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ACROBA

connect & produce through agile production

D6.6 Final Demonstration Tests in Electronic Device Setting

WP6. Evaluation of Performance and Sustainability of the ACROBA Framework

Ikor Sistemas Electronicos

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The ACROBA project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101017284.

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Approval Status

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History of Changes

Version	Date	Description of Changes	By
0.1	2024.09.30	First Draft	Iñaki Gil
0.2	2024.10.30	Second Version	Iñaki Gil

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1 Introduction of the Use Case

The assembly process of PTH electronic components is a process that is usually approached from two radically different perspectives: Either pick & place machines are used, to prepare predefined types of components for assembly in repetitive and low variability manufacturing processes, or on the contrary, fully manual processes are performed for the manufacture of high variability products.

This project aims to use a robot in the component insertion process (introduced below) as an intermediate solution between the two approaches, enhancing the flexibility of this type of automation in comparison to the manual process.

1.1 The Manual Process

The manual through-hole (THT) insertion process is a method of placing electronic components with wire leads into pre-drilled holes on a printed circuit board (PCB). This technique is widely used for components requiring strong mechanical bonds, such as large capacitors, connectors, and transformers.

Step-by-Step Process:

Component Preparation and Identification
The operator first identifies the component type and ensures it matches the PCB's component layout plan. Each component is checked for proper orientation, as some may have specific polarity or alignment requirements (e.g., diodes, connectors, electrolytic capacitors).

Component Lead Bending (If Needed)
In some cases, component leads (wires) are bent to match the PCB hole spacing. This bending is carefully done to avoid damaging the leads or affecting the component's functionality. Special lead-forming tools may be used to ensure uniformity and prevent strain on the component.

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Inserting Component Leads into PCB Holes

The operator inserts the component leads into the appropriate pre-drilled holes on the PCB according to the assembly diagram. Components are seated flush against the PCB surface to ensure a stable position during soldering and optimal electrical contact.

Wave Soldering

Once the insertion is completed, the PCB moves through a conveyor into the wave soldering machine, where it is automatically coated with flux and then passed over a wave of molten solder. The wave forms solder joints on all leaded connections simultaneously, providing a consistent and reliable electrical bond while reducing the labor required in hand soldering.

Lead Trimming

Any excess length of component leads extending beyond the PCB's soldering side is trimmed using wire cutters. The leads are cut to a suitable length to prepare for the soldering process.

Final Inspection and Quality Check

After soldering, the PCB undergoes a quality inspection to verify that all components are correctly positioned, properly soldered, and free from any defects, such as solder splashes or misaligned parts. Any identified issues are corrected before proceeding to the next stage of production.

1.2 The New Process

The robot-automated PCB part insertion process is divided into two main stages: **Refilling the Intermediate Buffer with Components** and **PCB Assembly Using Components from the Buffer**. Each stage has several steps to ensure precise component handling and placement.

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Stage 1: Refilling the Intermediate Buffer with Components

Order to Start Refill process

The system is initiated by an order to refill the buffer, identifying with a specified row (e.g., "row1") and a defined part type ("part_code") with a set quantity (e.g., 16 parts).

Scan Row for Refill Positions

The robot scans the specified row, identifying exact picking position for the first part in the row and calculating the number of positions needed to refill the buffer accurately. This is done by the “count component skill” specifically created for Ikor case.

Activate Vibratory System

The Acroba System activates the vibratory feeder system to deliver the requested part type ("part_code"). This system is in charge to provide a precise pickup coordinates.

Robot Move & Pick Part

The robot moves to the vibratory system, retrieves the part from the specified location, and places it in the buffer.

Orientation Alignment

As the vibratory system determines each part’s orientation, the robot adjusts its movements to ensure all parts in the buffer are uniformly aligned.

Final Buffer Check

The robot performs a final scan to verify that the buffer is fully stocked with the required number of parts.

Repeat for Additional Parts

This process is repeated for each of the four different part types required for complete PCB assembly.

