image processing technology for detecting and identifying surface defects.
- To automate the inspection process, minimizing dependence on manual labor.
- To classify conforming and non-conforming products based on predefined inspection criteria.
- To display inspection results through an intuitive interface for monitoring and supervision.
- To ensure system stability and scalability for real-world production environments.

3. Scope and Research Subjects

Scope of Research: The project focuses on visual inspection of small- and medium-sized post-casting products with observable surfaces. The system applies basic image processing algorithms without implementing advanced machine learning or artificial intelligence techniques. Product classification is limited to binary outcomes: pass or fail.

Research Subjects: The research involves post-casting products (plastic) and common surface defects such as porosity, cracks, burrs, deformation, and dimensional deviations. It also covers hardware components (industrial cameras, microcontrollers, mechanical structures) and image processing software.

4. Research Methods

- **Survey Method:** Researching and analyzing existing industrial visual inspection methods.

- Analytical and Synthetic Method: Analyzing typical defect types and technical requirements to propose suitable solutions.
- Experimental Method: Assembling, testing, and evaluating the prototype system through real product inspection.
- Engineering Design Method: Designing mechanical structures, selecting hardware, and developing image processing and control software.
- Evaluation Method: Measuring the system's defect detection accuracy, processing time, and operational stability through testing.

CHAPTER 1. OVERVIEW

1.1. Overview of post-casting visual inspection systems

The post-molding visual inspection machine is a device used to inspect the appearance of products, components or materials to find products that are difficult to identify cosmetically after the molding process (usually plastic injection, metal casting, or similar processes).

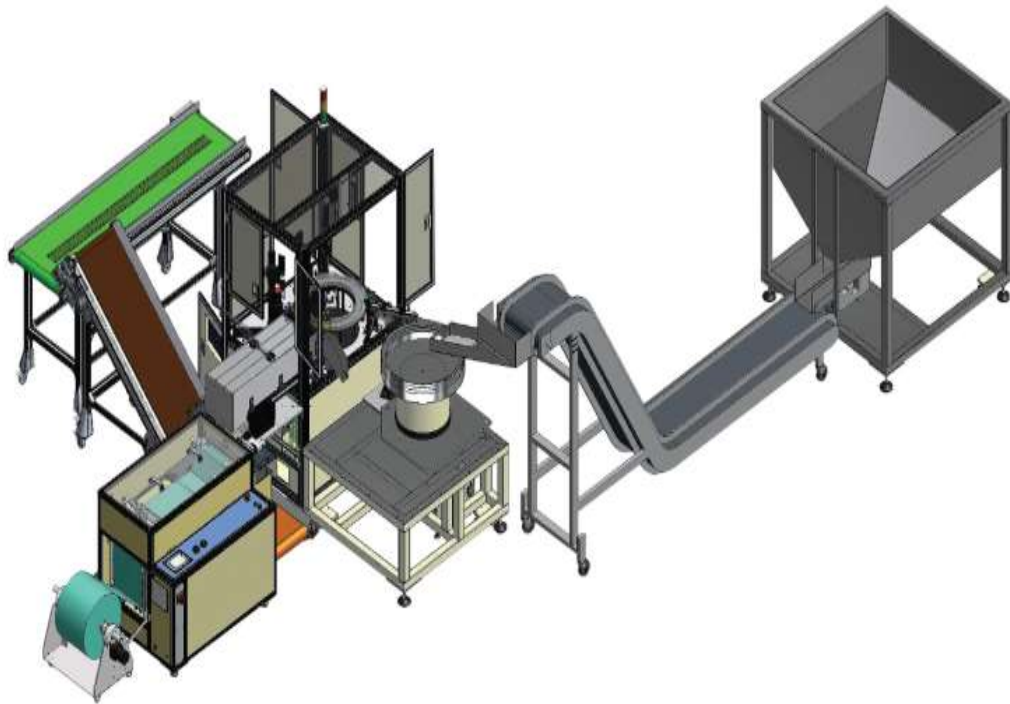


Figure 1.1. Post-casting visual inspection system (source: internet)

Key Functions:

- Surface defect detection: Identifies common surface defects such as cracks, air pockets (porosity), burrs, dimensional deviations, and other imperfections.
- Color and shape verification: Ensures product conformity in terms of color standards and structural integrity, detecting any deformation or discoloration.
- Process automation: Integrates industrial cameras, sensors, and artificial intelligence (AI) to perform automatic product classification based on predefined quality criteria.

1.2. Common types of visual inspection machines

1.2.1. *Acv-16049 series – automatic visual inspection and sorting system*

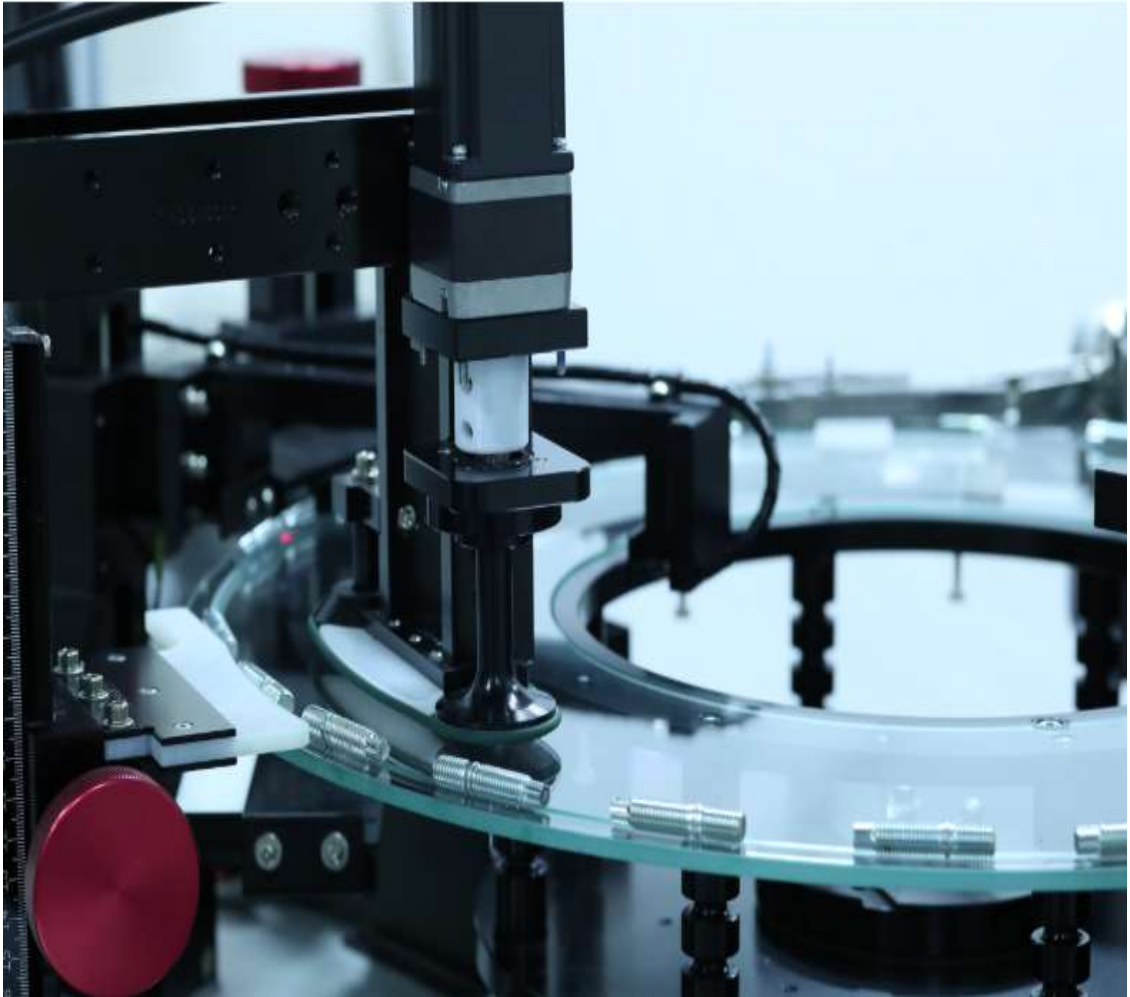


Figure 1.2. Acv-16049 series visual inspection and sorting machine (source: internet)

The ACV-16049 Series is a product line designed for automatic visual inspection. It is capable of both dimensional measurement and defect detection, comparing differences or identifying faults.

The system structure includes three main parts:

- Automatic part feeding: Mainly utilizes vibratory feeders to position and orient the samples in a specific direction for inspection.
- Automatic dimensional measurement: Consists of an optical system (German CCD cameras), dimensional measurement software capable of creating measurement programs corresponding to the sample under inspection as per user requirements, and a rotating table (typically made of glass or stainless steel). In addition to measurement functions, the software can identify surface defects and flaws using OCR (Optical Character Recognition).

- Automatic sorting mechanism: Automatically separates conforming and non-conforming products (OK/NG), or classifies defective items and those within specified tolerance ranges.

In addition, after sorting, the system can be integrated with automatic packaging mechanisms and conveyors to form a fully closed-loop production line.

Application scope: The ACV-16049 Series is designed for 100% automatic inspection and classification of small to medium-sized components.

Table 1.1. Technical specifications – acv-1609 series

Size range	Diameter: M4 ~ M30; Length: < 50 mm
Inspection speed	High-speed with German CCD cameras and lighting system
Optical system	German CCD cameras and industrial lighting
Number of cameras	1 to 6 (depending on requirements), standard setup: 2 cameras
Output classification	1–2 OK output lanes; 1–4 NG output lanes
Software	Intuitive GUI, user-friendly interface
Optional integration	Can be integrated with: Eddy current testing (non-destructive), 360° camera, auto packaging system
Inspection parameters	Diameter, thickness, bolt/nut head width, height, depth, groove in cavity, internal/external thread diameter, first thread detection, cracks, thread defects, angles, curvature radius, chamfering, etc.
Power supply	AC, single-phase, 220V, 50/60Hz
Dimensions	1065mm(L)×860mm(W)×1,855mm(H)

1.2.2. Visual inspection and packaging machine



Figure 1.3. Visual inspection and packaging machine (source: internet)

- Automatic visual inspection equipment for products
- Part feeding method: Part feeder
- Inspection method: Image processing via camera
- Counts the number of OK and NG products; packages OK products
- Productivity: 3600 pcs/hour

Technical Specifications:

- Dimensions: 800 × 1850 × 1500 mm
- Weight: 600 kg
- Voltage: 220 V
- Power: 0.3 kW
- Air pressure: 0.5 MPa

1.3. Advantages of using visual inspection machines

The implementation of visual inspection systems is becoming an essential trend in modern manufacturing processes. Below are the key benefits of using this solution:

a. High accuracy

Visual inspection machines are capable of detecting defects in quantity, dimensions, color, shape, characters, barcodes, and foreign objects within the production line. This ensures the output quality is consistent and significantly reduces product defects.

b. Fast processing speed

With high-speed inspection capabilities, the system can identify and correct defects in a short amount of time, ensuring high-quality products at the output stage. The machine accurately detects defective products even in high-speed, continuous production lines.

c. Simple programming and operation

Visual inspection systems are easy to program and operate, allowing businesses to perform reliable inspections without requiring highly skilled technical personnel.

d. Improved product quality

Utilizing visual inspection machines enhances production efficiency, ensures uniform product quality, and optimizes both inspection and operation processes. This leads to improved business performance and reduced operational costs.

e. Increased production output

This solution accelerates the inspection process and reduces inspection time compared to manual methods. As a result, companies can produce more in a shorter time, thereby improving overall productivity.

f. Minimization of defective products delivered

Visual inspection systems enable rapid and accurate defect detection, reducing the number of returned products, lowering production costs, and enhancing brand reputation.

g. Cost and time savings

Using visual inspection machines not only reduces labor costs but also optimizes inspection and product classification processes. This results in significant time and cost efficiency for enterprises.

In summary, implementing visual inspection machines is a comprehensive solution that helps businesses ensure product quality, improve production efficiency, and optimize operational costs.

1.4. Applications of visual inspection machines

a. Electronics industry

Visual inspection solutions help ensure the quality and finishing of electronic products, including printed circuit boards (PCBs), electronic devices, and high-tech components.

b. Medical industry

Automated inspection technology enhances safety and quality for medical products, ranging from surgical instruments and medical devices to pharmaceuticals, meeting the stringent standards of the industry.

c. Semiconductor industry

Modern inspection systems accurately evaluate the performance and quality of semiconductor components such as integrated circuits (ICs), transistors, LEDs, and other advanced components.

d. Manufacturing industry

Quality inspection solutions help optimize production processes, ensuring the finish of industrial products such as metals, plastics, wood, and many other materials, improving durability and aesthetics.

CHAPTER 2. SYSTEM DESIGN AND TECHNICAL CALCULATIONS SYSTEM REQUIREMENTS

2.1. System requirements

2.1.1. General requirements

The system must be capable of detecting and classifying conforming and non-conforming products based on inspection criteria.

It should operate reliably and accurately, align with the experimental model, and have the potential for real-world scalability.

The design must be cost-effective, easy to assemble, maintain, and upgrade when necessary.

2.1.2. Hardware requirements

Industrial Camera: Must have sufficient resolution to detect small surface defects.

Lighting System: Provides adequate lighting conditions to enhance contrast and improve defect detection accuracy.

Product Conveying System: Ensures stable product positioning within the inspection area at a speed compatible with the image processing system.

Processing and Control Unit: The system employs a PLC to control mechanical components such as sensors, conveyors, and sorting mechanisms, ensuring precise and stable operation. Image data is transmitted to a computer for processing, defect recognition, and product quality evaluation.

Product Sorting Mechanism: Automatically separates defective products from those that meet quality standards.

2.1.3. Software requirements

Image Acquisition and Processing: Software must be capable of identifying and analyzing images to detect defects such as air bubbles, cracks, burrs, and deformations.

Monitoring Interface: Displays inspection results, product images, and classification status for operator supervision.

Data Storage: Records inspection data for analysis and production process optimization.

Control Integration: Synchronizes control of components such as the dobot, camera,

and sorting mechanism.

2.1.4. Performance requirements

Inspection Accuracy: High defect detection accuracy with minimal errors.

Inspection Speed: Ensures processing time is suitable for experimental production scale.

Scalability: The system should be upgradeable to inspect a wider range of products or integrate with industrial production lines.

