UNIVERSITÀ DEGLI STUDI DI URBINO CARLO BO

Dipartimento di Scienze Pure e Applicate

Corso di Laurea in Informatica Applicata

Presentazione

Realizzazione di un sistema per la pulizia automatica basato su Internet of Robotic Things

Progetto di Programmazione per l'Internet of Things

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Contents

Introduction

Internet of Things (IoT)

- Internet of Things (IoT) devices exchange data with other devices across the Internet or other communication networks.
- Enables monitoring, control and automation of physical systems.

Internet of Robotic Things (IoRT)

- Extension of IoT where robots become active nodes.
- Robots not only sense and communicate, but also act and adapt to the environment.

Introduction

Problem

Commercial cleaning robots (e.g. Roomba) are limited:

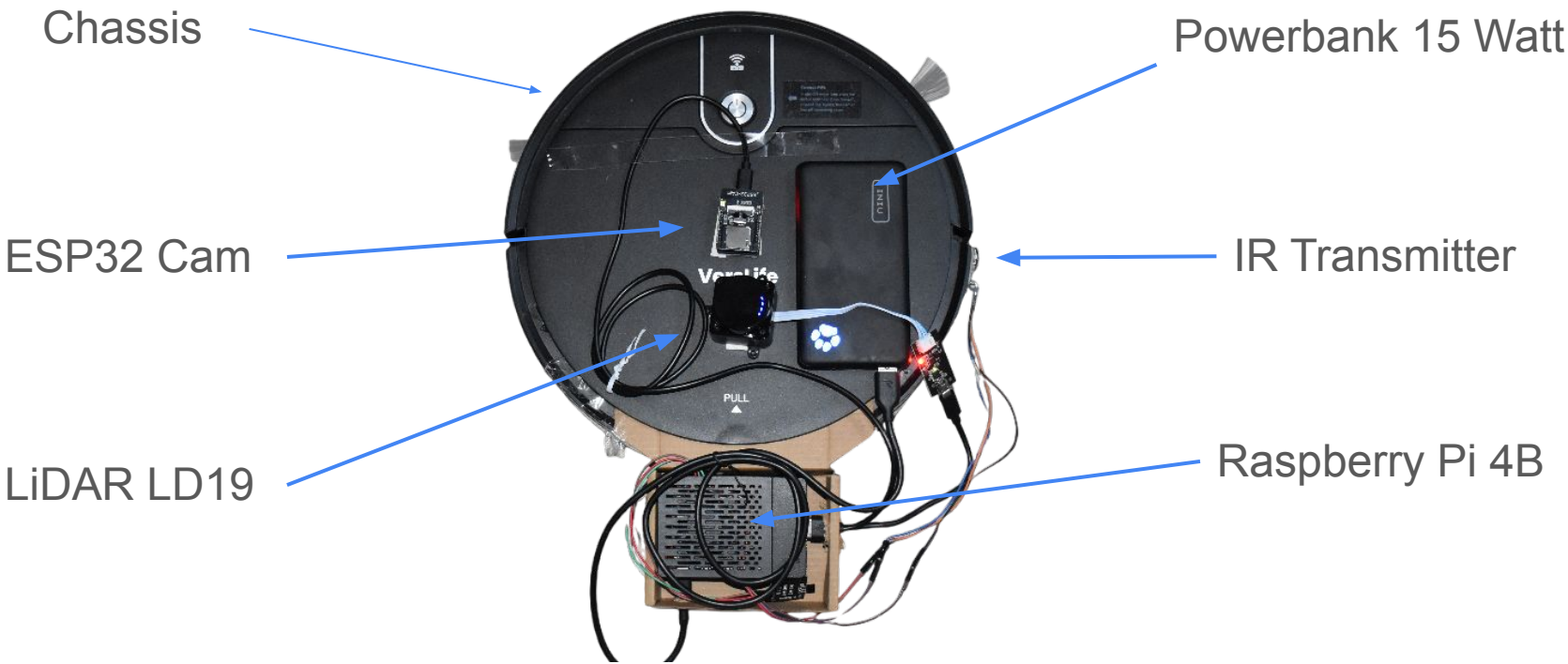
- Limited integration with IoT ecosystems.
- Closed platform.

Objective

Modify a cheap cleaning robot in order to:

- Extend its capabilities.
- Integrate it inside an IoRT system.

