ROB-GY 6103: Integrated Project, Spring 2023
Demo Date: May 15, 2023 (10am to 3pm), MakerSpace

Problem statement

Design and build an autonomous robot to assist in inventory monitoring and management for a warehouse by identifying and counting defective and non-defective widgets. The robot will navigate on the warehouse floor, with the help of **directional aids** (e.g., triangles) to make turn decisions, and it will count the number of defective and non-defective widgets (hosting corresponding **markers**, e.g., ArUco tags). The robot will display the number of defective and non-defective widgets at the end of its course.

The project's mock warehouse will have a layout with 3 major **sections** as shown in the Figure below. Each section will house an object (e.g., yellow color boxes in the Figure) with directional aids instructing whether the robot need to make left or right to turn (based on the direction pointed by the triangle). In addition to performing line-following, the robot needs to autonomously navigate based on the directional aids, detect the **widget stations** (e.g., red color boxes in the Figure) hosting the widgets, and count the inventory at each station based on the tag ID. At the end of its course, the robot must reach its final destination (e.g., green color boxes with mounted markers in the Figure), without a path to follow, and show the inventory count.

Describing the scenario

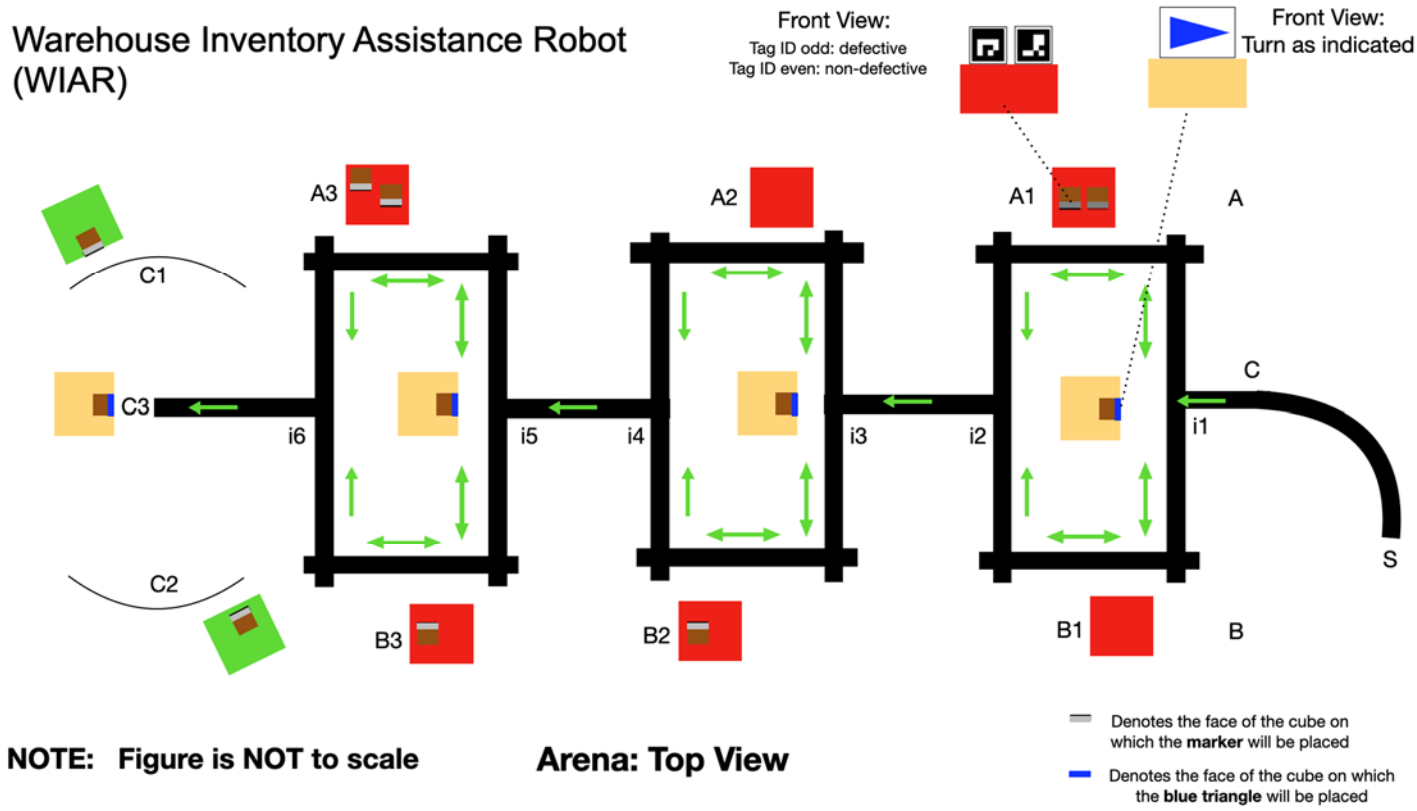

Figure 1: Warehouse layout (The arena)

- The robot will start at a **home** location S and move along the center lane C.
- The width of the tape will be between 1.8cm to 2.6cm.
- There will be a total of 6 **intersections** labeled i1, …, i6 on the center lane C.
- The green arrows represent the directions in which the robot will be allowed to move.

- The center lane C will be unidirectional whereas the lanes A (separated into three segments A1, A2, A3) and B (separated into three segments B1, B2, B3) will be bidirectional.
- Along the center lane C, at each odd intersection, the robot will need to detect a directional aid (e.g., left/right pointing triangles), and use the same for turn navigation. The directional aid will be placed on a platform of height 50 mm at 10 cm away from the intersection. Blue colored triangles of base 20mm and height 35mm will be given as directional aids.
