HW2

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Waypoint Following

The waypoint following mechanism was implemented using a combination of Pure Pursuit and dynamic obstacle avoidance. The function `navigate_to_goal` handles the robot's motion towards the target waypoint using the following steps:

- The current position and orientation of the robot are extracted then the goal waypoint is checked for if is a waiting point with a task
- The Pure Pursuit algorithm calculates linear and angular velocities based on the distance and angle to the goal, incorporating heading alignment as the robot approaches its destination.
- The function `pure_pursuit` dynamically adjusts speed based on proximity to obstacles, ensuring smooth navigation without collisions.

To handle waypoints requiring simulated tasks (e.g., picking up vegetables or waiting for cooking), the function `sleep_check` is invoked. It ensures a delay at specific waypoints before continuing to the next target. Also to ensure fast traversal throughout the pathway, minimum and maximum speeds were defined that are multiplied by factors depending on the surroundings to determine the optimal variables.

Handling Unexpected Obstacles

Obstacle detection and avoidance were implemented within the `scan_callback` and `navigate_to_goal` functions. The LaserScan data is divided into sectors (e.g., front, sides) and proximity factors are calculated to assess obstacle presence:

- Obstacles in the front trigger adjustments to reduce speed and increase angular velocity, preferring a direction with more free space.
- Side obstacles are penalized to ensure safer wall-following behavior while minimizing deviations from the planned route.
- The `prefer_right` flag dynamically determines the preferred avoidance direction based on the relative free space.

An alternative approach could involve generating a new local path using dynamic motion planning algorithms (e.g., DWA or RRT*). While this would improve navigation in cluttered environments, it would likely increase computational overhead and elapsed time for task completion. Algorithms like splining could also be utilized to create smoother paths. However, incorporating obstacle avoidance logic that dynamically modifies the spline is challenging. To address this, the current approach prioritizes fixing the robot's angle as it nears the target by dynamically increasing angular velocity to ensure smooth alignment.

Results

The robot successfully completed all assigned tasks, including waypoint navigation and obstacle avoidance. The overall elapsed time for task completion was approximately **318 seconds**, including the delays at waiting points due to predefined tasks which is really good. below my main output files screenshot can be found, I want to add more pictures but in the question sheet it was specified to be between 1-2 pages, but there was no strict constraint. I added two more screenshots in the appendix part of the report that you can check if you want, you can skip them if you dont want to :) .

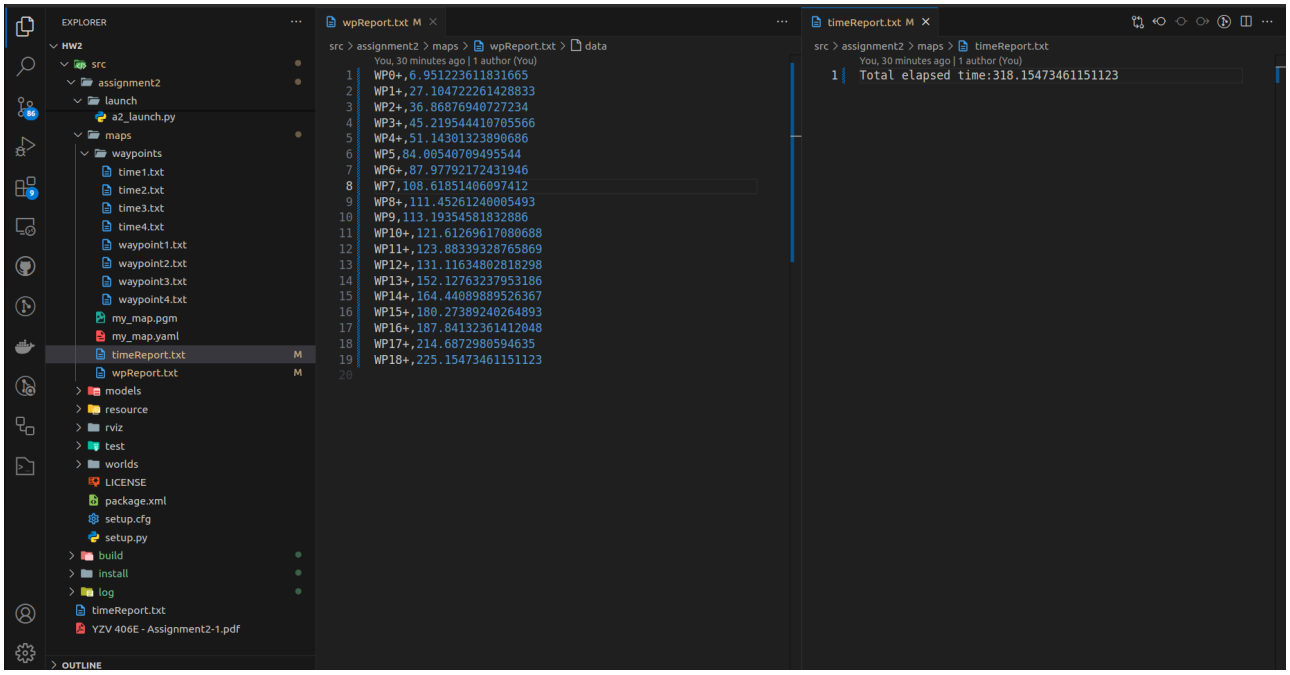

Figure 1: Output files.