2.2. Design approach

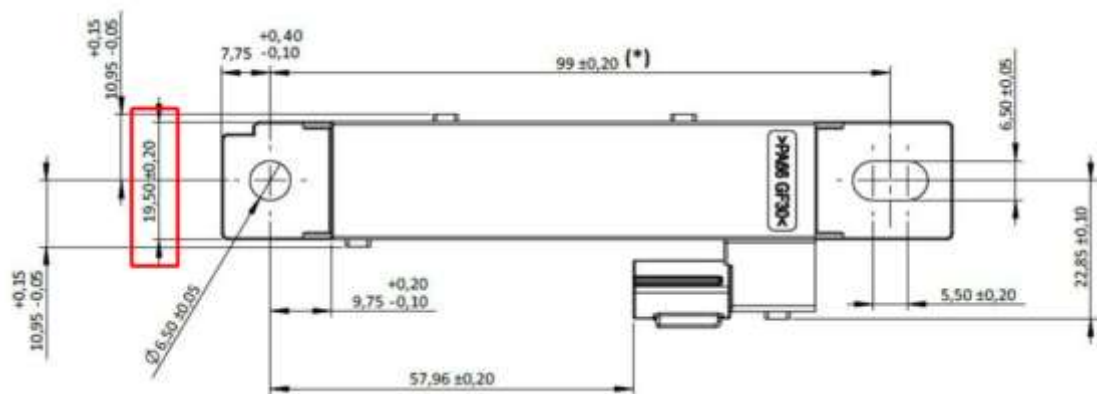


Figure 2.1. Dimensions of the casted part to be optically inspected



Figure 2.2. Actual casted part used for visual inspection

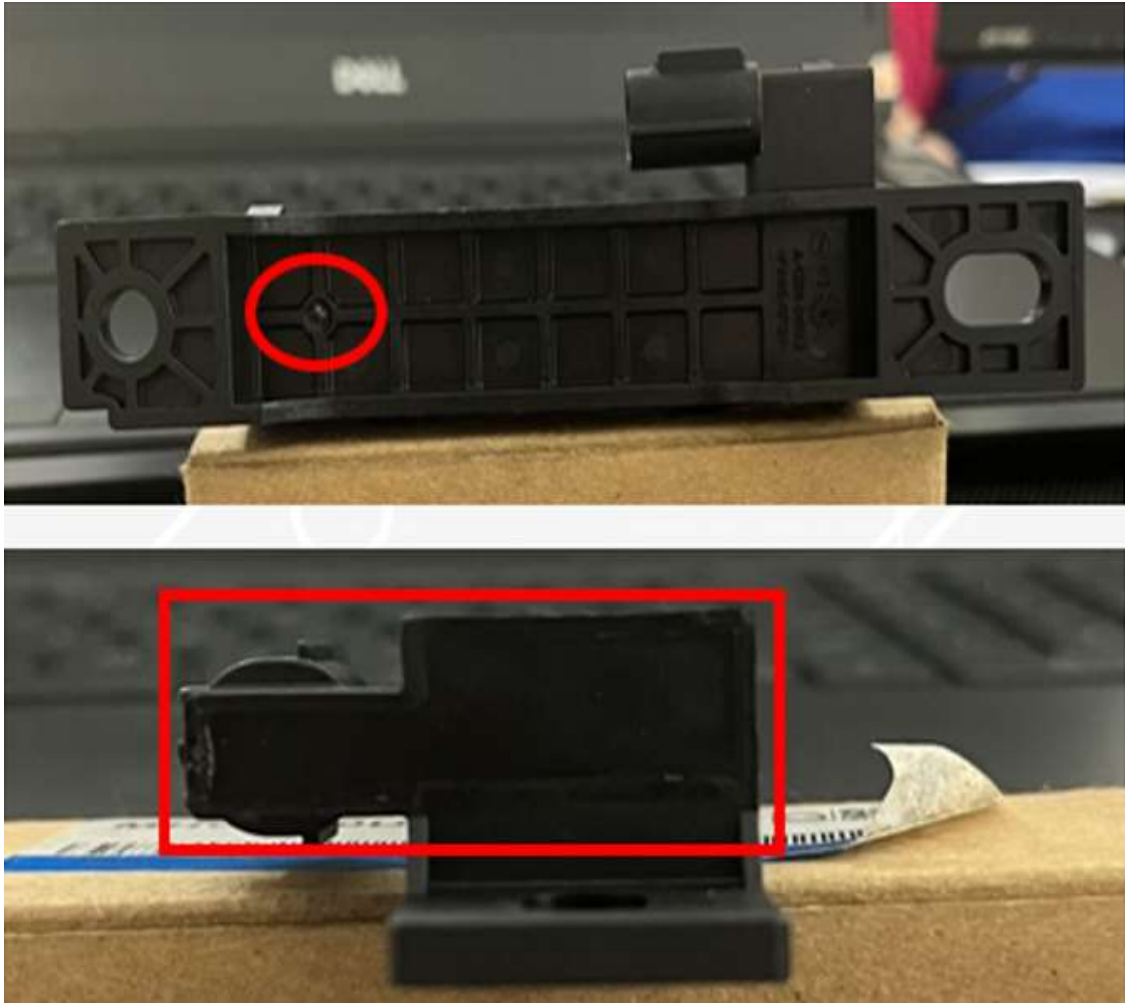


Figure 2.3. Casting surface for visual defect detection

To meet the requirements of visual inspection and automatic product classification after the casting process, the system is designed with the following key functional components:

a. Actuation mechanism

After casting, the product is transported to the inspection area via a lead screw mechanism combined with a linear rail. This mechanism ensures stable and precise linear motion, with flexible adjustability to accommodate different product sizes.

b. Visual inspection system

At the inspection position, a fixed industrial camera captures images of the product surface. The lighting system is optimally arranged to enhance contrast, enabling the camera to detect surface defects such as cracks, porosity, burrs, or deformation.

c. Central processing unit

The captured images are transmitted to a central processing unit, where image processing and quality assessment are performed. The processor uses evaluation algorithms to classify products into two categories: acceptable and defective.

d. Product sorting mechanism

Based on the analysis results from the processor, a Dobot robot performs the pick-and-place operation:

Defective products are placed into a rejection tray.

Acceptable products are transferred to the output station for subsequent steps in the production line.

e. System overview

The entire system is synchronously controlled by a PLC, ensuring fast response times, high precision, and scalability. A user interface displays inspection results in real time, allowing operators to monitor and store product data for traceability and production process optimization.

2.3. System block diagram

- Power Supply Unit: Provides electrical power for the entire system.
- Sensor Unit: Detects the presence of objects and sends signals to the PLC.
- PLC (Programmable Logic Controller): Serves as the central processing unit of the system.
- Camera: Captures images of the product and transmits them to the PC.
- PC (Personal Computer): Processes the images received from the camera, sends analysis results to the PLC, and displays the inspection interface.
- Actuator Unit: Receives control signals from the PLC and performs the corresponding operations.

2.4. Software-based design

2.4.1. Mechanical design

a. Product feeding and image processing section

After casting, the parts are placed on the positioning fixture (Figure 2.4) and transported to the inspection area via a drive mechanism using a lead screw combined with a sliding rail (Figure 2.5).

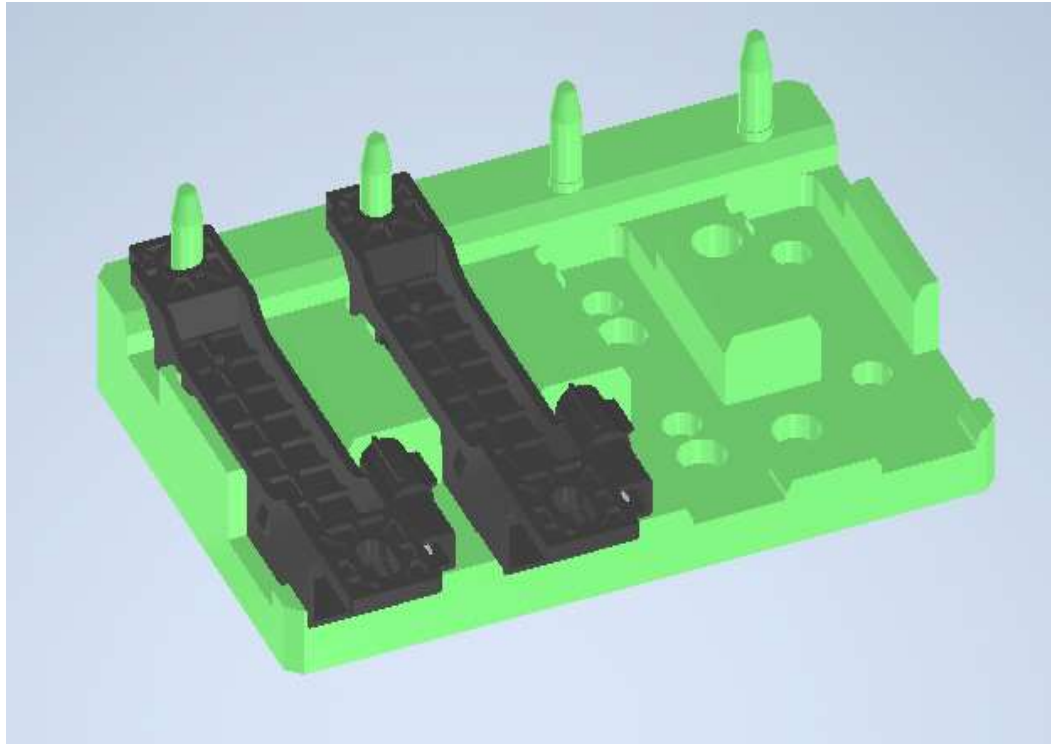


Figure 2.4. Product tray after casting

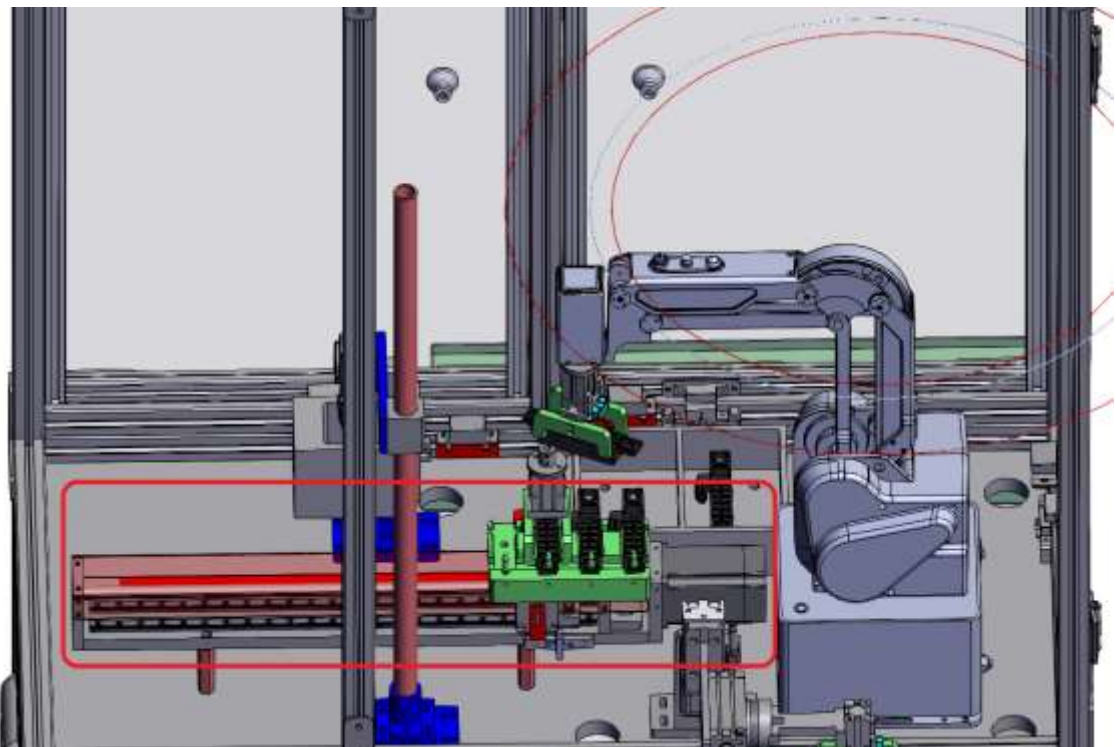


Figure 2.5. Product feeding section after casting

Products are moved into the camera inspection system where the surface quality is scanned and evaluated (Figure 2.6).

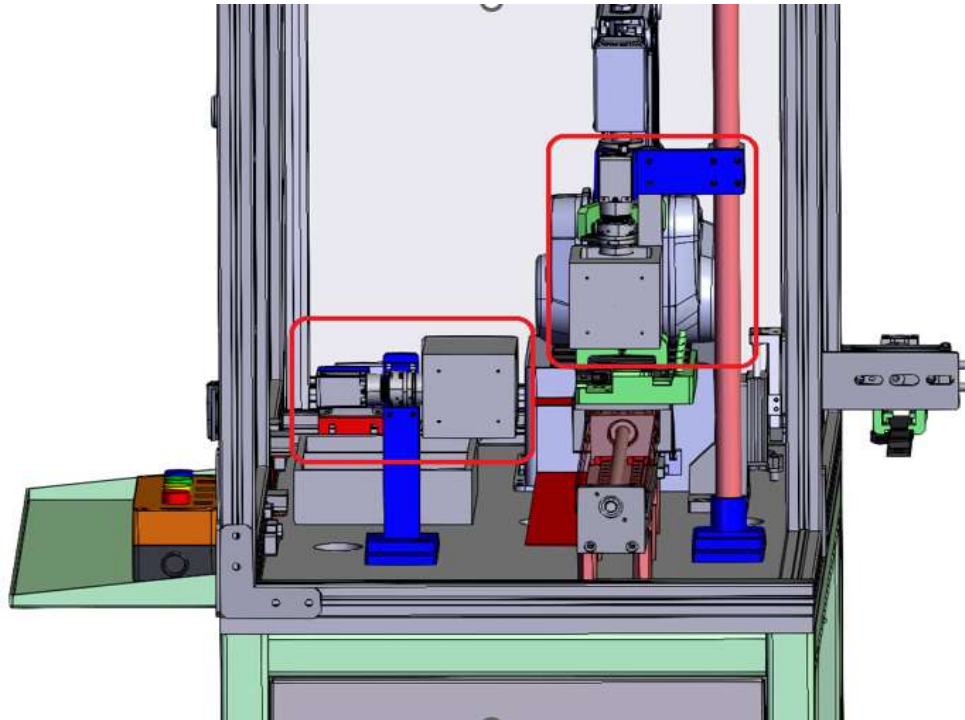


Figure 2.6. Camera for detecting defects on casted products

b. Sorting section

Based on the analysis results, the Dobot robot performs the sorting operation (Figure 2.7) if a product is identified as defective, it will be placed into the defective product tray; if it meets quality standards, it will be transferred to the output station (Figure 2.8) for subsequent production processes.

