Turtlebot Autonomous Navigation in ROS Gazebo

EE4308 Part 1 Project

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PRESENTATION OUTLINE

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2. Sensor Strategy
3. Navigation Strategy
4. Path Planning Strategy
5. Performance Analysis
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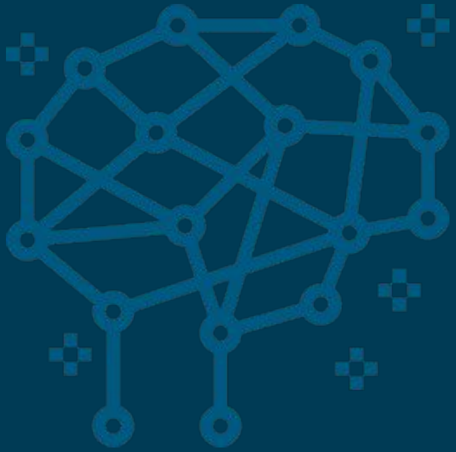
7. Demonstration



PROBLEM STATEMENT

Achieve autonomous navigation in known & unknown worlds with a Turtlebot

Problem Specifications

Autonomous navigation:

- Path planning
- Obstacle avoidance

Robotics Platform

- Turtlebot
    - RGB-D Kinect sensor
    - IMU
    - Odometry
    - Translational & rotational motion

Simulation Platform

- Ubuntu Xenial 16.04
- ROS Kinetic Kame
- Gazebo
    - 9m x 9m grid world
    - Start: (0, 0)
    - Goal: (4, 4)

Sensor Strategy

robot_pose_ekf
pos_info

robot_pose_ekf

- Combines odometry (/odom) & IMU data (/mobile_base/sensors/imu_data) with Extended Kalman Filter
- Increased accuracy, reliability in pose estimation
- tf tree had to be edited in empty_world.launch

pos_info

- Subscribes to /robot_pose_ekf/odom_combined
- Publishes pose estimate for localisation on grid in /auto_ctrl/pos_info

Sensor Strategy

`depth_info`

Subscribes to raw RGB-D Kinect camera readings

- `/camera/rgb/image_raw`
- `/camera/depth/image_raw`

Publishes depth information directly in front of Turtlebot

RGB-D Kinect sensor (middle point)

- `/auto_ctrl/depth_info`

Acts as basic obstacle detection directly in path of Turtlebot

Sensor Strategy `scan_info`

Subscribes to laserscan_nodelet_manager for ‘fake’ laserscan values from depth image.

- `/scan`

Publishes depth information for left most, right most and middle readings in horizontal axis of sensor

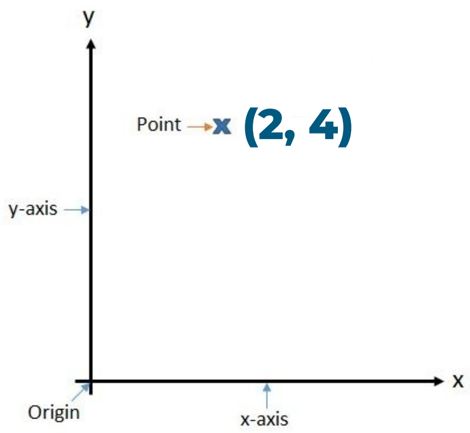
- `/auto_ctrl/scan_info`

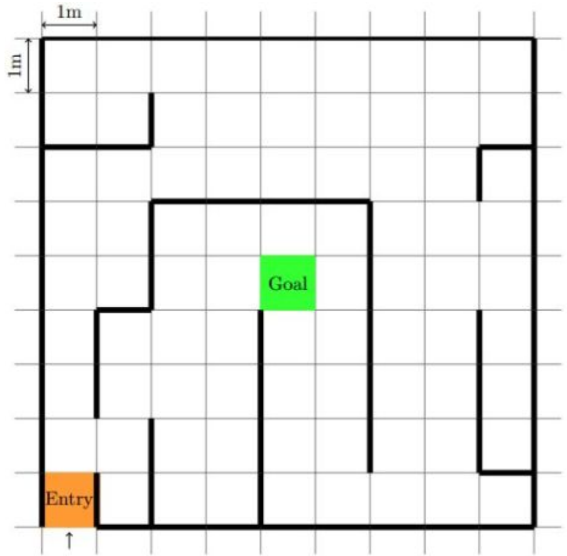
Acts as preemptive obstacle detection along Turtlebot current path

