Application of Labels Using Robotic Arm

Robotic Arms Identifying and Labeling Packages

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Introduction

The Semiautonomous Labeling Robot is a collaboration project with ROBOTIS and the Robotics Team of the BANSHEE UAV project. Many tasks, such as labeling boxes, are tedious, boring, and an error prone job for human workers. The goal of the project is to develop a robot capable of autonomously identifying and labeling packages. The Robotics Team aims to achieve this goal by designing a robotic arm that uses a webcam and OpenCV, an object detection software, for visual tracking, Dynamixel XM430 motors for robotic movement, and a server run on a Raspberry Pi to control the robot.

Problem Statement and Constraints

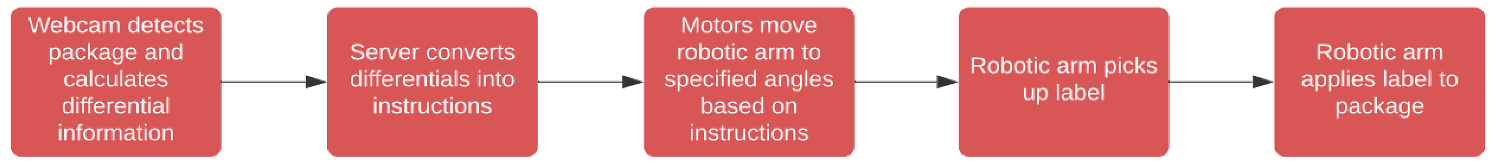

Figure 1: Labeling Robot Logic Diagram

Problem Statement:

- "Use a robotic arm with object detection to identify and label packages." –Dr. Zhen Yu

Constraints:

COVID-19 Remote Teamwork.

- Due to the COVID-19 Pandemic, we will need to work remotely.

- **Robotic Arm Design and Printing**
  - Using the robotic arm design from the previous team, we will reprint and redesign the manipulator.

Goal:

- Create and use a robotic arm to label packages.
- Use software and create a program to identify labels and packages.

The Robotic Manipulator

The Robotic Manipulator shown below will be used to apply labels to boxes autonomously.

- This manipulator has 3 Degrees of Freedom (DoF).
- Constructed with 3D-printed components.
- Equipped with DYNAMIXEL XM-430 actuators created by ROBOTIS INC.
- The OpenManipulator design was provided by ROBOTIS AMERICA.