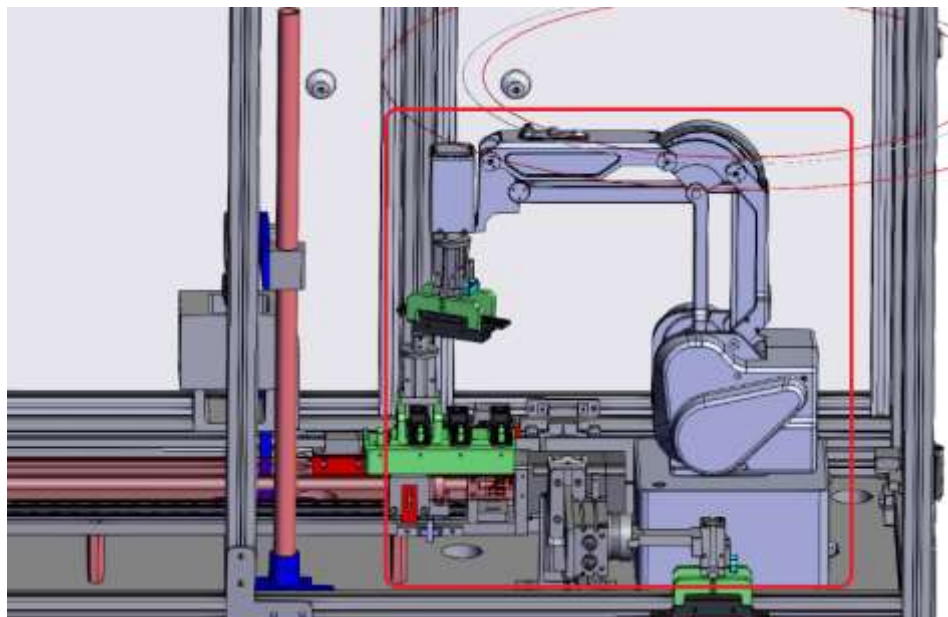


Figure 2.7. Sorting section after visual inspection of casted products

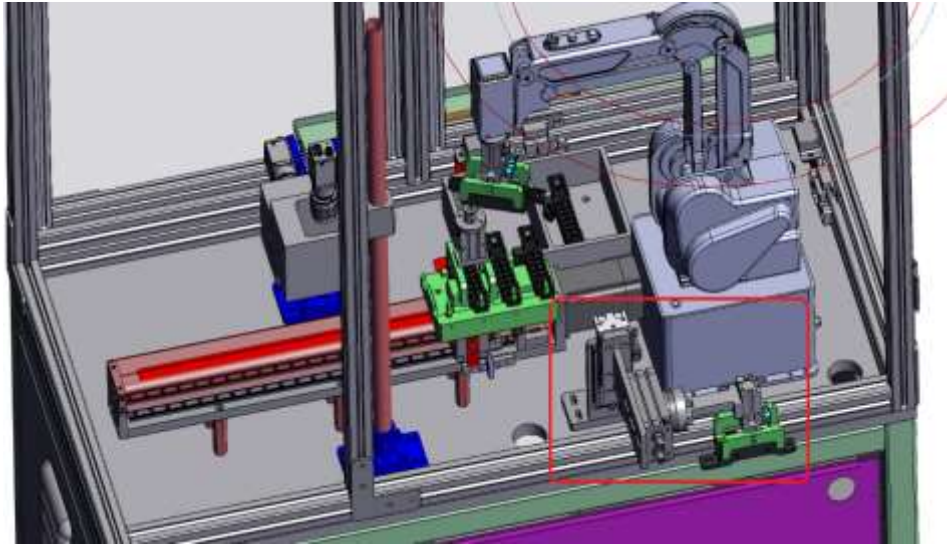


Figure 2.8. Output station after sorting

c. Overall drawing

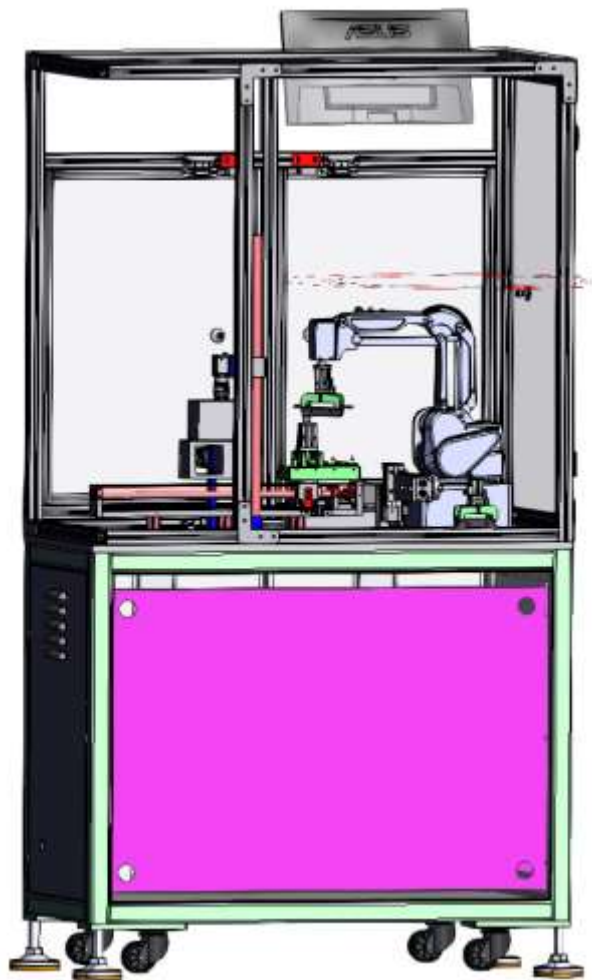


Figure 2.9. Completed 3d model

2.4.2. Electrical design

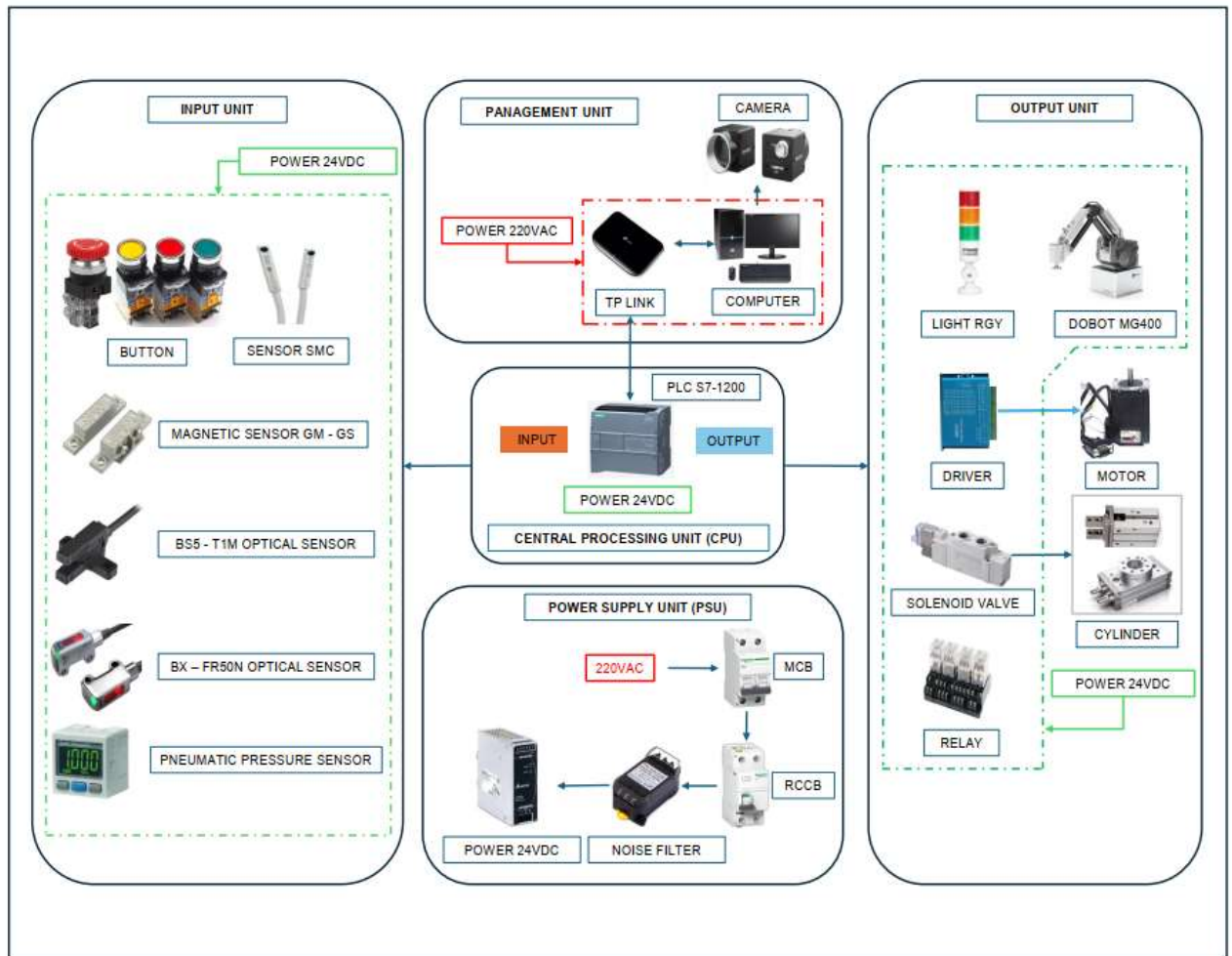


Figure 2.10. Device connection diagram of the post-casting visual inspection machine

a. Power Supply Unit (PSU)

Input: 220VAC.

Through protection devices:

- MCB (Miniature Circuit Breaker) – overload protection
- RCCB (Residual Current Circuit Breaker) – leakage protection
- Noise Filter – EMI filtering

Converts to 24VDC to power the entire system (PLC, sensors, actuators...).

b. Input Unit

Powered by 24VDC.

Includes sensors and input devices:

- Push buttons – manual controls (start/stop/reset)
- SMC sensors – proximity detection
- Magnetic sensors (GM-GS)
- Optical sensors (BS5-T1M, BX-FR50N)
- Pneumatic pressure sensors

→ All signals are sent to the S7-1200 PLC for processing.

c. Central Processing Unit (CPU – PLC)

Siemens S7-1200 PLC.

- Receives input signals
- Processes logic
- Sends control signals to outputs

Powered by 24VDC.

d. Management Unit

Includes:

- TP-Link (network switch) – connects PLC to computer
- Computer (PC) – processes images from camera
- Camera – captures product surface for inspection

Powered by 220VAC.

Communication between PLC – PC – Camera via LAN.

e. Output Unit

Powered by 24VDC.

Includes:

- 3-color signal light (RGY) – status indication
- Dobot MG400 robot arm – handles product movement
- Motor + driver – for mechanical actions
- Solenoid valves – pneumatic control
- Cylinders – actuators
- Relays – switch control for higher power loads

