2023 Manipulator Training Preprint 13 June 2023

Name: Hendrikus Hansen Witarsa

Colour-based A* Pathfinding Algorithm for Manipulator Arm

1 Overview

In front of the manipulator robot, there are 12 coloured squares (red or green), put in a 4×3 grid. The top left square is the start square, where there is a doll, while the bottom right square is the goal square. Green colored square means that it can be passed, while red colored square is an obstacle. The goal of this experiment is to search for a feasible path from start to goal square, and then give command to the robot to pick up and doll, follow the path, and put it on the goal square.

2 Equipments

The equipments used in this experiment are listed as follows:

1. C3 Manipulator
2. USB webcam (Logitech)
3. PC
4. Gripper (Attached to the endpoint)

3 Method

3.1 Recognizing colours with OpenCV

USB camera is used for the image processing. The first frame from the camera is used as an image, and using OpenCV, colours are recognized and analyzed based on their HSV values. First, the frame is converted from BGR colour space to HSV colour space. Then, two binary masks are created to threshold the image based on the pre-defined lower and upper thresholds of two colours, red and green. Next, contours are detected in both masks and the centroid of each contour are calculated. The coordinates and their corresponding colours are stored in a vector of tuples. The tuples are then sorted based on the y-coordinate of the centroid into three rows and the tuples in each row are then sorted again based on the x-coordinate. The colours of the sorted tuples in each row are converted to binary values (0 for green, 1 for red). A "maze" is then created by copying the binary values from the three tuples, resembling 4×3 grid with binary values. This "maze" will be used to generate the path planning trajectory.

3.2 A* Path Planning

A* path planning is a popular pathfinding algorithm used to find the shortest path between two points in a graph or grid. The algorithm starts by defining a start and goal node or point and initializing an open set to store nodes for exploration. Then, it repetitively selects the node with the lowest total cost (combining the cost from the start node and the estimated cost to the goal node) from the open set. The selected node is marked as visited, and its neighboring nodes are expanded and added to the open set if they have not been visited before (In this case, only neighbour inside the grid with binary value 0 are considered, as 1 is an obstacle). The process continues until the goal node is reached or the open set becomes empty. The algorithm then constructs the shortest path by following the parent references from the goal node back to the start node.

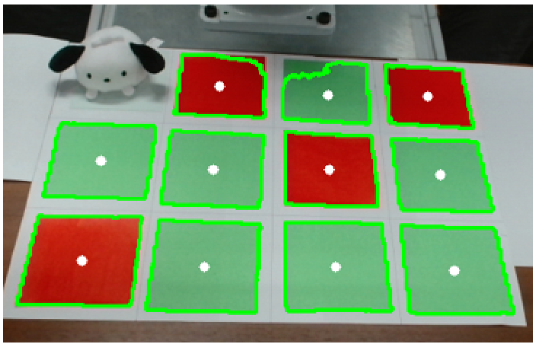

Fig. 1 4x3 grid with colored squares

4 Experiment

4.1 Initial configuration

As shown in Fig. 1, a grid paper is placed on top of the table. On each grid, a red or green paper will be placed, except for the top left corner, which has a doll, and a white paper will be placed instead. The end-effector will move from the start to goal square while gripping the doll. The centroids are marked and will be use for pathfinding. The centroid's coordinate of the top left square is $(-180, 240, -180)$ and the distance between two centroids is 120.

4.2 Discussion

Assuming the start square as $(0, 0)$ and the goal square as $(2, 3)$, each square is represented by their 2D coordinate (x, y). This 2D coordinate is then turned into its respective 3D coordinate ($TargetPoint[]$) for the end-effector to follow. To calculate the coordinate, this equation is used:

$$TargetPoint[0] = -180 + (120 \times x)$$

$$TargetPoint[1] = 240 + (120 \times y)$$

$$TargetPoint[2] = -180$$

The manipulator arm was able to follow the given path from start to goal square. Unfortunately, in this experiment, the gripper did not work as intended. Even so, the gripper is still attached so that we can better imagine the gripper picking up and putting down the doll.

5 Summary and Future Prospects

In this project, a camera is used to detect the grid while also recognizing red and green colours. A "maze" is created with binary values and A* pathfinding algorithm is implemented to find the shortest path from start to goal point.

As a future prospect, real obstacle might be used instead of just paper to simulate obstacles. And instead of fixing the position of the grid, we can make the camera detects the position of the whole grid, so that for different experiments, different position of grid can still work. A bigger grid might also be used, for example 5×5, where there is more path possibilities to take and more places for the obstacles to be placed.