LJCJ - UR20

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Background

This project explores the development and implementation of a palletizing application using a UR20 collaborative robot arm, designed to mimic a full-scale assembly line operation. The system integrates a conveyor belt that transports boxes to a designated stop point. A photoelectric sensor (photo-eye) monitors this stop point and halts the conveyor when the sensor beam is interrupted by an incoming box. The photo-eye is connected to a relay module, which controls the start/stop function of the conveyor belt. Once the conveyor is stopped, the UR20 robot arm is triggered to pick up the box and place it onto a pallet, following a predefined grid pattern to ensure organized and stable stacking. To prioritize safety in human-robot interaction, a safety scanner is implemented to monitor the surrounding area. The scanner automatically stops the robot's operation if a person enters the predefined safety zone. As an additional safety enhancement, a camera is mounted on the side of the system to monitor the scanner's blind spot or "dead zone." This camera serves as a secondary emergency stop (E-stop) by detecting any human presence within this range and halting the robot's activity accordingly.

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.

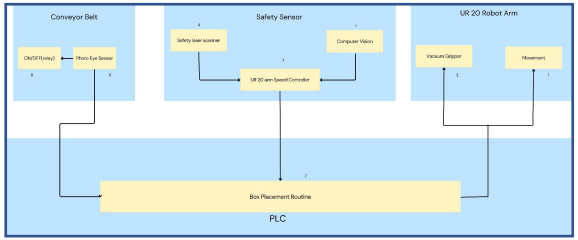
7) Camera System (Dead Zone Monitoring) Covers the blind spot for the safety scanner functions as an emergency stop by detecting human presence

8) Emergency Stop Functionality Multiple layers of safety: safety scanner and camera-based E-stop

Architectural Design

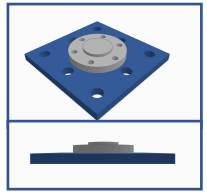
Architectural Design Diagram

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.



CAD Renderings

3D printed components designed for conveyor belt integration.
Left: Raspberry Pi 4 case with integrated mount for camera module, designed to attach to the conveyor belt rail
Right: Mechanical stopper used to halt incoming boxes at the photo eye checkpoint



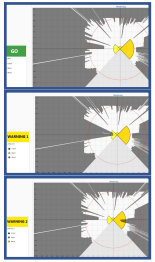
3D printed adapter and base plate designed to interface the UR20 robot with a vacuum gripper.

Implementation Details and Test Plan

The UR20 palletizing application is developed primarily through the UR 3PD Tech Pendant using UR20 PolyScope X to program and run URScript.

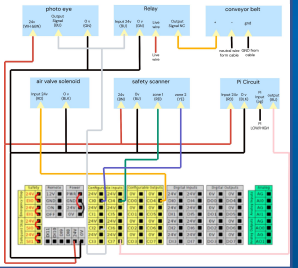
Palletizing Algorithm

Program core:
Polyscope provides a template for a palletizing application which uses reference TCP location and calculates box placement movement from a set of layer patterns. The template must be kept in loop, so until the current box count equals the total box count will the pallet be complete.
The UR20 will be at *center* position at the start of each loop waits for a box to arrive and then pick up the box and trigger the air valve solenoid (PIN C04) on, which will have the gripper create a vacuum to carry the box. The UR20 will then follow a path to the pallet and allow the template calculated TCP box placement movement to take box to placement location trigger the air valve solenoid off and exit palletizing generated movement set. Lastly, it returns to center position and repeats.
Conveyor Belt:
The UR20 is programmed to wait for a trigger of the photo eye sensor which sits at the end of the conveyor belt. A box_available boolean (PIN CI2) will set the UR20 to its next box placement and through the relay, stop the conveyor belt.



Safety Algorithm

The images to the left serve as a visual representation of the zone reading of the Datalogic Laser Sentinel which is powered from the UR20 control box and releases 2 signals warning 1 (zone 1, 4ft radius, CI4) and warning 2 (zone 2, 8ft radius, CI0). For zone 1 the program will cause an interrupt when the it detects someone in zone 1 which stops the program and saves the UR20's last known location for it to return to after it is manually restarted. For zone 2 the program runs a thread that continuously checks and updates a boolean variable is_clear which is continuously checked in the main program which will keep the robot still until the zone is cleared.
Additionally, the system employs a Raspberry Pi running a machine learning based detection script utilizing a TensorFlow Lite Model. The pi is dedicated to monitoring the UR20's deadzone, continuously capturing video via OpenCV and feeding raw frames into the pretrained model. When the model outputs a classification score > 0.63 for a human, the distance from the person to the base of the arm is calculated. If the distance is within the threshold (66 inches), the GPIO in is set to HIGH triggering the emergency E-stop. This setup serves as a secondary safety layer complementing coverage provided by the Laser Sentinel.
The program also keeps track of what action is it is doing which allows the robot return to its last action when paused or stopped.



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.improving the systems responsiveness to unexpected intrusions/additionally, addressing voltage interference issues from the Raspberry PI will be essential for ensuring consistency.

References

April 2025