UNIVERSITY OF LIVERPOOL

# Webots Report

COMP 329 Autonomous Mobile Robotics

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# Introduction

The aim of this assignment was to design an exploration strategy for a robot in the Webots simulator to make the robot move in an arena and create an occupancy grid map. The exploration strategy was capable of handling environmental complexity and sensor limitations, whereas the wall-following strategy was combined with proportional integral derivative (PID) control and reactive obstacle avoidance. The project aimed at creating a mapping system with the use of probabilistic approaches, path planning techniques and real-time environment perception and was based on the concepts covered in the labs.

# Approach Overview

The implementation involved three main components:

- Exploration Strategy: This module guides the robot through the environment while avoiding collisions.
- Occupancy Grid Mapping: This component updates the grid map using a log-odds inverse sensor model.
- Integration & Navigation: the sensor readings and navigation logic were integrated to produce a clear, detailed exploration and mapping system.

# Implementation Details

## Exploration Strategy

The robot navigation was achieved through the wall-following algorithm with the help of the PID controller. PID control tuning is the process of adjusting the proportional, integral and derivative gains to achieve the right response and stability of the system. The proportional term was increased during the iterative testing to reduce the steady-state error, while the derivative term was tuned to bring down the overshoot when the robot was correcting itself from the walls. This helped in navigation along the walls with minimum errors that could have been caused by sensor noise.

**Wall Following Algorithm:**

- Use proximity sensors to identify the walls.
- Use of a PID controller to maintain a constant distance.
- To maintain direction, any deviations are corrected using real-time sensor feedback.

**Waypoint Navigation:**

- The robot was using a static map to navigate when there were no walls in front of it.
- A utility-based planner was used to avoid already explored regions.
- The utility function included the robot's distance from its current location and the uncertainty of the area in the map.

**Obstacle Avoidance:**

- Reactive obstacle avoidance was also implemented using bumper sensors.
- The fallback navigation paths were also incorporated in case of any unexpected collision.

### Occupancy Grid Mapping

The occupancy grid was generated with the help of the OccupancyGrid class provided. I implemented the inverse sensor model for updating the map:

**Log-Odds Calculation:**

- Set initial probabilities for unoccupied and occupied cells based on testing results.
- Thresholds to distinguish between known and unknown areas.

**Sensor Model Implementation:**

- Readings from PioneerSimpleProxSensors were used.
- Based on proximity values, map cells were updated with appropriate log-odds values.
- Sensor fusion helped incorporate several sensors' readings, making the system more reliable.

### Integration & Navigation

The MyAssignmentController integrated sensor readings and navigation. The following was implemented

- Using the supervisor mode's get_real_pose() function for real pose retrieval.
- Using bumper sensors to handle edge cases to help with collision detection.
- Dynamically adjusted navigation paths when unexpected obstacles were encountered to recalculate routes.
- The robot terminated its exploration when the occupancy map reached 95% coverage or after a set time.

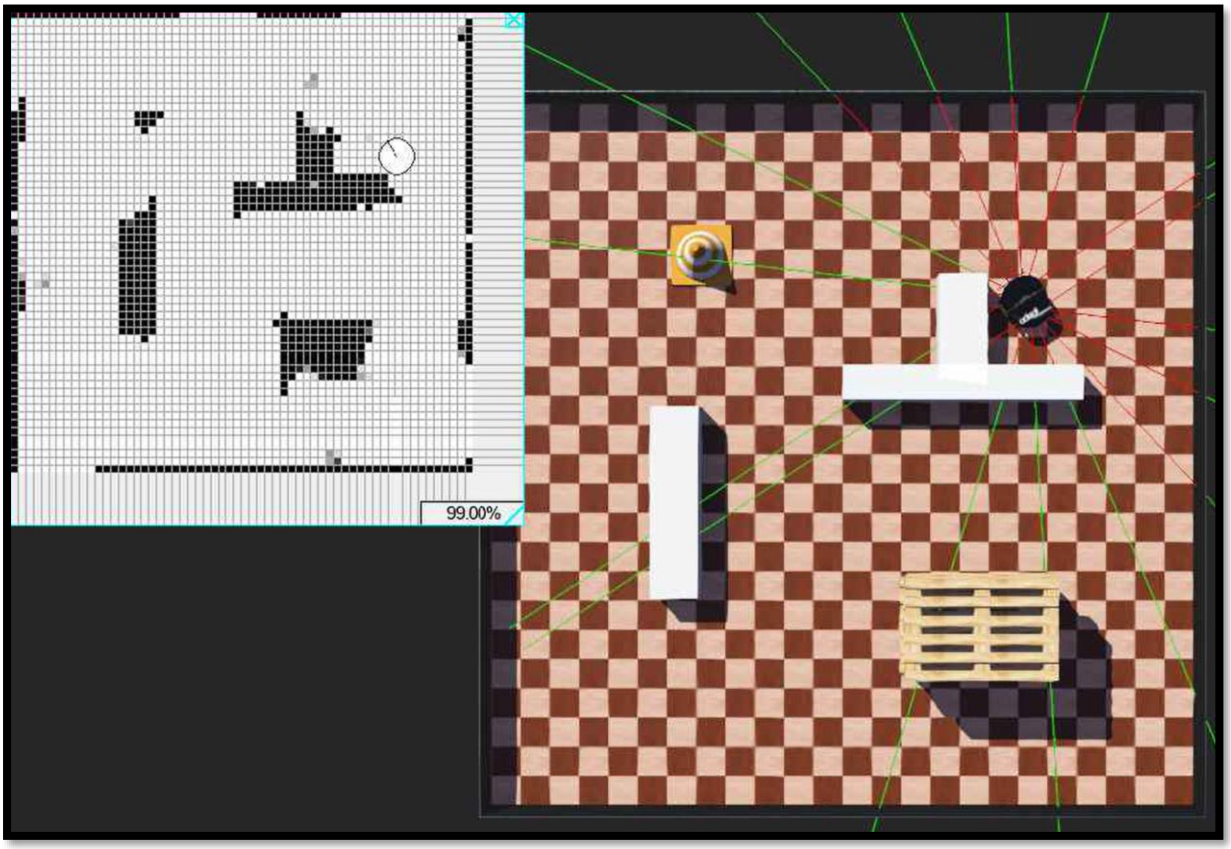
## Results: Simple World

**Navigation Strategy**

- Used wall-following and waypoint navigation to ensure complete coverage.
- Focused on maintaining simplicity with minimal path recalculations.

**Mapping Accuracy:**

- Nearly 100% coverage with clearly defined walls and minimal uncertain areas.



*Completed simulation of the simple world*

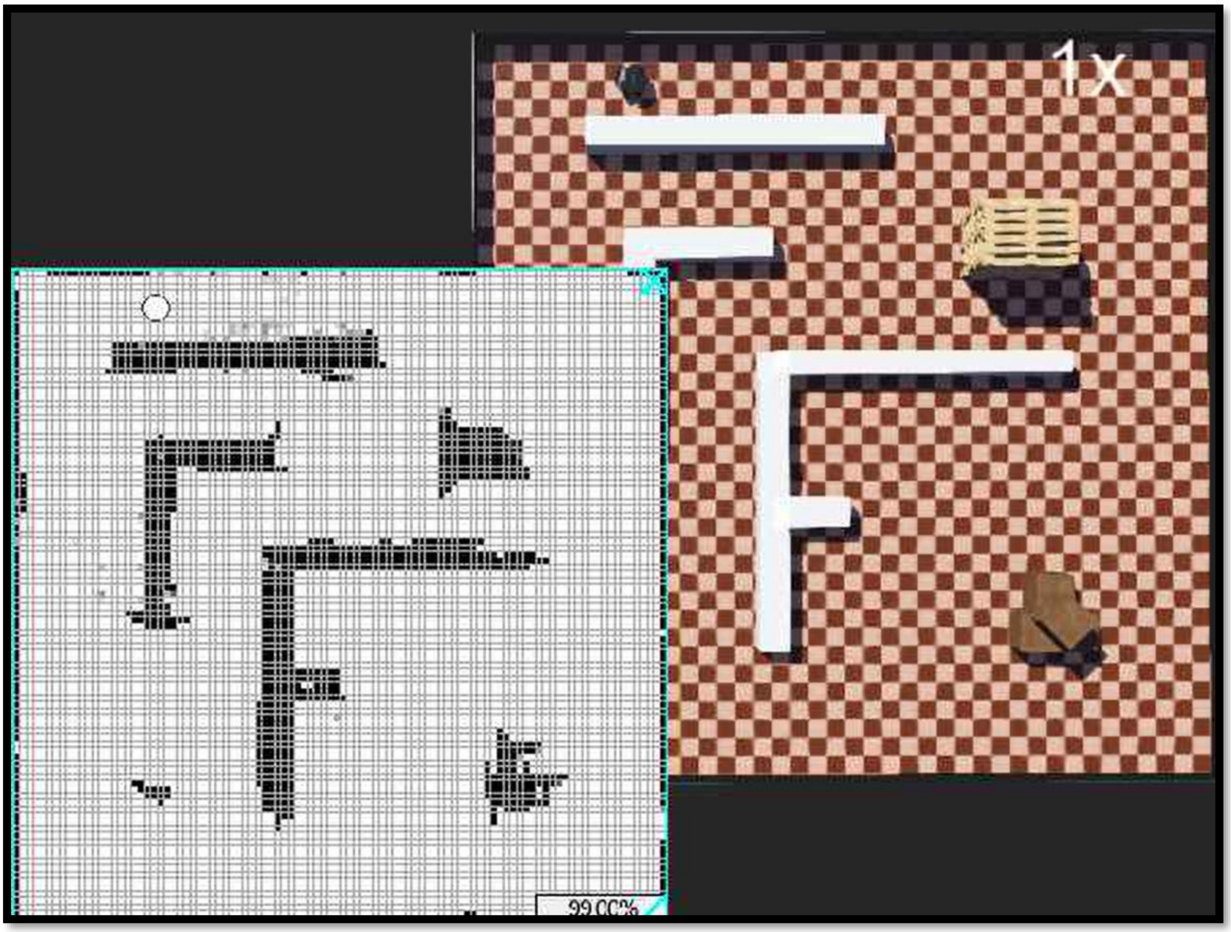
## Results: Complex World

**Navigation Strategy:**

- Used a combination of utility-based navigation and waypoint-following for unexplored areas.
- Implemented dynamic route recalculation in response to unexpected obstacles.

**Mapping Accuracy:**

- Approximately 95% coverage was achieved in some areas requiring multiple passes.
- Sensor noise and environmental complexity increased uncertainty in certain sections.



*Completed simulation of the complex world*

## Challenges and Solutions

**Sensor Noise:**

- Challenge: changes in proximity sensor readings caused mapping inaccuracies.
- Solution: Applied a moving average filter and sensor calibration routine.

**Localisation Drift:**

- Challenge: Small drift errors accumulated over time.
- Solution: Periodically reset the robot's pose using supervisor mode.

**Map Inaccuracy:**

Challenge: Walls sometimes appeared thicker or irregular due to environmental noise.

Solution: Adjusted sensor model parameters, reduced log-odds update thresholds, and tuned the PID controller.

## Reflection

This project was beneficial as it applied theoretical knowledge to real-life situations. Some of the takeaways are as follows:

- I improved my problem-solving skills by developing an inverse sensor model, which reinforced concepts from probabilistic robotics.

- Managing the exploration coverage and the navigation speed was a delicate task that required proper algorithm choice and configuration, which helped my critical thinking.
- Using Webots and dealing with custom sensors helped to understand the issues relevant to real-life robotics and helped to provide technical insight.

## Conclusion

The system that has been put in place has been able to achieve proper mapping and navigation with the use of probabilistic algorithms, PID control and a utility-based exploration planner. The maps used in the two environments, the simple and the complex ones, were quite accurate and covered almost all the environments even though the maps were affected by noise and the limitations of the sensors.