Stage 2: PCB Assembly Using Components from the Buffer

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Wait for PCB Arrival

After the buffer is refilled, the robot waits for the PCB to arrive on the conveyor. The conveyor triggers a digital input signal that the robot receives to start the assembly. This digital input signal is processed thanks to the digital input/output specific skill created for Ikor case.

PCB Scanning and Location

The robot scans the PCB, using another specific skill, “PCB locate” to accurately determine the PCB frame. This frame is used to adjust each theoretical coordinate, as provided by CAD data, to ensure precise component placement.

Load CAD Data

The system retrieves all required data from the database by means of different specific skills such as Get_point_data, Get_part_data, Get program_data and Get_sequence_data.

Component Pickup & Placement

Following the loaded program and sequence, the robot retrieves the required component from the buffer, moves to the PCB, and places it in the correct location. This pickup and placement cycle repeats until all components for the PCB are assembled.

Cycle Completion and Conveyor Release

Once all components are assembled, the robot moves to a safe position and sends a digital output signal to the conveyor to move the PCB to the next station.

In this process, the human is in charge of filling with appropriate components the vibratory systema and providing PCBs on the conveyor.

2 Integration

2.1 Hardware Integration

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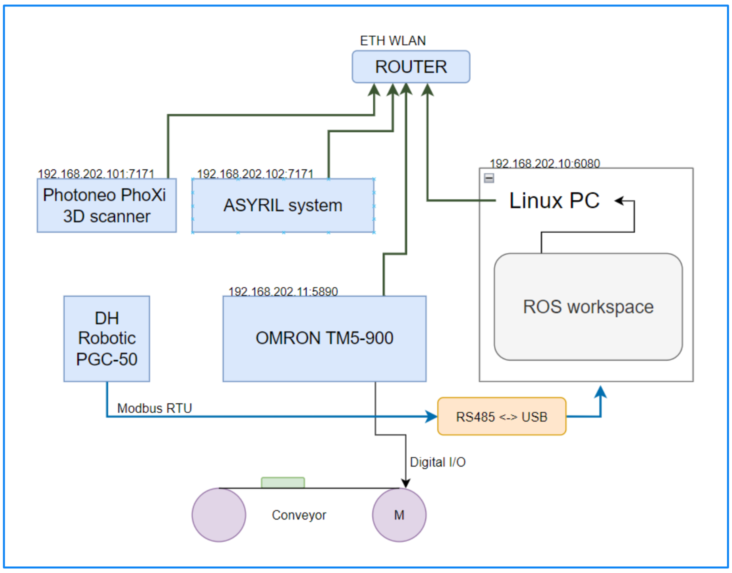
Main hardware components:

- Techman Omron robot TM5-900.
- Asyril vibratory feeder with Eye+ Controller. (Dual feeding system, two hoopers).
- Photoneo Phoxi 3D scanner (XS model).
- DH Robotic gripper (PGC-50 model).
- Linux PC computer.

Figure 1 Hardware Components Interconnection



2.2 Software (ACROBA) Integration

The system architecture used in the IKOR robotic cell is based on the standard ACROBA architecture, along with the Ikor_Config_Cell component. This latter component includes several additional Docker containers.

Firstly, the use of Photoneo hardware, whose ROS driver is only compatible with Linux Kinetic, required us to deploy a dedicated container for this device.

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A second container houses all specific skills, such as those needed to interact with the Asyril component feeder system, Modbus RS485 control of the DH robotic gripper, the Omron robot itself, and the digital input/output control skills, among others.

A final third container was deployed to host the web interface and the MongoDB database. This interface functions as a ROS node, publishing various topics. Additionally, several skills were developed to facilitate interaction with the MongoDB database.

For further information, please refer to the detailed documentation in the WP5 deliverables.

3 The Description of the Video Demonstrating for Testing

The video is divided into several sections.

The first section provides an overview of the developed robotic cell, along with close-up shots of each of its components.

The second section showcases the web interface developed, displaying the various screens and functionalities it provides. Specifically:

- **Components Tab:** This tab lists all components and their configuration parameters for use in subsequent processes. The video demonstrates viewing, modifying, and even deleting components.