Robot Hardware Design

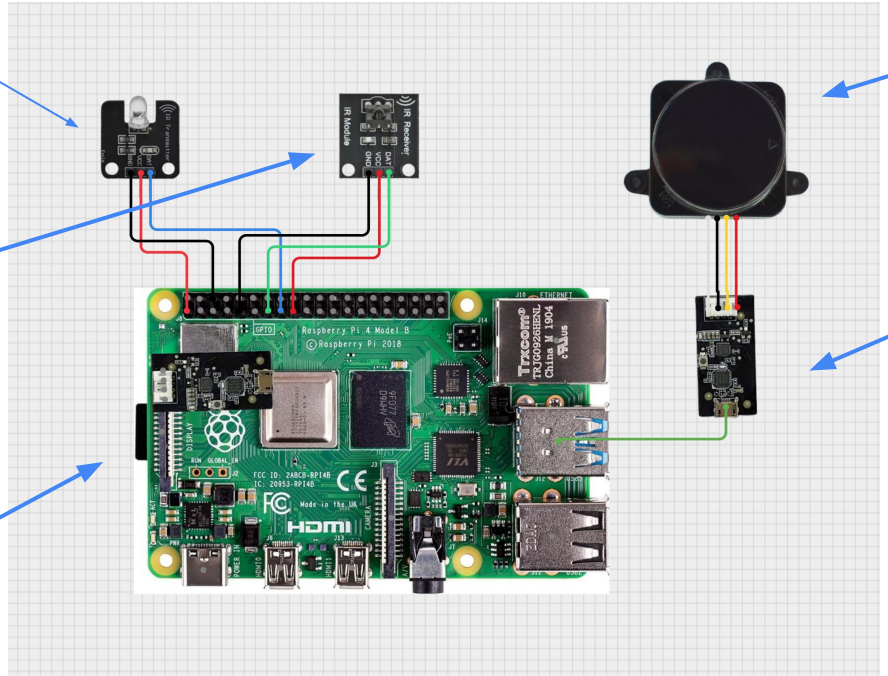


Robot Hardware Design

IR Transmitter

IR Receiver

Raspberry Pi 4B



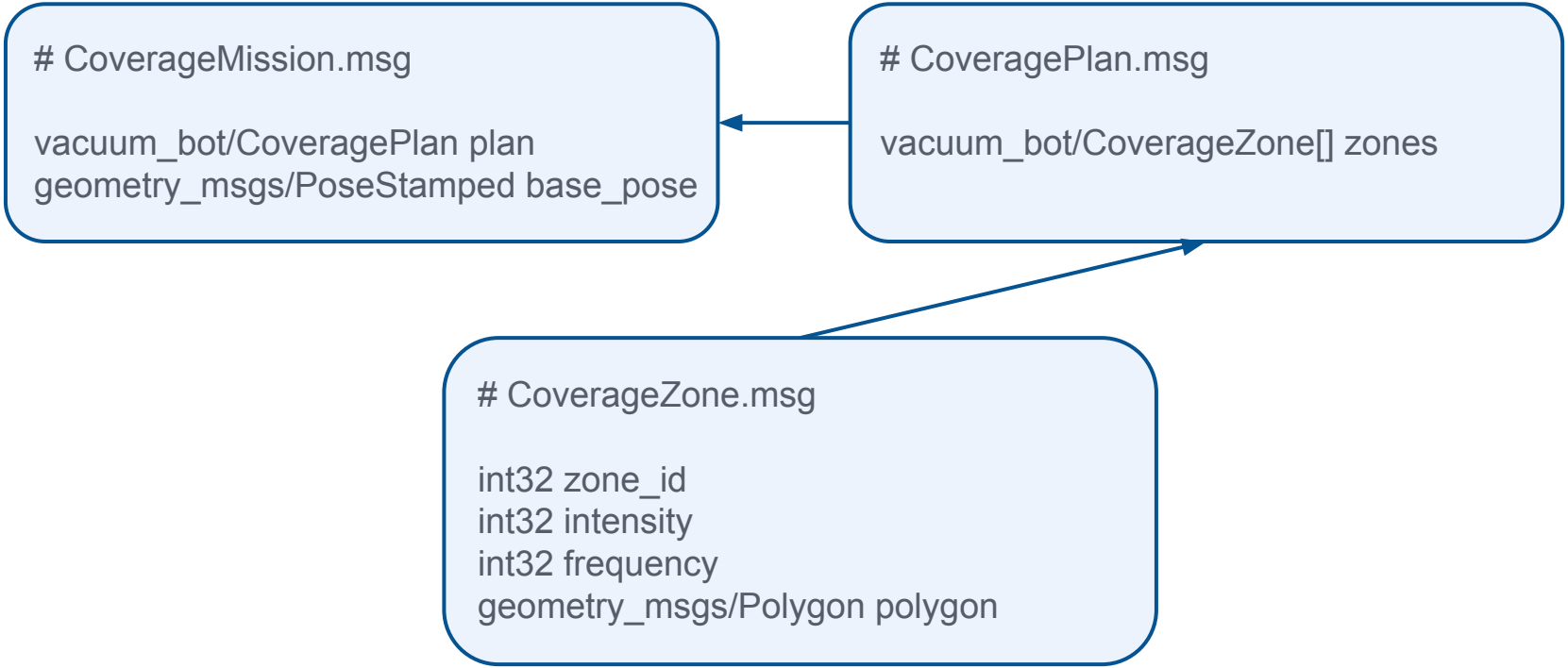
LiDAR LD19

UART to USB adapter

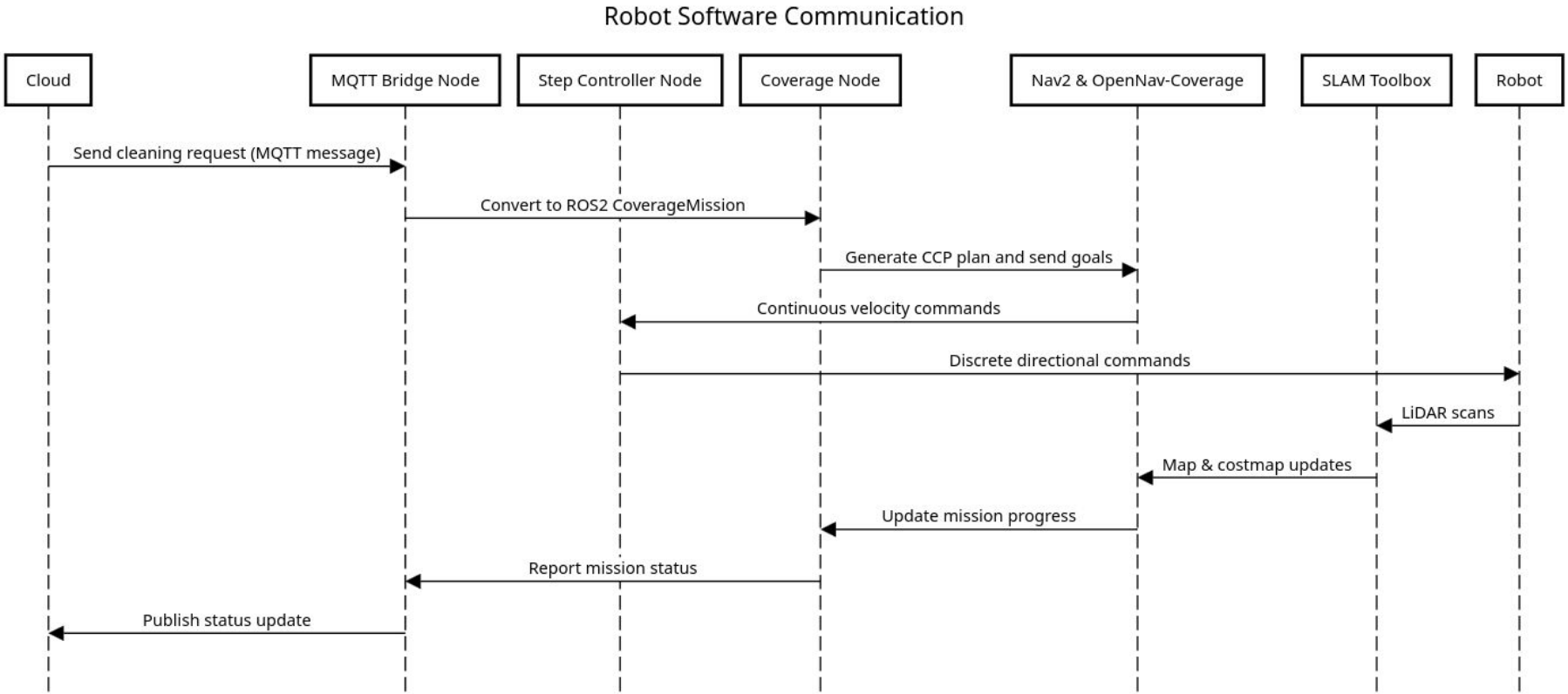
ROS2 Software Stack

- Step controller node: maps continuous velocity commands from Nav2 to discrete directional commands.
- MQTT bridge node: converts MQTT messages to ROS2 messages, and viceversa.
- Coverage node: accepts a CoverageMission message and create a CCP plan.
- Nav2 & Opennav-Coverage: libraries to navigate autonomously and follow a CCP plan.
- SLAM Toolbox: generates and publishes a map and costmap based on the LiDAR scans.