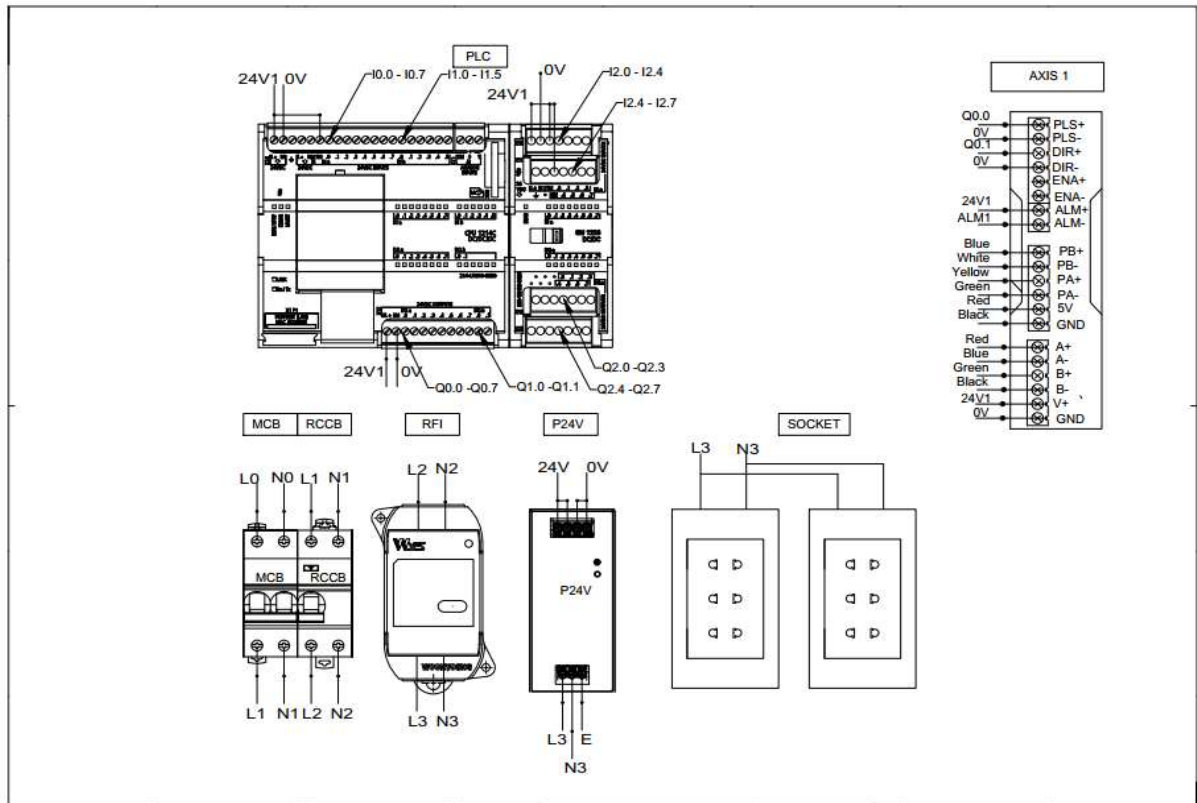


Figure 2.11. PLC connection diagram

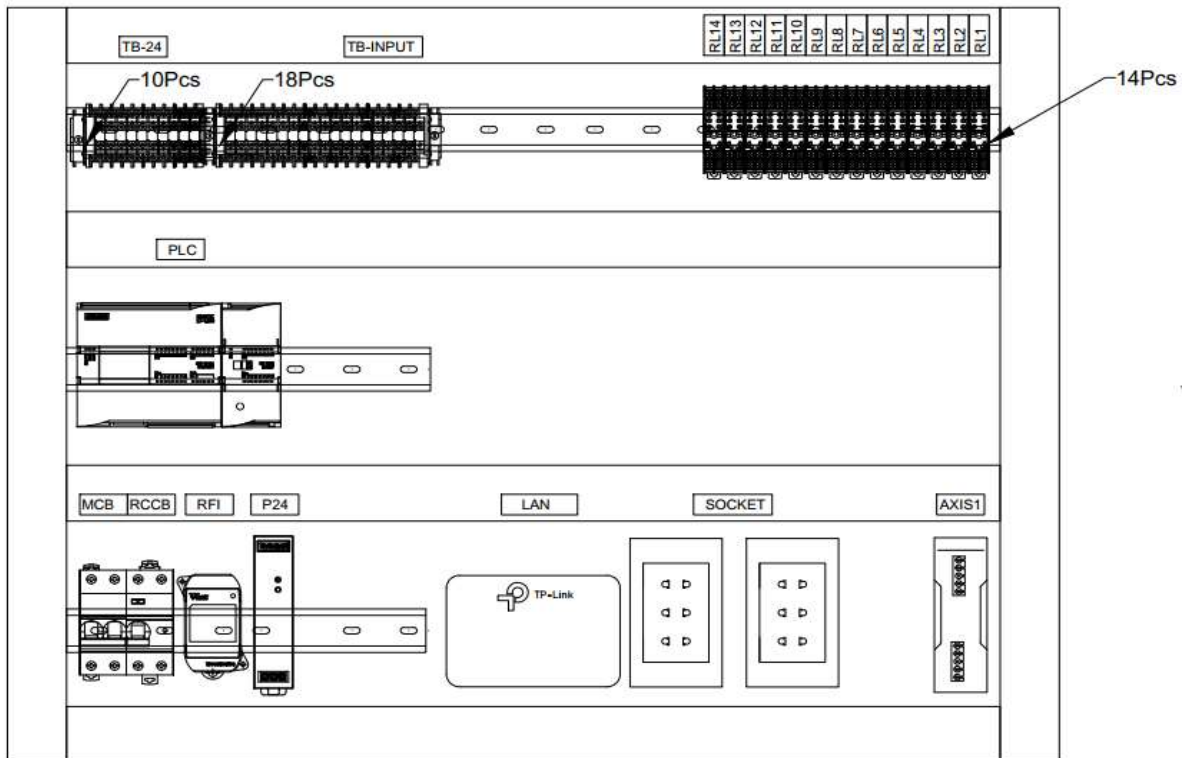


Figure 2.12. Layout diagram of the main electrical cabinet of the machine

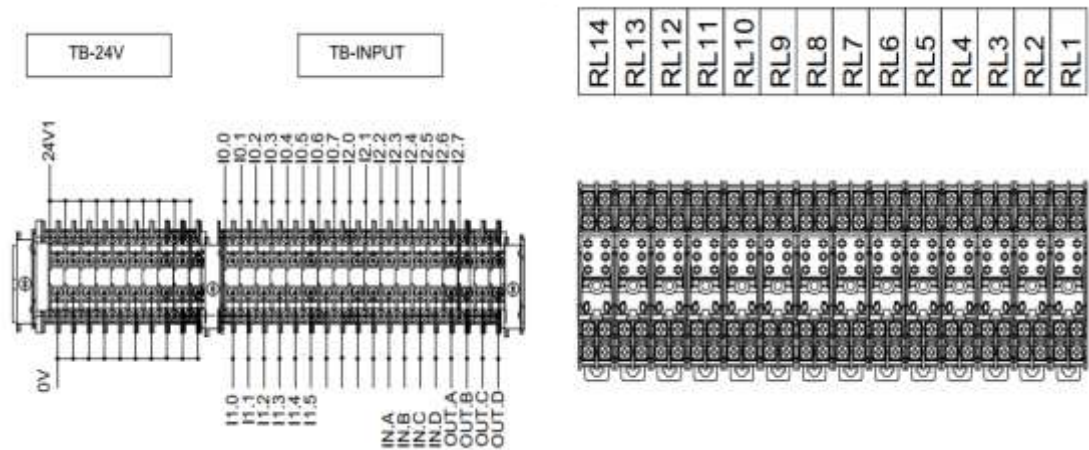


Figure 2.13. I/O and Relay Connection Diagram

Table 2.1. Relay connection diagram

NAME RELAY	PIN	COM	NO
RL1: Power 24V	0V	24V	24V1
	A		
RL2: Out1_RB	0V.RB	24V1	OUT1
	OUT1.RB		
RL3:Alarm_Axis	0V	0V	I0.1
	ALM-		
RL4: Request_RB_Xarm	0V	IN.A	IN.B
	Q0.5		
RL5: Request_RB_Dobot	0V	IN.C	IN.D
	Q0.6		
RL6: RB_Xarm_Done	OUT.A	0V	I0.7
	OUT.B		
RL7: RB_Dobot_Done	OUT.C	0V	I1.0
	OUT.D		
RL8: Request1_RB	0V	24V.RB	IN6
	Q2.0		
RL9: Request2_RB	0V	24V.RB	IN7
	Q2.1		
RL10: Request3_RB	0V	24V.RB	IN8
	Q2.2		

RL11: Request4_RB	0V	24V.RB	IN9
	Q2.3		
RL12: Out6_RB	0V.RB	0V	I2.0
	OUT6		
RL13: Out7_RB	0V.RB	0V	I2.1
	OUT7		
RL14: Spare			

2.5. Equipment selection

2.5.1. PLC

The Siemens S7-1200 is a new-generation PLC designed for compact to mid-range automation applications. It combines flexibility, modular expansion, and powerful communication capabilities. The S7-1200 PLC is ideal for standalone automation tasks or as part of a larger integrated automation system (TIA – Totally Integrated Automation). It supports real-time control, communication, and high-speed signal processing, aligning with the vision of Industry 4.0.

The CPU 1214C DC/DC/DC is one of the most commonly used models in the S7-1200 series.



Figure 2.14. PLC Siemens S7-1200 CPU 1214C DC/DC/DC (source: internet)

Main specifications of CPU 1214C DC/DC/DC:

- Power supply: 20.4V – 28.8V DC (operates with DC power).
- Number of digital inputs (DI - Digital Input): 14 DC inputs.
- Number of digital outputs (DO - Digital Output): 10 DC outputs (Transistor).

- Maximum output current: 0.5A per output.
- Number of analog inputs (AI - Analog Input): 2 channels (0–10V).
- Program memory: 100 KB.
- Communication port: Integrated Profinet (Ethernet) for programming and communication with other devices. Supports Modbus TCP/IP and S7 Communication protocols.
- Expansion capability: Supports expansion with I/O modules, communication modules, and signal modules.

The Siemens S7-1200 CPU 1214C DC/DC/DC offers a robust, flexible, and feature-rich control platform for automation engineers. With integrated communication, high-speed capabilities, and modular scalability, it is well-suited for modern industrial environments aiming to adopt smart manufacturing and digital transformation.

2.5.2. Power supply



Figure 2.15. DRL-24V120W1AS power supply (source: internet)

The DRL-24V120W1AS is a high-end DIN-rail-mounted Delta power supply, designed in a compact form. It is widely used in daily life, industry, civil applications, measurement, control, automation, buildings, medical equipment, etc. The DRL-24V120W1AS provides 24VDC power for Delta PLC control cabinets, Delta AC Servo systems, Delta HMI panels, and other devices.

Technical specifications of 24VDC DRL-24V120W1AS:

- Output voltage: 24V
- Output power: 120W
- Output current: 5A
- Input voltage: 90–264Vac

- Dimensions (H x W x D): 123.6 x 40 x 117.6 mm (4.87" x 1.57" x 4.63")
- Weight: 0.54 kg (1.19 lb)

Key features of DRL-24V120W1AS:

- Industrial design with compact size
- Wide input voltage range from 90–260Vac
- High efficiency up to 88%
- Built-in current regulation circuit for variable loads
- High power density
- Operating temperature from -10°C to +50°C at 230Vac, up to 5,000 meters (16,400 feet) altitude
- Reduced no-load power consumption
- Integrated DC-OK contact
- Complies with SEMI F47 standard @ 200Vac
- PCBAs coated with protective layer for resistance against dust and common chemical pollutants

2.5.3. Aptomat

a. A9K27225

A9K27225 is a 2P 25A miniature circuit breaker (MCB) from the Acti9 iK60 series by Schneider Electric.



Figure 2.16. Aptomat A9K27225 (source: internet)

A9K27225 is a 2P 25A miniature circuit breaker (MCB) from the Acti9 iK60 series by Schneider Electric.

Main technical specifications:

- Product line: Acti9 iK60

- Protection type: MCB – Miniature Circuit Breaker for overload and short-circuit protection
- Number of poles: 2P (2 poles, protecting both phase and neutral wires)
- Rated current: 25A
- Short-circuit breaking capacity (I_{cn}): 6000A (6kA) according to IEC/EN 60898-1
- Tripping curve: C (suitable for general loads with medium inrush currents such as lights, sockets, small motors, etc.)
- Operating voltage: 230/400V AC
- Frequency: 50/60Hz
- Mounting mechanism: DIN rail 35mm mounting

Applications:

- Overload and short-circuit protection in residential and light industrial electrical systems
- Used in distribution panels, main electrical cabinets, residential, office, and factory electrical systems
- Protection for electrical devices such as lights, fans, sockets, small motors, etc.

b. A9R50225



Figure 2.17. Aptomat A9R50225 (source: internet)

A9R50225 is an RCBO (Residual Current Circuit Breaker with Overcurrent Protection) from the Acti9 iID series by Schneider Electric. This device provides protection against earth leakage (electric shock) combined with overload and short-circuit protection.

Main technical specifications of A9R50225:

- Product line: Acti9 iID

- Protection type: RCBO (Leakage protection + Overload and short-circuit protection)
- Number of poles: 2P (2 poles, protecting both phase and neutral wires)
- Rated current (I_n): 25A
- Short-circuit breaking capacity (I_{cn}): 6000A (6kA) according to IEC/EN 61009-1
- Residual current sensitivity ($I_{\Delta n}$): 30mA (high sensitivity, protects humans)
- Leakage type: AC (detects AC leakage current)
- Tripping curve: C (suitable for loads with moderate inrush current)
- Operating voltage: 230V AC
- Frequency: 50/60Hz
- Mounting mechanism: DIN rail 35mm

Applications:

- Protection against earth leakage (electric shock) + overload and short-circuit protection in residential and light industrial electrical systems
- Used in main electrical cabinets, distribution boards, residential, office, and factory electrical systems
- Especially suitable for protecting electrical equipment and humans from electric leakage hazards

2.5.4. Noise filter



Figure 2.18. WYFS20TD noise filter (source: internet)

WYFS20TD is a single-phase noise filter from Woonyoung. This filter helps reduce electromagnetic interference (EMI) and radio frequency interference (RFI) in electrical systems, ensuring stable signals for electronic devices.

Technical specifications:

- Type: Single-phase noise filter
- Rated voltage: 250V AC
- Maximum current: 20A
- Operating frequency: 50/60Hz
- Noise attenuation range: 150KHz – 30MHz
- Mounting method: DIN rail or screw mounting
- Certifications: UL, cUL, KC, RoHS

Key features:

- Effectively reduces electromagnetic interference (EMI) over a wide frequency range from 150KHz to 30MHz
- Low leakage current, safe for use
- Compact design, suitable for industrial electrical cabinets
- Cost-effective, suitable for various applications

2.5.5. Tp link TL-SG1005D (source: internet)

TP-Link TL-SG1005D is a 5-port gigabit Ethernet switch designed to expand a wired network at high speed.



Figure 2.19. TP-Link TL-SG1005D (source: internet)

Main specifications of TL-SG1005D:

- Number of ports: 5 Gigabit Ethernet ports (10/100/1000 Mbps)
- Ethernet standards: IEEE 802.3, 802.3u, 802.3ab, 802.3x

- Switching capacity: 10 Gbps
- Operating mode: Plug & Play (no configuration required)
- Energy-saving technology: Automatically adjusts power consumption based on connection status and cable length
- Enclosure: Plastic, compact design
- Power supply: 5V DC adapter, 0.6A

Advantages of TL-SG1005D:

- Gigabit speed, suitable for high-bandwidth systems (IP cameras, data transfer, gaming, streaming)
- No configuration needed, just plug and play
- Silent operation, fanless design ensures no noise
- Energy-saving, automatically reduces power usage when there is no traffic

2.5.6. Magnetic sensor GLS-M1 + GLS-S1

GLS-M1 + GLS-S1 is a magnetic door sensor, commonly used to detect door open/close status in security systems or automation control.



Figure 2.20. Magnetic sensor GLS-M1 + GLS-S1 (source: internet)

General Specifications:

- Sensor type: Magnetic sensor with dry contact (reed switch)
- Structure: Consists of two parts: GLS-M1: Reed switch and GLS-S1: Matching magnet
- Detection distance: Typically from 5 to 15mm (depending on model)

- Output: NO (Normally Open) or NC (Normally Closed) contact
- Operating principle: When the door is closed, the reed switch closes; when the door opens, the switch disconnects
- Material: Durable ABS plastic
- Installation: Mounted on the door frame and the door itself

Applications:

- Detecting door open/close status in access control and security alarm systems
- Used in elevators, cold storage doors, automatic doors
- Position control for doors in mobile robots and automation systems

2.5.7. D-m9bl magnetic sensor

D-M9BL Magnetic Sensor is a non-contact position sensor by SMC, commonly used to detect the piston position in pneumatic cylinders.



Figure 2.21. Magnetic sensor D-M9BL (source: internet)

Main Specifications of D-M9BL:

- Sensor type: Magnetic sensor (reed switch)
- Operating voltage: 5V – 28V DC
- Current consumption: Max. 40mA
- Output type: NPN Normally Open (NO)
- Output signal: Voltage pulse
- Wiring: 3 wires (Brown – Power, Blue – GND, Black – Signal)
- Standard cable length: 3m
- Indicator LED: Red status LED

- Installation: Mounted on the groove of SMC pneumatic cylinders

Key Features:

- Detects the position of the pneumatic cylinder piston via the magnetic field of the magnet inside the piston
- Non-contact sensing increases durability and reduces mechanical wear
- Compact design suitable for various types of SMC pneumatic cylinders
- Built-in status LED makes it easy to check operation

2.5.8. Bs5-t1m optical sensor

The BS5-T ultra-compact optical sensor is a photoelectric sensor produced by Autonics.



Figure 2.22. BS5-T1M optical sensor (source: internet)

Key Specifications of BS5-T1M:

- Sensor type: Diffuse reflective photoelectric sensor
- Sensing distance: 5mm ± 1mm
- Power supply: 5V - 24V DC
- Output type: NPN Normally Open (NO)
- Response time: Max 0.5ms
- Status indicator: LED lights up when an object is detected
- Operating mode: Light ON (activated when an object is present)
- Compact size, easy to install in automation systems

Applications:

- Detecting small objects on conveyor belts, packaging machines, labeling machines
- Checking product positions on production lines

- Used in industrial robots, CNC machines for detecting stop positions

2.5.9. Bx-fr50n optical sensor

BX-FR50N is an optical sensor from Autonics, part of the BX series. It is a through-beam type sensor, ideal for long-distance object detection.



Figure 2.23. BX-FR50N optical sensor (source: internet)

Key Specifications:

- Sensor type: Through-beam photoelectric sensor
- Sensing distance: 50 meters
- Power supply: 12 – 24V DC
- Output type: NPN Normally Open (NO)
- Response time: $\leq 1\text{ms}$
- Operating modes: Light ON / Dark ON (selectable)
- Protection rating: IP65 (dust and water resistant)
- Connection: 3-wire cable

Applications:

- Long-distance object detection in conveyor systems and packaging machines
- Used in automated robots and AGV (Autonomous Guided Vehicles) to detect obstacles
- Product inspection in production lines
- Safety door monitoring or product counting as items pass the sensor

2.5.10. Pneumatic pressure sensor ISE30A-01-N-LD

The ISE30A-01-N-LD is a digital pressure sensor from SMC, used for measuring and monitoring pressure in pneumatic systems.



Figure 2.24. ISE30A-01-N-LD pneumatic pressure sensor (source: internet)

Key Specifications:

- Sensor type: Digital pressure sensor
- Pressure range: -0.1 to 1 MPa (positive pressure)
- Output: NPN (digital signal output)
- Supply voltage: DC 12 - 24V
- Display screen: 3-color LCD (LD = LED display)
- Accuracy: $\pm 1\%$ F.S.
- Connection thread type: R(PT)1/8 (standard pneumatic thread)
- Display mode: Adjustable pressure units (MPa, kgf/cm², bar, psi)

Applications:

- Monitoring pressure in pneumatic and hydraulic systems
- Pressure control in packaging machines, automation systems, and robots
- Equipment protection via pressure threshold alerts

2.5.11. Air filter regulator AW30-03DG-B

The AW30-03DG-B is an air filter regulator from SMC, designed to filter compressed air and regulate pressure in pneumatic systems.



