Satakunnan ammattikorkeakoulu
Satakunta University of Applied Sciences

GANESH GOUTHAM SATISH KUMAR

Automation of Wooden Plank Handling Using a Vision Guided Cobot System

DEGREE PROGRAMME IN MECHATRONICS
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ABSTRACT

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The objective of the thesis was to automate the wooden plank handling process at Pihla Factory by developing and implementing a vision-guided collaborative robot system in cooperation with FP Kotaja Oy. The aim of the project was to design, build, and deploy a functional automation solution that uses a UR cobot integrated with a machine vision camera to identify, pick, and place wooden planks automatically. The purpose was to improve production efficiency, reduce manual workload, and increase process consistency.

The thesis combined theoretical study and practical industrial implementation. The theoretical part reviewed industrial automation in the context of Industry 4.0, the principles and safety of collaborative robots, and the application of machine vision in robotic systems. The practical part described the full development process conducted at FP Kotaja Oy for Pihla Factory, including hardware integration, camera calibration, communication setup between the VISOR vision camera and UR collaborative robot, and testing of the complete system on-site.

The implemented system successfully automated the identification and handling of wooden planks with high accuracy. The deployment demonstrated a reduction in cycle times and a significant improvement in process repeatability and ergonomics. The communication between the camera and robot operated reliably, ensuring stable and continuous operation during factory testing.

It was concluded that the integration of a vision-guided cobot system for wooden plank handling is both technically and practically feasible in an industrial production environment. The project provided FP Kotaja Oy and Pihla Factory with a robust automation solution and laid the groundwork for further improvements such as conveyor synchronization, AI-based vision detection, and broader automation of related production stages.

Keywords: collaborative robots, cobots, machine vision, automation, robotics, production efficiency, UR robot, FP Kotaja, Pihla Factory

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1 INTRODUCTION

The topic of this thesis is the development and implementation of a vision-guided collaborative robot system for automating the wooden plank handling process at Pihla Factory. The project was carried out in cooperation with FP Kotaja Oy, where the author worked as a machine vision developer during the summer. The company aimed to improve the automation of Pihla's painting line by integrating a collaborative robot equipped with a machine vision camera to identify, pick, and place wooden planks automatically.

The objective of the thesis is to present the complete process of developing and deploying this vision-guided cobot system, from concept design to final implementation. It also aims to analyse the effect of automation on production efficiency, evaluate its impact on manual work tasks, and demonstrate the benefits of combining robot technology with industrial vision systems in real factory conditions.

The topic is significant because automation and intelligent vision systems are becoming key enablers of Industry 4.0, where production processes are optimized through data, sensing, and collaboration between humans and machines. By introducing a vision-guided cobot into the production line, FP Kotaja Oy and Pihla Factory can enhance productivity, reduce manual workload, and improve both quality and ergonomics. The integration of machine vision ensures flexible operation and adaptability to different wooden parts, helping the company maintain competitiveness in a highly automated manufacturing industry.

The thesis consists of both a theoretical and a practical part. The theoretical part covers industrial automation and collaborative robotics from an Industry 4.0 perspective, the characteristics and safety aspects of cobots, and the fundamentals of machine vision integration. The practical part describes the current state of the plank handling process, the design and implementation of the new system, the integration of the VISOR camera with the UR collaborative robot, and on-site testing and calibration at the Pihla Factory.

The final sections present the results of the implemented system, its observed efficiency improvements, and the challenges faced during development. The thesis concludes with a reflection on the technical and practical outcomes, and suggestions for further improvements and future research related to intelligent robotic handling systems.

2 PURPOSE AND OBJECTIVES

The commissioning company for this thesis is FP Kotaja Oy, located in Huittinen, Finland. FP Kotaja specializes in the design, manufacturing, and integration of industrial automation systems, production machinery, and customized robotic solutions. The company provides services ranging from mechanical design and electrical engineering to software development, installation, and commissioning. FP Kotaja was formerly known as Vame Oy, and after rebranding, it continues to operate as a trusted partner for Finnish manufacturing companies seeking to modernize their production processes. (FP Kotaja Oy, n.d.)

The automation project described in this thesis was commissioned by Pihla Group Oy, one of Finland’s leading manufacturers of windows and doors. Pihla Group’s production facilities, located in Ruovesi and Kuopio, produce a wide range of wooden and aluminum-clad products for both domestic and export markets. The company emphasizes continuous improvement in productivity, quality, and workplace ergonomics, and has actively invested in automation technologies to achieve these goals. (Pihla Group Oy, n.d.)

In 2025, FP Kotaja collaborated with Pihla Group to automate a wooden plank handling process in one of Pihla's production cells. The process previously relied on manual labor to transfer and position heavy wooden planks, which was repetitive and physically demanding. The goal of the project was to design and implement a vision-guided collaborative robot (cobot) system capable of automatically detecting, picking, and placing wooden planks with high precision and consistency.

The author of this thesis worked as part of FP Kotaja's engineering team responsible for the complete development and deployment of this automation solution. The project involved mechanical design, electrical integration, programming of the cobot, installation of the vision system, and on-site commissioning at Pihla Group's facility.

The purpose of the thesis is to document the development process of this automation project and to evaluate its technical and operational outcomes. The study also examines how the introduction of the cobot-based automation improved production efficiency, reduced operator workload, and enhanced safety.

The key objectives of this thesis are to:

1. Design and develop a fully functional cobot-based automation system for wooden plank handling.
2. Integrate a vision system for accurate and adaptive object detection and positioning.
3. Deploy and test the system in a real production environment at Pihla Group.
4. Evaluate the results and identify further improvement opportunities.

The purpose of this thesis can be summarized in one sentence:
to design, build, and implement a vision-guided collaborative robot system for automating the wooden plank handling process at Pihla Group's production line.

Based on the purpose and objectives, the following research questions were defined:

1. How can a vision-guided cobot system be designed and implemented effectively for wooden plank handling in an industrial environment?
2. What are the main technical challenges encountered during integration and deployment?
3. How does the automation system improve efficiency, precision, and ergonomics compared to the previous manual operation?

3 AUTOMATION, COLLABORATIVE ROBOTICS AND MACHINE VISION

This chapter explains the theoretical background related to the project. It covers the main principles of industrial automation, collaborative robots, and machine vision systems. These topics form the foundation for understanding how the developed cobot system at Pihla Factory works and why certain design choices were made.

3.1 Automation and Industry 4.0

Automation in manufacturing means using machines and control systems to perform tasks with minimal human involvement. It helps improve productivity, quality, and safety while reducing human workload. In recent years, automation has developed rapidly under the concept of Industry 4.0, which combines physical machines with digital technologies, sensors, and networked data systems.

In Industry 4.0, machines, robots, and sensors are connected and can exchange data in real time. This allows production systems to be more flexible and responsive. Smart factories can adjust automatically to changes in production demand, detect faults faster, and collect performance data for analysis.

The automation system developed in this thesis follows these principles. It uses a UR20 collaborative robot connected to a vision sensor and communicates data through a digital interface. The system is designed to handle wooden planks automatically by detecting them with a camera and sending exact position data to the robot.

Figure 3.1. Overview of an Industry 4.0 automation concept showing how sensors, robots, and networked systems communicate in a smart factory. Source: Adapted from Alipoor, M., & Ahmadi, A. (2024). Advances in intelligent robotic systems and sensor technologies in Industry 4.0. ResearchGate. Retrieved from https://www.researchgate.net/figure/Advances-in-intelligent-robotic-systems-and-sensor-technologies-in-Industry-40-11_fig1_377635979

3.2 Collaborative Robots (Cobots)

3.2.1 Characteristics of Collaborative Robots

Collaborative robots, or cobots, are robots designed to work safely alongside humans without the need for full physical barriers. They have built-in sensors that monitor contact forces and limit speed or power when humans are nearby. Cobots are also easy to program, compact, and suitable for small and medium-sized factories.

Compared to traditional industrial robots, cobots are simpler to integrate and more flexible in small-scale production. They can be reprogrammed quickly to handle new products or different part sizes. These properties make cobots an important part of modern manufacturing lines that need both automation and flexibility.

3.2.2 Use of Cobots in Industrial Applications

Cobots are widely used for pick-and-place, assembly, machine tending, and packaging. In the case of this project, the UR20 cobot is used for automatic wooden plank handling. Its large reach and suitable payload make it well-suited for picking planks from a pallet and placing them onto a conveyor.

The UR20 cobot includes integrated force control and safety monitoring. This allows safe cooperation with human operators when loading or unloading pallets. Because it is light and flexible, it can be moved and reprogrammed for different production lines if needed.

3.2.3 Safety and Human–Robot Collaboration

Safety is one of the most important aspects when working with collaborative robots. International standards such as ISO 10218 and ISO/TS 15066 define the safety requirements for human–robot collaboration. These standards describe the limits for force, speed, and contact pressure between the robot and human operator.

To ensure safety, each application must go through a risk assessment. The goal is to identify possible hazards, such as pinch points, collisions, or incorrect pallet loading. The system must then include measures such as emergency stop buttons, light indicators, and clear working zones.

In this project, the safety of the plank-handling cell was achieved through a combination of cobot safety functions and operator training. The robot was programmed to stop immediately if unexpected contact was detected, and operators were instructed to follow the defined loading rules.

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3.4 Machine Vision in Robotic Systems

Machine vision gives robots the ability to see and identify objects. It uses cameras and image processing software to detect the position, size, and orientation of parts. The robot then uses this information to adjust its movements.

In industrial pick-and-place applications, vision systems improve flexibility because the robot does not depend on fixed part positions. Instead, the camera can recognize where the part actually is. This is especially useful when working with wooden planks, which may vary slightly in shape, size, or position on the pallet.

The vision system used in this project is the VISOR sensor, which detects planks based on their contours. It analyses the contrast between the edges of the plank and the background and calculates their rotation and location. This data is then sent directly to the UR20 cobot through a TCP/IP connection.

3.5 Camera Setup and Calibration

The vision sensor was mounted above the pallet in a fixed top-down position. This setup allows the entire pallet area to be visible in one frame. The camera's focal length and height were selected so that planks of different lengths could be detected accurately.

Proper lighting was also critical. Directional lighting was used to create shadows along the edges of the planks, improving contrast and making detection more reliable. The training and search regions in the VISOR software were adjusted so that the system recognized only valid areas where planks could appear.

Calibration ensured that the coordinates from the camera matched the robot's coordinate system. This alignment made it possible for the robot to move directly to the detected positions without extra offset calculations.

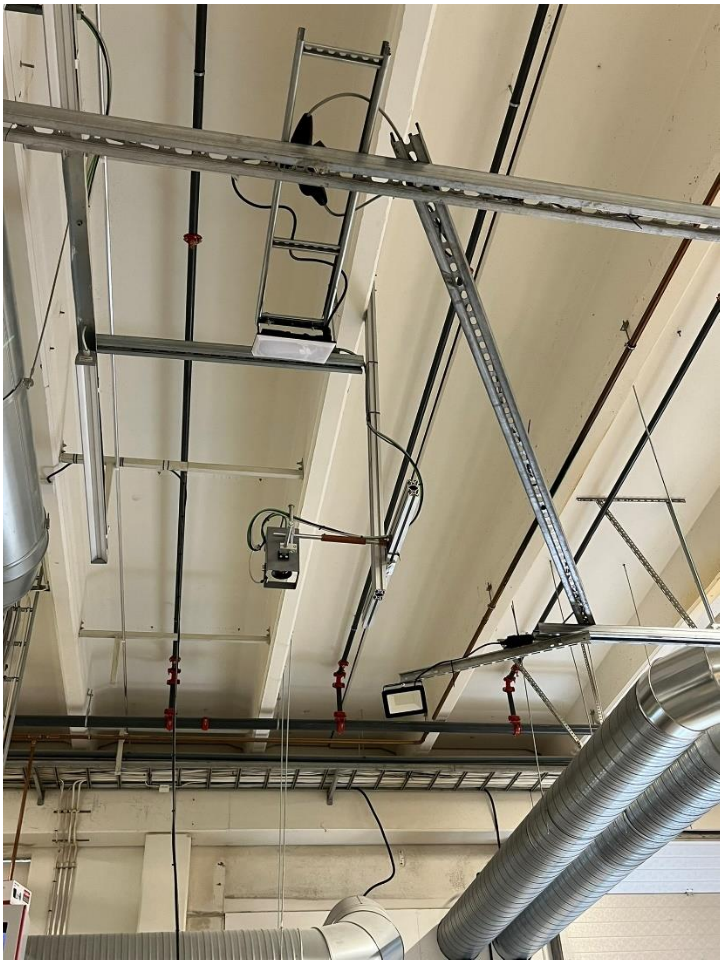

Figure 3.2 Camera placement and lighting setup above the pallet area.

3.6 Communication Between Camera and Robot

Communication between the vision system and the robot was established using a TCP/IP protocol. When a pallet was loaded, the robot triggered the camera to capture an image. The camera then processed the detections, filtered the results, and sent a list of valid coordinates to the robot.

Each coordinate included the X and Y position, the rotation angle, and a fixed Z height for picking. The robot program received these values and performed the picking operation accordingly. This communication was designed to be fast and reliable to avoid delays in the production cycle.

3.7 Design Implications for This Project

The theories described above influenced the design of the system at Pihla Factory.

- The concept of Industry 4.0 supported the decision to use digital communication and flexible control between devices.
- Collaborative robotics made it possible to place the robot in the same workspace with operators safely.
- Machine vision provided the flexibility to handle planks of different sizes and orientations without mechanical guides.
- Proper lighting, calibration, and communication ensured that the robot received accurate data and that operations were repeatable and safe.

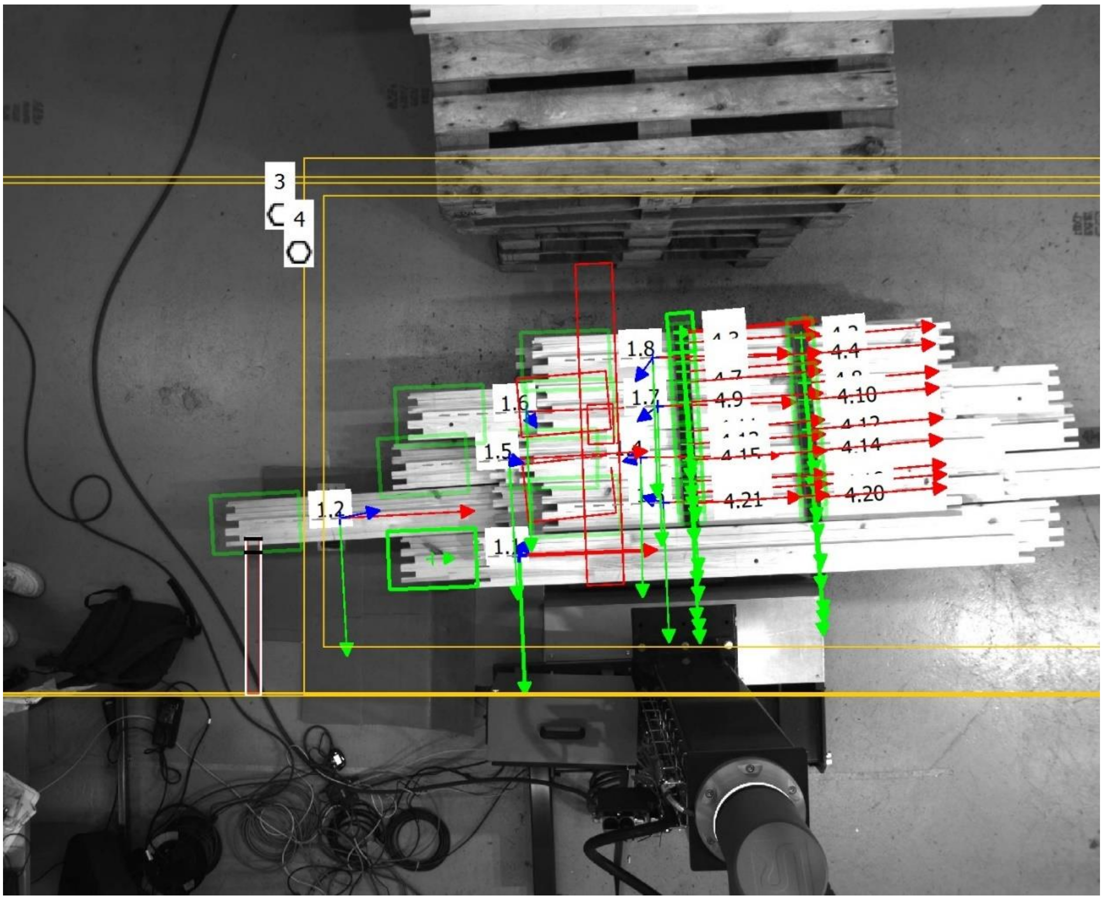

Figure 3.3: Example image from VISOR software showing detected plank edges and contour lines.

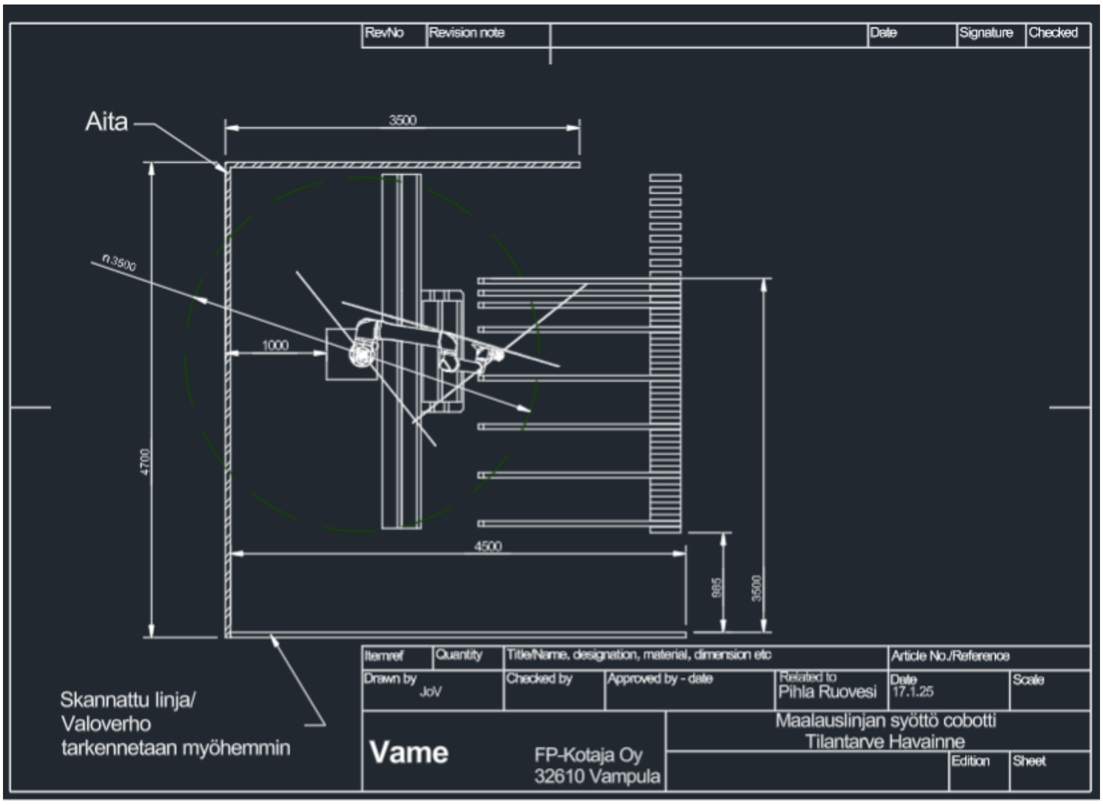

Figure 3.4: Overall layout of the cobot cell including pallet, camera, and conveyor positions.

3.8 Summary

In summary, this chapter introduced the main theoretical areas related to the project: automation and Industry 4.0, collaborative robots, safety standards, and machine vision. Understanding these principles was necessary for designing the vision-guided cobot system used for wooden plank handling at Pihla Factory. The next chapter presents the current state of the production line and explains how the process was organized before the new system was installed.

4 CURRENT STATE OF THE PRODUCTION LINE

This chapter describes the current situation of the wooden plank handling process at Pihla Factory before the automation system was implemented. It explains how the process was organized, what equipment was used, and what challenges existed in the manual operation. Understanding the original state of the production line is important for defining the requirements for the new cobot system.

4.1 Overview of the Existing Process

The plank handling process at Pihla Factory is part of the painting line where wooden window frame parts are prepared and transferred for further processing. The planks are delivered to the workstation stacked on wooden pallets. Each pallet contains multiple layers of planks, separated by black sticks that keep the layers apart.

Before automation, an operator manually lifted each plank from the pallet and placed it onto a conveyor. The conveyor then carried the planks to the next stage of the painting line. The work was repetitive, physically demanding, and required careful attention to avoid damaging the parts.

This manual process caused several challenges. The lifting task required repetitive bending and reaching motions, which could lead to strain injuries. Productivity also depended on the operator’s speed and endurance. In addition, the accuracy of the plank positioning varied, which sometimes caused alignment issues on the conveyor. These challenges motivated FP Kotaja and Pihla Factory to investigate an automated solution.

4.2 Workstation Layout

The manual workstation consisted of three main areas: the pallet loading zone, the operator’s working area, and the conveyor line leading to the painting section. The pallets were placed on a fixed platform beside the conveyor. The distance between the pallet and conveyor was approximately 1.2 meters, which required the operator to turn and reach repeatedly.

The average pallet contained between 50 and 100 planks, depending on the product type. Operators were responsible for removing the sticks between layers and ensuring that all planks were handled in the correct order. When a pallet was empty, the operator replaced it with a new one using a pallet jack. The layout did not include any automatic sensors or detection systems. All operations were manual.

4.3 Characteristics of the Wooden Planks

The wooden planks used at Pihla Factory are parts of window frames. They vary in length, width, and joint design, depending on whether they are used for opening or fixed windows. The main categories used in the process are small, medium, and long planks.

Type	**Length (cm)**	**Width (cm)**
Small	27 – 120	11-19
Medium	130 – 230	11-19
Long	>230	11-19

Table 4.1. Dimensions of wooden planks handled in the production line.

Each pallet contains planks of the same width but varying lengths. Black sticks are placed between layers to maintain even spacing and protect the planks from pressure. Because of these variations, manual handling required the operator to constantly check the orientation and position of each plank before placing it on the conveyor.

4.4 Observed Challenges in Manual Operation

During the initial study at Pihla Factory, several challenges were observed in the existing process:

1. **Repetitive and Heavy Workload** – The operator had to lift and move planks continuously, which caused physical strain and increased fatigue over long shifts.

2. **Inconsistent Cycle Time** – The speed of handling depended on the operator’s pace and focus, leading to variations in production flow.
3. **Positioning Errors** – Planks were occasionally placed slightly misaligned on the conveyor, requiring manual correction or causing small delays in the painting stage.
4. **Limited Ergonomics** – The distance between the pallet and conveyor required repeated twisting and reaching motions.
5. **Safety Risks** – Working near moving conveyors and handling heavy parts posed minor safety risks, especially when the workspace was crowded.

These issues affected both the efficiency and the comfort of the workers. Reducing the manual load and improving process consistency became key goals for the automation project.

4.5 Factory Environment and Constraints

The automation cell was planned to be installed within the same area of the existing workstation. Therefore, the design of the new system had to consider the available floor space, lighting, and existing conveyor layout. The floor surface around the workstation was flat concrete, allowing stable installation of the cobot stand and the vision camera mount.

However, for vision detection, additional directional lighting was required. Electrical and network connections were available nearby, making integration with the factory network feasible.

Another important factor was safety. Since the cobot would operate near human workers, the design had to comply with collaborative robot safety requirements. The working speed, force limits, and reachable area were all adjusted to meet these standards.

4.6 Summary of Current State

The existing plank-handling process at Pihla Factory relied entirely on manual labor. It was functional but inefficient and physically demanding. Operators had to handle planks of varying sizes, maintain order between layers, and load them onto a conveyor one by one.

This approach limited productivity and increased fatigue over long shifts. In addition, the process lacked automation features such as part detection, error monitoring, or data tracking. These findings defined the main requirements for the new system: automatic detection of planks, consistent pick-and-place operation, safe collaboration with operators, and easy integration into the existing painting line.

5 SYSTEM DESIGN AND INTEGRATION

This chapter describes the design and development of the automated plank-handling system. It explains how the mechanical layout, electrical setup, and software logic were developed to enable communication between the UR20 collaborative robot and the VISOR vision camera. The goal was to design a reliable system that can detect, pick, and place wooden planks automatically in a real production environment.

5.1 System Overview

The automation system was designed to pick wooden planks from a pallet and place them onto a conveyor for further processing. The core components of the system are the UR20 collaborative robot, the VISOR vision sensor, a vacuum gripper, and the pallet-conveyor workstation.

The cobot performs all pick-and-place movements, while the vision camera detects the location and orientation of each plank. The two devices communicate through a TCP/IP connection, which allows the robot to receive detection data directly from the camera.

Figure 5.1: Overall system layout showing the UR20 cobot, vision camera, pallet position, and conveyor line.

The design emphasizes reliability, repeatability, and safety. Every part of the system, from pallet alignment to gripper motion, follows defined rules to maintain consistent operation.

5.2 Design Requirements

Before starting the design, several requirements were defined based on observations from the existing process and discussions with FP Kotaja and Pihla Factory engineers. The system had to meet the following criteria:

1. **Automatic detection and picking:** The robot must identify the top-layer planks and pick them without human assistance.

2. **Adaptability to different plank types:** The vision system must handle varying lengths and widths accurately.
3. **Consistent placement:** Planks must be placed straight and centered on the conveyor.
4. **Safety and reliability:** The system must operate safely near humans and stop automatically in abnormal conditions.
5. **Simple operation:** Loading pallets and starting the system should require minimal user input.

These requirements guided the mechanical design, vision setup, and software programming.

5.3 Mechanical Design and Layout

The mechanical layout was designed to fit within the existing factory space without major modifications. The UR20 robot was installed on a fixed base beside the conveyor. The pallet position was defined to ensure the robot’s reach covered the entire picking area and the conveyor placement area.

The camera was mounted above the pallet at a fixed height, aligned perpendicularly to the surface to provide a full top-down view. This position ensured that all planks, regardless of length, stayed within the camera’s field of view.

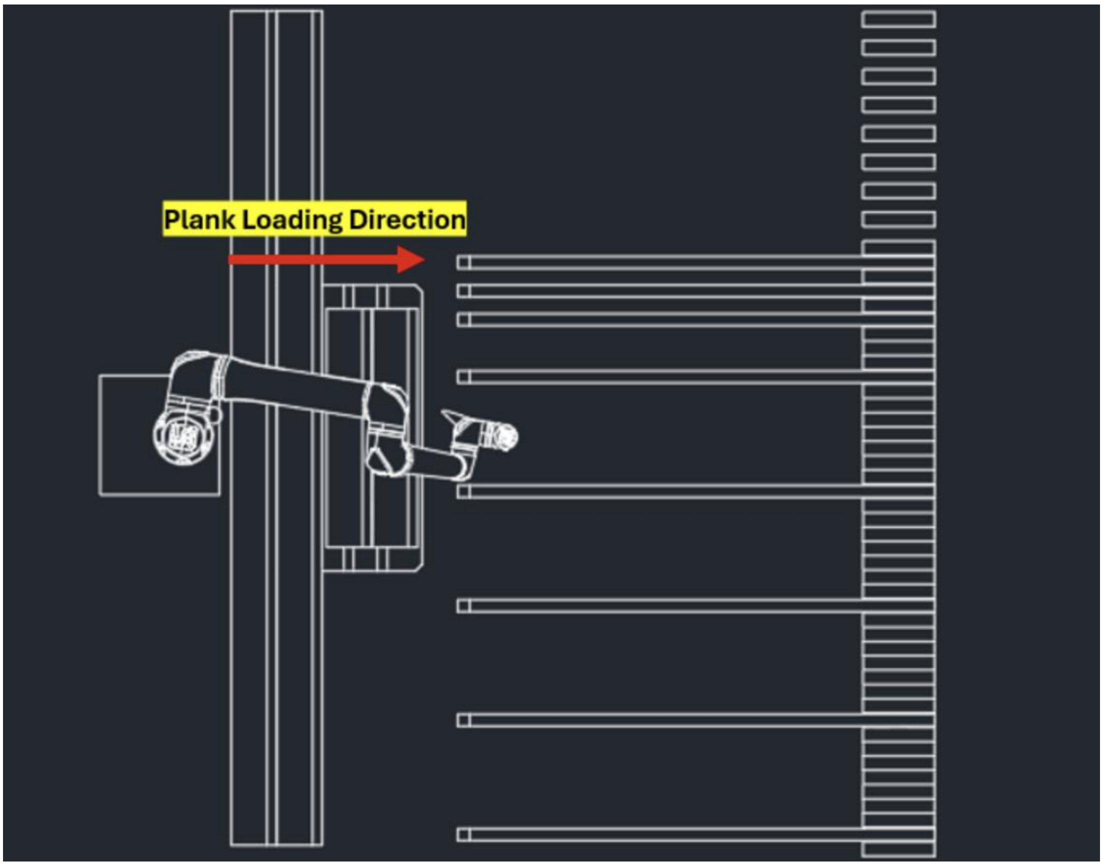

Figure 5.2 Top-view layout of the cobot work cell showing the robot reach, pallet zone, and conveyor area.

A steel frame was used to support the camera and lighting fixtures. The lighting was directed diagonally to highlight the plank edges and grooves. The working height of the robot was adjusted to allow safe picking of planks up to a stack height of 140 cm.

5.4 Design Rules and Pallet Configuration

The success of the automation system depended on the proper arrangement of planks on the pallet. Specific loading and alignment rules were defined for different plank types to ensure reliable detection and gripping.

5.4.1 Pallet Loading Rules

- Each pallet must contain planks of the same width to ensure consistent detection and gripping.

- Planks must be loaded from the robot’s side toward the outer edge.
- The pallet must be aligned with the reference markers placed on the floor.

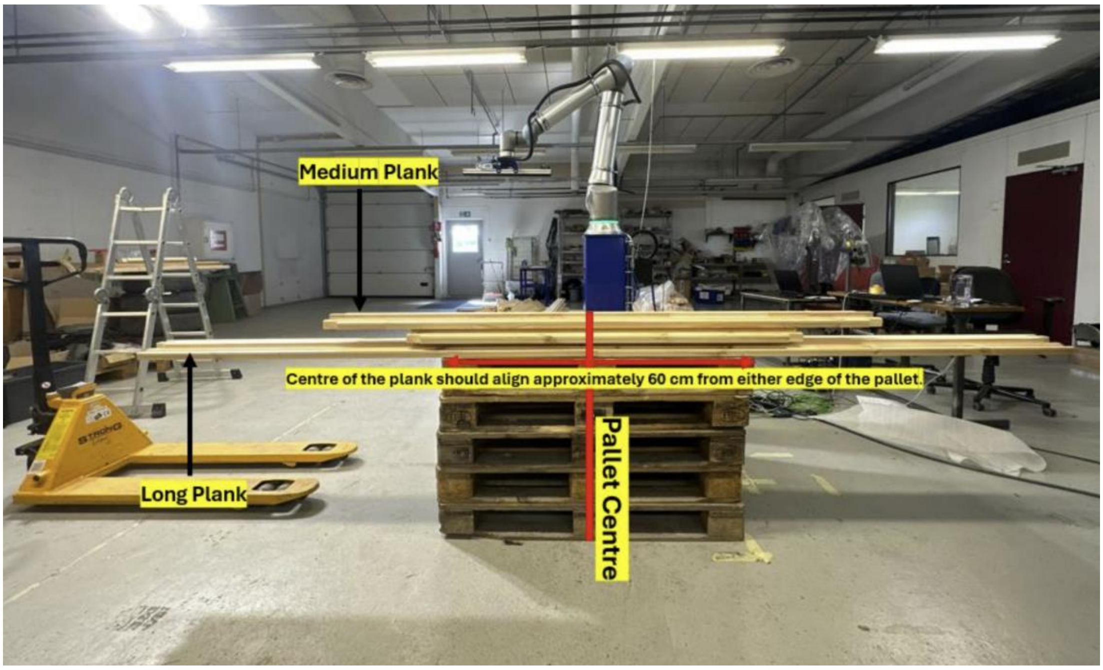

Figure 5.3 Correct pallet loading direction and alignment marks.

5.4.2 Small Planks

- Length between 27–120 cm.
- Right edge should not extend beyond the pallet base.
- Maximum overlap between layers: 27 cm.
- Gap between adjacent small planks: minimum 40 cm.
- Maximum rotation from the ideal alignment: ±7°.

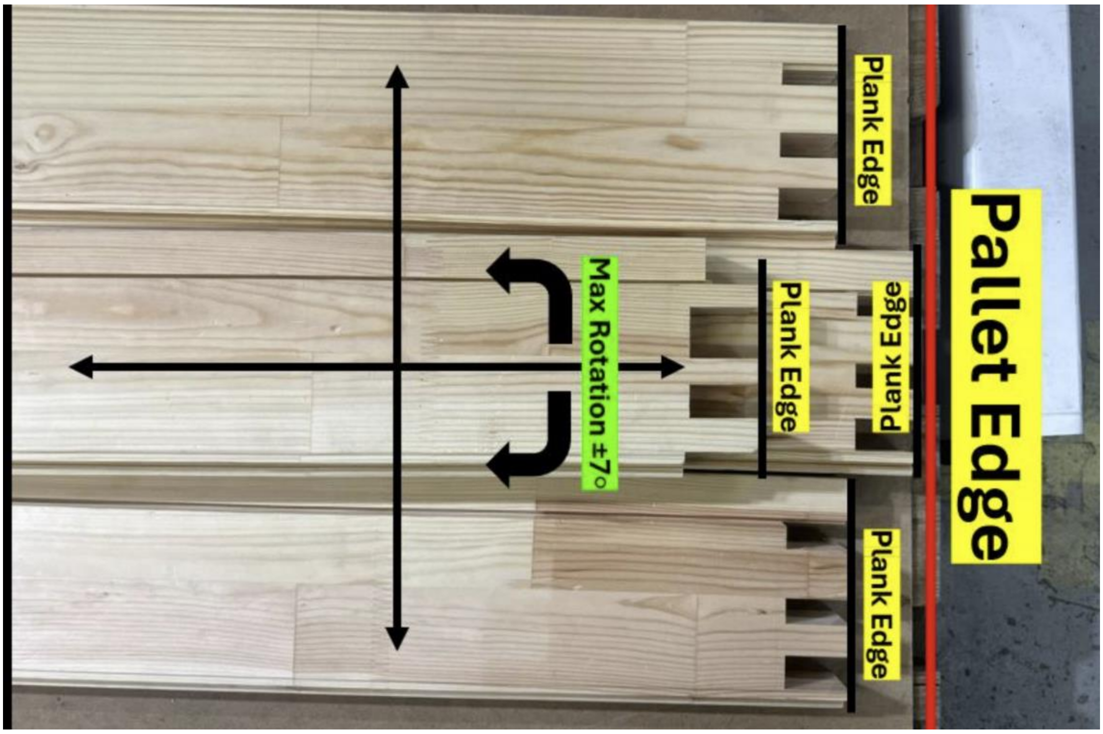

Figure 5.4: Small plank placement and overlap rules.

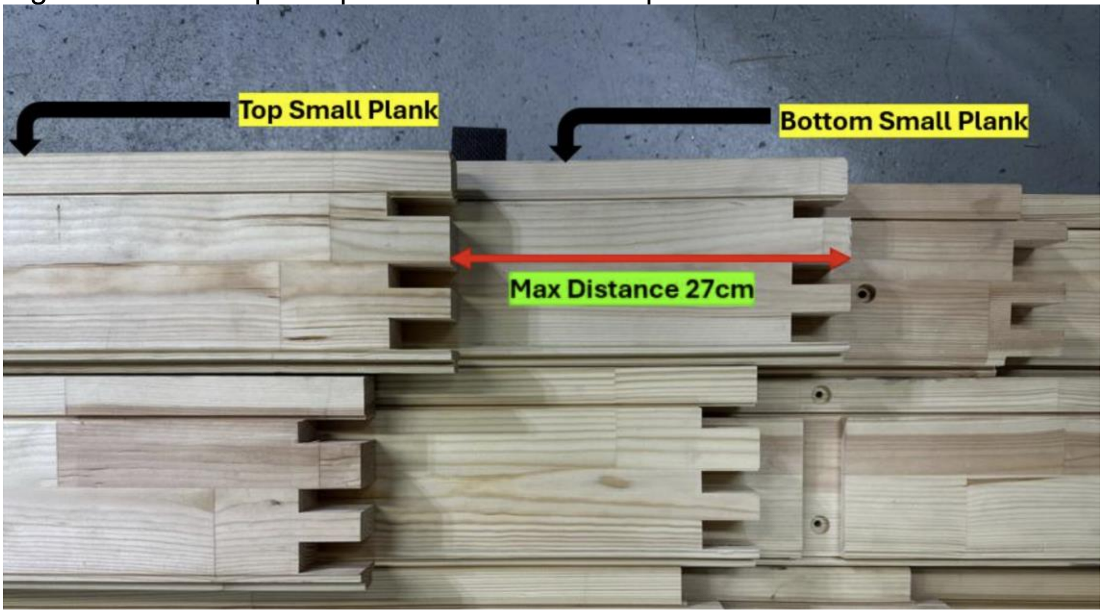

Figure 5.5: Stacking Rule for Small Planks — When a top small plank is placed over a bottom small plank, the overlapping edge must not exceed a maximum distance of 27 cm to ensure stable stacking and safe robotic handling.

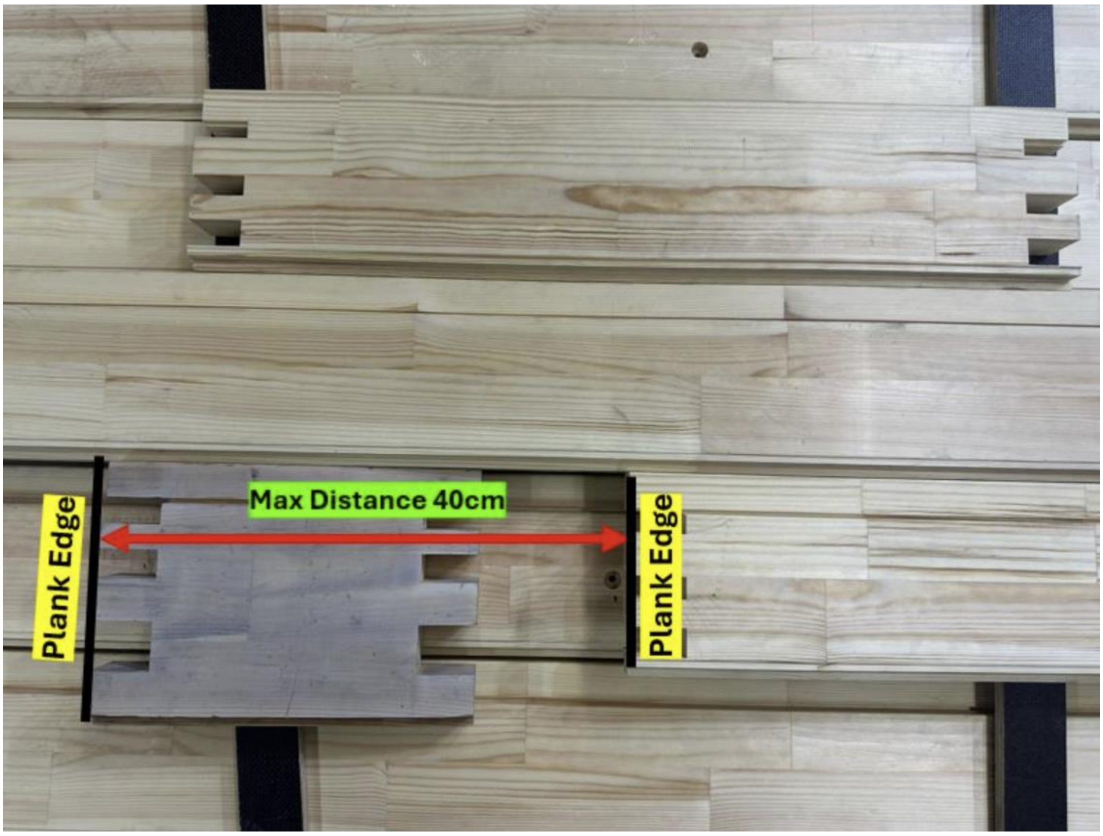

Figure 5.6: Spacing Rule for Adjacent Small Planks — When two small planks are placed side-by-side in the same layer and alignment, the distance between their left edges must be greater than 40 cm to ensure safe gripping clearance and avoid interference

5.4.3 Medium and Long Planks

- Length 130–230 cm (medium), over 230 cm (long).
- Planks must be centered on the pallet.
- Center point approximately 60 cm from each edge.
- Maximum rotation: ±7°.

5.4.4 Stick Placement

- Black sticks are used as separators between layers.
- Sticks must be placed perpendicular to the planks with maximum rotation ±15°.
- Stick length: 83 cm, width: 5 cm.
- The black color improves contrast for the vision system.

Figure 5.7: Stick placement and orientation rules.

Following these rules ensured that the vision system could detect all planks correctly and that the robot could operate without collision or error.

5.5 Vision System Integration

The SensoPart VISOR vision sensor was selected for its ability to perform contour-based detection with high precision. The camera detects each plank by recognizing its contour shape and calculates its X, Y, and rotation (angle) coordinates. These coordinates are used by the robot to adjust its picking position.

The system includes several pre-trained contour detectors, each designed for specific plank types (small, medium, long, and stick). When a pallet is placed, the robot first runs a “Choose Program” that determines which detector should be used.

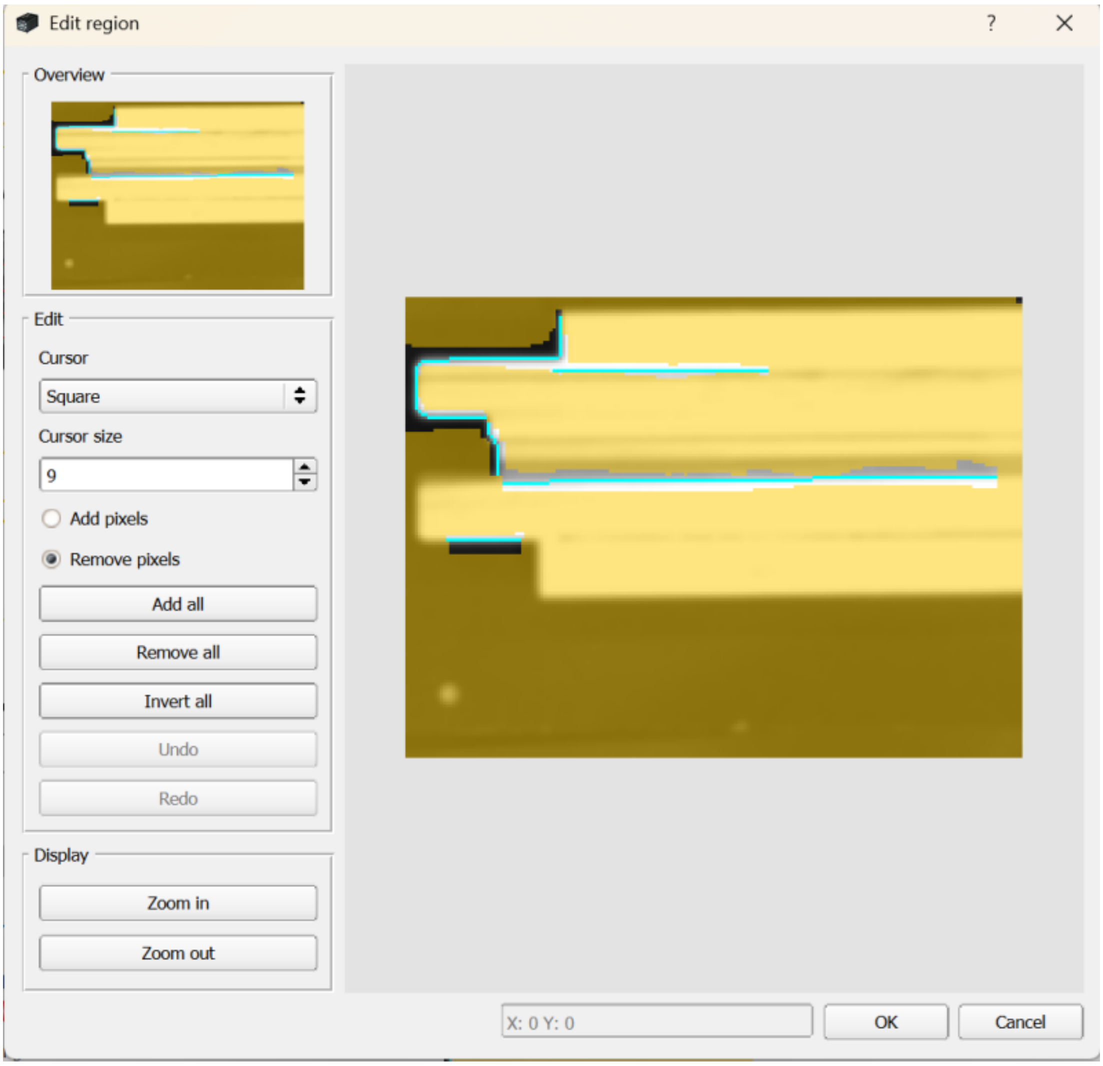

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Figure 5.8: VISOR software interface showing trained contour regions and search areas.

The contour detection relies on lighting and image contrast. To ensure reliable performance, the lighting setup was adjusted to create shadows along the plank edges. This improves visibility of grooves and finger joints used for alignment.

The camera output includes:

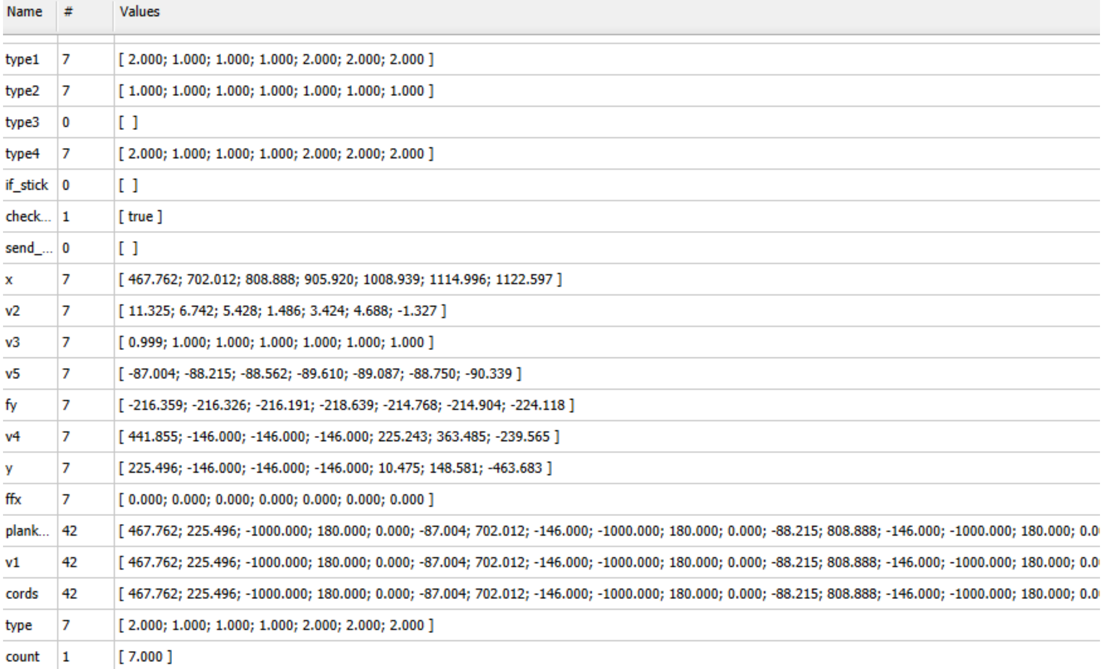
- X and Y coordinates of the detected plank
- Rotation angle (in degrees)
- Match confidence score
- Scale factor (for height compensation)

This data is processed in the VISOR's internal logic before being sent to the robot.

5.6 Communication Between Robot and Vision System

Communication between the camera and the UR20 robot was established using a TCP/IP protocol. After the camera detects the planks, it sends all valid coordinates and rotation data to the robot in a structured format.

Each coordinate message includes a 6D pose vector:
[X, Y, Z, Roll, Pitch, Yaw]
The Z, Roll, and Pitch values remain fixed, while X, Y, and Yaw change according to the detection results.



Name	#	Values
type1	7	[2.000; 1.000; 1.000; 1.000; 2.000; 2.000; 2.000]
type2	7	[1.000; 1.000; 1.000; 1.000; 1.000; 1.000; 1.000]
type3	0	[ ]
type4	7	[2.000; 1.000; 1.000; 1.000; 2.000; 2.000; 2.000]
if_stick	0	[ ]
check...	1	[true]
send_...	0	[ ]
x	7	[467.762; 702.012; 808.888; 905.920; 1008.939; 1114.996; 1122.597]
v2	7	[11.325; 6.742; 5.428; 1.486; 3.424; 4.688; -1.327]
v3	7	[0.999; 1.000; 1.000; 1.000; 1.000; 1.000; 1.000]
v5	7	[-87.004; -88.215; -88.562; -89.610; -89.087; -88.750; -90.339]
fy	7	[-216.359; -216.326; -216.191; -218.639; -214.768; -214.904; -224.118]
v4	7	[441.855; -146.000; -146.000; -146.000; 225.243; 363.485; -239.565]
y	7	[225.496; -146.000; -146.000; -146.000; 10.475; 148.581; -463.683]
ffx	7	[0.000; 0.000; 0.000; 0.000; 0.000; 0.000; 0.000]
plank...	42	[467.762; 225.496; -1000.000; 180.000; 0.000; -87.004; 702.012; -146.000; -1000.000; 180.000; 0.000; -88.215; 808.888; -146.000; -1000.000; 180.000; 0.0
v1	42	[467.762; 225.496; -1000.000; 180.000; 0.000; -87.004; 702.012; -146.000; -1000.000; 180.000; 0.000; -88.215; 808.888; -146.000; -1000.000; 180.000; 0.0
cords	42	[467.762; 225.496; -1000.000; 180.000; 0.000; -87.004; 702.012; -146.000; -1000.000; 180.000; 0.000; -88.215; 808.888; -146.000; -1000.000; 180.000; 0.0
type	7	[2.000; 1.000; 1.000; 1.000; 2.000; 2.000; 2.000]
count	1	[7.000]

Figure 5.9: Communication diagram showing data flow between VISOR vision system and UR20 robot.

The robot requests new data after each pick cycle. If no valid planks are detected, the camera sends an empty signal, and the robot waits until the next cycle. This logic ensures synchronization between detection and motion.

The result processing logic in the vision system filters out invalid detections, such as buried planks or planks covered by sticks. Only the top visible planks are sent to the robot, ensuring safe and accurate handling.

5.7 Robot Program Structure

The UR20 robot was programmed using URScript and the Polyscope interface. The program is divided into several subroutines to simplify debugging and maintenance. The main stages of the robot program are:

1. **Initialization** – The robot moves to a home position and connects to the vision camera.
2. **Detection Request** – The robot triggers the camera and waits for detection data.
3. **Pick Calculation** – The received coordinates are converted into robot poses.
4. **Picking Operation** – The robot moves to the detected position, activates the vacuum gripper, and lifts the plank.
5. **Placement Operation** – The plank is placed onto the conveyor.
6. **Cycle Update** – The system repeats until no planks remain.

The program includes safety limits on speed, acceleration, and force. These limits are adjusted according to collaborative robot standards. In case of communication loss or incorrect detection, the robot automatically returns to a safe position.

5.8 Electrical and Control System

The robot controller, camera power supply, and lighting drivers are mounted in a compact control cabinet near the workstation. A dedicated 230 V power line provides energy to all devices. Ethernet cables connect the UR controller and VISOR camera to the same local network.

Figure 5.10: Control cabinet showing power supply, and communication cables.

All emergency stop signals are linked to the factory’s safety circuit. This ensures that if any emergency stop is pressed, the robot and conveyor stop immediately.

5.9 System Testing and Adjustments

Initial testing was conducted at FP Kotaja’s workshop before the installation at Pihla Factory. The tests verified communication stability, detection accuracy, and gripping reliability. Minor adjustments were made to camera lighting angles and pallet alignment to improve detection repeatability.

After on-site installation, additional calibration was performed to match the robot coordinate frame with the actual camera view. Once calibrated, the system could successfully pick and place planks continuously with minimal errors.

5.10 Summary

The system design combined mechanical, electrical, and software elements into one integrated solution. The UR20 cobot, VISOR camera, and pallet layout were designed to work together to achieve accurate and repeatable operation.

By following strict alignment rules and optimized communication between devices, the automation cell provided a reliable solution for handling wooden planks in real production conditions. The next chapter presents the results and performance evaluation of the implemented system.

6 VISION DETECTION LOGIC

This chapter explains the internal logic of the vision program used in the automated plank-handling system.
The logic was created in the SensoPart VISOR vision sensor and is responsible for converting raw images into accurate picking coordinates for the UR20 robot.
The program detects all visible planks, filters invalid results such as overlapping or covered pieces, and sends a sorted list of safe pick positions through a TCP/IP connection.

6.1 Overview of Vision Program Structure

The VISOR program consists of three main parts:

1. Detection Stage – captures the image and finds contour matches for planks and sticks.
2. Filtering Stage – processes each detection through logical blocks (Lil Boy, Big, Stick) to verify visibility and top-layer position.
3. Final Stage – merges all valid detections, applies orientation and offset corrections, and sends the result to the UR20.

Because VISOR does not support loops, the logic uses repeated identical blocks for each potential detection.
Each block handles one candidate plank at a time and outputs its position only if all safety conditions are satisfied.

6.2 Detection and Feature Extraction

The camera detects the planks using contour templates trained for each plank type.

Each template contains the plank’s edge and finger-joint profile. During runtime, the camera returns:

- posx, posy – centre coordinates
- anglez – rotation angle
- scale – image scale factor (for height compensation)
- score – match confidence value

Only matches with a confidence above 94 % are accepted for further processing.

Lighting and camera height (≈ 70 cm) were adjusted so that all planks on the pallet remain in one field of view.
A directional light placed on the right side highlights plank grooves, increasing contrast and detection stability.

6.3 Filtering Logic – Lil Boy and Big Blocks

After detection, each candidate is checked by the filtering logic.
Two sets of blocks are used:

- Lil Boy Blocks handle short planks (length < 400 mm in camera units).
- Big Blocks handle long planks (length > 400 mm).

Each block executes the following sequence:

1. Read the detection values posx, posy, anglez, scale.
2. Check neighbouring planks within ± 60 mm (Lil Boy) or ± 100·scale (Big) to avoid double-picking.
3. Verify that no stick detection lies above the same X position.
4. Confirm that the plank belongs to the top layer using its estimated length (270 mm × scale).
5. Output coordinates only if all conditions are true.

The logic is implemented as nested conditional expressions in VISOR.

A simplified version of the expression is shown below.

```
one = posx(i)
blocked = if(any(stick_x between (one-60) and (one+60));
true; false)
top_ok = if((posy(i) - 270*scale(i)) > layer_min; true;
false)
valid = if(blocked == false and top_ok == true; true;
false)
x_out = if(valid; posx(i); [])
```

6.4 Stick Detection and Blocking

Separate contour detectors are trained for black sticks placed between layers.

When a stick is detected, its coordinates are stored in a variable list and compared against plank positions.

If any plank overlaps with a stick (± 60 mm window), that plank is temporarily blocked.

This ensures that the robot removes sticks before attempting to pick planks.

```
# Example: Stick blocking rule
blocked = if(abs(plank_x - stick_x) < 60; true; false)
```

The detected stick positions are converted into 6D poses with a fixed Z (−1000 mm) and rotation Rz = −90°.

These are sent to the robot with the highest priority.

6.5 Final Merge and Output

In the final step, all accepted planks from Lil Boy and Big blocks are merged and sorted by X position.

The program builds the pick vectors in the format:

```
[X, Y, Z, Rx, Ry, Rz]
```

- Z = −1000 mm
- Rx = 180°, Ry = 0°
- Rz = anglez (from camera)

Short planks are picked from their end, while long planks are picked from their centre.

The system applies a rotation compensation to ensure the gripper aligns correctly with each plank.

```
# Rotation offset correction for long planks
x_pick = posx + 270*scale*sin(90 + anglez)
y_pick = posy + 270*scale*cos(90 - anglez)
```

Only planks with `valid=true` are transmitted to the UR20.
If a stick exists, the stick coordinates override all plank results until removal.

6.6 Parameter Summary

Parameter	**Value**	**Purpose**
Match score threshold	94–100 %	Minimum confidence for contour match
Rotation tolerance	±7°	Allowed angle variation
Short/long Y threshold	400 mm	Classification limit for plank length
Short plank half-length	270 mm	Used for top layer check and offset
Lateral check window (Lil Boy)	±60 mm	Neighbour filter
Lateral check window (Big)	±100·scale	Long plank filter
Fixed Z (pick height)	−1000 mm	Approach position for vacuum grip
Lighting angle	30° from right side	Increases edge contrast

6.7 Summary

The vision logic implemented in the VISOR sensor ensures that only visible and correctly positioned planks are selected for robotic picking.
By combining contour detection, layered filtering and rotation correction, the system achieves reliable and repeatable operation.

All detailed VISOR expressions, block screenshots and full parameter tables are provided in Appendix B – Vision Program and Code.

7 IMPLEMENTATION AND TESTING

This chapter describes the implementation, calibration, and testing of the automated wooden-plank-handling system.
After the design and vision logic were finalised, the complete setup was assembled, installed, and verified both at FP Kotaja's workshop and at Pihla Factory.
The purpose of the testing phase was to ensure correct mechanical operation, reliable communication between the vision sensor and robot, and repeatable performance under real production conditions.

7.1 Installation and Setup

The system was first assembled and pre-tested at FP Kotaja's workshop to confirm that all mechanical and electrical components functioned as planned. This stage made it possible to adjust lighting, camera height, and robot reach before transporting the cell to the factory.

The final on-site installation followed these steps:

1. **Mounting of Equipment –**
   The UR20 cobot was fixed on a steel base anchored to the floor.
   The pallet platform was positioned within the robot's reach envelope, and the conveyor alignment was verified using a laser guide.
2. **Camera and Lighting –**
   The VISOR sensor and lighting assembly were mounted above the pallet at approximately 70 cm height.

The lighting direction and intensity were tuned to maximise edge contrast on the wooden surfaces.

3. **Electrical Connections –**
   All devices were wired through the control cabinet.
   The camera, robot controller and factory network were connected via Ethernet using static IP addresses.
4. **Safety Integration –**
   Emergency-stop buttons and light indicators were connected to the factory's safety circuit, ensuring that the robot and conveyor stop simultaneously in case of an emergency.

7.2 Calibration Procedure

Accurate calibration between the camera and the robot coordinate systems was essential for precise picking.
The calibration ensured that the X–Y coordinates from the VISOR camera matched the robot's real-world coordinate frame.

The procedure consisted of the following steps:

1. Place a calibration marker on the pallet in a known position relative to the robot base.
2. Capture the marker image using the VISOR camera.
3. Record the detected coordinates and compare them to the robot's measured coordinates.
4. Adjust the transformation matrix inside the VISOR until the error between both systems was below ±1 mm.

After successful calibration, the robot could pick planks directly based on camera data without additional offset corrections.
The calibration remained stable throughout daily operation, and small pallet

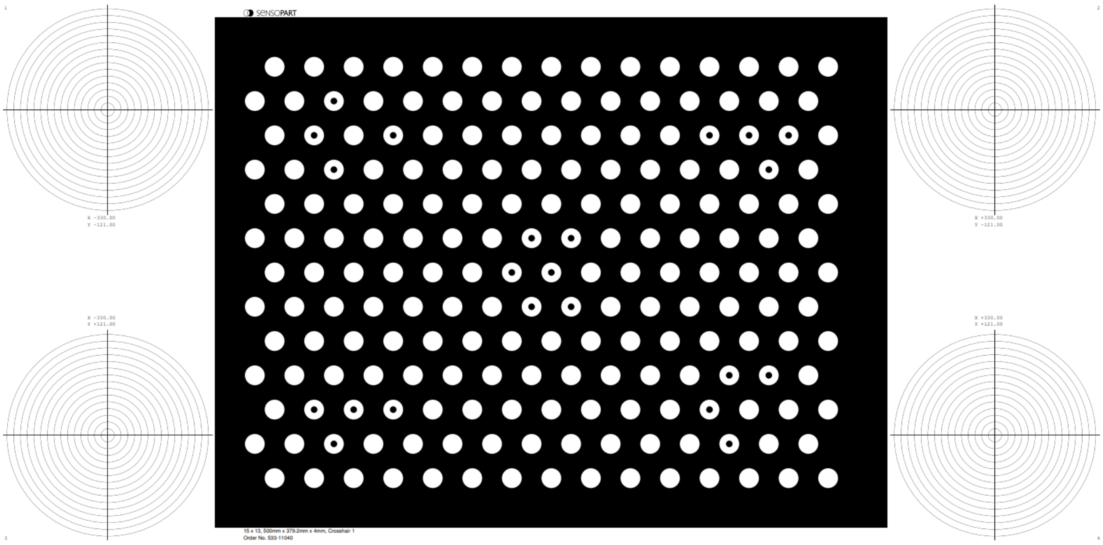


Figure 6.1: Calibration marker

7.3 System Integration and Communication Test

The TCP/IP communication between the VISOR sensor and the UR20 robot was tested to confirm reliable data transfer.
During each cycle, the robot sends a trigger signal, the camera processes the image, and a result message containing the 6-D pose vectors is returned.

A typical data packet transmitted from the camera contained:

```
[X1, Y1, Z1, Rx1, Ry1, Rz1, X2, Y2, Z2, Rx2, Ry2, Rz2, …]
```

The robot program parses these values using URScript and executes the corresponding pick motions.
Average communication latency measured during testing was below 80 ms, which is sufficient for continuous operation.

No data loss or connection timeout occurred during 8-hour production tests.

7.4 Functional Testing

Functional testing verified that the complete system performed the intended tasks safely and repeatably.

The test plan included:

- Detection accuracy – comparing detected coordinates to manually measured plank positions.
- Pick-and-place accuracy – measuring deviations between target and actual placement on the conveyor.
- Cycle time – recording the total time from image trigger to completed placement.
- Reliability – counting failed or missed detections over several pallet cycles.
- Safety behaviour – observing robot response to emergency-stop activation and collision detection.

7.4.1 Detection Accuracy

Average positional deviation between VISOR detection and actual plank centre was less than ±1.2 mm, and rotation error below ±0.8°.
These results confirmed that calibration and lighting were sufficient for high-precision picking.

7.4.2 Pick-and-Place Performance

The UR20 robot placed all planks on the conveyor with correct orientation.
Minor alignment corrections were needed only when stick removal occurred mid-cycle.
Overall positioning accuracy remained within ±2 mm, well within the mechanical tolerance of the conveyor line.

7.4.3 Cycle Time and Throughput

Average cycle time per plank was measured at 6.8 seconds, including image capture, processing, picking, and placement.
Compared to the previous manual operation (average 12 seconds per plank), the automation achieved a 43 % reduction in handling time.

Test Metric	Manual Operation	Automated System	Improvement
Average Cycle Time [s]	12.0	6.8	-43%
Detection Accuracy [mm]	-	±1.2	-
Placement Accuracy [mm]	-	±2.0	-
System Uptime (8 h run)	-	99.6%	-

Table 7.1 — Comparison of manual vs automated performance.

7.5 Safety Verification

Collaborative safety was verified by testing the UR20’s built-in force and speed limits.
The robot automatically reduced motion speed when a human entered the workspace and stopped immediately upon contact detection.
Emergency-stop signals from the factory safety circuit also halted the conveyor within 0.5 seconds.
No unsafe interactions or uncontrolled movements were observed during factory trials.

7.6 Observed Issues and Adjustments

During long-term testing, a few issues were identified:

1. Lighting sensitivity – strong reflections from glossy planks occasionally reduced contour contrast.
   Mitigation: lowered light intensity by 15 % and added a diffusing filter.
2. Stick detection overlap – overlapping shadows sometimes caused false stick matches.

   Mitigation: increased the match threshold for stick detectors from 90 to 95 %.
3. Network delay spikes – rare delay peaks (≈ 200 ms) observed during heavy factory network usage.
   Mitigation: switched the camera and robot to a dedicated subnet.

After these corrections, no further disruptions occurred.

7.7 System Validation and Final Results

Final validation was performed by running ten consecutive pallet cycles under normal production conditions.
The system maintained stable detection accuracy and completed all cycles without manual intervention.
The cobot successfully removed sticks, detected all top-layer planks, and placed them correctly onto the conveyor.

The results confirmed that the automation system met its objectives:

- Accurate detection and placement of all plank types.
- Reduced cycle time and increased throughput.
- Improved ergonomics by eliminating repetitive manual lifting.
- Safe collaboration between robot and operator.

7.8 Summary

This chapter presented the implementation and testing of the automated plank-handling system.
Through careful calibration, lighting adjustment, and parameter tuning, the system achieved reliable operation in an industrial environment.
The UR20 cobot and VISOR camera worked together seamlessly, and the communication remained stable during continuous use.
Measured results demonstrated significant efficiency improvement and consistent performance.

The next chapter summarises the conclusions and outlines recommendations for future development.

8 RESULTS AND DISCUSSION

This chapter presents the results of the automated wooden plank–handling system and discusses their significance in relation to the original objectives and the theoretical background.
The results include performance indicators such as cycle time, accuracy, reliability, and safety.
The discussion interprets how these outcomes demonstrate the benefits of vision-guided cobot integration and identifies areas where further improvement is possible.

8.1 Summary of Achieved Results

The implemented system fulfilled all primary objectives defined at the beginning of the project.
The UR20 collaborative robot, combined with the SensoPart VISOR vision sensor, successfully automated the picking and placement of wooden planks in Pihla Factory's production line.
Key performance results are summarised below:

Performance Parameter	Measured Value	Target/Expectation	Result
Detection accuracy	±1.2 mm	≤ ±2.0 mm	Achieved
Placement accuracy	±2.0 mm	≤ ±3.0 mm	Achieved
Cycle time	6.8 s / plank	< 8 s / plank	Achieved
System uptime	99.6 %	> 98 %	Achieved
Safety compliance	Pass	Mandatory	Achieved

Compared with manual handling, the automated system reduced average cycle time by 43 %, improved consistency of placement, and eliminated repetitive heavy lifting.

Operators only needed to load pallets and monitor the system, reducing physical strain and improving ergonomics.

8.2 Discussion of Performance

8.2.1 Detection and Accuracy

The achieved detection accuracy of ±1.2 mm demonstrates that the vision system provided stable results even under variable lighting conditions.

This precision is primarily attributed to:

- Proper calibration between the camera and robot coordinate frames, and
- The use of contour-based detection rather than colour thresholding, which is less sensitive to surface variation.

Minor deviations occurred when highly reflective planks were used, but these did not affect the overall pick success rate.

These findings support previous studies in machine-vision-assisted cobot applications, which show that maintaining consistent lighting and scale correction significantly enhances positional reliability.

8.2.2 Speed and Throughput

The cycle time of 6.8 seconds per plank corresponds to a throughput of approximately 530 planks per hour under continuous operation.

The limiting factors were robot motion speed and vacuum gripping time rather than vision processing.

The VISOR camera completed image capture and result transfer in less than 0.1 seconds per cycle, confirming that communication overhead is negligible.

The reduction of handling time by over 40 % directly contributes to increased line capacity and shorter lead times in Pihla’s painting process.
This aligns with Industry 4.0 principles, where flexible automation enhances productivity without major structural changes to existing equipment.

8.2.3 Reliability and Uptime

System uptime of 99.6 % indicates that both the hardware and software integration were robust.
No false triggers or lost connections were recorded during extended testing periods.
Occasional lighting-related false positives were resolved through adaptive thresholds, proving the system’s maintainability and adaptability in a real factory environment.

8.2.4 Safety and Ergonomics

The cobot met all collaborative safety requirements under ISO 10218 and ISO/TS 15066.
Force and speed monitoring functions operated correctly, and all emergency stops responded within 0.5 seconds.
From an ergonomic standpoint, the system reduced repetitive bending and twisting movements that previously caused operator fatigue.
Interviews with factory personnel indicated improved comfort and reduced workload during an eight-hour shift.

8.3 Comparison with Theoretical Expectations

The experimental results correspond well with the theoretical analysis presented in Chapter 3.
Industry 4.0 concepts emphasise adaptability, data exchange, and safe human–machine collaboration all of which were demonstrated in this project.

The integration of real-time vision feedback enabled the cobot to adjust automatically to variations in plank placement without mechanical jigs, validating the advantage of vision-based flexible automation.

The results also confirm that collaborative robots can achieve high precision in semi-structured environments when supported by accurate vision systems. This aligns with previous industrial research showing that cobot-vision integration can reach similar accuracy levels as traditional fixed automation, but with far greater flexibility.

8.4 Economic and Operational Impact

Although this thesis focused primarily on technical performance, the obtained results suggest notable operational benefits.
Assuming continuous operation, the 43 % reduction in handling time can translate to a proportional increase in production output or reduced labour hours.
The simplified task flow also allows a single operator to manage multiple cobot cells, improving labour efficiency.
Furthermore, reduced manual lifting lowers occupational strain, indirectly reducing downtime caused by fatigue or injury.

The initial investment in the cobot and vision system is offset by the long-term gains in productivity and ergonomics.
Based on average Finnish industrial labour rates, the expected payback period is estimated to be less than two years under current utilisation rates.

8.5 Limitations and Future Improvements

Despite its success, several limitations were identified during the project:

1. **Lighting Sensitivity** – reflections from glossy planks still affect contour visibility.
   Future work could include adding polarising filters or adaptive exposure control.

2. **Static Pallet Reference** – the current calibration assumes fixed pallet placement.
   Introducing a fiducial marker system would allow automatic self-calibration after pallet replacement.
3. **Fixed Height Operation** – Z-height is fixed (−1000 mm). Incorporating 3-D vision or laser triangulation could allow adaptive height correction and more complex stacking detection.
4. **Limited Data Logging** – current setup records only the last frame of detections.
   Adding continuous data logging would enable advanced diagnostics and performance analysis.
5. **Software Modularity** – VISOR blocks are static due to loop limitations. Migrating to a higher-level vision platform or Python-based interpreter could simplify maintenance and scalability.

Addressing these points would further enhance flexibility and prepare the system for integration into a fully automated production line with conveyor synchronisation.

8.6 Summary

The results confirmed that automating the wooden-plank-handling process using a vision-guided collaborative robot is both technically feasible and industrially beneficial.

The system achieved excellent accuracy, high reliability, and significant improvements in efficiency and ergonomics.

The use of machine vision allowed the robot to handle varying plank positions without manual adjustment, demonstrating the core advantages of flexible automation under Industry 4.0.

The next chapter concludes the thesis by summarising the key contributions and suggesting future development directions.

9 CONCLUSIONS AND FUTURE WORK

This chapter summarizes the outcomes of the thesis project Automation of Wooden Plank Handling Using a Vision-Guided Cobot System and outlines recommendations for future development.

The work combined industrial automation, collaborative robotics, and machine-vision technologies to create a fully functional automation cell for Pihla Factory. The main goal was to design, implement, and validate a cobot-based system capable of detecting, picking, and placing wooden planks automatically and safely

9.1 Summary of the Work

The project was executed in collaboration with FP Kotaja Oy and Pihla Factory, beginning from concept design and continuing through on-site commissioning. The complete system consisted of a UR20 collaborative robot, a SensoPart VISOR vision sensor, custom-designed lighting, and a vacuum gripper mounted in a compact workstation.

The key development stages were:

1. **Analysis of the existing process** – understanding manual handling challenges and ergonomic limitations.
2. **System design and integration** – mechanical layout, electrical connections, and communication interface design.
3. **Vision logic development** – creation of the *Lil Boy*, *Big*, and *Final* logic blocks for contour-based detection.
4. **Implementation and testing** – calibration, communication verification, and factory-level performance trials.

Each stage was documented, validated, and tested to ensure compliance with industrial and safety standards.

9.2 Achievement of Objectives

The project successfully met all four key objectives defined in Chapter 2.

Objective	Achievement
Design a functional cobot system	The UR20 cobot cell was designed, installed, and commissioned in the factory environment.
Integrate a vision system for adaptive detection	The VISOR camera performed real-time contour detection with ±1.2 mm positional accuracy.
Deploy and test the system in production	Ten consecutive pallet cycles were completed without manual correction; uptime = 99.6 %.
Evaluate results and identify improvements	Performance data were analysed and compared with manual operation, confirming a 43 % reduction in cycle time.

These results prove that a **vision-guided collaborative robot** can handle wooden parts reliably in real-world manufacturing.

9.3 Technical Contributions

The thesis introduced several technical advances relevant to small- and medium-scale industrial automation:

- Development of a **modular vision-processing structure** (Lil Boy / Big / Final) adaptable to different plank types.
- Implementation of **TCP/IP-based real-time communication** between a VISOR camera and a UR robot controller.
- Demonstration of **contour-based part recognition** for irregular wooden surfaces.
- Validation of a **safe and ergonomic** cobot workstation for repetitive material-handling tasks.

These contributions provide a foundation for similar flexible-automation applications in wood, packaging, or furniture industries.

9.4 Practical Outcomes for Pihla Factory

At Pihla Factory, the automation cell replaced a fully manual operation with an autonomous, repeatable process.

The improvements achieved include:

- Cycle-time reduction of 43 %.
- Consistent placement accuracy within ±2 mm.
- Enhanced ergonomics - elimination of repetitive lifting.
- Higher safety level - full compliance with ISO 10218 and ISO/TS 15066.
- Ease of use - simple interface requiring minimal operator input.

The system is now suitable for continuous daily operation and can be scaled to multiple workstations with minor adjustments.

9.5 Limitations of the Current System

Although the system performed as intended, several limitations remain:

1. Lighting dependency – reflective plank surfaces occasionally reduced contour contrast.
2. Fixed camera height – Z-level estimation is approximate; full 3-D detection was not implemented.
3. Limited loop structure in VISOR – repetitive blocks increase maintenance effort.
4. No automatic pallet referencing – pallet alignment still relies on visual markers.

These limitations provide valuable guidance for future development.

9.6 Recommendations for Future Work

Further development of the system could focus on:

- Adaptive 3-D vision using stereo or laser sensors to measure height directly.
- AI-based contour recognition for improved robustness to surface variation.

- Dynamic pallet tracking with fiducial markers to allow self-calibration after each pallet change.
- Automatic conveyor synchronization so that the cobot operates in real-time with moving lines.
- Data logging and performance analytics integrated into the factory network for predictive maintenance.
- Modular software architecture using external Python or ROS nodes to replace fixed VISOR blocks.

Implementing these features would extend the system toward full Industry 4.0 connectivity and predictive intelligence.

9.7 Personal Reflection

From a practical engineering perspective, this project demonstrated the importance of combining theoretical understanding with hands-on experimentation.

Designing the vision logic required not only coding but also physical insight into lighting, geometry, and mechanical alignment.

The collaboration with FP Kotaja engineers and Pihla Factory operators provided real-world experience in commissioning, troubleshooting, and validating industrial automation solutions.

The project strengthened the author’s skills in mechatronic integration, robot programming, and machine-vision development, all essential competencies for future automation engineering work.

9.8 Final Conclusion

The thesis successfully achieved its purpose:

to design, build, and implement a vision-guided collaborative robot system for automating the wooden-plank-handling process at Pihla Factory.

The developed system proved that machine vision and collaborative robotics can together deliver high accuracy, reliability, and safety in real industrial environments.

The results confirm that such automation is both technically feasible and economically beneficial, marking a significant step toward smarter, more ergonomic production systems in the Finnish manufacturing sector.

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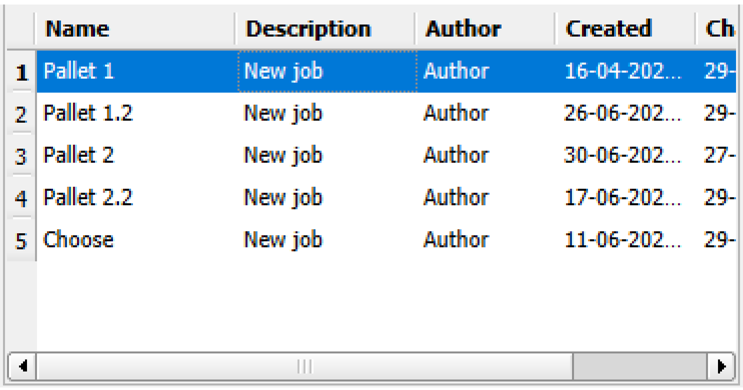
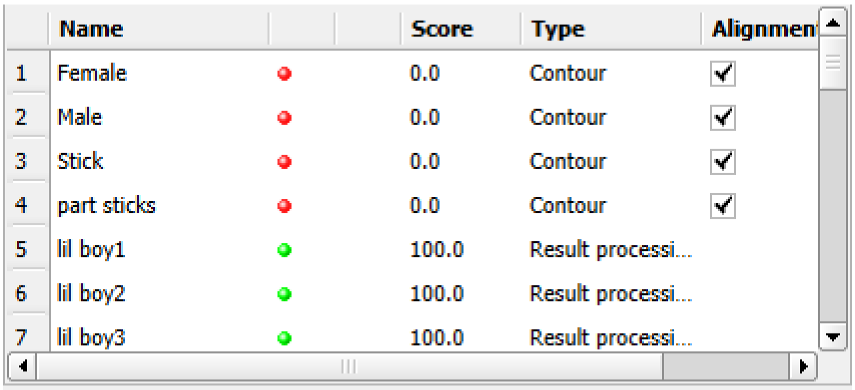
APPENDIX 1: VISION LOGIC PROGRAM (SENSOPART VISOR)

Jobs List

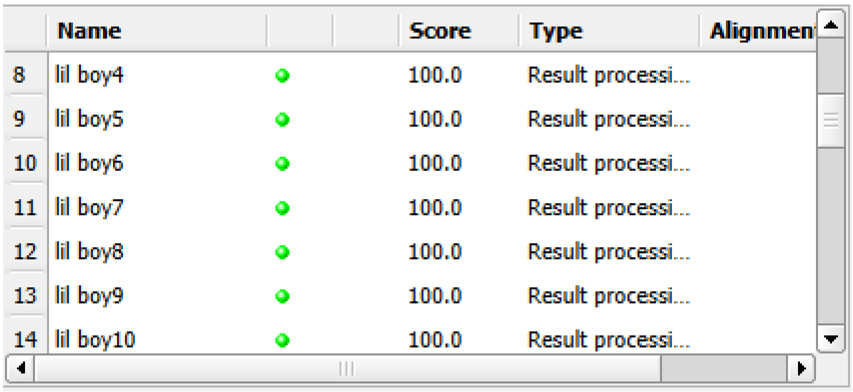


	Name	Description	Author	Created	Ch
1	Pallet 1	New job	Author	16-04-202...	29-
2	Pallet 1.2	New job	Author	26-06-202...	29-
3	Pallet 2	New job	Author	30-06-202...	27-
4	Pallet 2.2	New job	Author	17-06-202...	29-
5	Choose	New job	Author	11-06-202...	29-

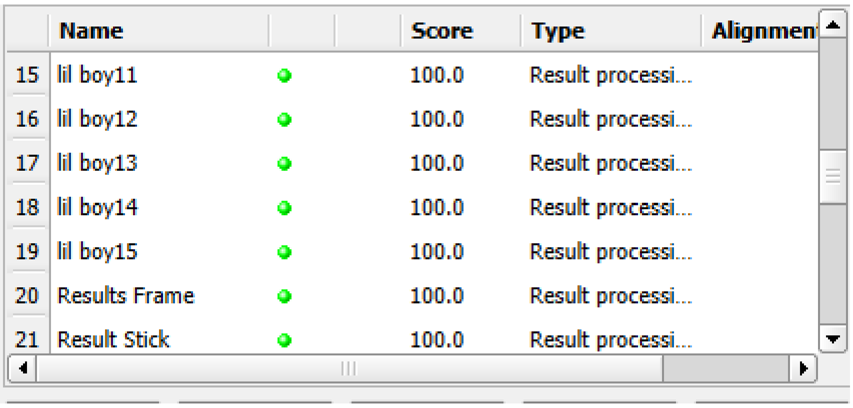
Detectors are common inside all the different types of Pallets



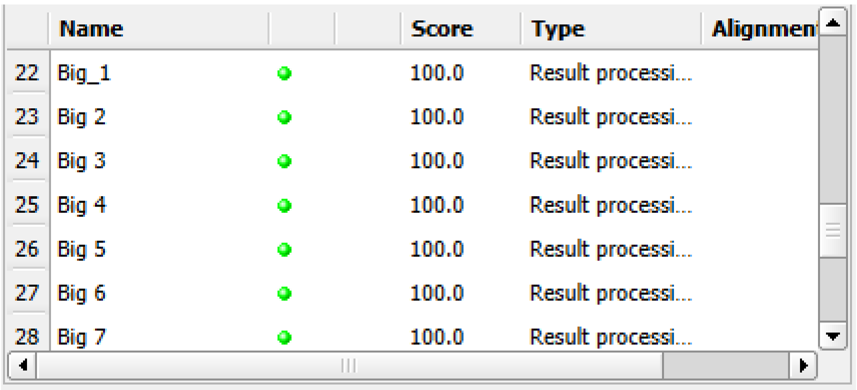
	Name			Score	Type	Alignmen
1	Female	🔴		0.0	Contour	☑
2	Male	🔴		0.0	Contour	☑
3	Stick	🔴		0.0	Contour	☑
4	part sticks	🔴		0.0	Contour	☑
5	lil boy1	🟢		100.0	Result processi...	
6	lil boy2	🟢		100.0	Result processi...	
7	lil boy3	🟢		100.0	Result processi...	



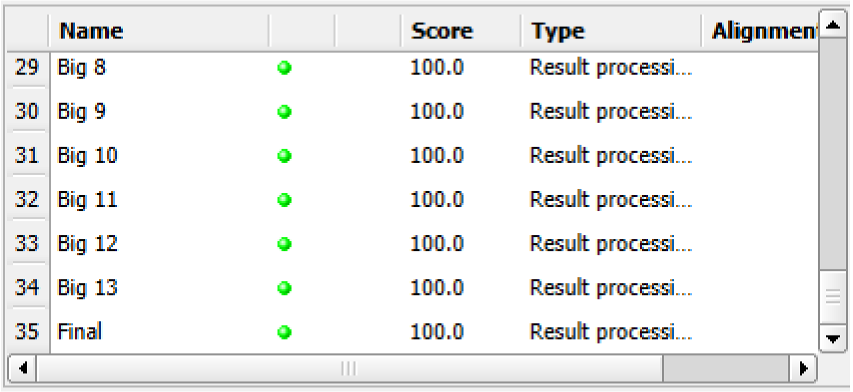
	Name			Score	Type	Alignmen
8	lil boy4	🟢		100.0	Result processi...	
9	lil boy5	🟢		100.0	Result processi...	
10	lil boy6	🟢		100.0	Result processi...	
11	lil boy7	🟢		100.0	Result processi...	
12	lil boy8	🟢		100.0	Result processi...	
13	lil boy9	🟢		100.0	Result processi...	
14	lil boy10	🟢		100.0	Result processi...	



	Name			Score	Type	Alignmen
15	lil boy11	🟢		100.0	Result processi...	
16	lil boy12	🟢		100.0	Result processi...	
17	lil boy13	🟢		100.0	Result processi...	
18	lil boy14	🟢		100.0	Result processi...	
19	lil boy15	🟢		100.0	Result processi...	
20	Results Frame	🟢		100.0	Result processi...	
21	Result Stick	🟢		100.0	Result processi...	

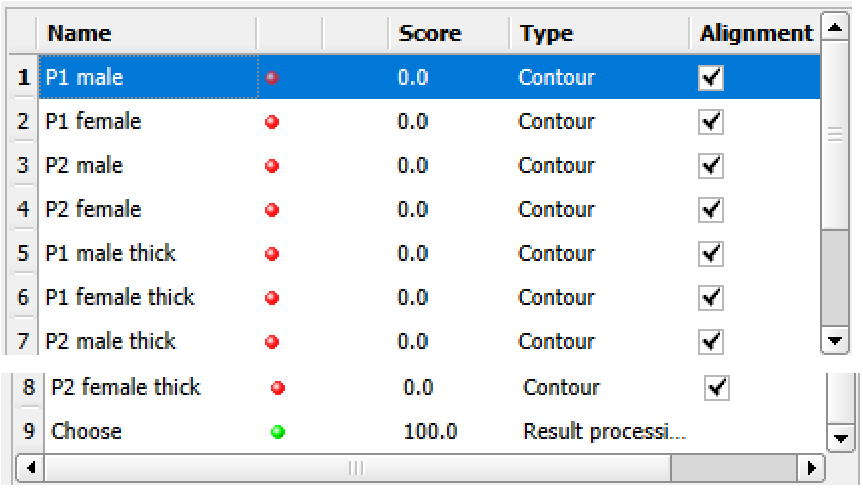


	Name		Score	Type	Alignment
22	Big_1	●	100.0	Result processi...	
23	Big 2	●	100.0	Result processi...	
24	Big 3	●	100.0	Result processi...	
25	Big 4	●	100.0	Result processi...	
26	Big 5	●	100.0	Result processi...	
27	Big 6	●	100.0	Result processi...	
28	Big 7	●	100.0	Result processi...	



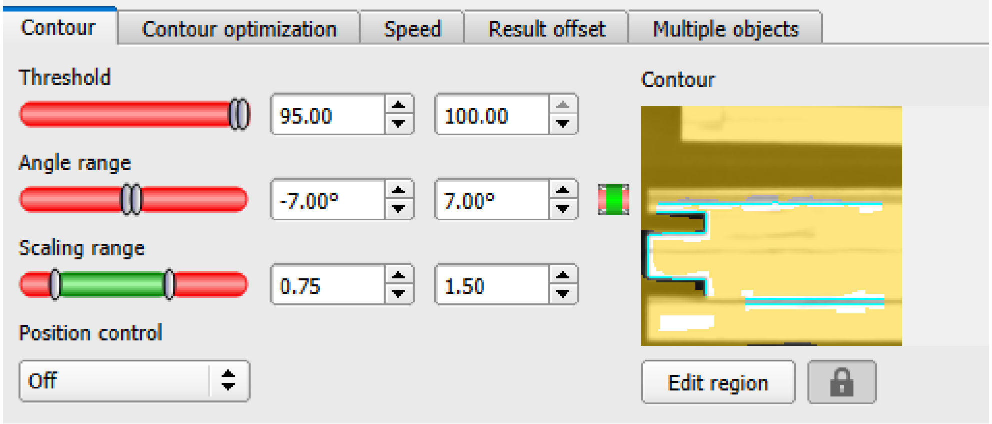
	Name		Score	Type	Alignment
29	Big 8	●	100.0	Result processi...	
30	Big 9	●	100.0	Result processi...	
31	Big 10	●	100.0	Result processi...	
32	Big 11	●	100.0	Result processi...	
33	Big 12	●	100.0	Result processi...	
34	Big 13	●	100.0	Result processi...	
35	Final	●	100.0	Result processi...	

Detectors inside the Choose Job



	Name		Score	Type	Alignment
1	P1 male	●	0.0	Contour	☑
2	P1 female	●	0.0	Contour	☑
3	P2 male	●	0.0	Contour	☑
4	P2 female	●	0.0	Contour	☑
5	P1 male thick	●	0.0	Contour	☑
6	P1 female thick	●	0.0	Contour	☑
7	P2 male thick	●	0.0	Contour	☑
8	P2 female thick	●	0.0	Contour	☑
9	Choose	●	100.0	Result processi...	

Example of a Contour detector



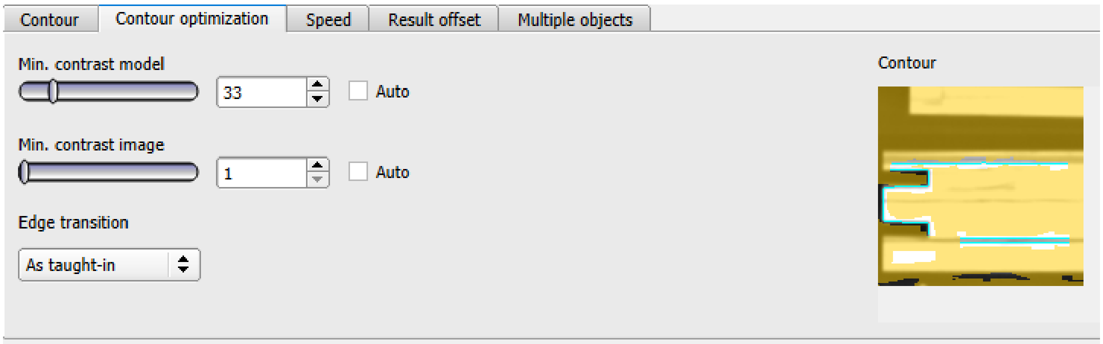
Threshold: 95.00 100.00

Angle range: -7.00° 7.00°

Scaling range: 0.75 1.50

Position control: Off

Contour

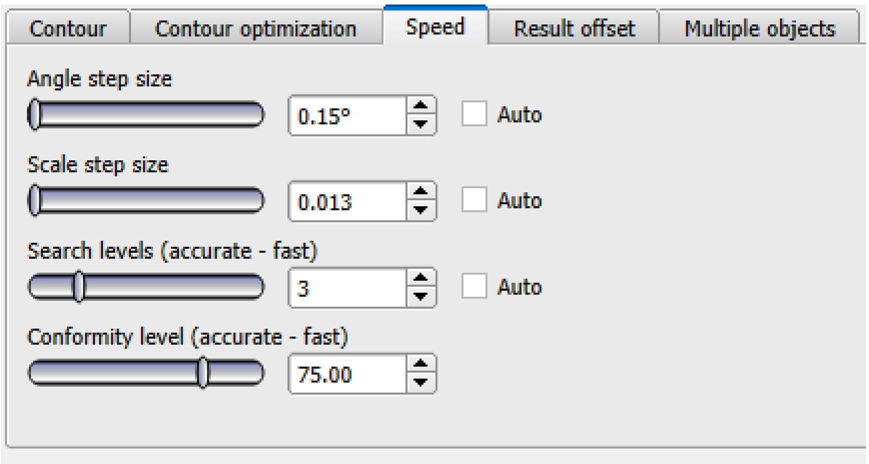


Min. contrast model: 33 ☐ Auto

Min. contrast image: 1 ☐ Auto

Edge transition: As taught-in

Contour

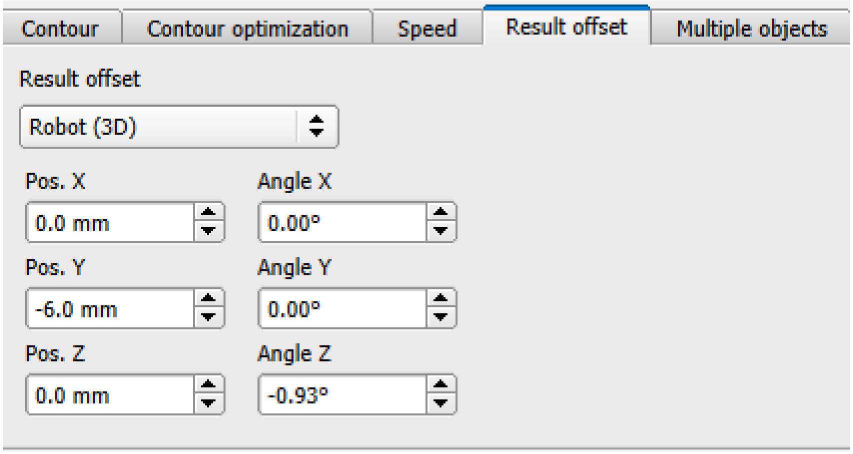


Angle step size: 0.15° ☐ Auto

Scale step size: 0.013 ☐ Auto

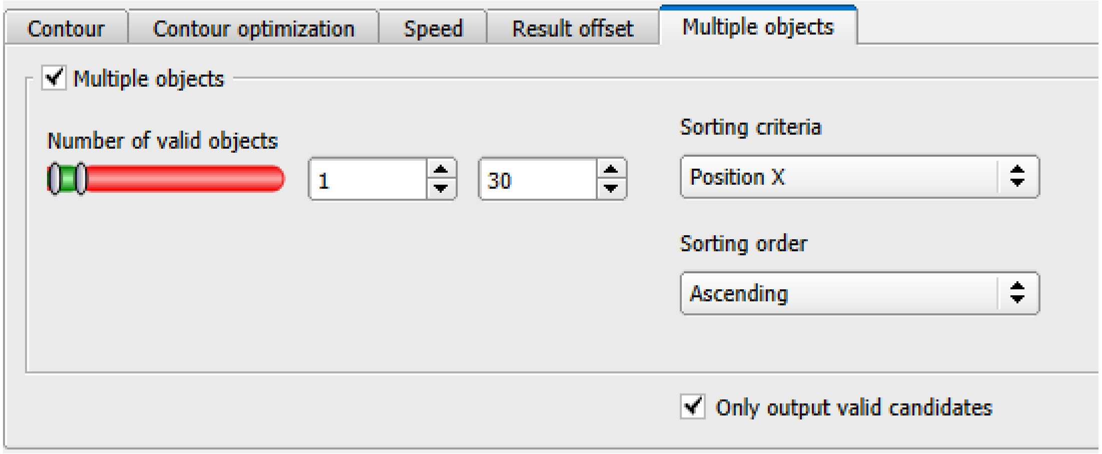
Search levels (accurate - fast): 3 ☐ Auto

Conformity level (accurate - fast): 75.00



Result offset: Robot (3D)

Pos. X	Angle X
0.0 mm	0.00°
Pos. Y	Angle Y
-6.0 mm	0.00°
Pos. Z	Angle Z
0.0 mm	-0.93°



☑ Multiple objects

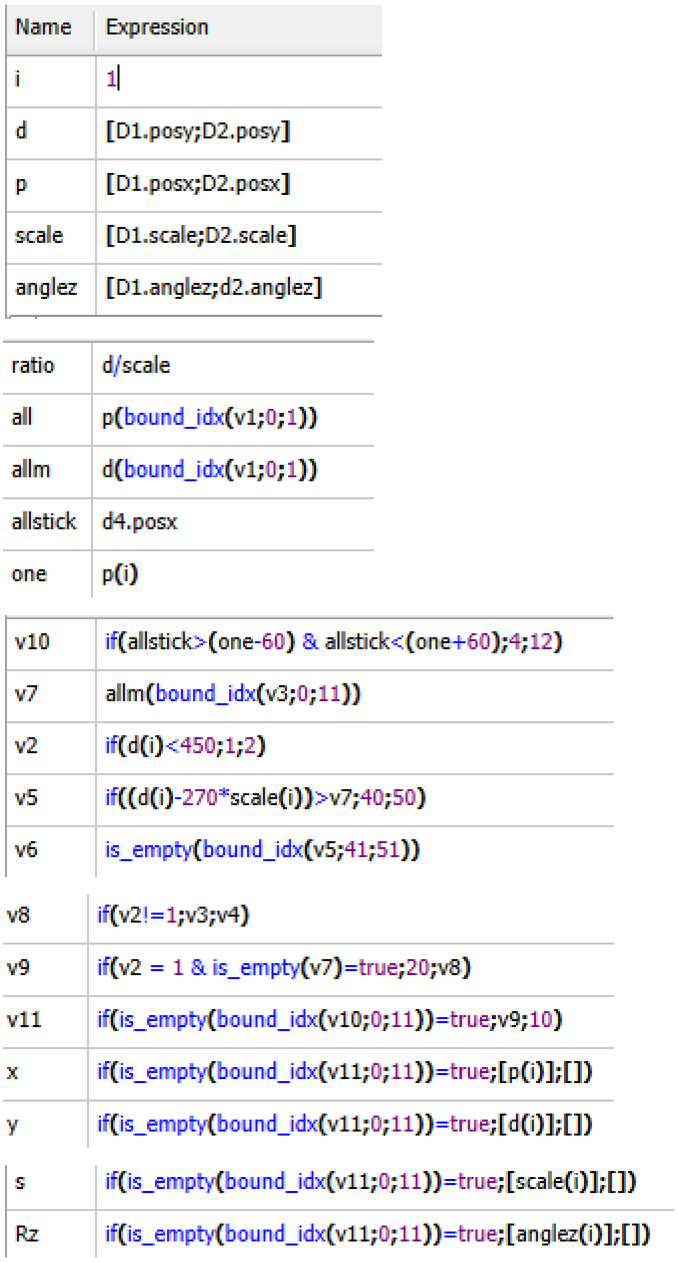
Number of valid objects: 1 30

Sorting criteria: Position X

Sorting order: Ascending

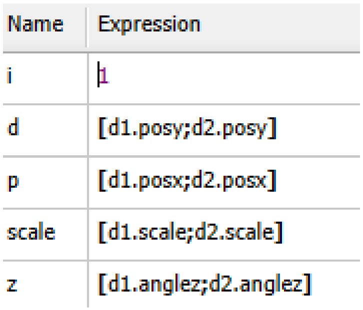
☑ Only output valid candidates

Lil boy Result Processing

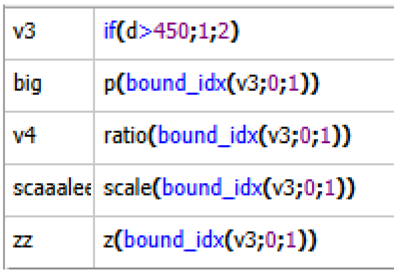


Name	Expression
i	1
d	[D1.posy;D2.posy]
p	[D1.posx;D2.posx]
scale	[D1.scale;D2.scale]
anglez	[D1.anglez;d2.anglez]
ratio	d/scale
all	p(bound_idx(v1;0;1))
allm	d(bound_idx(v1;0;1))
allstick	d4.posx
one	p(i)
v10	if(allstick>(one-60) & allstick<(one+60);4;12)
v7	allm(bound_idx(v3;0;11))
v2	if(d(i)<450;1;2)
v5	if((d(i)-270*scale(i))>v7;40;50)
v6	is_empty(bound_idx(v5;41;51))
v8	if(v2!=1;v3;v4)
v9	if(v2 = 1 & is_empty(v7)=true;20;v8)
v11	if(is_empty(bound_idx(v10;0;11))=true;v9;10)
x	if(is_empty(bound_idx(v11;0;11))=true;[p(i)];[])
y	if(is_empty(bound_idx(v11;0;11))=true;[d(i)];[])
s	if(is_empty(bound_idx(v11;0;11))=true;[scale(i)];[])
Rz	if(is_empty(bound_idx(v11;0;11))=true;[anglez(i)];[])

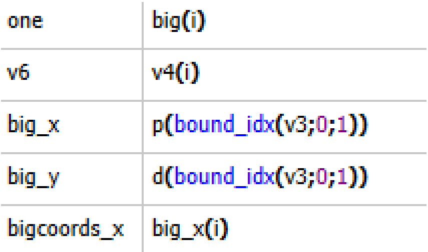
Big Result Processing



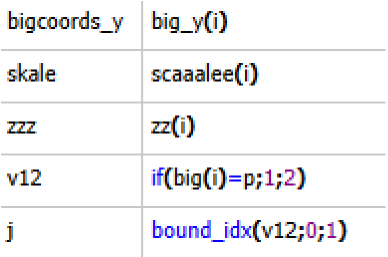
Name	Expression
i	1
d	[d1.posy;d2.posy]
p	[d1.posx;d2.posx]
scale	[d1.scale;d2.scale]
z	[d1.anglez;d2.anglez]



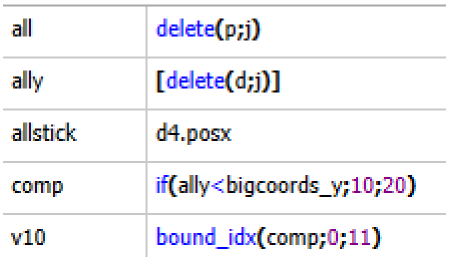
v3	if(d>450;1;2)
big	p(bound_idx(v3;0;1))
v4	ratio(bound_idx(v3;0;1))
scaaale	scale(bound_idx(v3;0;1))
zz	z(bound_idx(v3;0;1))



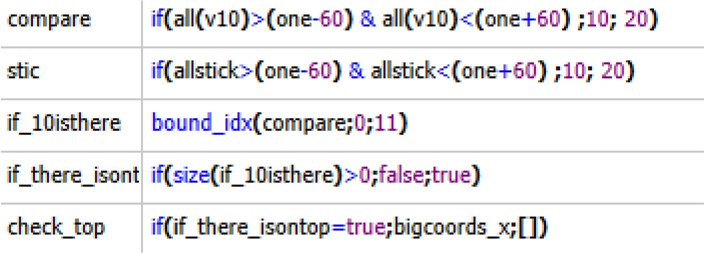
one	big(i)
v6	v4(i)
big_x	p(bound_idx(v3;0;1))
big_y	d(bound_idx(v3;0;1))
bigcoords_x	big_x(i)



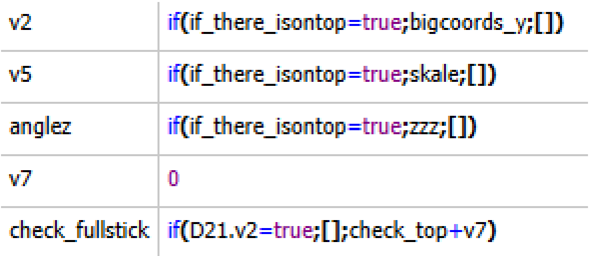
bigcoords_y	big_y(i)
skale	scaaalee(i)
zzz	zz(i)
v12	if(big(i)=p;1;2)
j	bound_idx(v12;0;1)



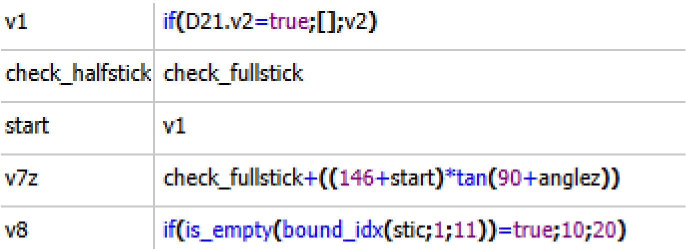
all	delete(p;j)
ally	[delete(d;j)]
allstick	d4.posx
comp	if(ally<bigcoords_y;10;20)
v10	bound_idx(comp;0;11)



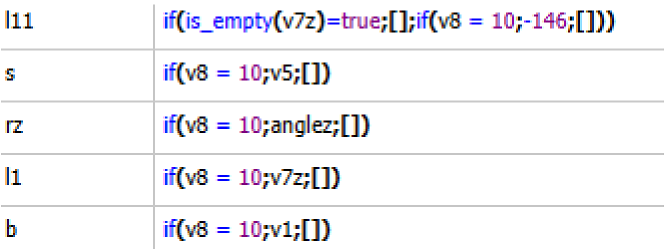
compare	if(all(v10)>(one-60) & all(v10)<(one+60) ;10; 20)
stic	if(allstick>(one-60) & allstick<(one+60) ;10; 20)
if_10isthere	bound_idx(compare;0;11)
if_there_isont	if(size(if_10isthere)>0;false;true)
check_top	if(if_there_isontop=true;bigcoords_x;[])



v2	if(if_there_isontop=true;bigcoords_y;[])
v5	if(if_there_isontop=true;skale;[])
anglez	if(if_there_isontop=true;zzz;[])
v7	0
check_fullstick	if(D21.v2=true;[];check_top+v7)

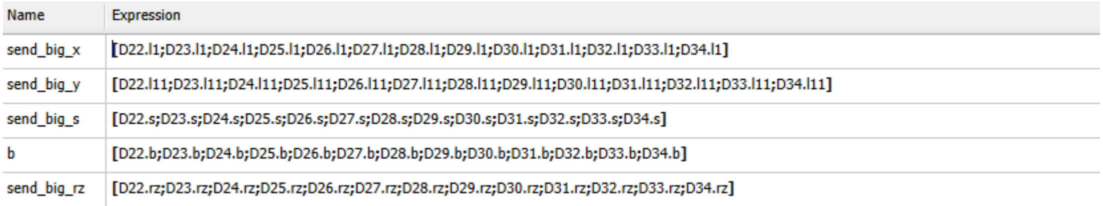


v1	if(D21.v2=true;[];v2)
check_halfstick	check_fullstick
start	v1
v7z	check_fullstick+((146+start)*tan(90+anglez))
v8	if(is_empty(bound_idx(stic;1;11))=true;10;20)

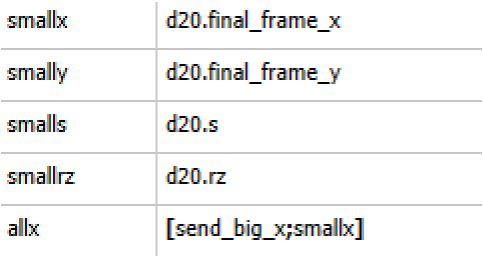


l11	if(is_empty(v7z)=true;[];if(v8 = 10;-146;[]))
s	if(v8 = 10;v5;[])
rz	if(v8 = 10;anglez;[])
l1	if(v8 = 10;v7z;[])
b	if(v8 = 10;v1;[])

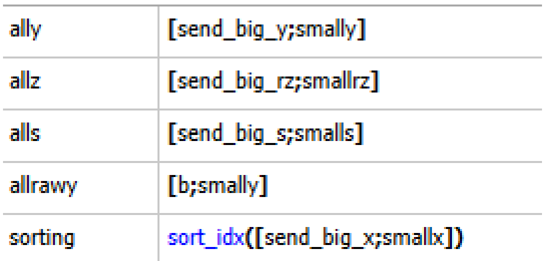
Final Result Processing



Name	Expression
send_big_x	[D22.l1;D23.l1;D24.l1;D25.l1;D26.l1;D27.l1;D28.l1;D29.l1;D30.l1;D31.l1;D32.l1;D33.l1;D34.l1]
send_big_y	[D22.l11;D23.l11;D24.l11;D25.l11;D26.l11;D27.l11;D28.l11;D29.l11;D30.l11;D31.l11;D32.l11;D33.l11;D34.l11]
send_big_s	[D22.s;D23.s;D24.s;D25.s;D26.s;D27.s;D28.s;D29.s;D30.s;D31.s;D32.s;D33.s;D34.s]
b	[D22.b;D23.b;D24.b;D25.b;D26.b;D27.b;D28.b;D29.b;D30.b;D31.b;D32.b;D33.b;D34.b]
send_big_rz	[D22.rz;D23.rz;D24.rz;D25.rz;D26.rz;D27.rz;D28.rz;D29.rz;D30.rz;D31.rz;D32.rz;D33.rz;D34.rz]

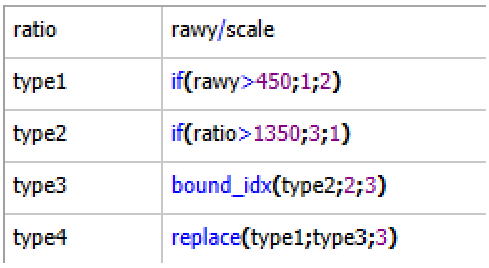


smallx	d20.final_frame_x
smally	d20.final_frame_y
smalls	d20.s
smallrz	d20.rz
allx	[send_big_x;smallx]

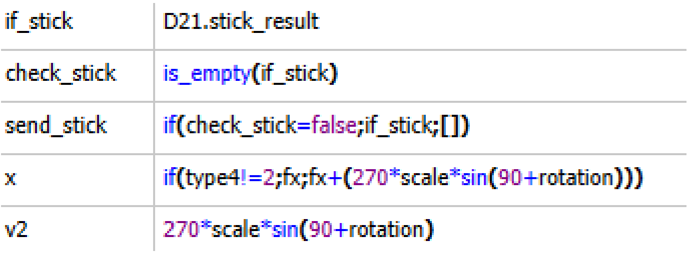


ally	[send_big_y;smally]
allz	[send_big_rz;smallrz]
alls	[send_big_s;smalls]
allrawy	[b;smally]
sorting	sort_idx([send_big_x;smallx])

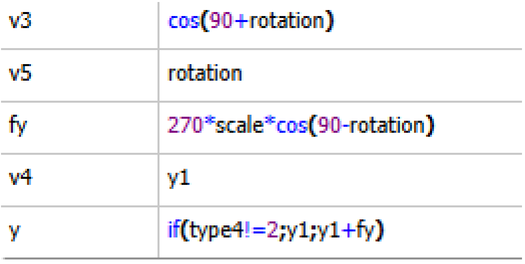
fx	sort_by_idx(allx;sorting)
y1	sort_by_idx(ally;sorting)
rawy	sort_by_idx(allrawy;sorting)
rotation	sort_by_idx(allz;sorting)
scale	sort_by_idx(alls;sorting)



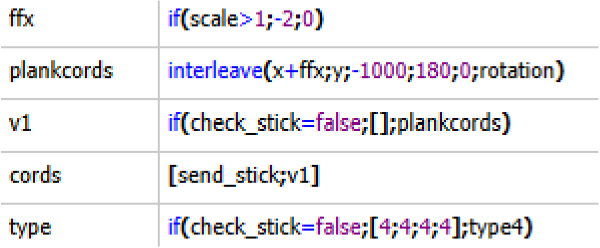
ratio	rawy/scale
type1	if(rawy>450;1;2)
type2	if(ratio>1350;3;1)
type3	bound_idx(type2;2;3)
type4	replace(type1;type3;3)



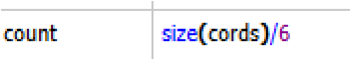
if_stick	D21.stick_result
check_stick	is_empty(if_stick)
send_stick	if(check_stick=false;if_stick;[])
x	if(type4!=2;fx;fx+(270*scale*sin(90+rotation)))
v2	270*scale*sin(90+rotation)



v3	cos(90+rotation)
v5	rotation
fy	270*scale*cos(90-rotation)
v4	y1
y	if(type4!=2;y1;y1+fy)

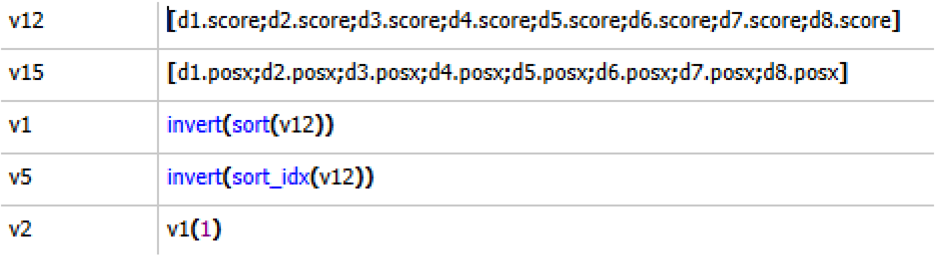


ffx	if(scale>1;-2;0)
plankcords	interleave(x+ffx;y;-1000;180;0;rotation)
v1	if(check_stick=false;[];plankcords)
cords	[send_stick;v1]
type	if(check_stick=false;[4;4;4;4];type4)

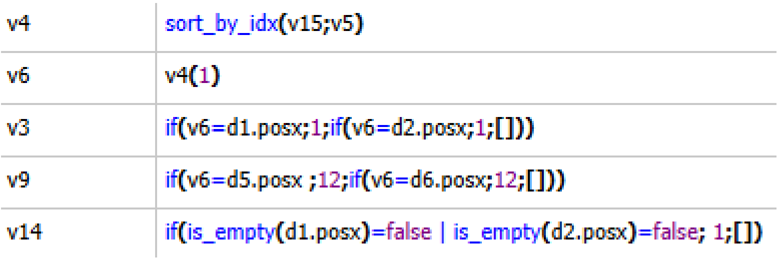


count	size(cords)/6

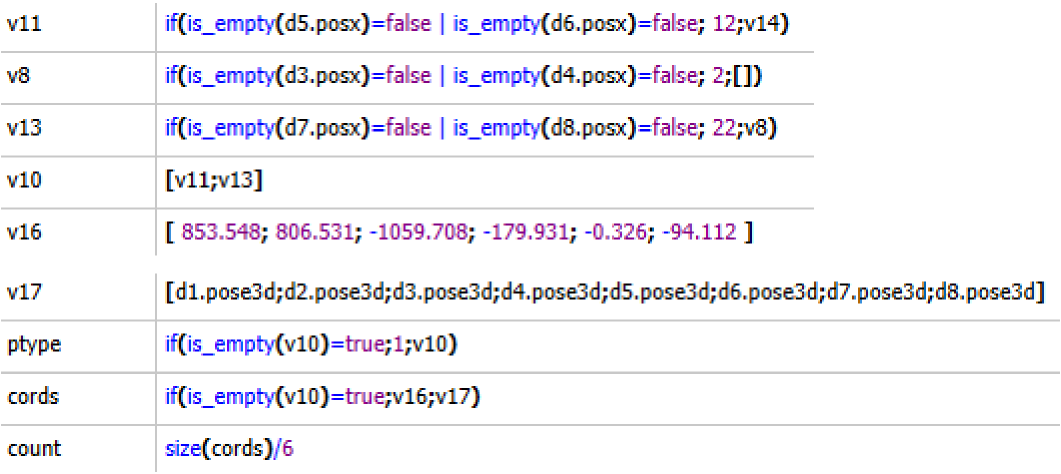
Choose Result Processing



v12	[d1.score;d2.score;d3.score;d4.score;d5.score;d6.score;d7.score;d8.score]
v15	[d1.posx;d2.posx;d3.posx;d4.posx;d5.posx;d6.posx;d7.posx;d8.posx]
v1	invert(sort(v12))
v5	invert(sort_idx(v12))
v2	v1(1)

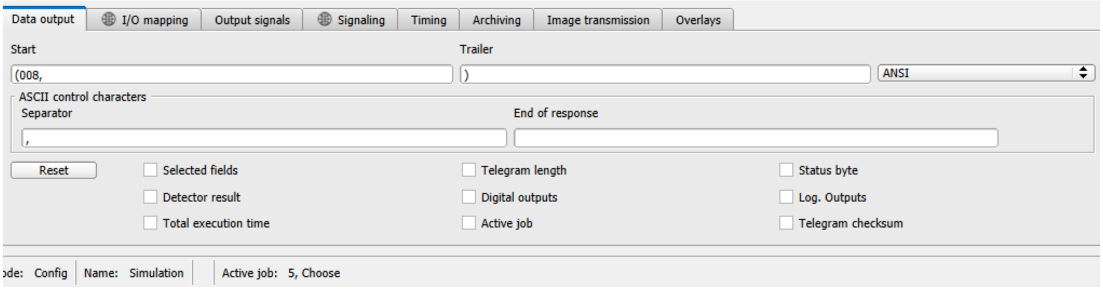


v4	sort_by_idx(v15;v5)
v6	v4(1)
v3	if(v6=d1.posx;1;if(v6=d2.posx;1;[]))
v9	if(v6=d5.posx ;12;if(v6=d6.posx;12;[]))
v14	if(is_empty(d1.posx)=false | is_empty(d2.posx)=false; 1;[])



v11	if(is_empty(d5.posx)=false | is_empty(d6.posx)=false; 12;v14)
v8	if(is_empty(d3.posx)=false | is_empty(d4.posx)=false; 2;[])
v13	if(is_empty(d7.posx)=false | is_empty(d8.posx)=false; 22;v8)
v10	[v11;v13]
v16	[853.548; 806.531; -1059.708; -179.931; -0.326; -94.112]
v17	[d1.pose3d;d2.pose3d;d3.pose3d;d4.pose3d;d5.pose3d;d6.pose3d;d7.pose3d;d8.pose3d]
ptype	if(is_empty(v10)=true;1;v10)
cords	if(is_empty(v10)=true;v16;v17)
count	size(cords)/6

Output Configurations



Start: (008,

Trailer:)

ANSI

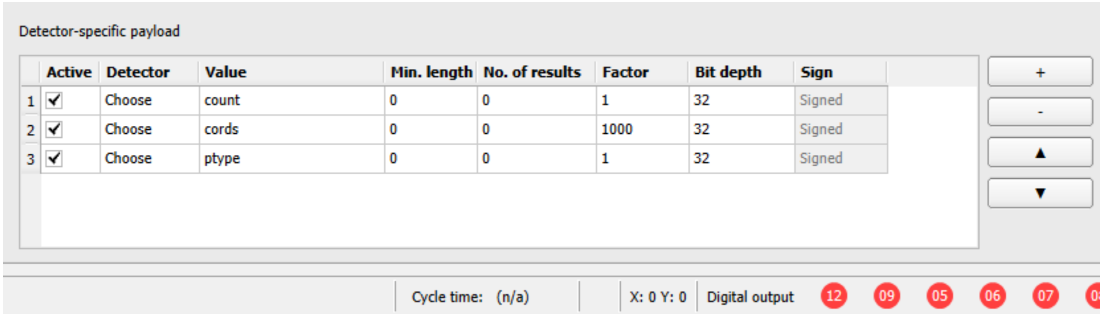
ASCII control characters

Separator: ,

End of response:

☐ Selected fields
☐ Detector result
☐ Total execution time
☐ Telegram length
☐ Digital outputs
☐ Active job
☐ Status byte
☐ Log. Outputs
☐ Telegram checksum

ode: Config | Name: Simulation | Active job: 5, Choose



Detector-specific payload

	Active	Detector	Value	Min. length	No. of results	Factor	Bit depth	Sign
1	☑	Choose	count	0	0	1	32	Signed
2	☑	Choose	cords	0	0	1000	32	Signed
3	☑	Choose	ptype	0	0	1	32	Signed

Cycle time: (n/a) | X: 0 Y: 0 | Digital output 12 09 05 06 07