- You will be free to use your own symbols (e.g., circles, rectangles etc.) for the directional aids. You will not be allowed to use any markers (ArUco, April, etc.) for this purpose. If you want to use your own directional aids, inform the GAs about it at the start of your demo, provide them your directional aids, and they will change the same for you at the start of the demo.
- There will be six stations in the arena where the widgets will be placed. Each segment A1, A2, A3, B1, B2, B3 will contain one station. These stations will not be at any fixed position along the horizontal lanes (A/B) of their corresponding section, however they will all be about 10 cm away from their lane A/B. Each station will be of 50mm height and 75mm width.
- The widgets will be cubes of dimension 25mm×25mm×25mm. The widgets will be placed on the stations. There will be at most two widgets per station. The widgets orientation will be fixed and facing towards lane A/B, but they will be subject to a random position on the station. Some random configurations of widgets placed on stations are indicated in the Figure.
- The widgets will be affixed with unique ArUco tags as shown in the Figure. If the marker/tag ID on the widget is an odd number, the widget is defective and if it is an even number, the widget is non-defective.
- You will be free to use your own markers (ArUco, April, etc.) for this purpose. If you want to use your own markers, inform the GAs about it at the start of your demo, provide them your markers, and they will change the same for you at the start of the demo.
- After the robot passes intersection i6 and when it reaches ‘C3’, there will be no line (tape) for the robot to follow. This area is called “**No man’s land**”.
- A platform at a 15 to 30 cm distance away from ‘C3’ will host a directional aid to support the robot in turn navigation in the No man’s land. Specifically, based on the turn direction, the robot will establish its target docking area C1 or C2 as shown in the Figure.
- Each arc C1 and C2 is at approximately 30 cm from C3. Along each arc, at an offset of approximately 5 cm, a docking station will be placed at a random position facing towards C3 (in the direction away from the center lane). Two random configurations of the docking positions are shown in the Figure.
- The docking station will be of 50mm height and 75mm width and it will host an ArUco marker on a platform of 25mm×25mm×25mm.

Task descriptions

- Your robot must use at least two controllers: (a) Raspberry Pi and (b) Arduino UNO or Propeller Activity Board.
- You will be directed to place your robot at home location ‘S’.
- The robot must always stay on the path (black tape) until it reaches position ‘C3’.
- The robot must NOT stop at any time during its full run except while facing a marker/directional aid.
- The robot must detect directional aid and check the widget station on the side (left or right) indicated by the directional aid. Specifically, upon detecting a directional aid at intersections i1/i3/i5, it should proceed in the direction indicated by that directional aid. The directional aid only tells the robot which station to visit first at each section.
- Upon making the turn, the robot should continue line-following and detect the widget station, determine the number of defective/non-defective widgets at the station, and provide a distinctive indication for each defective and non-defective widgets (e.g., using LEDs, an LCD, a seven-segment LED, etc.).

- If a marker/tag ID on a widget is an odd number, the widget is defective and if it is an even number, the widget is non-defective.
- Next, the robot should visit the widget station on the other side of the current section and perform the widget quality detection and indication operation. Then, the robot can proceed to move toward the next section using line following while observing the directionality rules (green arrows) of the lanes.
- Then, the robot should complete the same turn navigation, widget station detection, as well as widget quality detection and indication tasks for the remaining two sections.
- For any section of the layout, the turn direction of the directional aid and for any widget station the type of widgets will not be revealed for hard coding of the solution, instead these must be found by means of a camera mounted on your robot along with corresponding computer vision algorithms.
- By default, the directional aids will be blue triangles and the widgets will have unique 6x6 ArUco tags. However, as a flexible and open-ended solution strategy, you are free to select your own directional aids: rectangles, circles etc. (strictly no markers for directional aids) and April tags or any numbered markers instead of ArUco markers.
- If you want to use your own directional aids and markers, inform the GAs about it at the start of your demo, provide them your markers, and they will place the same for you on the layout at the start of the demo.
- When the robot reaches 'C3', depending on the direction pointed by the directional aid, the robot should either go to the docking station on arc 'C1' or arc 'C2'.
- The robot should now search for the marker on platform on the docking station, approach towards the marker, and stop at the arc present before the docking station, facing the marker. This tracking must be done only with the vision sensor (camera).
- After reaching the docking station the robot should display the number of defective and non-defective widgets (using a seven-segment LED or an LCD).

Deliverables and Grading (Total: 100 points)

1. Line following robot - **10 points**
2. Detect and indicate intersections (i1-i6) - **15 points (6 intersections x 2.5 points)**
3. Detect and turn as indicated by the directional aid - **20 points (4 turns x 5 points)**
4. Detect the station and stop to detect the markers - **15 points (6 stops x 2.5 points)**
5. Detect the markers/tags and indicate the number of the defective and non-defective widgets at each station - **15 points (6 stops x 2.5 points)**
6. Reach the docking station by following the tag at the end of the course - **15 points (5 points each: detect the tag, navigate to approach the tag, reach and stop at the tag)**
7. Calculate and display the total number of defective and non-defective widgets - **10 points (5 points each)**

Note 1:

- **Penalty –** hitting any of the stations (platforms) or widgets (cubes) due to large footprint of the robot and/or cables, power supply, etc, will result in a penalty of 5 points for each such occurrence
- IR remote control allowed only for deliverables 3 and 5
  (Max points = 70% of the points for those tasks)
- Autonomous control preferred (100% of the points)

Note 2

- 80% of the overall grade for the project will come from the demonstration.
- 20% of the overall grade for the project will come from the project report.

- A team member who is absent during project demo will receive a grade of 0 for project demonstration. Any team or team member who report late for project demo will be penalized in project demo grade. Any significant delay (over 15 minutes) will result in a grade of 0 for project demonstration.
- Late submission of project report will not be accepted and will be awarded a grade of 0. Project reports will be due at 10am on the day of project demonstration.

For any questions, please feel free to reach to out the TA's:

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