The Vacu-Arm

Senior Design

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Background

Many industries rely on repetitive manual tasks that involve picking up and moving objects work that can lead to worker fatigue, injuries, and inconsistencies in production. To address these challenges, the team developed the Vacu-Arm, a suction-based robotic arm designed to automate object handling. Unlike traditional mechanical grippers, the Vacu-Arm uses suction technology, allowing it to lift a wide range of items such as boxes, circuit boards, and irregularly shaped components without requiring custom tools or risking damage.

This project integrates sensors, suction control, and automated motion planning to create a reliable, adaptable, and cost-efficient material-handling solution. Built around the UR20 robotic arm, the system is designed for palletizing tasks: detecting incoming boxes on a conveyor, lifting them using vacuum suction, and stacking them in a palletized arrangement. The goal is to demonstrate how a flexible and affordable robotic solution can streamline operations, reduce labor demands, and minimize human error in manufacturing, warehouse, and logistics settings.

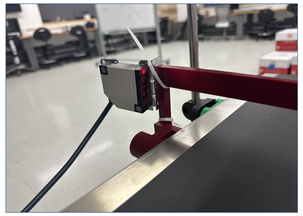
Key Requirements

1) **Collaborative Robot** UR20 robot arm capable of palletizing operations with predefined grid placement
2) **Conveyor System** Functional conveyor belt to transport boxes to stop at a point
3) **Photoelectric Sensor(Photo-eye)** detects incoming boxes at the stop point. Connected to a relay module to control conveyor start stop
4) **Relay Module** interfaces with photo-eye to control the conveyor belt
5) **Palletizing Logic** Predefined grid pattern for precise and organized box stacking
6) **Safety Scanner** monitors the surrounding work area. Triggers automatic robot stop when a person enters the safety zone.
7) **Camera System (Dead Zone Monitoring)** covers the blind spot for the safety scanner. Functions as an emergency stop by detecting human presence
8) **Emergency Stop** Functionality multiple layers of safety: safety scanner and camera-based E-stop

Architectural Design

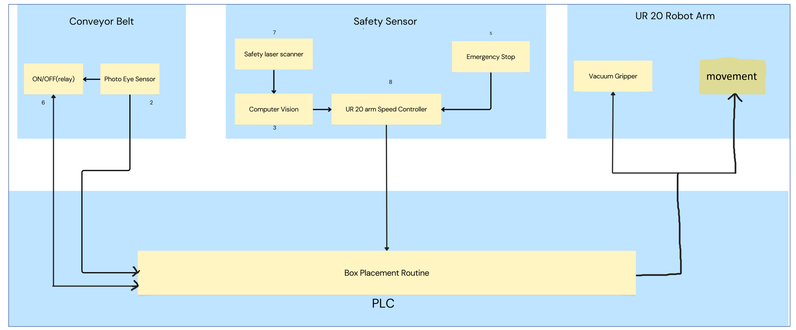
Photo-eye Sensor

The photo-eye sensor is on the side of the conveyor belt near the front. It is wired through the conveyor belt to stop the belt and the PLC to send a signal for the UR20 arm to begin the palletizing program.



Architectural Design Diagram

The architectural diagram outlines the high-level flow of the palletizing system, including the conveyor controller, safety sensor integration, and robot actuation. Each component works in coordination through the central PLC, ensuring synchronized operation and safe interaction within the workspace.



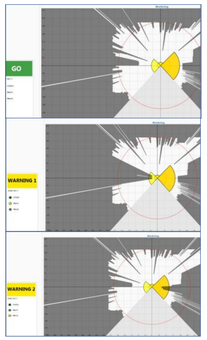
Implementation Details and Test Plan

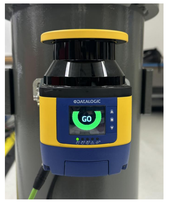
Palletizing Algorithm

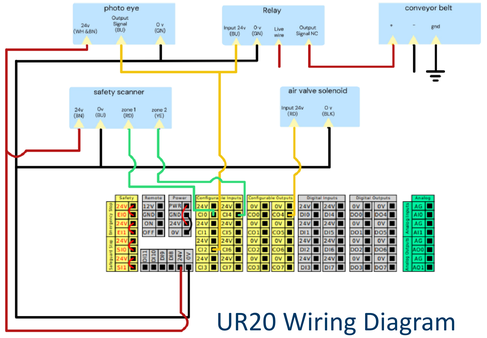
Polyscope provides a palletizing template that uses a reference TCP location to calculate how each box should be placed based on preset layer patterns. The program runs in a loop and continues until the number of boxes placed matches the total required for the pallet.
The UR20 begins each cycle from a center “home” position. It waits for a signal from a photo-eye sensor located at the end of the conveyor. When the sensor detects a box, it triggers a boolean (PIN CI2), which tells the UR20 to begin the next box placement. This signal also stops the conveyor through a relay, ensuring the box stays in position while the robot picks it up.
Once triggered, the UR20 moves in to pick up the box and activates the air valve solenoid (PIN C04), creating a vacuum in the gripper. The robot then follows the calculated path to the pallet and places the box in the correct spot. After placement, it turns off the solenoid, exits the palletizing motion sequence, and returns to the center position to wait for the next box.

Safety Sensor

The sensor is powered by the UR20 control box and provides two warning signals: **Warning 1** (CI4) and **Warning 2** (CI0).
Both zones function the same way, when either zone is triggered, Polyscope’s event function immediately stops the robot’s motion. The event continues to run in the background, monitoring the sensor input, and the robot remains stopped until the zone is clear and the system is manually restarted or reset.







UR20 Wiring Diagram

Conclusions and Future Work

This project successfully demonstrates a functional palletizing application using a UR20 collaborative robot, integrating conveyor control, sensor-based automation, and layered safety Mechanisms. The system effectively mimics a real-world assembly line, ensuring both operational efficiency and human safety. For future improvement, the current dead zone camera setup can be enhanced by repositioning it to a bird’s-eye view, allowing for broader and more effective coverage of the safety scanners blind spot. Another main project is to adjust the vacuum gripper to identify the size of a box and sort the boxes on different pallets.

References

1. Liu, S., and Bobrow, J. E., “An Analysis of a Pneumatic Servo System and Its Application to a Computer-Controlled Robot,” *ASME Journal of Dynamic Systems, Measurement, and Control*, 1988, Vol 110 pp 228-235.
2. A. Robotics, “Automated palletizing solutions,” ABB White Paper, 2023, accessed: 2025-07-11.
3. J. Shintake, S. Rosset, B. Schubert, D. Floreano, and H. Shea, “Versatile soft grippers with intrinsic electro adhesion based on multifunctional polymer actuators,” Advanced Materials, vol. 30, no. 29, p. 1707035, 2019.
4. R. Huang, Y. Ma, and Z. Wang, “Design and evaluation of a multi-cell vacuum gripper for surface- adaptive gripping,” in 2018 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2018, pp. 5604–5610.
5. S. Patel, “Diy vacuum gripper using arduino and servo,” https://www.instructables.com/Arduino-Vacuum-Gripper-Robot-Arm/ ", 2021, accessed: 2025-07-11.

December 2025