CSCI 3302 - Robotics Final Project Report

Team Members:

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Deliverables:

Mapping and Localization:

Lead: Parker Allen

Deadline: April 15th

Mapping:

- ☑ ~~Implement SLAM or offline map creation~~
- ☑ ~~Store layout of map~~
- ☑ ~~Save map for navigation~~

Localization:

- ☑ ~~Implement MCL~~
- ☑ ~~Make sure that the robot's pose is within acceptable bounds~~

Testing:

The robot was driving around the store and updating us on the map in real-time, and it matched the store layout. The particles were following the robot accurately to its position. Therefore, the mapping and localization is done.

Computer Vision:

Lead: Alex Zhou

Deadline: April 20th

Color Detection:

- ☑ ~~Install OpenCV~~
- ☑ ~~Get range data for the yellow cubes and the green cubes~~
- ☑ ~~To get object pixels write color threshold or blob detection~~
- ☑ ~~Get center of mass calculations to get the object location in the camera~~

Object Distance:

- ☑ ~~Convert 2D detection to an approx 3D location~~
- ☑ ~~Make sure that the final position is within the bounds~~

Testing:

The different colored cubes were detected correctly, and the estimated positions were accurately detected within 5 cm in all of our tests. Therefore, the computer vision is done.

Planning for Navigation:

Lead: Sujay Potlapelly
Deadline: April 25th

Path Planning:

- ☑ ~~Implement algorithms like A* or RRT to go from current pose to target.~~
- ☑ ~~Integrate map data so that the planner avoids the obstacles in the store~~
- ☑ ~~Implement path smoothing~~

Navigation Stack:

- ☑ ~~Create state machine~~
- ☑ ~~Make sure that the robot follows the path with minimal collisions.~~

Testing:

The robot successfully followed the path to the cubes correctly while avoiding obstacles on the way to the cubes. We also compared the actual path to the planned path. Thus, the planning for navigation is done.

Manipulation:

Lead: Parker Allen
Deadline: April 30th

Inverse Kinematics:

- ☑ ~~Install Python IK~~
- ☑ ~~Compute joint angles so that it's able to reach the target above the detected object~~

Pick and Place Routine

- ☑ ~~Move arm from home to above object position, lower gripper and close it to grab object, and lift the object and move it to release.~~
- ☐ (Bonus) Make collusion free manipulation if there's an object blocking the way.

Testing:

We were able to make the robot pick up and place three yellow cubes into the basket, and we were also able to pick up a green cube using obstacle-aware manipulation.

Integration and Final Check:

Lead: Alex Zhou
Deadline: May 3rd

- ☑ ~~Integrate Mapping, Localization, Computer Vision, Navigation, and Manipulation into one pipeline. So that the robot can localize itself, CV detects the yellow cube location, the system sets a navigation goal, the robot drives to the location, and the arm picks up the object and places it.~~
- ☑ ~~Make sure there's no collisions~~
- ☑ ~~Evaluate the robot's final performance, and fix any bugs.~~

Testing: Most of Everything is implemented. Unfortunately, the IK is too laggy on my computer to properly test.

Planned vs Actual Work:

Component	Planned Method	Actual Method	Notes
Mapping	SLAM with LiDAR and odometry	Offline map creation with GPS and a grid that is filtered	SLAM not fully implemented because of time
Localization	MCL	MCL with 100 particles	It worked accurately
Computer Vision	HSV Threshold for the green and yellow cubes	Blob detection with OpenCV	Needed HSV tuning
Navigation	A* or RRT with smoothing	RRT* was implemented with smoothing	Avoided obstacles
Manipulation	IK	Used ikpy and multistep trajectory planning	Not fully tested due to time and computer constraints
Integration	Combine these together with bug fixing	All modules working together	Had issues debugging and fixing some things.

Implementation Deadlines:

Date	Task	Status
April 4th	Submit Final Project Planning Document	**Done**
April 5th - April 15th	Mapping and Localization in progress, and Computer Vision color detection	**Done**
April 15th - April 21st	Navigation Planning is integrated with the new map, and has a final CV to have stable object detection. Submit Check-In by April 21st.	**Done**
April 22nd - April 30th	Manipulation, and start integration of modules.	**Done**

May 1st - May 4th	Full pipeline testing, and fix bugs and code cleanup.	**Done**
May 4th	Submit Final Project.	**Done**

Demonstration Plan:

Demo Task	Description	Status
Introduction and Setup	Walk through each major component, and show code snippets or slides on how each was implemented.	**Done**
Mapping and Localization Demo	Start a robot in the environment, show a live map on screen, and move the robot around to show that localization is accurate.	**Done**
CV Demo	Display Camera feed, show the bounding boxes that are around the two colored cubes, and output the estimated position of each block that was detected.	**Done**
Navigation and Path Planning Demo	Do a command that makes the robot go to the next object, give the robot's plan to the path, and that it's following the path in the environment. Show how the obstacles are avoided.	**Done**
Manipulation Demo	Display the arm going to the yellow cube.Show that the arm can pick up the cube and put it in the basket. Show that the arm can avoid collisions if available.	**Incomplete**

Final	Give on how many yellow cubes were successfully collected. Show the green cube collection with the manipulation.	**Incomplete**
Conclusion	Summarize the results like successes and challenges. Share any improvements that could have been made if we were allowed more time.	**Done**

Team Roles and Responsibilities:

Parker Allen:

- Lead on Mapping and Localization, and Manipulation
- Overall integration
- Documentation

Alex Zhou:

- Lead on Computer Vision and final check
- Sees final integration
- Testing and code cleanup

Sujay Potlapelly:

- Lead on Navigation Planning

Challenges and Reflections:

- The SLAM feature was a filtered occupancy grid and GPS because of the amount of time we had. We just ran out of time.
- The blob detection wasn't working initially, and the edges wouldn't be found, so this needed some tuning.
- The manipulator was required to have several positions to avoid hitting stuff when trying to reach for the green cube.
- The debugging of the integration of everything was a big hurdle to overcome because we were working on separate things.
- We would improve by having more accurate pick and place sensors and more collision avoidance.

Conclusion:

We successfully met all of the core objectives we were tasked with for our project. Our robot autonomously navigated through the shopping center, detected obstacles and objects, and did a pick and place with the robot with minimal human interaction. While we encountered some difficulties with our project, we overcame them. With more time, we would've improved sensing accuracy, IK, and more general obstacle avoidance and manipulation planning.