Figure 2.25. AW30-03DG-B air filter regulator (source: internet)

Key Specifications:

- Product type: Air filter + pressure regulator (Filter Regulator)
- Thread size: Rc(PT) 3/8"
- Pressure adjustment range: 0.05 - 0.85 MPa
- Maximum airflow rate: 2,200 L/min
- Filtration grade: 5 μ m (removes dust and water from compressed air)
- Maximum input pressure: 1.0 MPa
- Drain type: Automatic (D = Auto Drain)
- Pressure gauge: Included (G = Gauge)
- Mounting direction: Vertical, with standard PT threaded connection

Applications:

- Filters and regulates compressed air pressure for automation machines, pneumatic cylinders, and industrial robots
- Used in packaging machines, conveyor systems, and pneumatic networks
- Ensures system stability and protects valves and cylinders from damage due to contaminants or unstable pressure

2.5.12. 5/2 solenoid valve

SY5120-5LD-01 is a pneumatic solenoid valve from SMC, belonging to the SY5000 series. This type of valve controls airflow in pneumatic systems and is commonly used to operate cylinders or other pneumatic devices.



Figure 2.26. SY5120-5LD-01 solenoid valve (source: internet)

Key Specifications of SY5120-5LD-01:

- Valve type: 5/2 (5 ports, 2 positions)
- Control method: Solenoid
- Number of coils: Single coil

- Actuation type: Normally Closed (NC) – Valve remains closed when de-energized
- Coil voltage: 24V DC
- Power consumption: Around 0.35W (with LED and protection circuit)
- Port size: 1/8" (PT, NPT, G)
- Operating pressure: 0.15 - 0.7 MPa
- Connection type: 01 – Standard threaded (PT)
- Response speed: Fast, suitable for applications requiring quick air switching

2.5.13. Cylinder

a. MHZ2-16D Cylinder



Figure 2.27. MHZ2-16D cylinder (source: internet)

This is a type of cylinder with two parallel-opening gripper fingers.

Features of the MHZ series:

- High rigidity achieved by integrating guide rail, main jaw, and fingers with linear guide bearings.
- Offers five mounting options from three directions (top, side, and bottom), increasing flexibility in design.
- Various options for workpiece mounting direction and finger width are available.

Basic specifications:

- Cylinder type: Parallel gripper
- Model number: MHZ2-16D
- Bore size (piston diameter): 16 mm
- Gripping stroke: 6 mm (each finger moves 6 mm)
- Number of fingers: 2 (parallel motion)

- Operation type: Double acting
- Repeatability: ± 0.01 mm (very precise)

Cylinder selection calculation:

- Workpiece weight: $F_m = mg = 0,5 \times 9,81 = 4,905$ N
- Surface material is hard plastic, so the coefficient of friction $\mu = 0,4$
- Gripping force per side: $F_k = \frac{F_m}{2 \cdot \mu} = \frac{4,905}{2 \cdot 0,4} = 6,13$ N
- Apply safety factor $K = 2$ (for vibration and robot acceleration):

$$F_k = 6,13 \times 2 = 12,26 \text{ N}$$

So, each finger must generate at least ~ 12.3 N of gripping force.

- With common pneumatic pressure: $P = 0.5 \text{ MPa} = 0.5 \times 10^6 \text{ N/m}^2 = 0.5 \text{ N/mm}^2$
- Force equation: $F = P \times A = P \times \frac{\pi D^2}{4}$
- Solving for D: $D = \sqrt{\frac{4F}{\pi P}} = \sqrt{\frac{4 \cdot 6,13}{\pi \cdot 0,5}} = 3,95$ mm

Therefore, the MHZ2-16D cylinder is chosen.

b. SMC MSQA7A Rotary Cylinder

The MSQA7A pneumatic rotary cylinder from SMC belongs to the MSQ series, with a rotation angle range from 0 to 190°.

There are two types in this series: the basic MSQB type and the high-precision MSQA type.

The MSQ cylinders are widely used in industrial applications.



Figure 2.28. MSQA7A rotary cylinder (source: internet)

Technical Specifications:

- Model: MSQA7A
- Adjustable rotation angle: 0 – 190°
- Operating pressure: 0.1 – 0.7 MPa
- Bore size: ø6
- Working medium: Air
- Ambient temperature: 0 – 60°C (non-freezing)

2.5.14. Hybrid servo motor 57HSE2.2N and HBS57 driver



Figure 2.29. Hybrid servo motor 57HSE2.2N and HBS57 driver (source: internet)

Motor selection and calculation:

Input parameters:

- Total load (m): Includes the fixture plate, 4 cast parts, and the support bracket → $m = 2.5 \text{ kg}$
- Desired rapid travel speed (v): To ensure short cycle time → $v = 0.3 \text{ m/s}$
- Acceleration time (t): Time to accelerate from 0 to max speed → $t = 0.2 \text{ s}$
- Ball screw lead (p): Distance the slide moves with one full revolution → $p = 5 \text{ mm} = 0.005 \text{ m}$
- Gravitational acceleration (g): $g = 9.81 \text{ m/s}^2$

Calculate Total Required Force:

- Gravitational Force (F_g): $F_g = m \times g = 2.5 \times 9.81 = 24.525 \text{ N}$
- Frictional Force (F_{friction}): Assuming linear guide friction coefficient is 0.02:

$$F_{\text{friction}} = 0.02 \times F_g = 0.02 \times 24.525 = 0.49 \text{ N}$$

- Inertial Force (F_a):

$$A = \frac{v}{t} = \frac{0.3}{0.2} = 1.5 \text{ m/s}^2 \Rightarrow F_a = m \times a = 2.5 \times 1.5 = 3.75 \text{ N}$$

- Total Required Force (F_{total}):

$$F_{\text{total}} = F_g + F_{\text{friction}} + F_a = 24.525 + 0.49 + 3.75 = 28.765 \text{ N}$$

Convert Force to Required Torque:

- Calculation of the required torque at the motor:

$$T = \frac{F_{\text{total}} \times p}{\pi} = \frac{28.765 \times 0.005}{6.2832} \approx 0.0229 \text{ Nm}$$

- Apply Safety Factor (usually 2–3):

$$T_{\text{required}} = 0.0229 \times 3 = 0.0687 \text{ Nm}$$

Since the required torque is only 0.0687 Nm, which is much smaller than the rated torque of 2.2 Nm of the 57HSE2.2N hybrid servo motor, this motor is a suitable and reliable choice for the system.

Required Motor Speed Calculation:

To ensure the system reaches the desired travel speed, we need to calculate the required motor speed based on the lead of the ball screw:

$$N = \frac{p}{v} = \frac{0.3}{0.005} = 60 \text{ revolutions/second} = 3600 \text{ RPM}$$

Therefore, the motor must be capable of reaching at least 3600 RPM to meet the system's motion speed requirements.

a. Hybrid servo motor 57HSE2.2N

- Hybrid servo motor (a combination of stepper and servo technologies)
- Flange size: 57mm (NEMA 23)
- Maximum torque: 2.2 N·m
- Motor shaft diameter: Ø8mm
- Rated current: 6.0A
- Step angle: 1.8°
- Feedback sensor: 1000 pulses/rev encoder

Advantages:

- High torque like a stepper motor, but smooth operation like a servo

- No missed steps thanks to encoder position feedback
- Smoother motion with less vibration compared to traditional stepper motors

b. HBS57 driver

The HBS57 is a dedicated driver used to control the 57HSE2.2N Hybrid servo motor.

Specifications:

- Power supply voltage: 24V - 60V DC
- Output current: 0 - 6A (adjustable)
- Control signal: Pulse (Pulse/Direction or CW/CCW)
- Encoder port: To receive feedback signals from the motor
- Protection features: Overcurrent, overvoltage, and overtemperature protection

Main functions:

- Controls the hybrid servo motor with closed-loop feedback
- Automatically adjusts current to save energy
- Easy integration with Arduino, PLCs, Mach3, GRBL, etc.

2.5.15. Dobot MG400

The DOBOT MG400 is a compact, lightweight desktop robotic arm designed for a wide range of manufacturing needs. It is flexible to deploy and easy to use, making it ideal for applications in confined spaces. The MG400 is especially well-suited for desktop automation scenarios in tight workspaces that require quick deployment and changeover.



Figure 2.30. Dobot MG400 (source: internet)

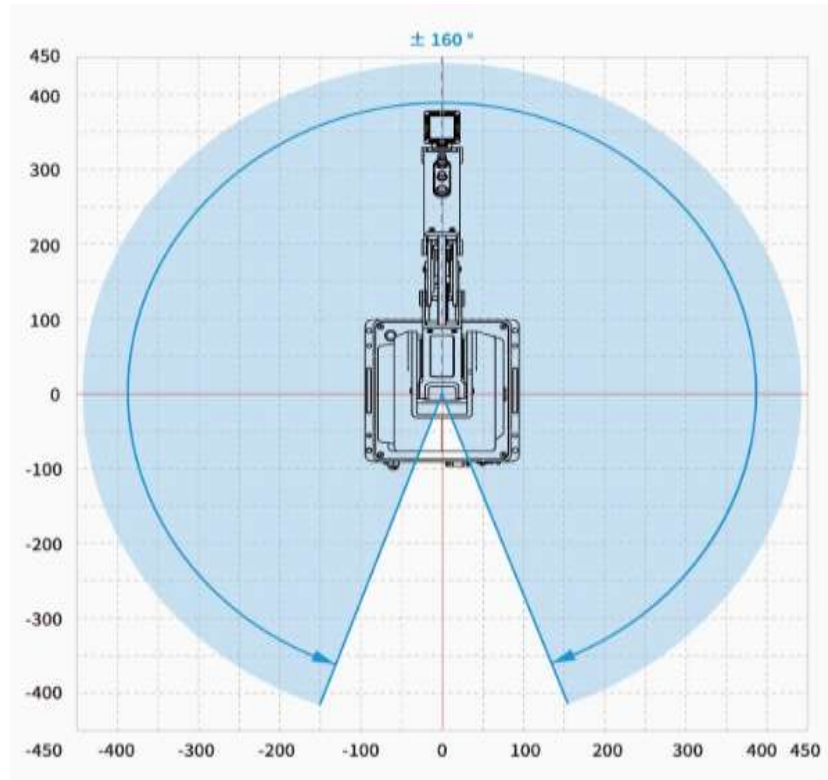


Figure 2.31. Working range J1 (source: internet)

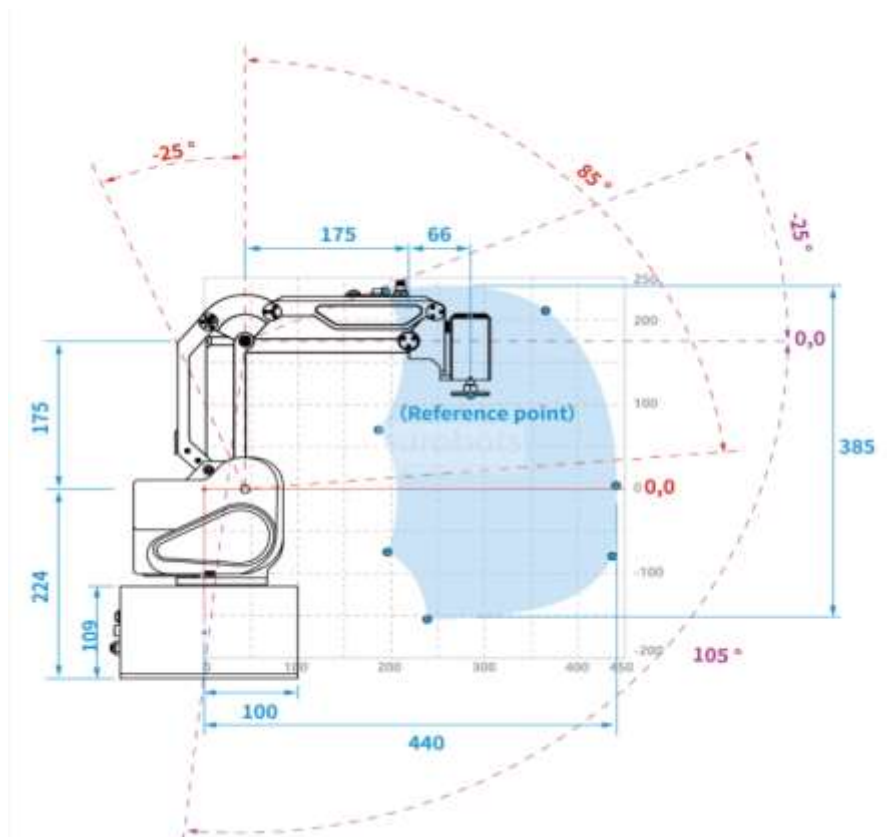


Figure 2.32. Working range J2, J3, J4 (source: internet)

Table 2.2. Technical specifications – Dobot MG400

Product Name		Dobot MG400
Model		DT-MG-P4R07-011
Payload		500g (Max 750g)
Working Range	J1	$\pm 160^\circ$
	J2	$-25^\circ \sim 85^\circ$
	J3	$-25^\circ \sim 105^\circ$
	J4	$-180^\circ \sim 180^\circ$
Maximum Joint Speed	J1	300°/s
	J2	300°/s
	J3	300°/s
	J4	300°/s
Rated Voltage		48V
Communication Protocol		TCP/IP, Modbus TCP
Weight		8kg
Dimensions		190mm x 190mm
Operating Environment		0°C ~ 40°C
Software		DobotStudio 2020, SCStudio