CoverageMission Custom Message

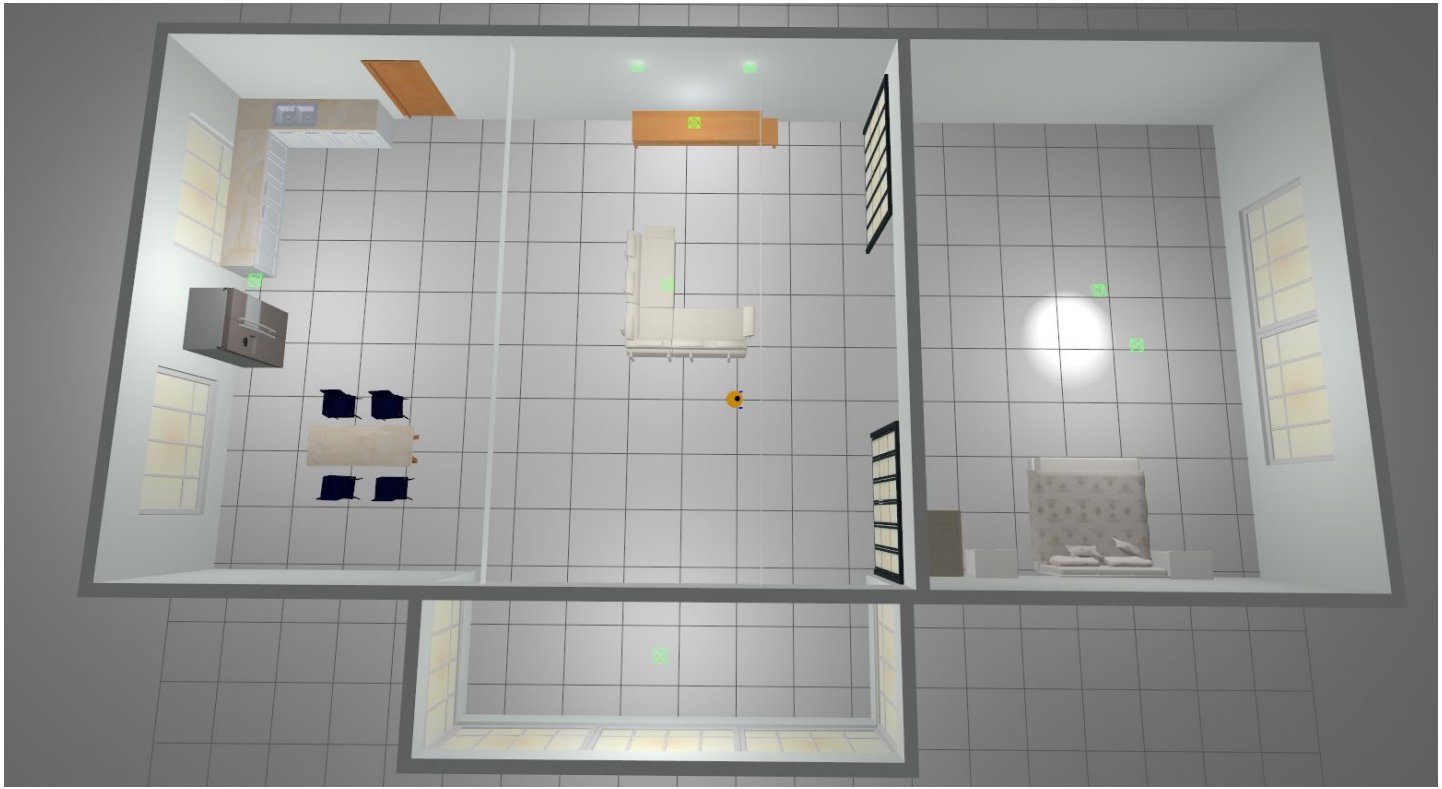


ROS2 Internal Communication



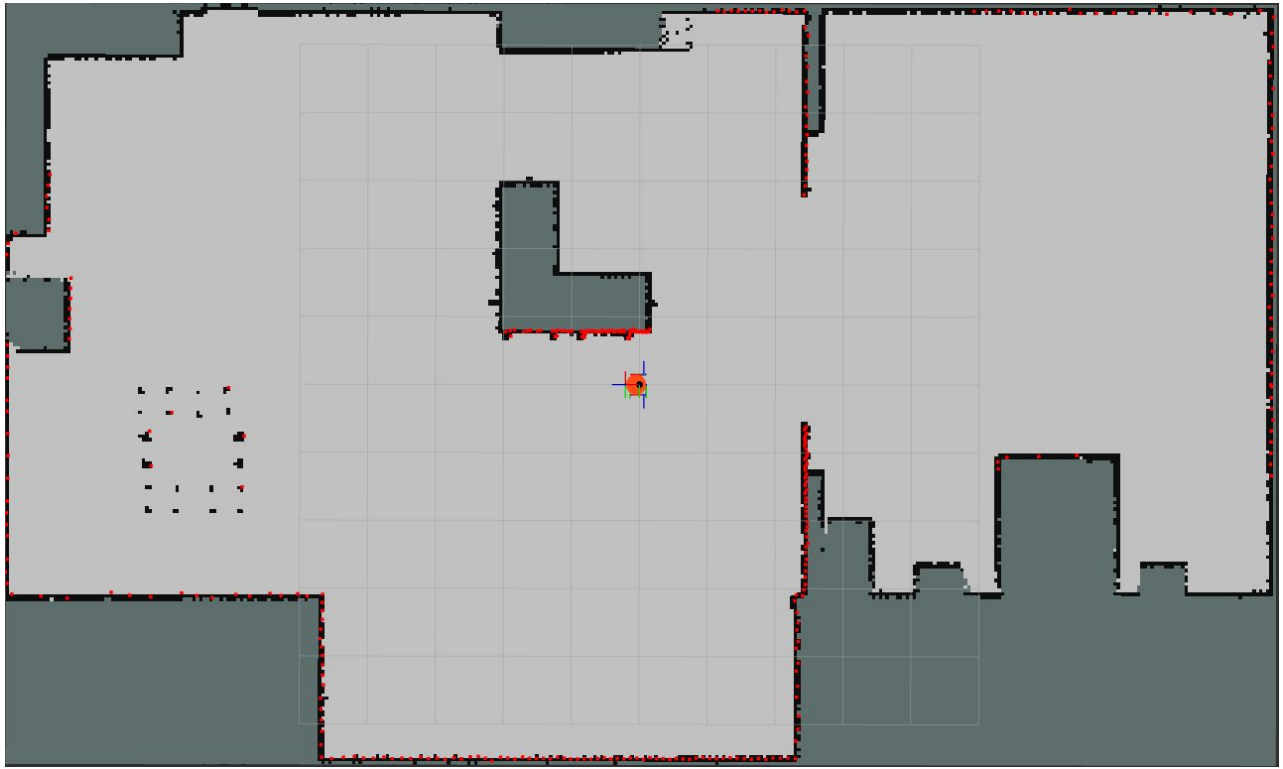
Simulation Software: Gazebo

What the robot **sees**.