Navigation Strategy `bot_control`

Coordinate System

- 9 x 9 grid representing world frame
- Cartesian coordinates

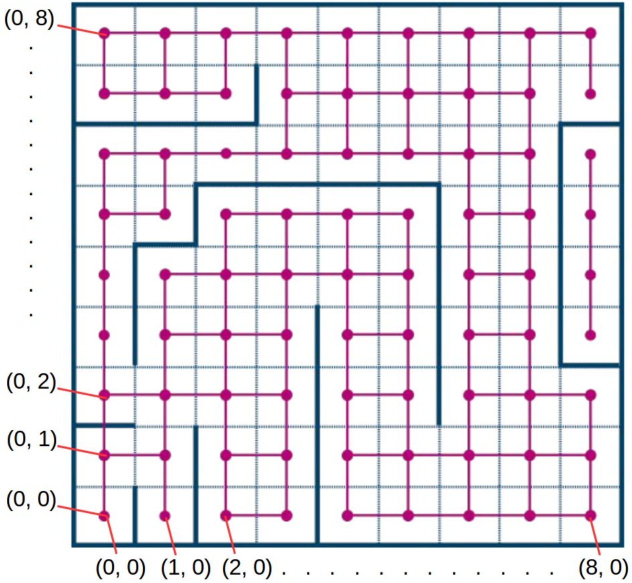




Navigation Strategy `bot_control`

Coarse Motion Control

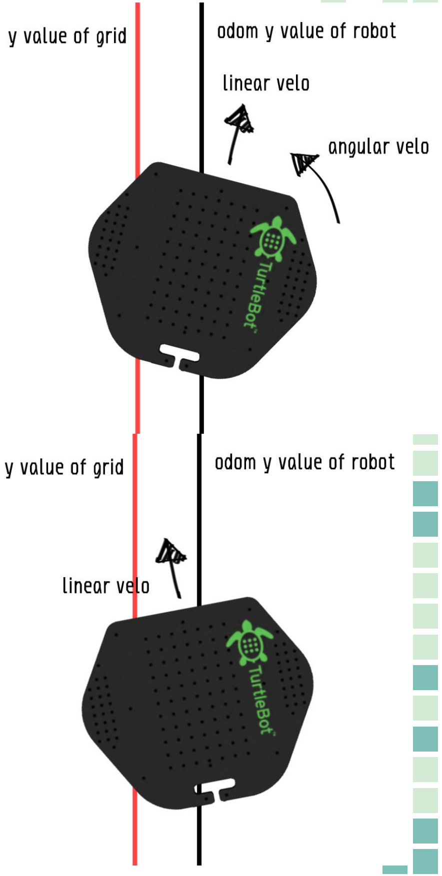
- Navigate between coordinates (middle of grid cells)
- 4 translational movement (up, down, left, right)
- 2 rotational movement (ACW, CW)
- Uses `pos_info` yaw data to check current direction Turtlebot is facing



Navigation Strategy `bot_control`

Fine Motion Control

- Compensates for movement errors and prevents bot from colliding into walls
- Continuous check for the 'middle' of each grid
- Adjusts pose by traversing towards said middle path based on distance / direction offset
- When Turtlebot drifts from middle line, it adds angular velocity to current linear motion to turn inwards
- If Turtlebot is already turned inwards, then no angular velocity is added



Obstacle Avoidance Strategy `bot_control`

Basic Obstacle Avoidance

- Detects obstacles directly in front of Turtlebot using `depth_info`
- Turtlebot has to turn to face the obstacle to detect it

Preemptive Obstacle Avoidance

- Detects obstacles along the path ahead of Turtlebot using `scan_info`
- Allows for continuous motion while scanning for obstacles ahead instead of stopping and turning
- Increases overall speed

Preemptive Obstacle Detection

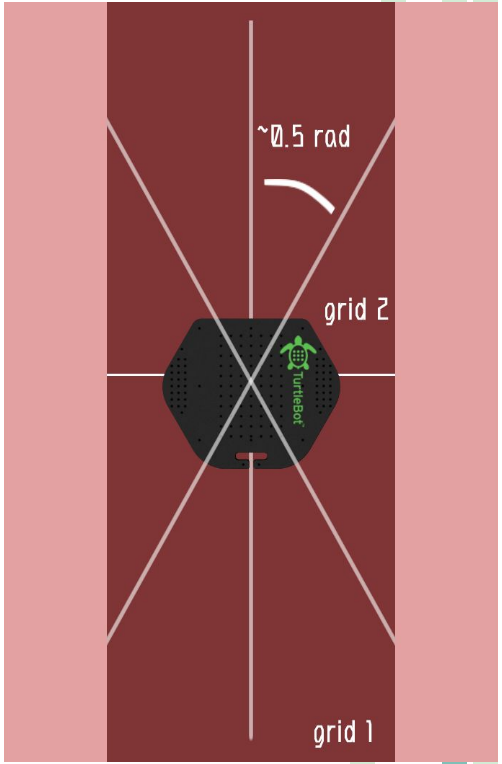
Works based on geometry of map grid and laser FOV

- Laserscan max right and left is ~0.5 rad (30 degrees) from the middle
- By keeping Turtlebot in middle of path with fine motion control, can detect presence of side walls effectively

Check is done when:

- Moving straight between coordinates
- Moved 0.5m from previous grid position

Updates internal map if walls are detected



Path Planning Strategy `algo.h`

Includes functions for creating / maintaining internal map grid as well as search algorithms

Internal map grid

- 9 x 9 2D array of cell structs
- Each cell contains:
  - Own coordinates
  - Neighbours coordinates
  - Previous cell coordinate in path
  - Presence of walls in 4 directions
  - Cost values for search algorithms

Search algorithms

- Flood Fill
- A*

A* Algorithm

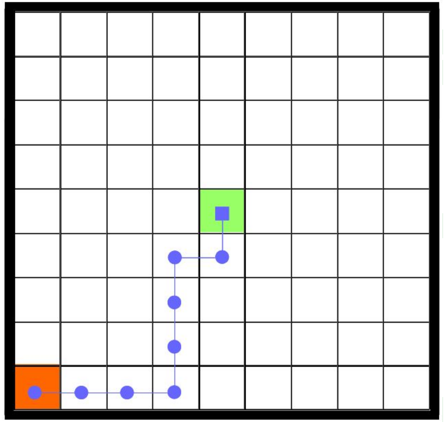
Slightly modified from typical A* implementation

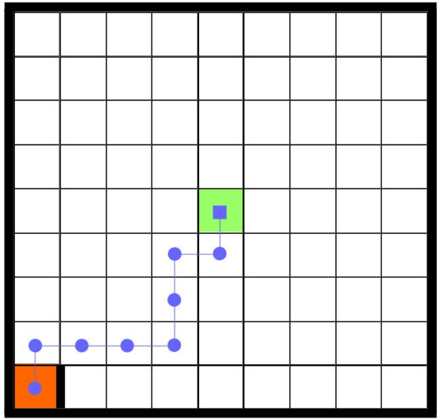
On initialisation:

- Algorithm will compute as if no obstacles in the maze except for maze boundaries

Upon moving:

- Continuous update of internal map grid when a wall is detected (either basic / preemptive)
- Algorithm will re compute to find new path, returning the next coordinate in path





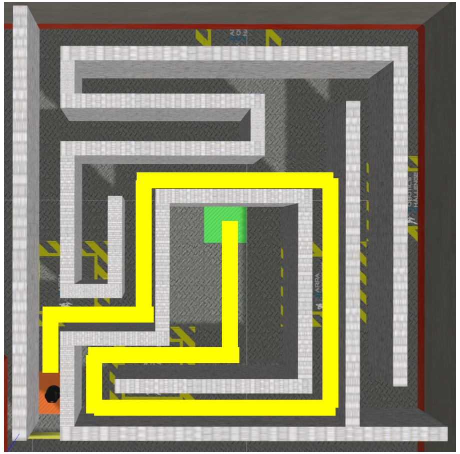
Performance Analysis

World 1

- Cleared with shortest possible route
- Average time to goal: ~50s
- Failure Rate: 0

World 2

- Cleared with shortest possible route
- Average time to goal: ~100s
- Failure Rate: 0



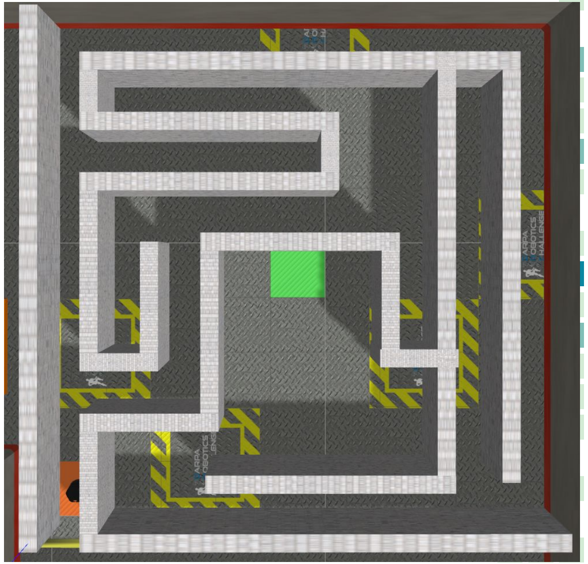
Performance Analysis

Custom World

- Worst case test of multiple dead ends
- Cleared after U-Turning at dead ends
- Average time to goal: ~2200s
- Failure Rate: 0

Most complicated world compared to Worlds 1 and 2

Proves algorithm implemented is able to recover from dead ends and still reach goal



Conclusion

Potential Improvements

- Smoothing turns to allow the robot to continue moving around a corner instead of stopping and rotating
- Allowing for diagonal grid motion

Knowledge Gained

- Understanding how to sync modules
  - Movement controller: Controls robot movement
  - Algorithm: Search for path and provide the next coordinate for Movement Controller
  - Sensors: Provide info for algorithm path planner

DEMONSTRATION

Known Environment (World 2)

DEMONSTRATION

Unknown Environment