CHAPTER 3. SYSTEM IMPLEMENTATION

3.1. Hardware implementation

3.1.1. Product feeding and image processing section

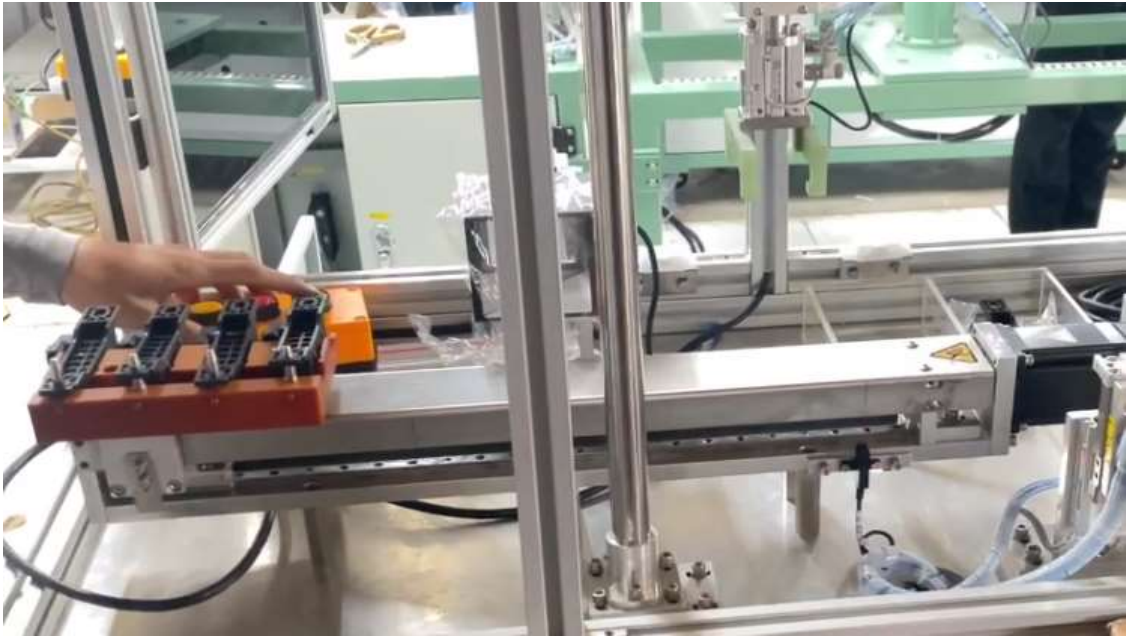


Figure 3.1. Post-Casting Product Feeding Stage

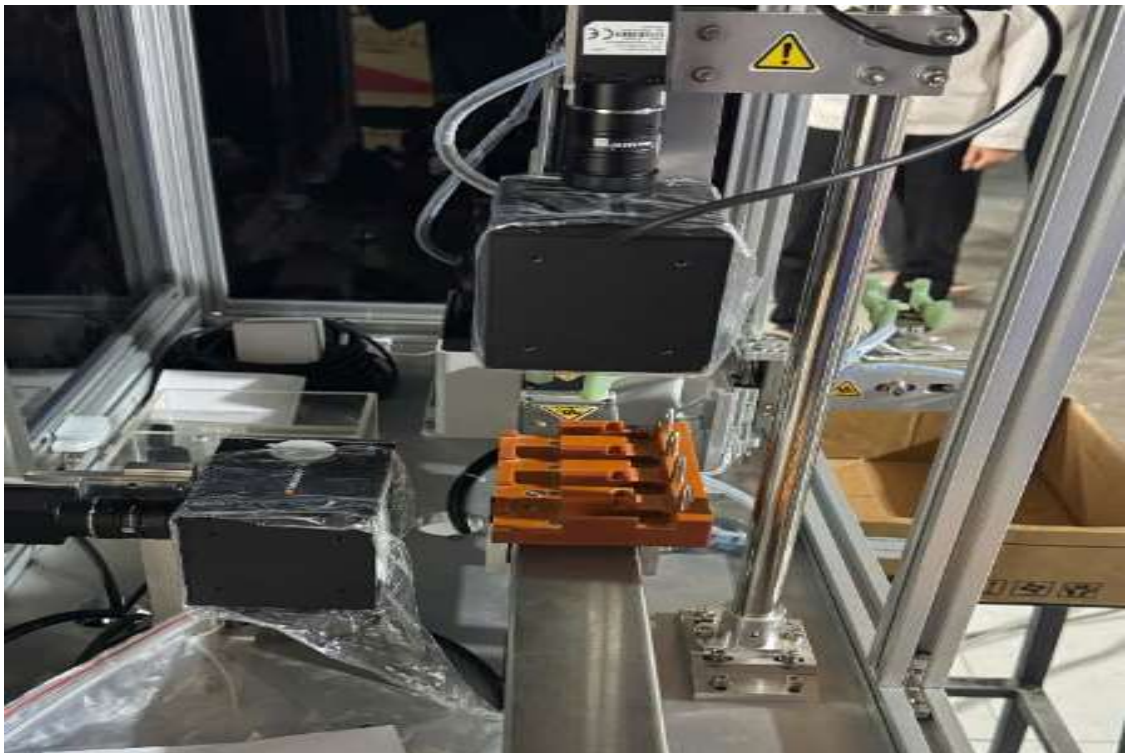


Figure 3.2. Installation of Image Processing System

3.1.2. Sorting section



Figure 3.3. Sorting cast parts with Dobot after defect detection

3.2. Software implementation

3.2.1. Algorithm flowchart

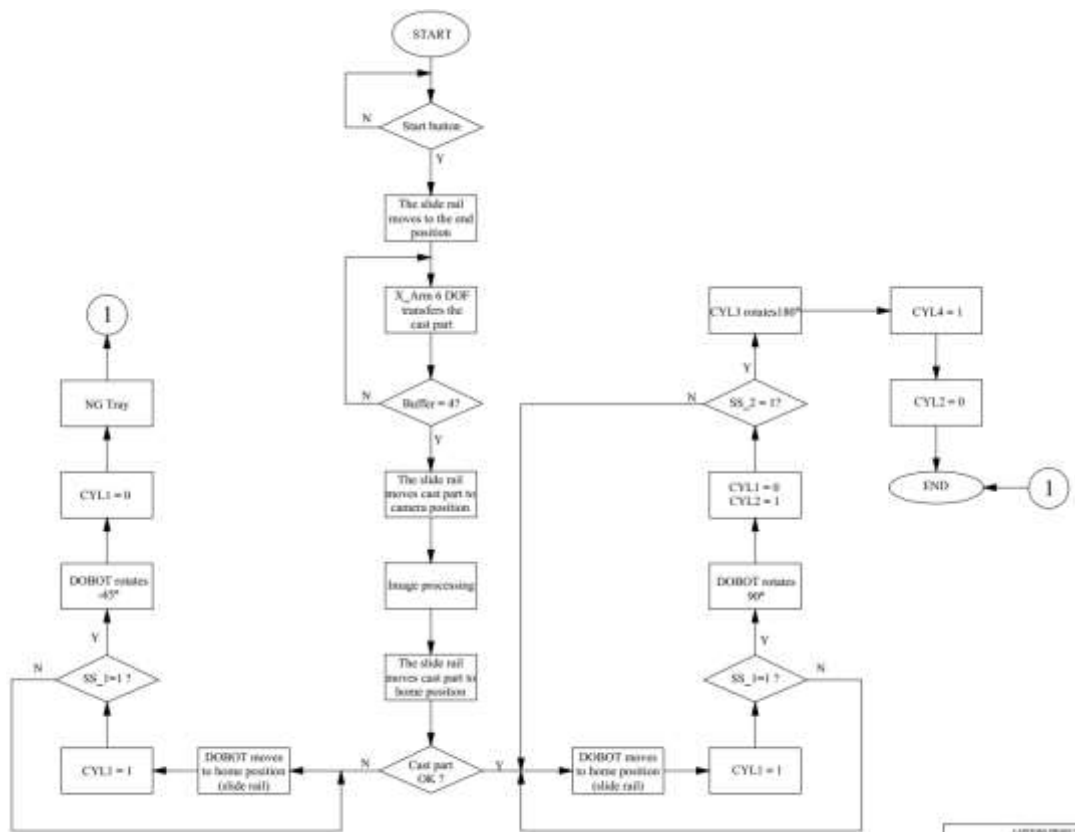


Figure 3.4. Overall algorithm flowchar

3.2.2. Images processing

To develop the visual inspection system for casted products, our team used the following tools and software:

- Google Colab: A free cloud-based platform with GPU support, used to train the YOLOv8 model for detecting surface defects.
- YOLOv8 (Ultralytics): A modern deep learning model for object detection, capable of quickly and accurately identifying defects such as cracks, burrs, and deformations in images of casted parts.
- Python: The main programming language used to build the image processing program, connect with the YOLO model, handle classification logic, and control the user interface.
- PyQt5: A Python library for designing graphical user interfaces (GUIs), used to display product images and inspection results in a clear and intuitive way.
- Qt Designer: A drag-and-drop GUI design tool, used to create interface layouts easily and later integrate them with Python code.
- OpenCV (optional): A computer vision library used to support image preprocessing tasks such as resizing, format conversion, or image display if needed.

Step 1: Data collection and labeling

First, the system uses two cameras to capture images of the casted parts from two different angles:

Camera 0 captures the side view:



Figure 3.5. Camera 0 captures the side view of the product.

Camera 1 captures the top view:



Figure 3.6. Camera 1 captures the top view of the product

The collected images are labeled using tools such as LabelImg, Roboflow, or the CVAT.AI web platform.

The defects annotated include: cracks, burrs, deformations, etc.

(Due to company data confidentiality policies, we were unable to use actual product images. Instead, the team used a set of sample images available on the computer to simulate the visual inspection process. This demonstrates that we are fully capable of carrying out this workflow.)

The annotated defects in this simulation include: broken copper wires, incomplete solder joints, and components attached incorrectly to the surface.

Each image is saved along with a .txt file that contains bounding box coordinates and class labels (e.g., label: NG) for each defect.

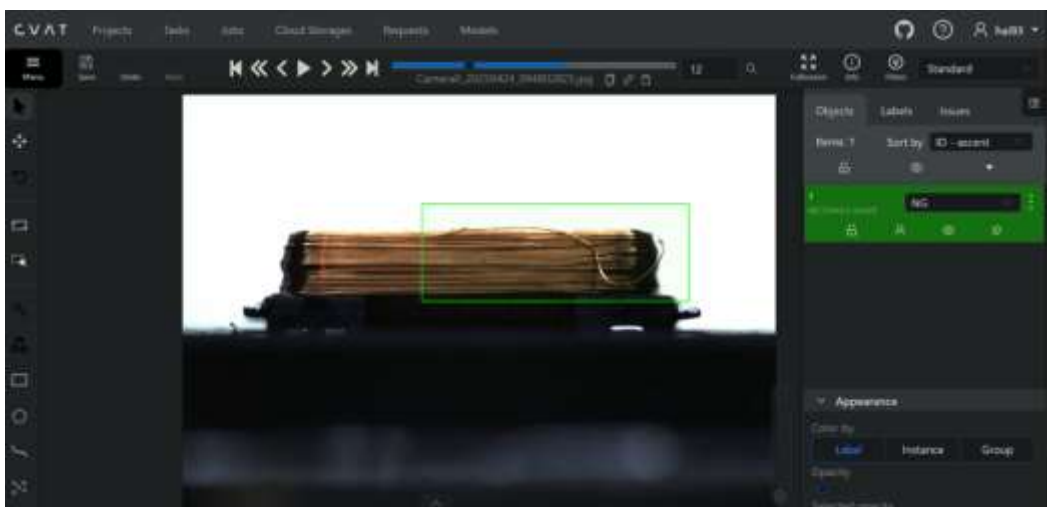


Figure 3.7. Labeling with CVAT.AI

The dataset is divided into:

- Training set: images/train, labels/train
- Validation set: images/val, labels/val

Step 2: Training the YOLOv8 Model on Google Colab

The entire training process was conducted on Google Colab to take advantage of its free GPU resources, significantly improving training speed.

The basic steps include:

- Installing the Ultralytics YOLOv8 library:

```
!pip install ultralytics  
  
from ultralytics import YOLO
```

- Initializing and training the model:

```
model = YOLO('yolov8n.pt') # or yolov8s/m/l depending on model size
```

```
model.train(data='data.yaml', epochs=72, imgsz=640)
```

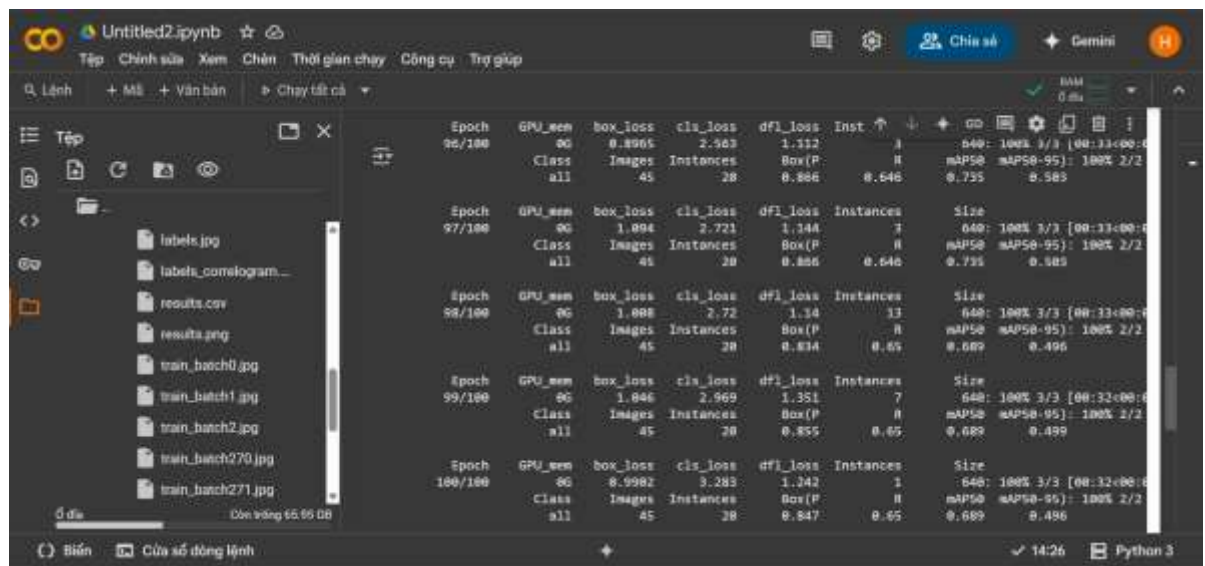


Figure 3.8. Training YOLOv8 Model on Google Colab

Explanation of Training Parameters:

- imgsz: Image size (resolution) – the input image will be resized to this dimension before training.
- epochs: Number of epochs – the total number of times the model will iterate through the entire training dataset.

- data: Path to the dataset configuration file (data.yaml) – this file defines the class names and paths to the training and validation data.

After training is complete, the model automatically saves the best-performing weights as best.pt, which will be used later for inference.

Result:

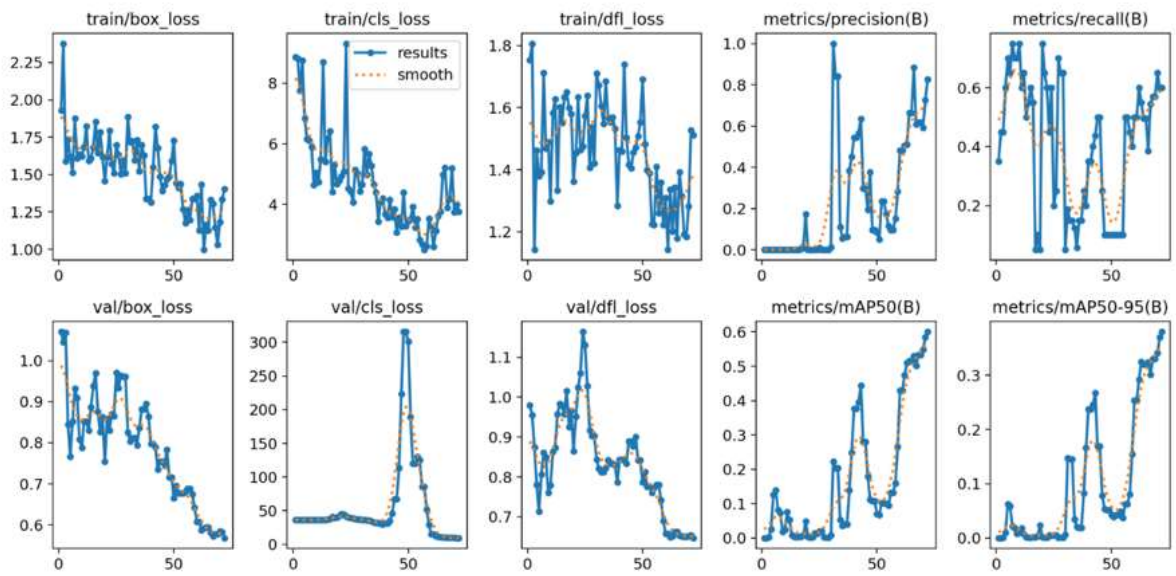


Figure 3.9. Loss Curves and Performance Metrics of YOLOv8 During Training

Training and Validation Losses:

train/cls_loss:

- Initial value ~ 1.8 , decreased to ~ 1.2 .
- Slight decrease, indicating the model is learning class labels (e.g., “NG”) fairly well, but still shows some fluctuations.

train/dfl_loss:

- Started at ~ 1.6 , dropped to ~ 1.2 .
- Gradual decline, but strong fluctuations toward the end suggest that more training epochs are needed for stabilization.

val/cls_loss:

- Initially very high at ~ 300 , dropped significantly to ~ 50 .
- Sharp decrease early on, then remained at a relatively high level.

val/dfl_loss:

- Started at ~1.1, decreased to ~0.7.
- Declining trend with some fluctuations toward the end, similar to the other loss functions.