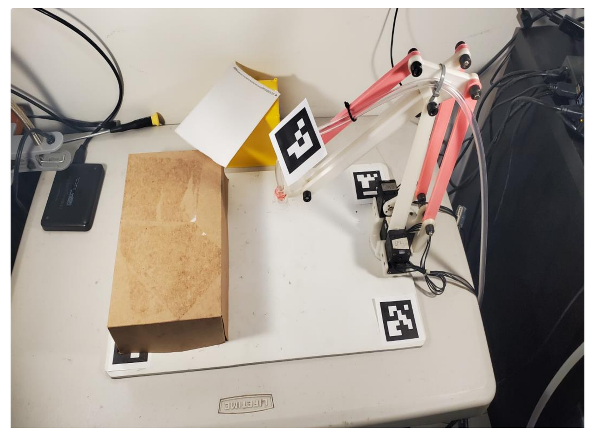

Figure 2: Labeling Robot, Design Provided by ROBOTIS AMERICA

Figure 3: Dynamixel XM430-W350-R Motors Provided by ROBOTIS AMERICA

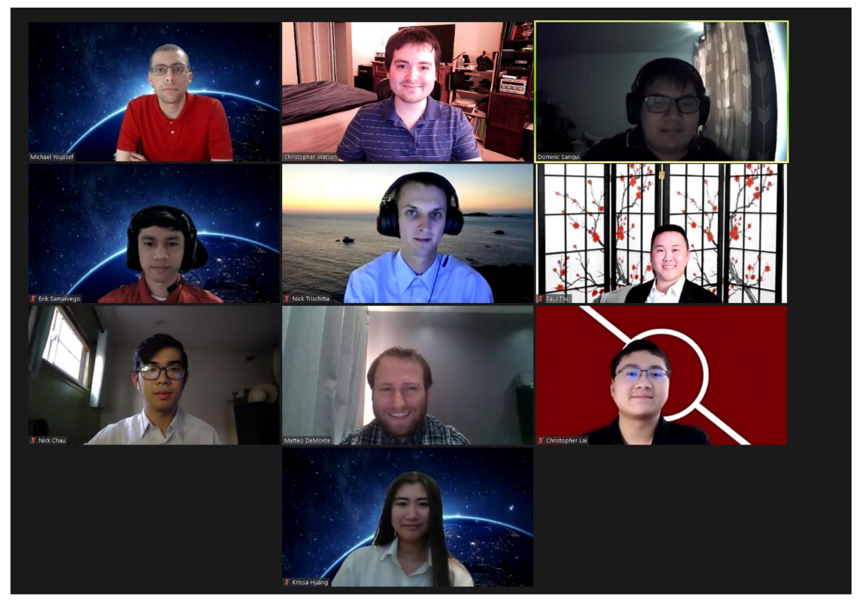

Figure 4: Team Organization

Computer Vision for Visual Tracking

- The Computer Vision task is to:
  - **Identify** the location of the arm and target box.
  - **Locate** their geometric centroid and the label destination.
  - **Calculate** the distance (differential) between the arm and target box

  This allows us to know where the robotic arm needs to go to pick up the desired components.

- **Using OpenCV**, a real-time library optimized for computer vision and hardware, we will use to gather all required data.
  - **Contour Detection:** Defines the object contours in the image.
    - **Adaptive Threshold**: Filtration method that targets and isolates subspaces of high-intensity pixels
    - **HSV Filter**: Filtration method that targets and isolates regions on the image that have specific colors
  - **Image Localization:** Determines the locations of encapsulated objects.
    - **Contour Sorting**: In the case of multiple contours being detected, place all contours into a list and sort them by size. Target the smallest contour and assign the object with ID: 0
  - **Image Detection Speed**: using a 30 FPS camera we were able to get rapid image processing rates of 25-30 FPS depending on the lighting.
  - **Homography:** detection and correction algorithm to correct for any angular camera offset and simulate the camera viewing the testbed from a 90-degree top-down angle.