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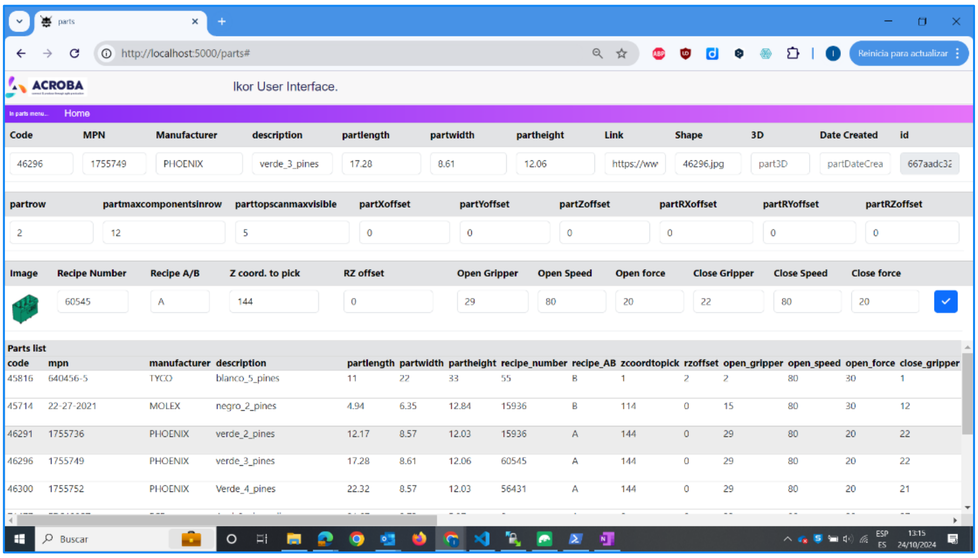
Figure 2 Components Window



- **PCB Window:** This window allows the user to upload data from a PCB CAD file, containing all the information about the mounting positions for each component.

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Figure 3 PCB Window

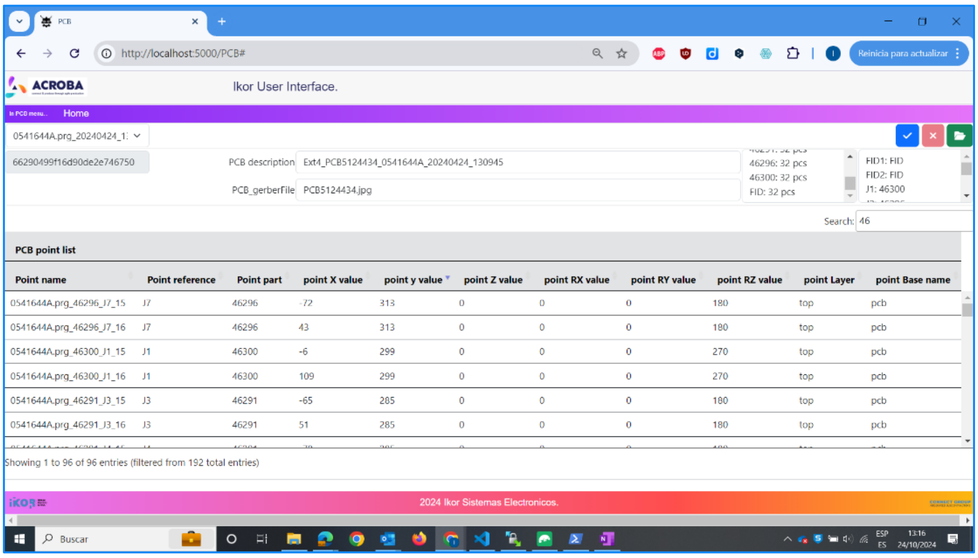
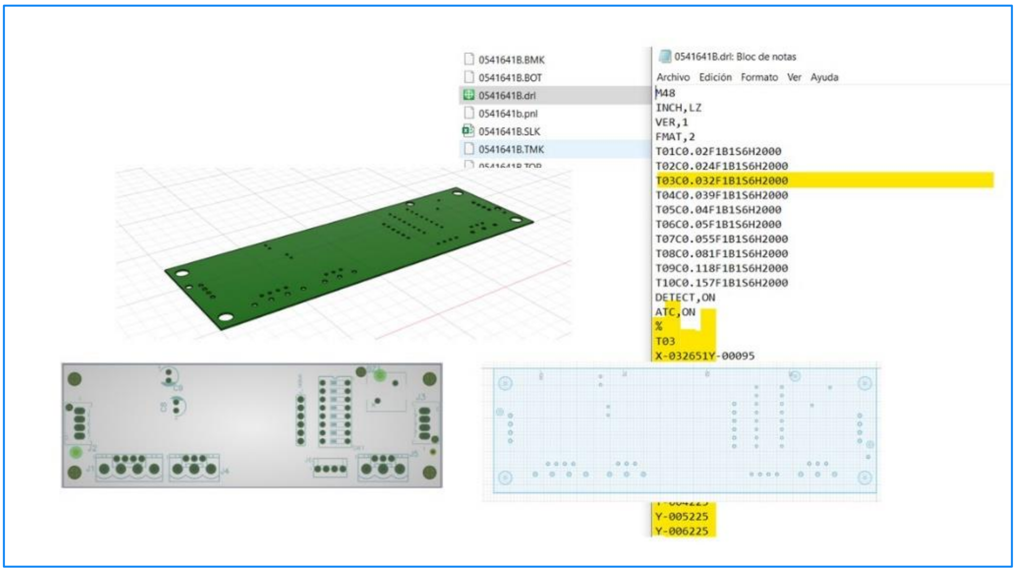