Comment:

- Loss values on both training and validation sets decreased, showing that the model is learning from the data.
- However, the fluctuations in the later stages (especially on the validation set) and the high val/cls_loss may be due to a small dataset or an insufficient validation set.

Performance Metrics:

metrics/precision(B):

- Increased from ~0.0 to ~0.8.
- Steady improvement, indicating that the model is getting better at reducing false positives.

metrics/recall(B):

- Dropped from ~0.6 to ~0.2.
- Decreasing trend suggests that the model is missing more objects as training progresses.

metrics/mAP50(B):

- Rose from ~0.0 to ~0.6.
- Consistent increase, indicating good performance at the IoU 0.5 threshold.

metrics/mAP50-95(B):

- Grew slowly from ~0.0 to ~0.3.
- Slow progress shows the model is struggling with higher IoU thresholds.

Comment:

- Precision and mAP50 improved significantly, but recall dropped and mAP50-95 remains low.
- This suggests the model performs well at lower IoU thresholds (0.5) but is not yet optimized for more complex cases (higher IoU).
- This could be due to a small dataset or an incomplete validation set.

Conclusion:

- This model shows good potential with a precision of ~0.8 and recall around ~0.6–0.7 at a confidence threshold of 0.3.
- However, to improve performance consistency and boost mAP50-95, it is necessary to expand the dataset and extend the training duration.

After obtaining the trained model, we created a Python program on the computer to use this model:

- The program scans the input image folder (where images are saved by the camera).
- When a new image is detected, the system calls the YOLOv8 model to process it:

```
model = YOLO('best.pt')
results = model('image.jpg', save=True, save_txt=True)
```

For each processed image, the following outputs are generated:

- The original image with bounding boxes drawn around defects and labeled as OK/NG.
- A result file (.txt) containing the detection information

Step 3: GUI design

a. Purpose of the Interface

This graphical user interface (GUI) was developed to support an automated product inspection and classification system after the casting process. The interface allows operators to:

- Monitor inspection results from two cameras (Camera0 and Camera1)
- View both the original and processed images using YOLO
- Start the detection system using the START button
- Visually observe product status (e.g., OK/NG) via images or labels

b. Tools Used

- Qt Designer: For designing the GUI layout with widgets such as QLabel, QPushButton, etc.
- PyCharm: The integrated development environment (IDE) used for Python coding and execution

- PyQt5: A Python binding for the Qt framework used to build GUI applications
- YOLO (You Only Look Once): A deep learning model used to detect surface defects in product images

c. Main Interface Layout

- The interface includes the following key areas:
- Left logo: Displays the logo of the University of Danang – University of Science and Technology
- Right logo: Shows the logo of the Faculty of Mechanical Engineering
- Title label: Displays the project name: “Visual Inspection and Defect Detection Module”
- Two large boxes: QLabel widgets to display the output images from Camera0 and Camera1
- START button: Starts the detection thread to begin automatic inspection
- Status box: Showing Classification Result (OK/NG)

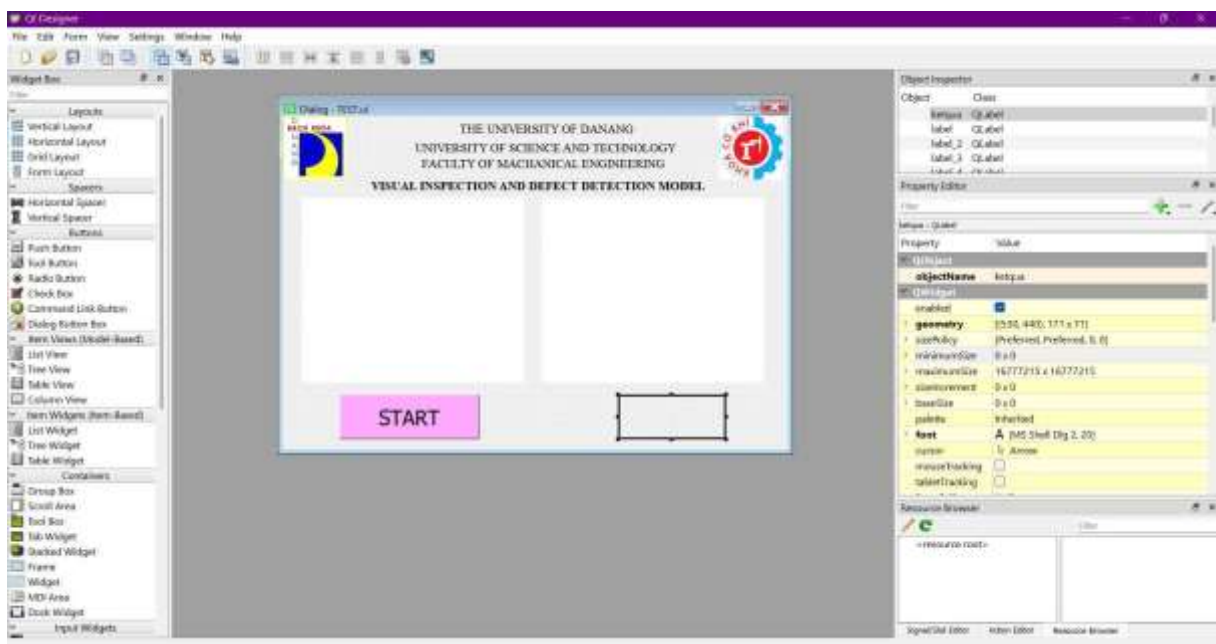


Figure 3.10. Interface Design in Qt Designer

d. Inspection Workflow and Image Processing

When the user clicks the START button, the software automatically scans and processes new images from two cameras:

- Camera 0 captures the side view of the casted part.

- Camera 1 captures the top view of the casted part.

Each image is processed using a YOLO model to detect surface defects. If any defect is found on either side, the result will be displayed as "Not OK". If both sides pass inspection, the result "OK" will be shown.

The original and processed images are displayed side by side on the interface, allowing users to monitor the inspection visually. The results are also saved in a results folder for tracking and analysis.

CHAPTER 4. IMPLEMENTATION RESULTS

4.1. Mechanical assembly results



Figure 4.1. Machine after assembling all components

After assembling the components, each part was fitted accurately and precisely, demonstrating carefulness and attention to detail during the assembly process. The parts were securely fastened using appropriate mechanical methods, ensuring stability and durability for the entire system. The assembly was carried out in a proper sequence to avoid misalignment or looseness, helping the machine operate efficiently and safely during use. Proper installation also facilitates easier maintenance and repairs in the future.



Figure 4.2. Completed mechanical structure of the machine

The mechanical part is designed to be compact, sturdy, and well-organized. Components are arranged logically to save space and ensure smooth operation. The materials used are lightweight but durable, reducing overall weight while maintaining strength. The machine's movements are precise and stable thanks to careful assembly.

The frame is also solid, making it easy to install sensors, control devices, and the camera system.

4.2. Electrical assembly results



Figure 4.3. Electrical wiring and setup of the machine

Electrical System Evaluation: The electrical system of the machine is designed and installed in a well-organized manner, ensuring safety and stable operation. Wiring is neatly arranged and meets standards, minimizing the risk of short circuits and facilitating maintenance. Electrical components such as sensors, controllers, relays, and power supplies operate reliably and respond quickly to control signals. Proper circuit protection and insulation are implemented, ensuring operator safety and extending the machine's lifespan.

4.3. Monitoring interface results

Due to the company's data security requirements, we are unable to use actual product images during operation. Instead, the team uses a set of available images on the computer to simulate the visual inspection process, aiming to demonstrate that we are fully capable of carrying out this procedure.



Figure 4.6. GUI Display Result of Defect Inspection for Product Not Meeting Requirements

The interface below displays the defect inspection results of actual products that we have tested. These results demonstrate the system's ability to detect acceptable (OK) and unacceptable (NG) regions.

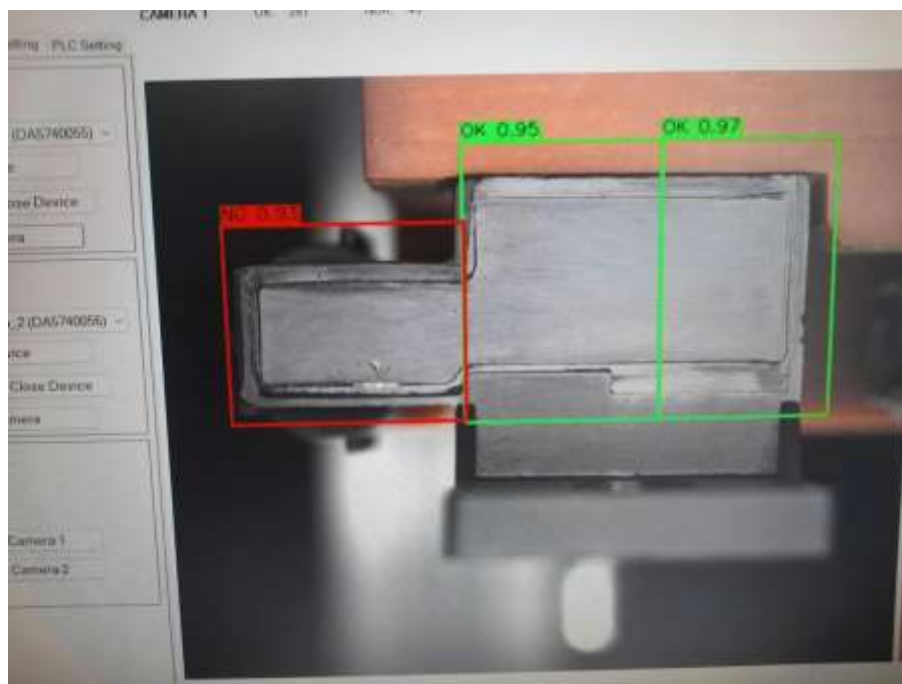


Figure 4.7. Actual defect inspection results for NG (non-conforming) casted parts (image 1)



Figure 4.8. Actual defect inspection results for NG (non-conforming) casted parts (image 2)

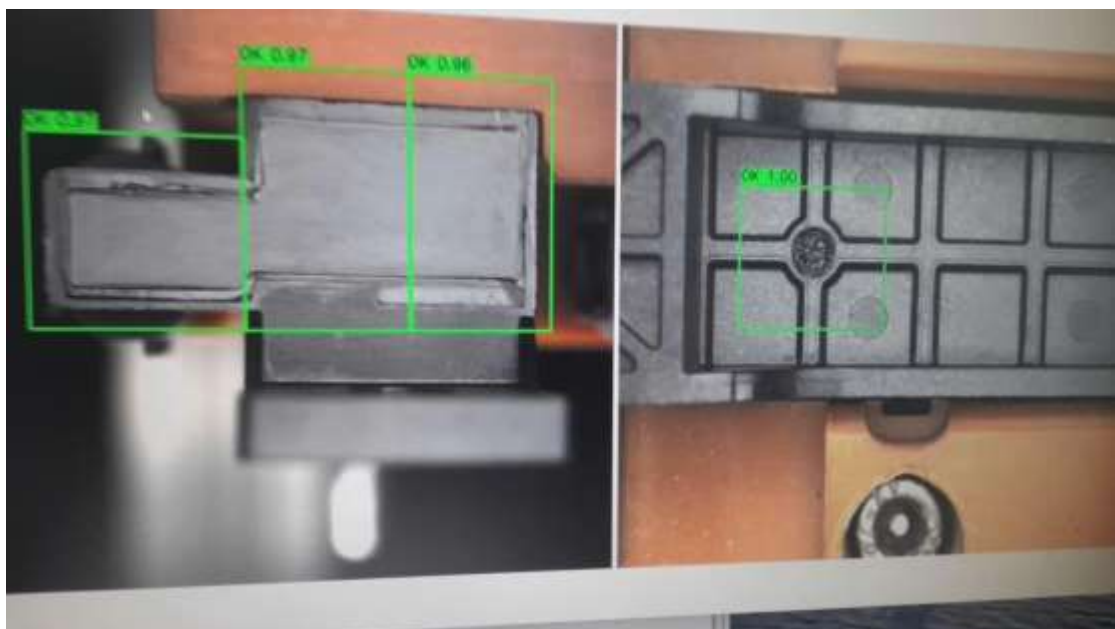


Figure 4.9. Actual defect inspection results for OK (conforming) casted parts

The automated visual inspection and classification system for cast parts after the casting process yields the following results:

- Total cycle time for 4 cast parts: 28 seconds
 - Average processing time per cast part: 7 seconds
 - Processing throughput: approximately 8.57 parts per minute, or 514 parts per hour
- Defect Detection Accuracy:
- The system achieves a defect detection accuracy ranging from 90% to 95%, depending on lighting conditions, surface contrast, and the specific type of defect.
 - The classification performance for both acceptable and defective parts is stable and suitable for post-casting inspection.

CHAPTER 5. CONCLUSION AND FUTURE DEVELOPMENT

5.1. Conclusion

Through the process of research, design, and fabrication, the project successfully developed a prototype of a post-casting visual inspection machine using image processing technology. The system is capable of detecting common surface defects such as air bubbles, cracks, burrs, and deformation on cast products. The integration of a camera system and processing algorithms has helped improve the accuracy and objectivity of quality control, while minimizing human error and increasing inspection efficiency. The model has met the basic objectives of the project and demonstrated the potential for practical application in production environments.

5.2. Future development

In the future, this project can be expanded and improved in the following directions:

- Enhancing defect detection accuracy and classification capabilities by applying artificial intelligence (AI), especially convolutional neural networks (CNN).
- Optimizing image processing algorithms to increase processing speed and improve performance under varying lighting conditions or harsh industrial environments.
- Building a larger defect dataset to train and validate the system with a wide variety of product types.
- Integrating the system into automated production lines, enabling real-time 100% inspection and immediate feedback to the control system.
- Developing monitoring and reporting interfaces on computers or mobile devices for convenient tracking, analysis, and production data storage.