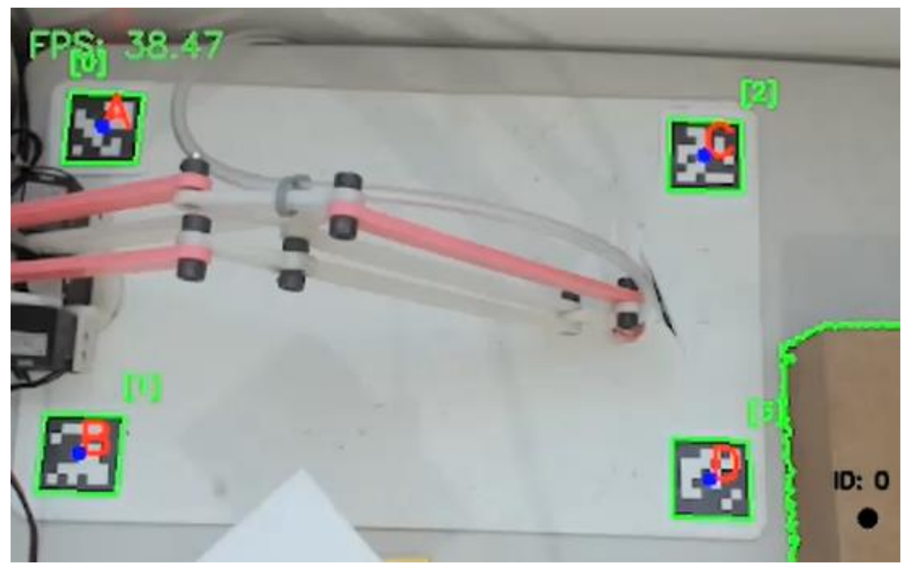

Figure 5: Camera View of Setup

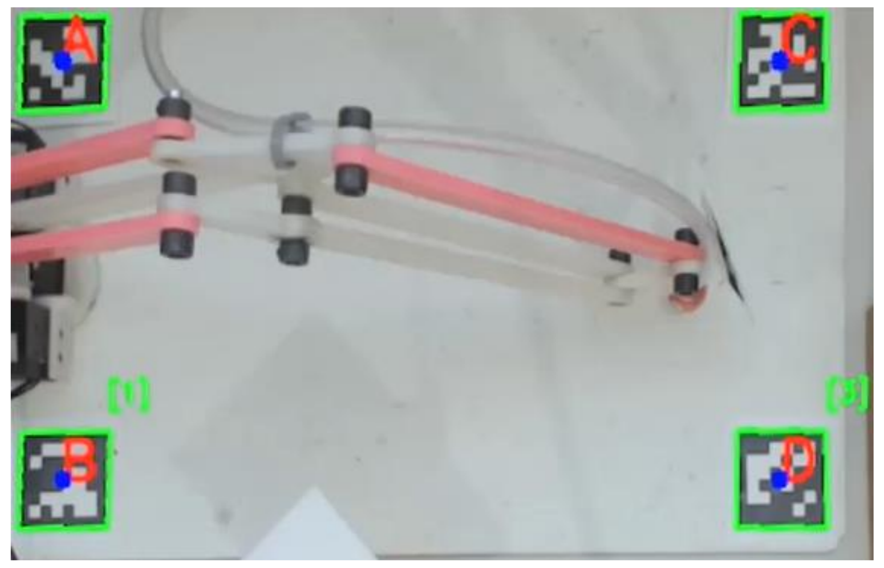

Figure 6: Camera View of Setup with Homography Correction

Arm Control Server

The **Arm Control Server** can be broken down into three components: **Communications and Management**, **Coordinate Translation** , and **Basic Mapped Motion.**

- **Communications and Management** runs as a basic socket server that contains a state machine and basic information about the arm. The state machine determines the actions taken based on client input.

- **Coordinate Translation** Uses a series of algorithms to guess and then check the calculated angles for the arm to move. They are based on the triangles created by the arm and the polar distance calculations.

- **Basic Mapped Motion** was designed to help prevent hitting the label on another surface before it is dropped. The arm will always attempt to move up first, then above the location, then straight down. This is currently a simple implementation based on steps in order not to overtax the serial communications with the motors.