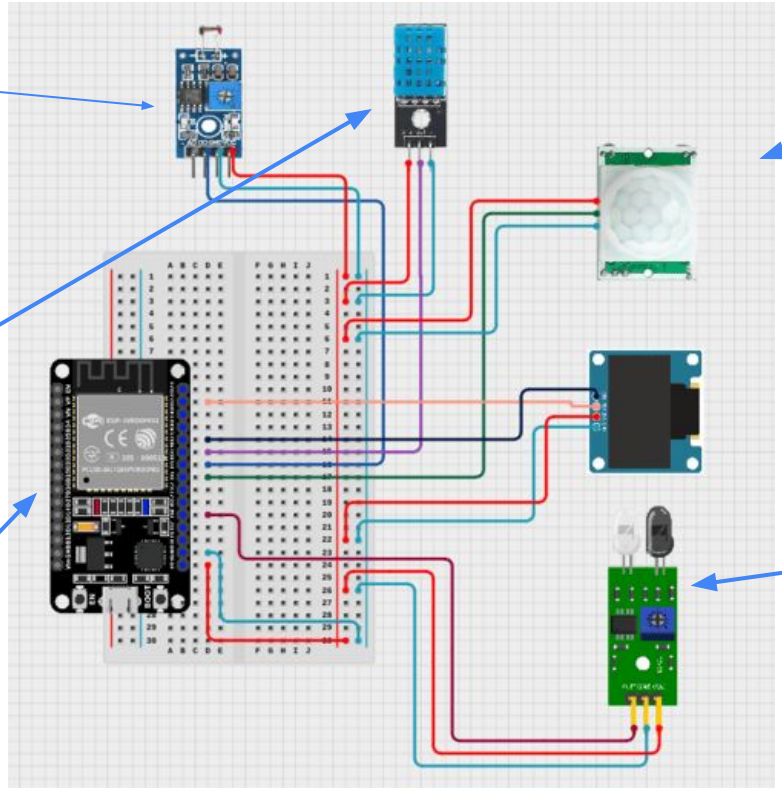


Visualization Software: Rviz

What the robot **thinks**.



IoT Environmental Sensing



Light sensor

DHT11 Humidity sensor

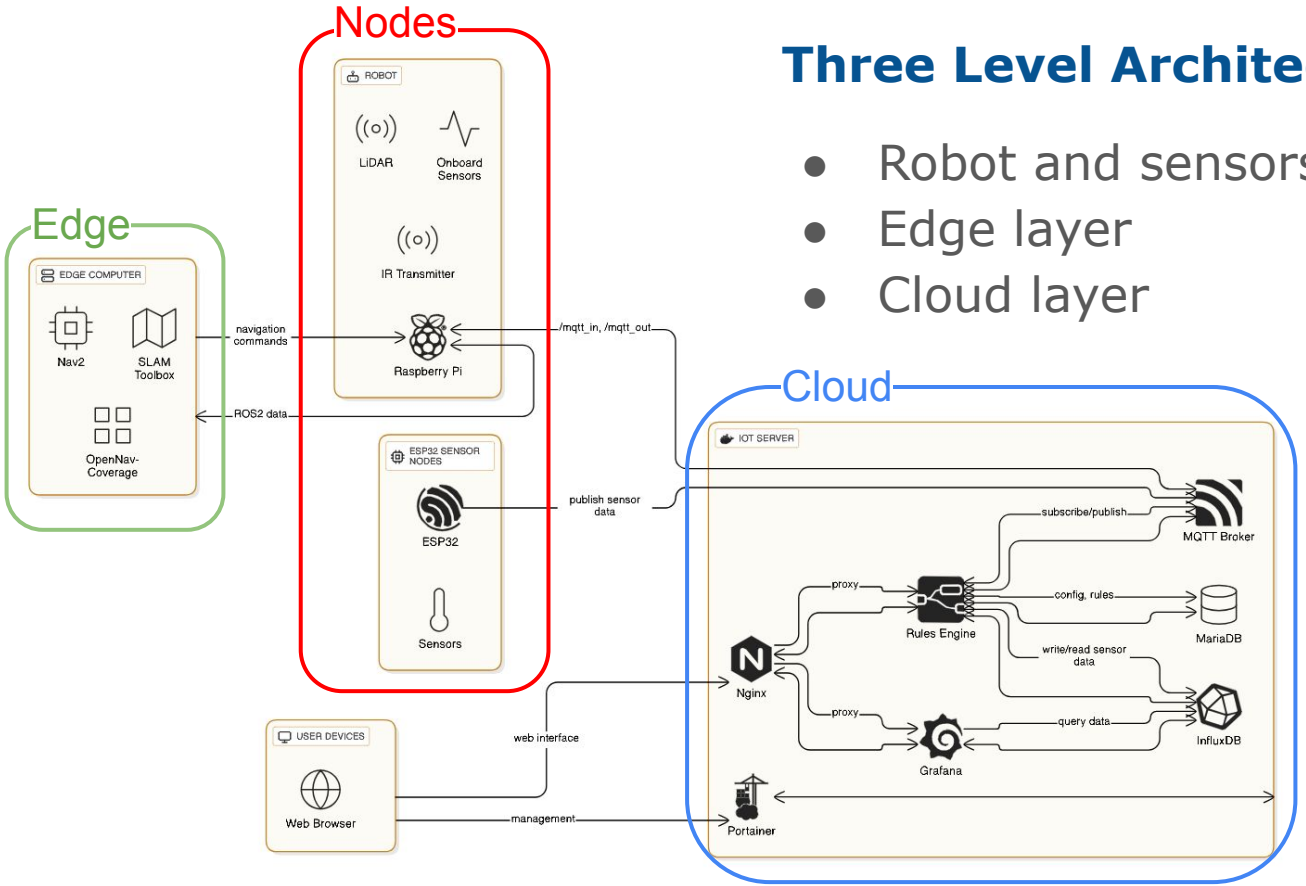
ESP32 Devkit

PIR sensor

OLED Display

IR Proximity sensor

IoRT System Design



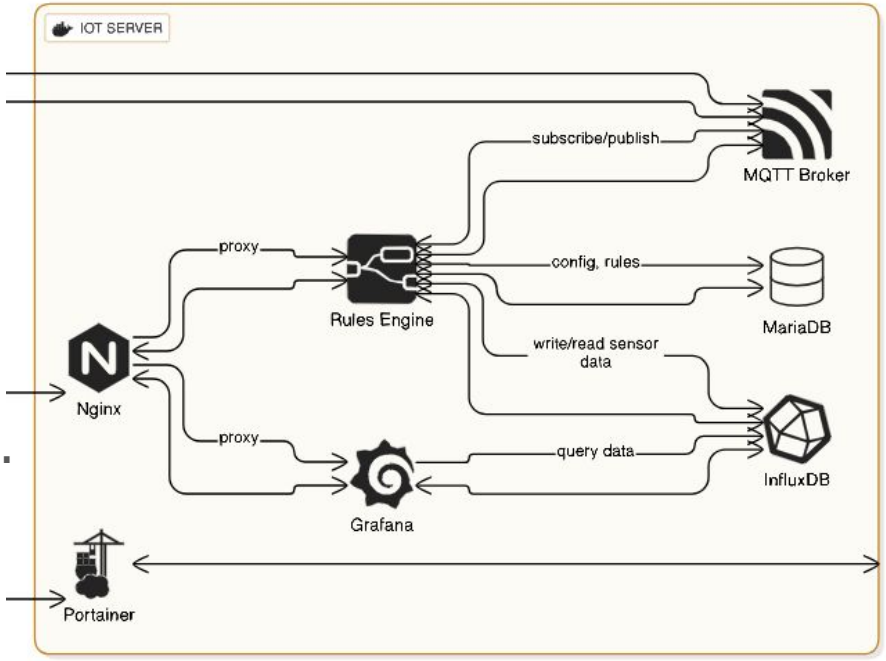
Three Level Architecture:

- Robot and sensors layer
- Edge layer
- Cloud layer

Docker Containers

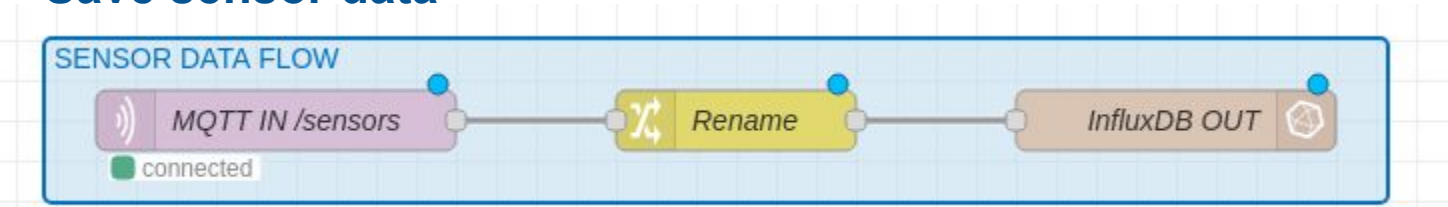
Containers

1. Node-RED: data flow management.
2. Mosquitto: MQTT broker.
3. InfluxDB: saves sensor data.
4. Grafana: visualizes sensor data.
5. MariaDB: save user configurations.
6. Nginx: reverse proxy and web server.
7. Portainer: containers dashboard.

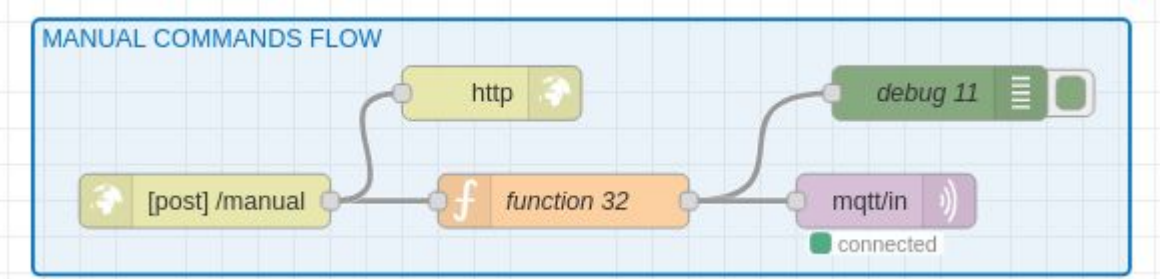


Node-RED Flows (1)

Save sensor data

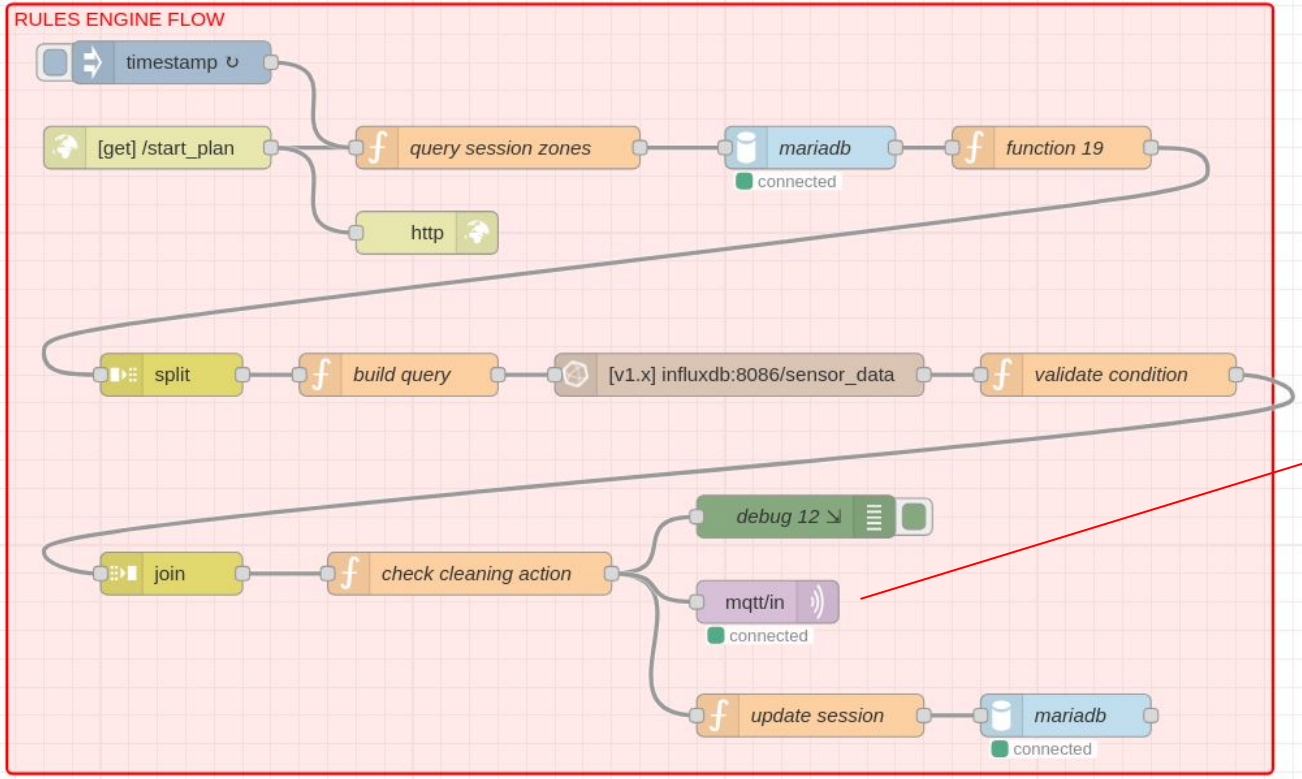


Proxy robot manual commands



Node-RED Flows (2)

Check cleaning sessions and rules

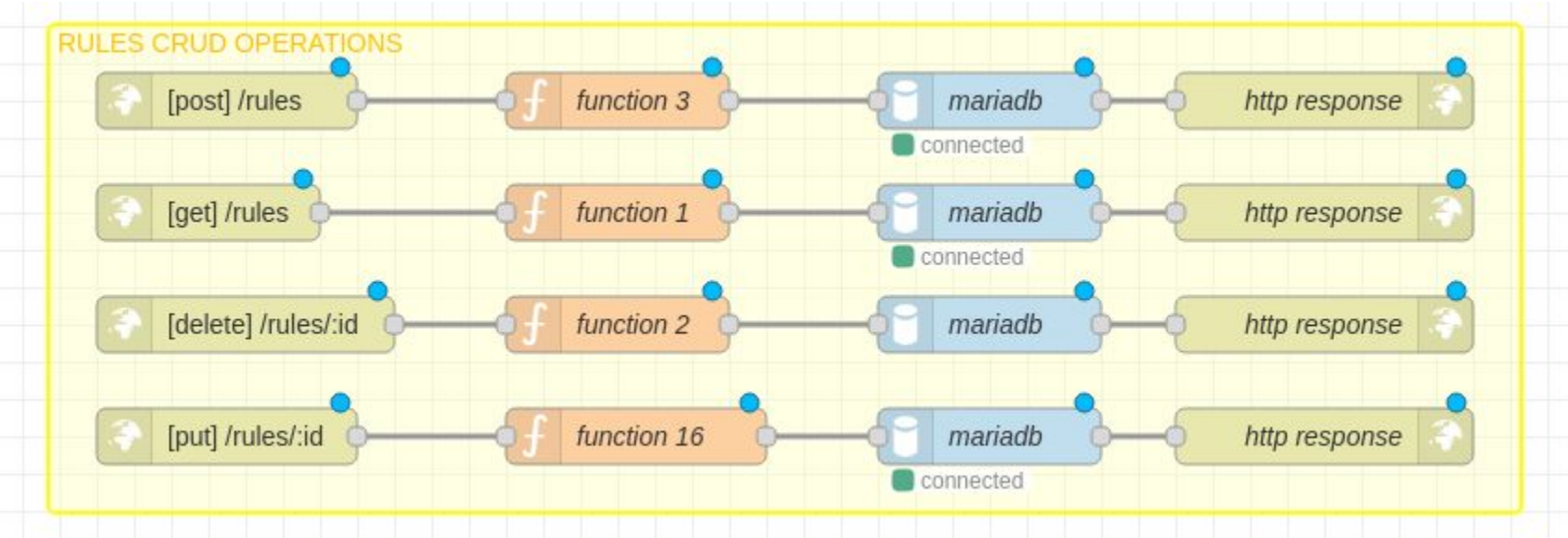


JSON Plan Message

```
{
  "type": "plan",
  "zones": [
    {
      "zone_id": 2,
      "intensity": 1,
      "frequency": 1,
      "ros_points": [...]
    },
    ...
  ],
  "ros_base_pos": {
    "x": -1.62,
    "y": -5.11
  }
}
```

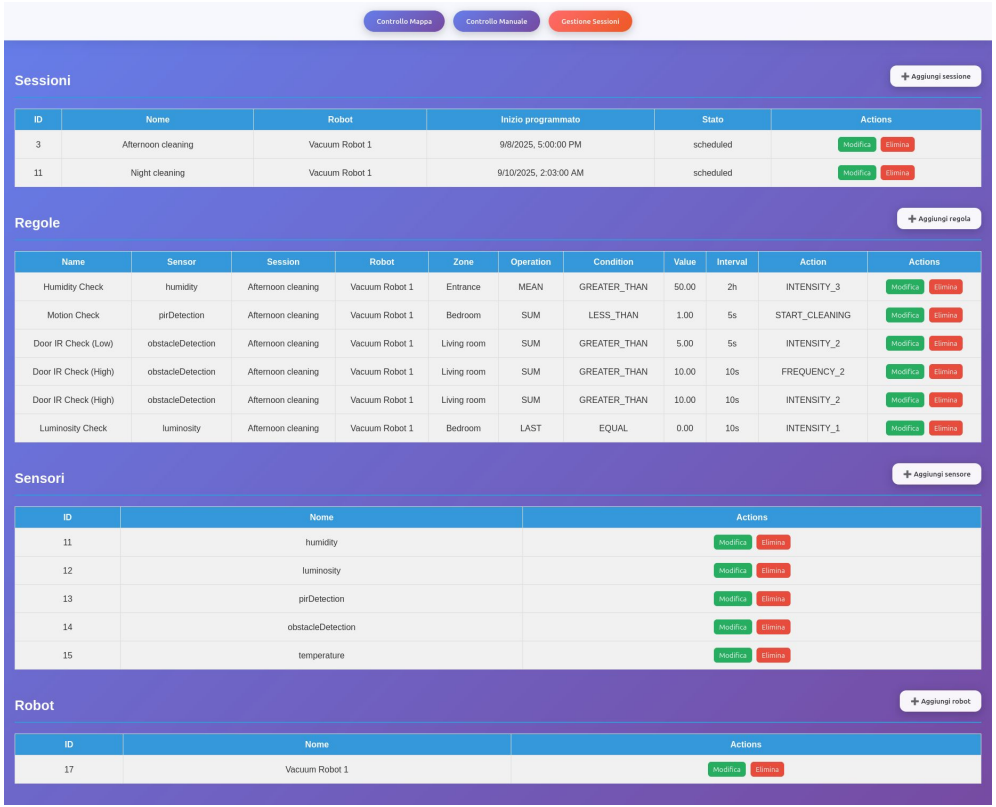
Node-RED Flows (3)

CRUD operations



Web Interface: Map Control Page

Web Interface: Sessions Page



Use Cases

- Motion detection: start cleaning when the room is empty (no PIR detections).
- Adapt to weather conditions: use humidity readings to try and predict raining conditions. Increase intensity near entrance.
- Room activity level: increase cleaning intensity if door passages cross over a user defined limit.
- Night mode: use minimum intensity when light goes below a certain threshold to not disturb sleep.

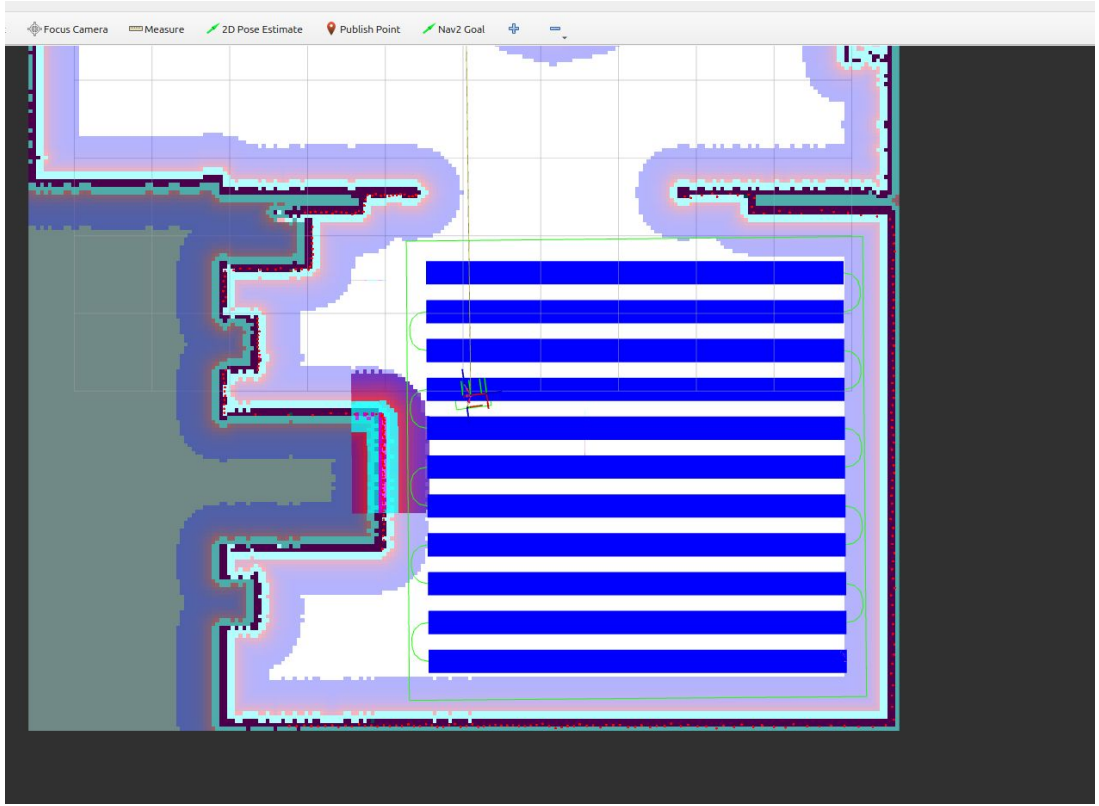
Results

No PIR detections in the time period.

START CLEANING.

First room: Bedroom.

Default intensity and frequency levels.

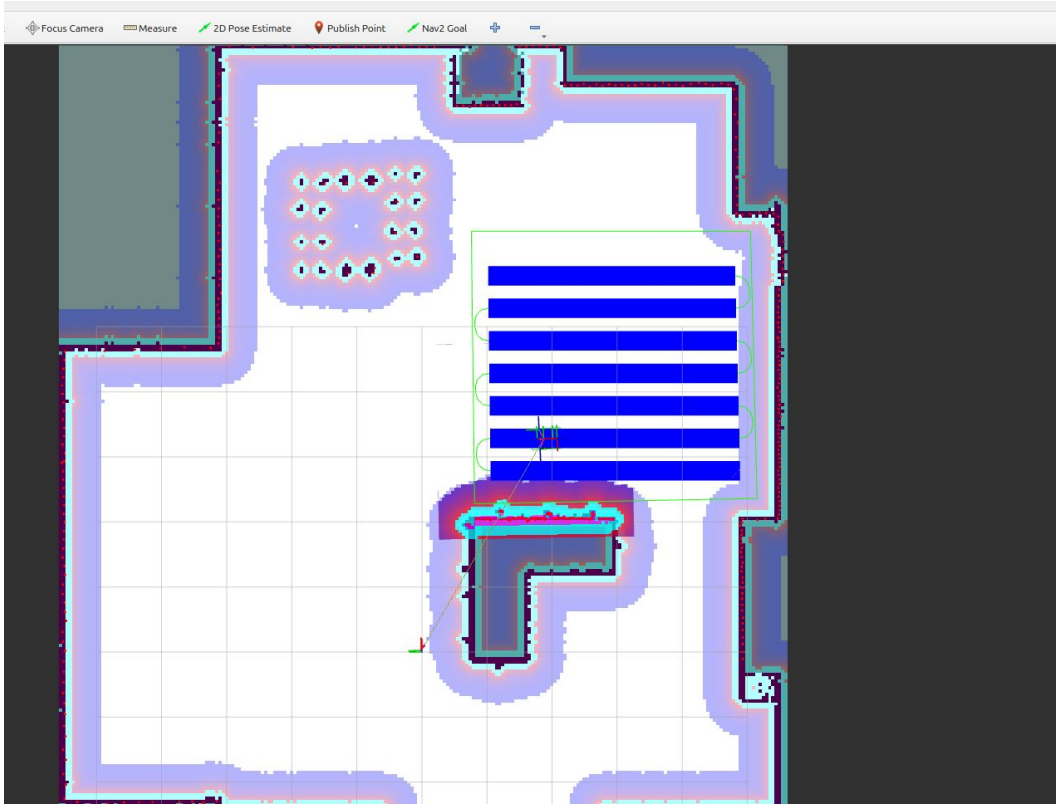


Results

Second room:
Entrance.

Humidity level greater than threshold.

INTENSITY = 3.

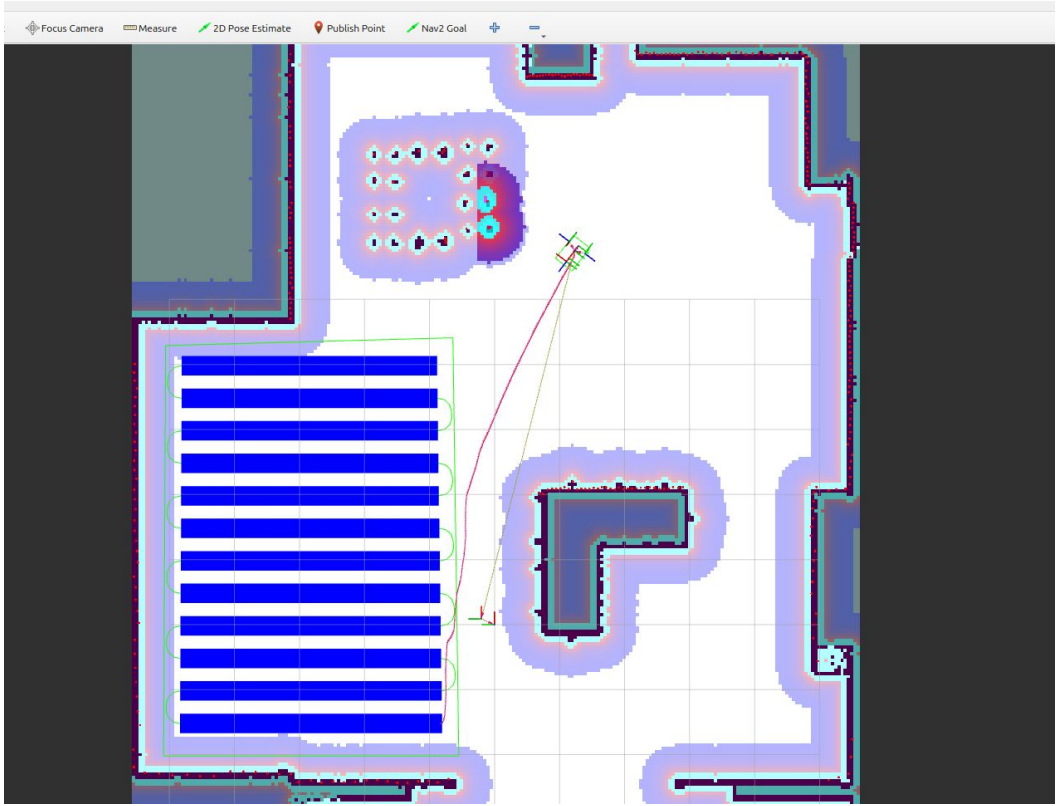


Results

Third room:
Living room.

Number of passage detections greater than threshold.

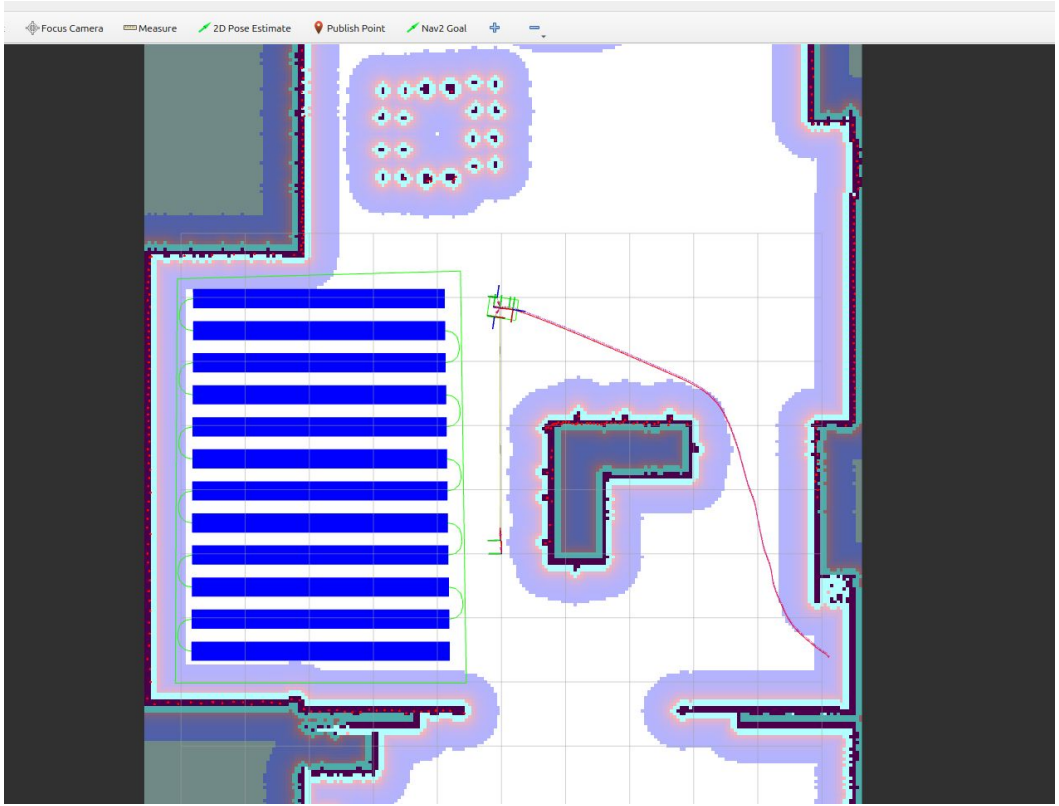
INTENSITY = 3.
FREQUENCY = 2.



Results

No more rooms.

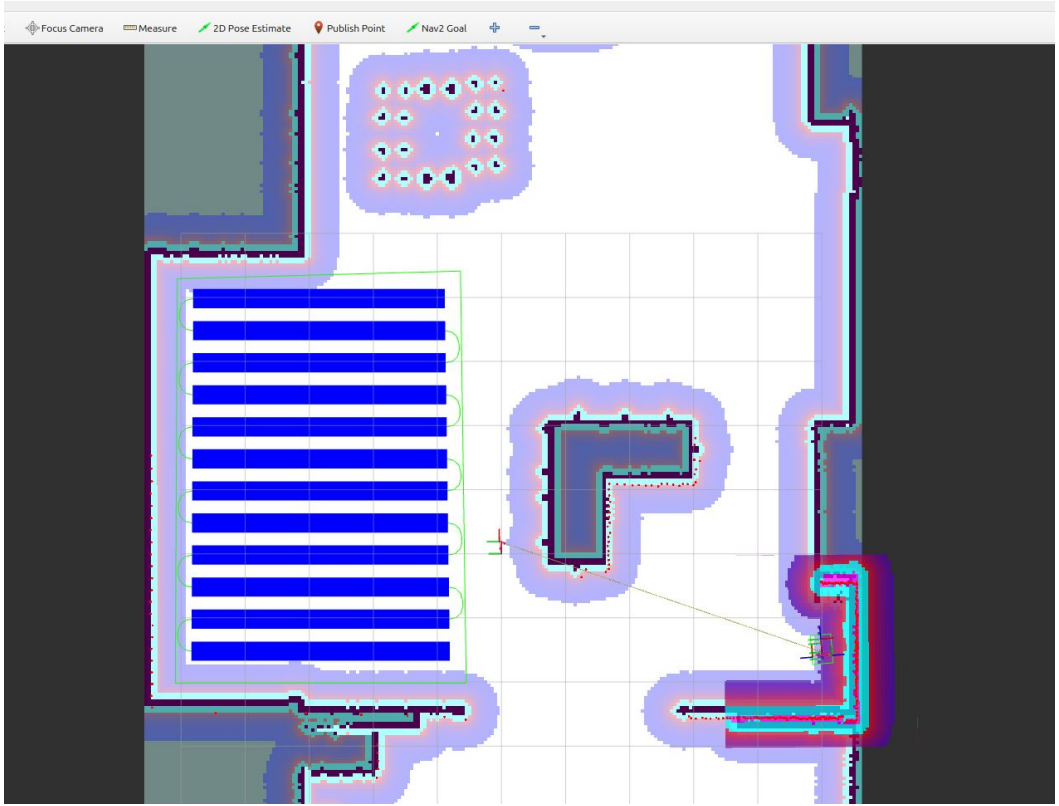
RETURN TO BASE.



Results

Reached base station.

STOP.



Conclusion and Future Work

Conclusions

- Demonstrated the IoRT paradigm applied to automated cleaning.
- Enhanced a low-cost vacuum robot with additional components and ROS integration.
- Developed a system for event-based cleaning rules.

Future directions

- Machine learning for context-aware cleaning (e.g., RL).
- Multi-robot collaboration.
- Explore more resilient protocols (LoRa, ZigBee, 5G).

Thanks for the attention