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APPENDIX

Python GUI programming:

```
import sys

import os

from PyQt5 import QtWidgets, QtGui, QtCore
from PyQt5.QtGui import QPixmap
from PyQt5 import uic
from ultralytics import YOLO

class MyWindow(QtWidgets.QDialog):

    def __init__(self):

        super(MyWindow, self).__init__()

        uic.loadUi('TEST.ui', self)

        # Set font cho các QLabel

        default_font = QtGui.QFont("Times New Roman", 12)

        for widget in self.findChildren(QtWidgets.QLabel):

            widget.setFont(default_font)

        # Set font và căn giữa cho ô text ketqua

        text_font = QtGui.QFont("Times New Roman", 16)

        self.ketqua.setFont(text_font)

        self.ketqua.setAlignment(QtCore.Qt.AlignCenter)

        self.model_path = r"D:\DATA_XLA\best5.pt"

        self.output_folder = r"D:\DATA_XLA\KETQUA"

        self.camera_labels = {

            "Camera0": self.label_6,

            "Camera1": self.label_7,

        }

        self.nutnhan.clicked.connect(self.select_and_process_images)

    def select_and_process_images(self):

        options = QtWidgets.QFileDialog.Options()

        files, _ = QtWidgets.QFileDialog.getOpenFileNames(
```

```
self,
"Chọn hai ảnh để xử lý",
"",
"Image Files (*.png *.jpg *.jpeg *.bmp)",
options=options
)
if len(files) >= 2:
    self.image_paths = files[:2]
    print("Ảnh đã chọn:", self.image_paths)
    model = YOLO(self.model_path)
    error_detected = False
    for idx, (camera_name, image_path) in enumerate(zip(self.camera_labels.keys(), self.image_paths)):
        label = self.camera_labels[camera_name]
        if image_path and os.path.exists(image_path):
            filename = os.path.basename(image_path)
            results = model.predict(
                source=image_path,
                save=True,
                save_txt=False,
                save_conf=False,
                project=self.output_folder,
                name='result',
                exist_ok=True
            )

            detected_img_path = os.path.join(self.output_folder, 'result', filename)
            print(f"Đường dẫn ảnh đã xử lý: {detected_img_path}")
            if os.path.exists(detected_img_path):
                pixmap = QPixmap(detected_img_path).scaled(label.size(), QtCore.Qt.KeepAspectRatio)
                if not pixmap.isNull():
                    label.setPixmap(pixmap)
```

```
        label.setText("")

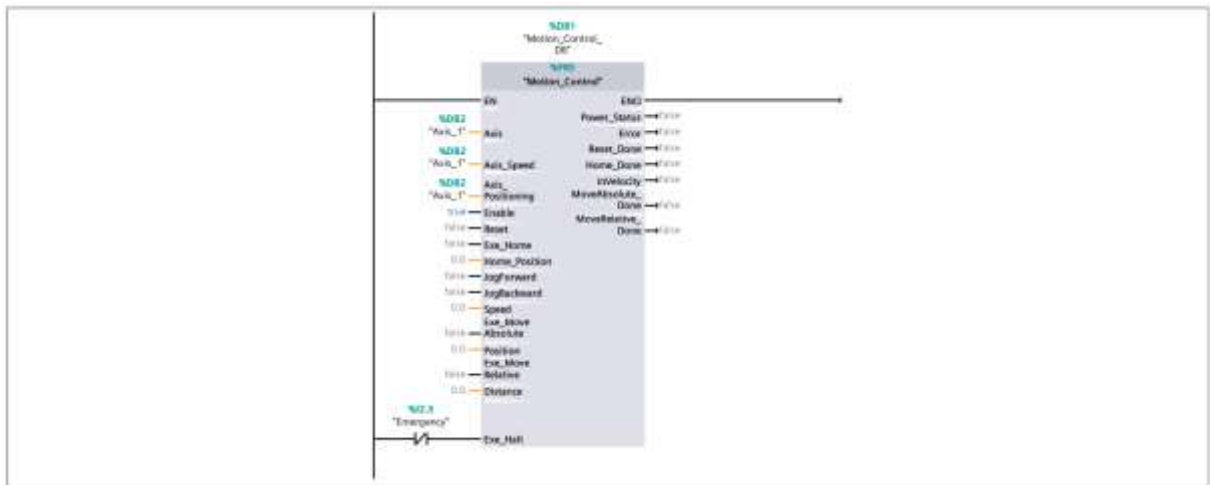
        if results[0].boxes.xyxy.numel() > 0:
            error_detected = True
        else:
            label.setText("Lỗi: Không tải được ảnh đã xử lý")
        else:
            label.setText("Lỗi: Không tạo được ảnh đã xử lý")
        else:
            label.setText("Lỗi: Đường dẫn không hợp lệ")

    if error_detected:
        self.ketqua.setText("NG")
    else:
        self.ketqua.setText("OK")
    else:
        QtWidgets.QMessageBox.warning(self, "Cảnh báo", "Vui lòng chọn ít nhất 2 ảnh!")

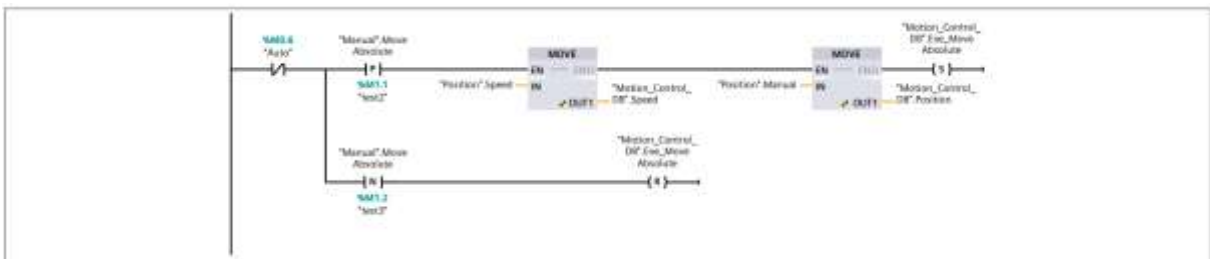
if __name__ == "__main__":
    app = QtWidgets.QApplication(sys.argv)
    window = MyWindow()
    window.show()
    sys.exit(app.exec_())
```

PLC Main Program:

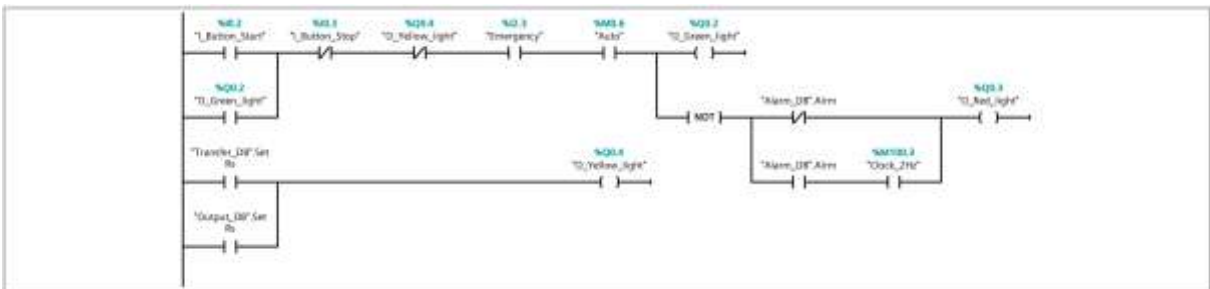
Network 1:



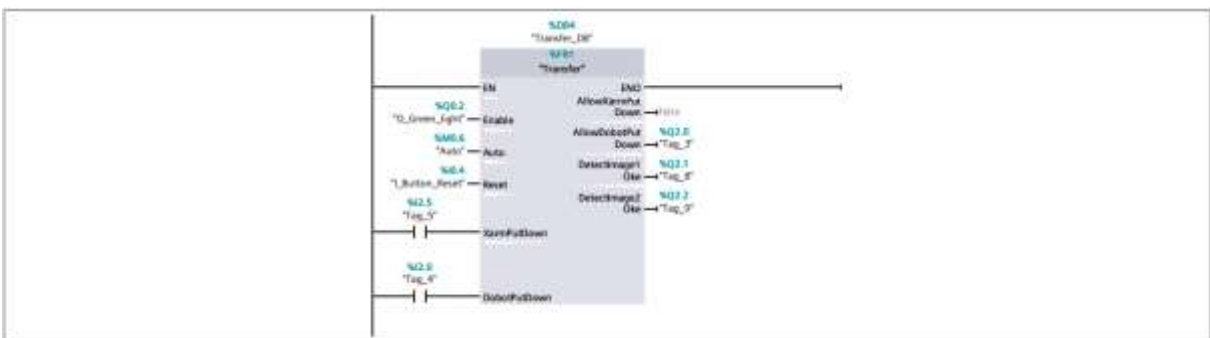
Network 2:



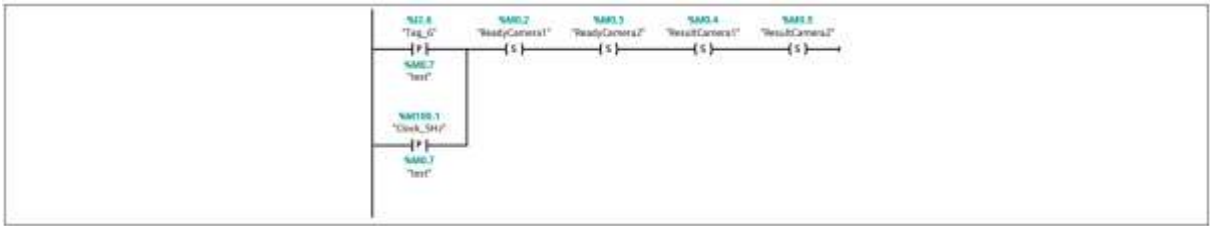
Network 3:



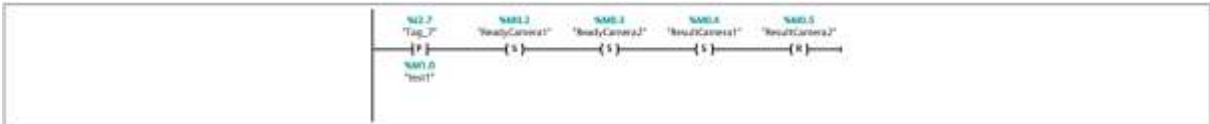
Network 4:



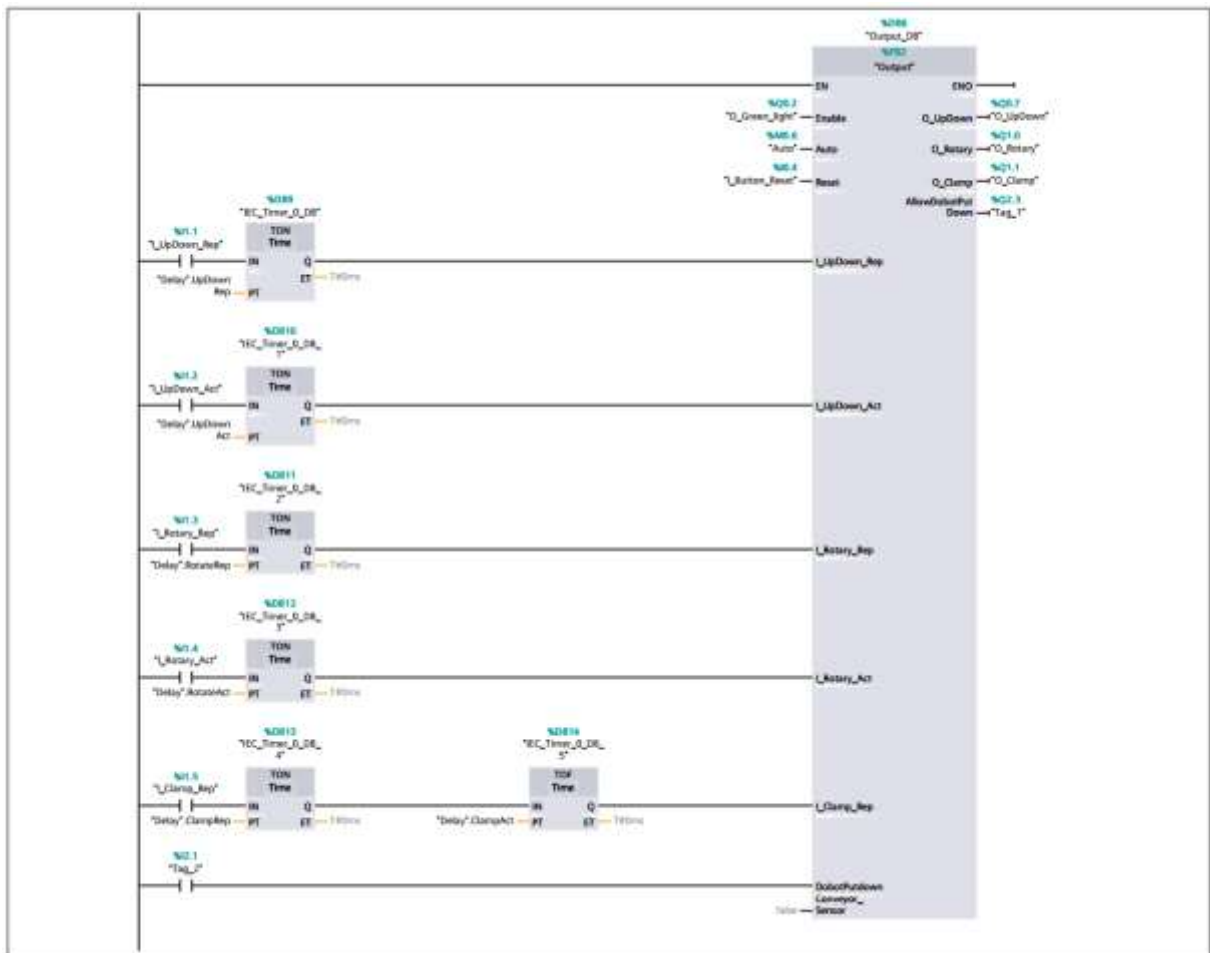
Network 5:



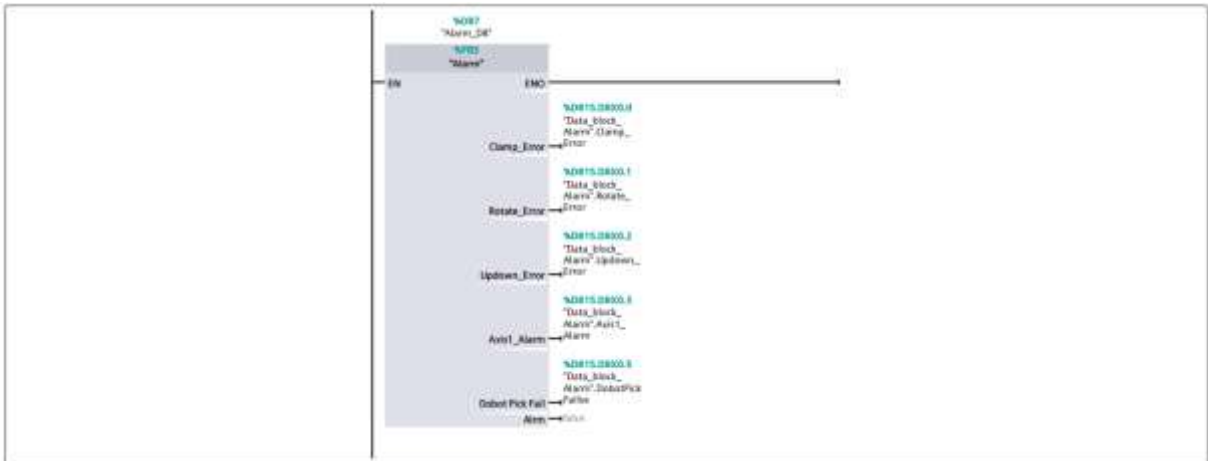
Network 6:



Network 7:



Network 8:



Network 9:

