Robot Localization with ROS: Final Presentation (Steps 1–3)

Mini-Project 1 Final Report

Nicholas Birch de la Calle (IST1116701)
Antonio Maria Trigueiros de Aragão Moura Coutinho (IST196837)
Gabriel Badan (IST1116537)
Janaína da Silva Pacheco (IST1117233)

Instituto Superior Técnico

September 24, 2025

Outline

Scope for This Week

- **Step 1 :** Compared `odom` and `filtered odometry` against mocap ground truth and evaluated the error
- **Step 2 :** Built a map from the real robot; created a playback `.bag`
- **Step 3 :** Navigation on the built map with AMCL and Monte Carlo Localization

Our Method: EKF Sensor Fusion

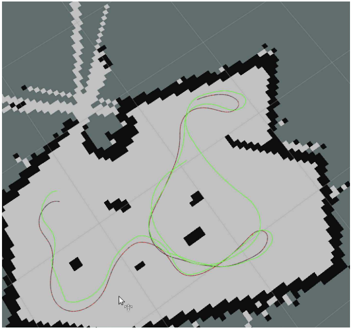
- We used **Extended Kalman Filter (EKF)** to combine:
  - Wheel odometry (where the robot thinks it is)
  - IMU data (robot's rotation and acceleration)
  - Ground truth at 1Hz (like GPS corrections)
- Compared 3 trajectories: Raw sensors vs EKF vs True path
- Measured errors in real-time (around **110mm average**)

Real-World Application

This simulates indoor robots using periodic position updates from WiFi/beacon systems

What We Achieved

- **Three trajectories** visualized in real-time:
  - Blue: Raw wheel sensors
  - Red: EKF filtered (our system)
  - Green: True robot position
- **Error measurement:** 110mm average
- EKF successfully fuses all sensor data



Three-way comparison showing our EKF system performance

How gmapping Works

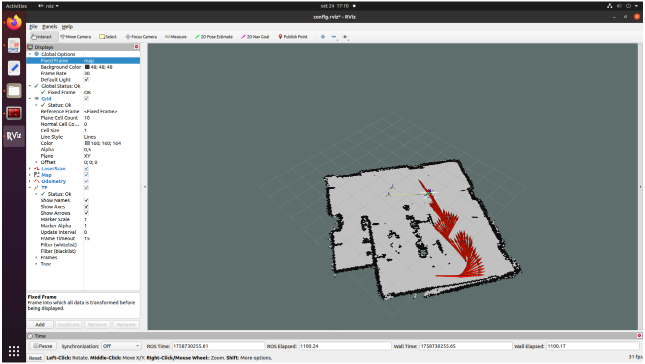
- **gmapping = SLAM algorithm** (Simultaneous Localization and Mapping)
- Uses **particle filter** where each particle represents a possible robot path
- Each particle builds its own version of the map as it moves
- **Laser scans** detect walls and obstacles
- **Wheel odometry** estimates robot movement between scans

The Process

1. Robot drives around unknown environment
2. Laser continuously scans surroundings (360°)
3. Algorithm builds map while tracking robot position
4. Final result: Complete occupancy grid map

Building the Map

- Built the map using **live data collection** with the TurtleBot3 robot
- Used gmapping SLAM to create occupancy grid from laser scans
- Robot navigated the lab environment while simultaneously mapping
- Generated map saved for subsequent localization experiments



What is AMCL?

- **AMCL = Adaptive Monte Carlo Localization**
- Uses **particle filter** to find robot position on the map
- Combines laser scans + odometry + map to localize
- Each particle represents a possible robot position

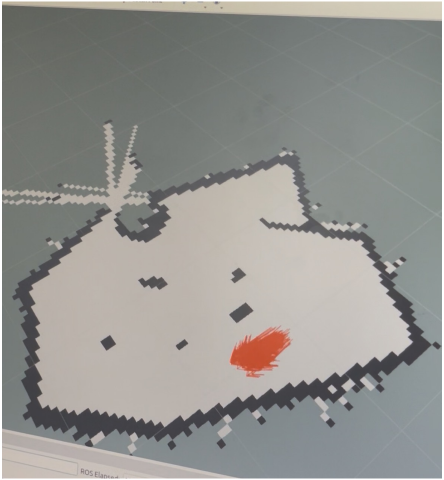
How it Works

1. Scatter particles across the map (possible positions)
2. Compare laser scans with map at each particle location
3. Keep particles that match well, remove bad ones
4. Converge to the most likely robot position

AMCL Implementation Results

- Successfully implemented AMCL localization
- Particle filter **converges** to correct position
- Robot accurately tracked on the map
- System ready for navigation tasks

Next Step: Autonomous navigation with waypoint following (future work)



AMCL particle cloud localizing the robot on the map

Project Summary

What We Accomplished

✓ **Step 1:** EKF sensor fusion with 110mm average error
✓ **Step 2:** Used professional dataset map
✓ **Step 3:** AMCL localization successfully implemented

Key Technical Achievements

- Multi-sensor fusion (odometry + IMU + ground truth at 1Hz)
- Real-time error measurement and visualization
- Particle filter localization on pre-built map
- Complete ROS navigation stack integration

Thank you for your attention!

Questions?