Challenges

Several challenges were encountered during the implementation:

- **Picking Correct Parameters:** During multiple instances, the robot would produce either exaggerated effects or very minimal responses, resulting in collisions, misalignment, or slow behavior. To address that I tuned my parameters
- **Smooth Obstacle Avoidance:** Balancing linear and angular velocities to ensure smooth yet efficient obstacle avoidance was complex. This was addressed by tuning parameters in `pure_pursuit` as mentioned in the first point. Initially, side LIDAR data was underutilized; incorporating multiple angle segments to calculate obstacle proximities helped the robot move continuously without stopping.
- **Proper alignment upon arrival:** While maintaining a good speed throughout the traversal of the waypoints and avoiding obstacles, my robot found it difficult to have the proper alignment at arrival. I fixed this challenge by increasing the angular velocity of the robot when its closing at the waypoints giving it more importance to ensure the target angle is met

Through iterative testing and parameter tuning, these challenges were overcome to achieve a robust navigation solution.

Appendix

```
[referee-8] [INFO] [1736600302.389822134] [referee]: Elapsed secs:300.1501386165619
[referee-8] [INFO] [1736600303.417621844] [referee]: Elapsed secs:301.1775827407837
[referee-8] [INFO] [1736600304.444738261] [referee]: Elapsed secs:302.20514941215515
[referee-8] [INFO] [1736600305.474499846] [referee]: Elapsed secs:303.2350494861603
[referee-8] [INFO] [1736600306.482558748] [referee]: Elapsed secs:304.2432999610901
[referee-8] [INFO] [1736600306.926382326] [referee]: ACHIEVED WAYPOINT 17 with lateness of 214.6872980594635
[referee-8] [INFO] [1736600306.926852191] [referee]:   (linear error 0.19879243618303075 angle_error 0.138123512
92872005)
[referee-8] [INFO] [1736600306.927303867] [referee]: ACHIEVED ORIENTATION
[referee-8] [INFO] [1736600307.507102542] [referee]: Elapsed secs:305.26778650283813
[referee-8] [INFO] [1736600308.535062488] [referee]: Elapsed secs:306.29457235336304
[referee-8] [INFO] [1736600309.559720040] [referee]: Elapsed secs:307.3203902244568
[referee-8] [INFO] [1736600310.583842527] [referee]: Elapsed secs:308.3445439338684
[referee-8] [INFO] [1736600311.612418066] [referee]: Elapsed secs:309.3731060028076
[referee-8] [INFO] [1736600312.640950969] [referee]: Elapsed secs:310.40116477012634
[referee-8] [INFO] [1736600313.665637349] [referee]: Elapsed secs:311.4264602661133
[referee-8] [INFO] [1736600314.689996557] [referee]: Elapsed secs:312.4506230354309
[referee-8] [INFO] [1736600315.712953884] [referee]: Elapsed secs:313.4736113548279
[referee-8] [INFO] [1736600316.744006491] [referee]: Elapsed secs:314.5047161579132
[referee-8] [INFO] [1736600317.764694273] [referee]: Elapsed secs:315.52556562423706
[referee-8] [INFO] [1736600318.787871323] [referee]: Elapsed secs:316.5484824180603
[referee-8] [INFO] [1736600319.812471617] [referee]: Elapsed secs:317.5733711719513
[referee-8] [INFO] [1736600320.393735784] [referee]: ACHIEVED WAYPOINT 18 with lateness of 225.15473461151123
[referee-8] [INFO] [1736600320.394133122] [referee]:   (linear error 0.19985330503759663 angle_error 5.962780756
035846e-05)
[referee-8] [INFO] [1736600320.394669919] [referee]: ACHIEVED ORIENTATION
[referee-8] [INFO] [1736600320.427994321] [referee]: Meal has been succesfully delivered.
[referee-8] [INFO] [1736600320.428795546] [referee]: With total lateness of 2173.6734914779663
[referee-8] [INFO] [1736600320.429209197] [referee]: Total elapsed time:318.15473461151123
```

Figure 2: Referee node showing my robot finished the course and tasks correctly

```
[referee-8] [INFO] [1736600248.199183668] [referee]: Elapsed secs:245.95947813987732
[referee-8] [INFO] [1736600248.680531241] [referee]: ACHIEVED WAYPOINT 14 with lateness of 164.44089889526367
[referee-8] [INFO] [1736600248.681381689] [referee]:   (linear error 0.19514780074489343 angle_error 0.056103201
375943934)
[referee-8] [INFO] [1736600248.682442739] [referee]: ACHIEVED ORIENTATION
[referee-8] [INFO] [1736600249.204141085] [referee]: Elapsed secs:246.96245169639587
[referee-8] [INFO] [1736600250.213642181] [referee]: Elapsed secs:247.97400856018066
[referee-8] [INFO] [1736600251.237359629] [referee]: Elapsed secs:248.9974331855774
[referee-8] [INFO] [1736600252.265682126] [referee]: Elapsed secs:250.0262050628662
[referee-8] [INFO] [1736600253.278838980] [referee]: Elapsed secs:251.03891706466675
[referee-8] [INFO] [1736600254.300380196] [referee]: Elapsed secs:252.06021118164062
[referee-8] [INFO] [1736600255.327456262] [referee]: Elapsed secs:253.08772230148315
[referee-8] [INFO] [1736600256.354831299] [referee]: Elapsed secs:254.11557388305664
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[referee-8] [INFO] [1736600258.404866283] [referee]: Elapsed secs:256.16553950309753
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[referee-8] [INFO] [1736600261.479885245] [referee]: Elapsed secs:259.2405409812927
[referee-8] [INFO] [1736600262.505408964] [referee]: Elapsed secs:260.2659351825714
[referee-8] [INFO] [1736600263.530657806] [referee]: Elapsed secs:261.2911214828491
[referee-8] [INFO] [1736600264.513676920] [referee]: ACHIEVED WAYPOINT 15 with lateness of 180.27389240264893
[referee-8] [INFO] [1736600264.514730858] [referee]:   (linear error 0.19780380212168983 angle_error 0.037511013
32507478)
```

Figure 3: Another Example of correct orientation