Figure 4 A Detailed View of PCB Data



- **Configuration Window:** This window is used to add, edit, or delete auxiliary robot positioning coordinates that are essential for process automation, such as the

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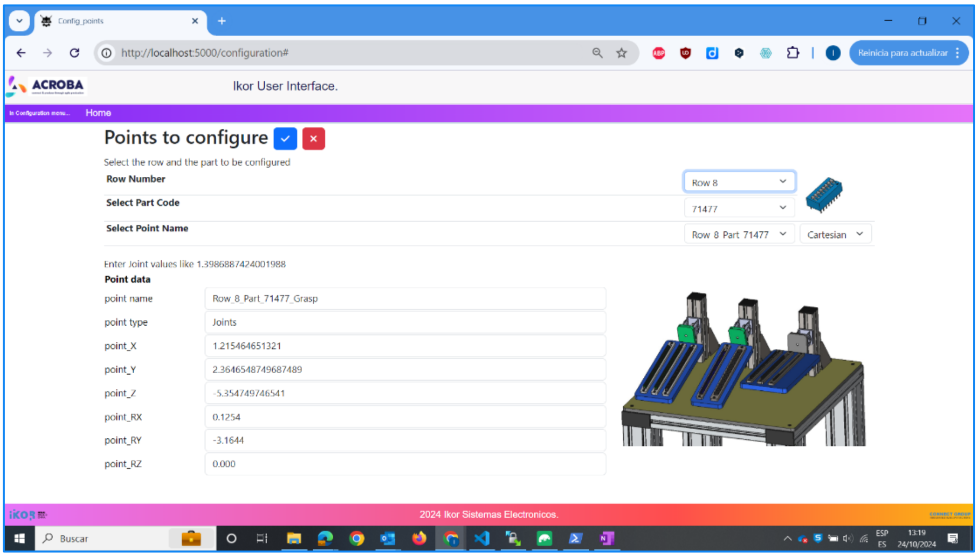
theoretical coordinates where the PCB stops on the conveyor, or the locations of certain ARUCO markers used for robot calibration.

Figure 5 Configuration Window



- **Programing Window:** This section is for creating programs. A program is an ordered selection of PCB points that need to be assembled in a specific sequence. The video quickly shows how a program can be created by first selecting one of the two PCBs targeted in this project, choosing components as desired by the operator, assigning sequence numbers (i.e., assembly order), and even modifying assembly coordinates. These features ensure the flexibility of the ACROBA system in an IKOR production environment. Once the points are selected, the program can be named and saved to the database.

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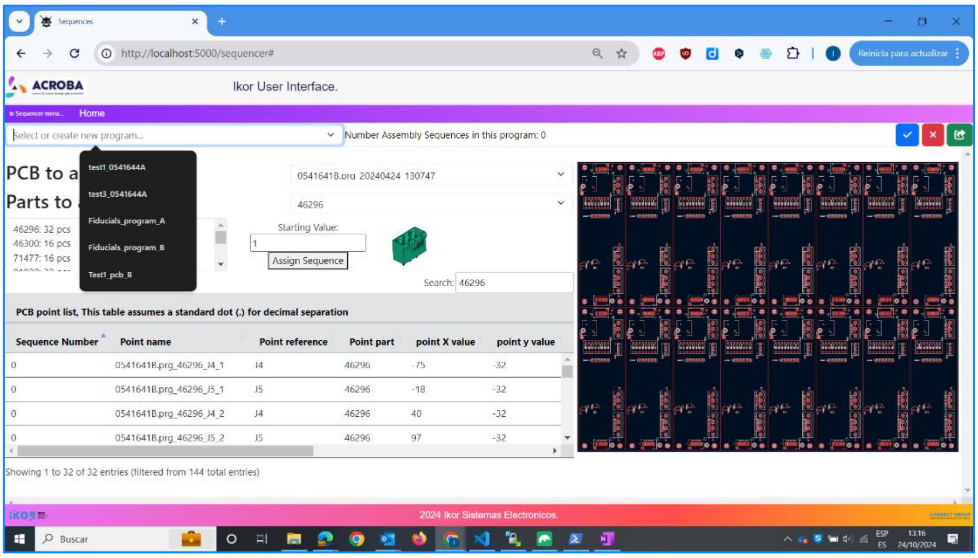
Figure 6 Programing Window



- **Execution Interface:** This window shows the interface connection to the ROS system. Through selection widgets, the operator can select the program created in the previous tab and specify the starting sequence for the robot's operation. The video demonstrates how pressing an action button triggers the publication of a topic containing the program name and sequence name. These names are then used by a directing script to query the MongoDB database.

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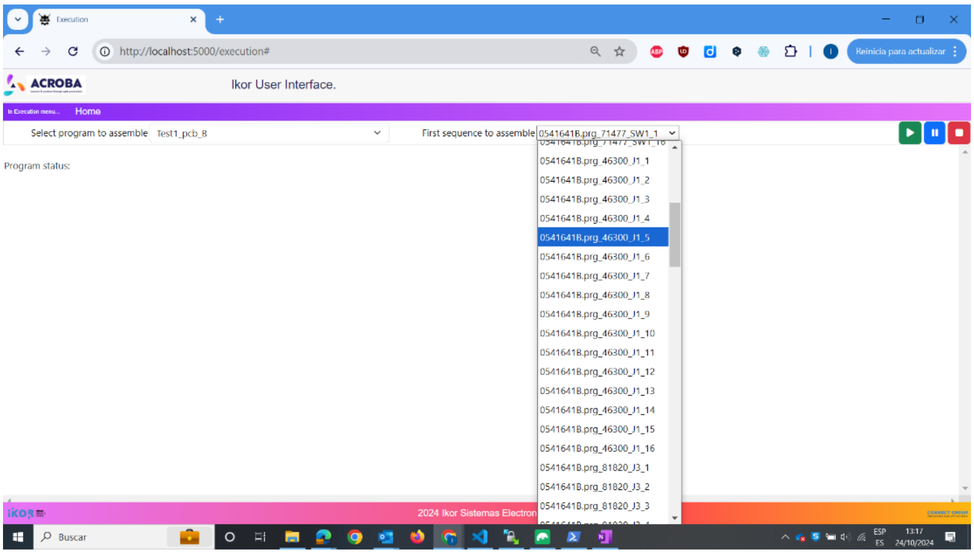
Figure 7 Execution Window



The underlying logic follows these steps:

1. The operator selects the program and sequence.
2. The web interface publishes this information to a topic.
3. A script subscribed to the topic receives this information and initiates the process.
4. It runs the *Get_program_data* skill and receives a list of ordered assembly sequences.
5. It runs the *Get_sequence_data* skill and receives the assembly coordinates and the component code to be placed at those coordinates.
6. It runs the *Get_part_data* skill and retrieves all configuration parameters for that component.

With all this data, the script is ready to execute the assembly sequence. If it does not receive any pause or stop signals, the script will repeat the same querying process for each of the sequence names received initially until the list is completed.

The video includes a **third section** where the refill process is demonstrated through different records. Some of them permit us to see the component feeding system vibrating to provide new gripping opportunities for components. Using a cenitar RGB camera, the system compares the captured image against a collection of pre-recorded images until it identifies the pieces that match the identified target pose. The system is capable to force different vibrating movements to move/rotate the existing pieces in the bowl.

The video also includes a short segment to demonstrate how two major developments from the Acroba project have been utilized: the **Virtual Gym**, a virtual testing bench created as a digital twin of the robotic cell, and the DRL (**Deep Reinforcement Learning**) mechanism. A few seconds into that video sequence, permit to observe the extensive work done to transfer the physics of the movements of the pieces to the virtual environment, as well as the massive training and learning processes involved in determining the optimal vibration sequence to achieve the greatest number of target poses for the components in the vibrating bowl.

The video continues by showing the complete regrasping process for several of the components used. At some points, the video is sped up to minimize its duration.

The **next section of the video** focuses on demonstrating the process of inserting THT components. It shows how the robot waits until an operator forces the movement of the PCB to position it in the work area. The robot detects its presence and begins the assembly process, first scanning the PCB and then performing the assembly. This process is shown from two different perspectives; in the last one, the video displays the complete assembly process of a PCB from a static viewpoint.

A final section of the video shows various assembly faults, the most representative ones, to provide a visual reference for the subsequent conclusions of this project.

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4 Conclusion

The video demonstrates the achievement of automated assembly of the green components in all sizes and positions. Other components have also been extensively tested, and despite partial successes, they have not been sufficiently repeatable to be considered validated.

The process of picking components from the intermediate buffer has proven to be one of the most critical phases in the automation process. Even slight deviations in the way the component is grasped can cause it to be forced into its designated location on the electronic circuit. In worse cases, these deviations may result in collisions with already-mounted components or even with the PCB itself, preventing the component pins from fitting into the correct PCB holes. In such cases, the force sensors on the robot lack the precision to detect these collisions, and consequently, several already-placed components may be displaced upon impact with the PCB.

In addition, some of the target components involved insurmountable challenges given the mechanical design of the cell. For example, the tilting movements required to rotate the black connectors were impossible to perform without collision.

The lighting conditions have also been a major influencing factor. The RGB camera used in the component power supply system is extremely sensitive to lighting conditions. This is why alternative lighting systems were incorporated to overexpose the image capture. However, these fixed lighting conditions do not allow for adapting the contrast for all components initially targeted. As a result, we had to discard the white or semi-transparent components and replace them with solid-colour equivalents.

To mitigate some of the detailed issues, the following improvements have been identified:

- Redesign the intermediate component buffer to further refine component positioning in the pickup zone. This could include, for example, reducing tolerances in the rail along which components slide to ensure a more deterministic final position.

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- Introduce a mechanism in the component buffer to prevent the dragging effect observed in the video, where the component grasped by the robot pulls the next component along the rail. One proposed solution is adding a magnet beneath the buffer that exerts slight traction to prevent such dragging.
- Equip the robot with a force sensor of adequate sensitivity to detect collisions and halt or retract movement before any of the identified negative effects occur.
- Add a mechanism to immobilize the printed circuit board to prevent unwanted movements, which would otherwise necessitate re-scan strategies throughout the assembly cycle.
- Improve lighting by incorporating different color source of illumination with dimming capabilities.

There are additional improvement ideas, such as adding a second, stationary scanner to inspect the pins of the components once they are picked up by the robot, allowing for a relative offset adjustment for the actual grip position of each case. However, this would significantly increase the cycle time, which is challenging to accommodate within the operation.

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