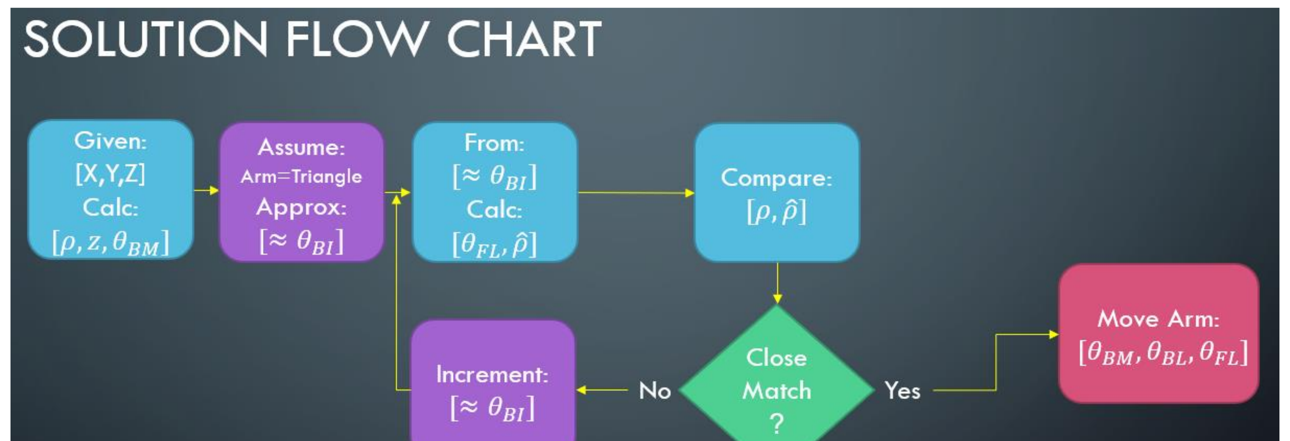

Figure 7: Server Logic Diagram

Motor Interface Logic

Purpose: Based on the Dynamixel SDK library, the Motor Interface Logic (MIL) is written to help the server communicate with the Dynamixel motors controlling the robotic arms by simply calling user-defined functions from the MIL. Those functions from the MIL takes care of the low-level serial communication between the motors and the control server dictating the speed and position of the motors.

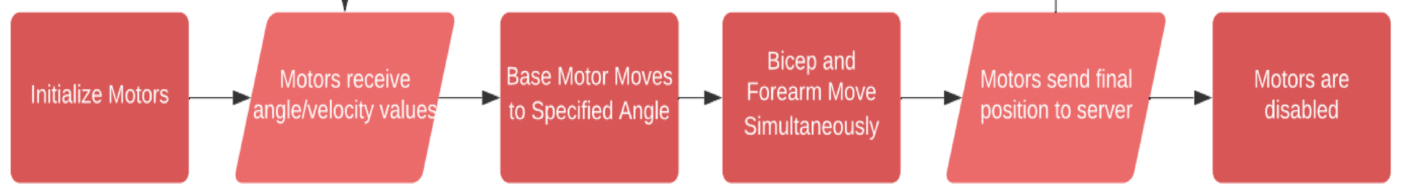

Figure 8: Motor Interface Logic Diagram

End Effector Design

Purpose: Improve grasping of label from printer and application to package's surface

Current Design: The current design consists of an air-hockey inspired ctead, where there are a multitude of holes on the bottom of the end effector that will uniformly provide suction across the entire label.

Design Process: The design process began with the understanding of the physics of suction. From there, how could we enhance the suction while spreading the force such that the label will not be damaged?

Figure 9: 3D Printed End Effector

Results and Impact

Impact: We hope that this project will encourage people and companies to introduce more automation into their tasks to free up resources, . Automation will allow for resources and people to be redeployed to more important tasks. We also hope this project shows that automation can be cheap and reliable. The estimated cost of this project was $1100 and has reliable performance.

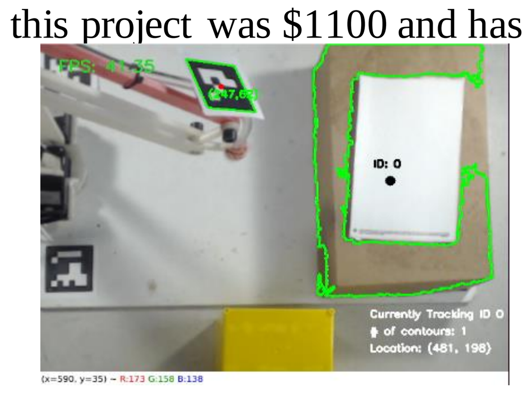

Figure 10: Label on Package with Contour

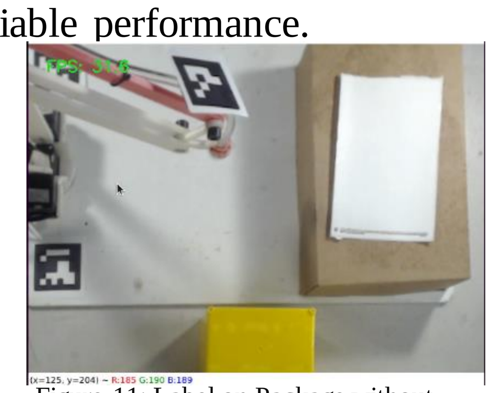

Figure 11: Label on Package without Contour

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Advisors

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