



AMR for infrastructure assistance

Tested in: Road maintenance - highway near Gran Sasso Nord, Italy

Ivan Villaverde de la Nava, TECNALIA

AMR for infrastructure maintenance

Summary

- Objectives:
 - Mobile robot able to drive autonomously in an outdoor road environment.
 - Measure retroreflectivity of horizontal signals.
 - Communicate with DT.
- Tasks
 - Develop a mobile robot able to operate in outdoor roads.
 - Outdoor navigation capabilities.
 - Integration of a retroreflectometer.
 - Accurate positioning over horizontal signals.
 - Communication with DT for data and commands.

AMR for infrastructure maintenance

Vehicle - Sensor and systems integration

Sensor and systems integration.

- Sensors:
 - GPS for outdoor global positioning (CGI-410 RTK GNSS).
 - Custom ROS driver.
 - IMU for inertial navigation (Integrated into CGI-410).
 - Custom ROS driver.
 - 3D LiDAR for outdoor mapping/localization and obstacle detection (x2 Robosense RS16).
 - 2D LiDAR for safety (x2 Sick OutdoorScan3).
 - Optical cameras for horizontal signs detection and teleoperation (2x Backfly S).



AMR for infrastructure maintenance

Vehicle - Sensor and systems integration

Sensor and systems integration.

- Systems:
 - CAN interface.
 - Custom ROS CAN interface.
 - Odometry by CAN and RTK fusion.
 - Communications.
 - Ethernet (Cisco 110 switch): Devices and sensors interconnection.
 - WiFi, 4G/5G (Teltonika RUTX50 5G): DT communications and remote monitoring and teleoperation.
 - Bluetooth (Dongle): Retroreflectormeter communications.

AMR for infrastructure maintenance

Vehicle - Retroreflectometer integration

Integration of the retroreflectometer

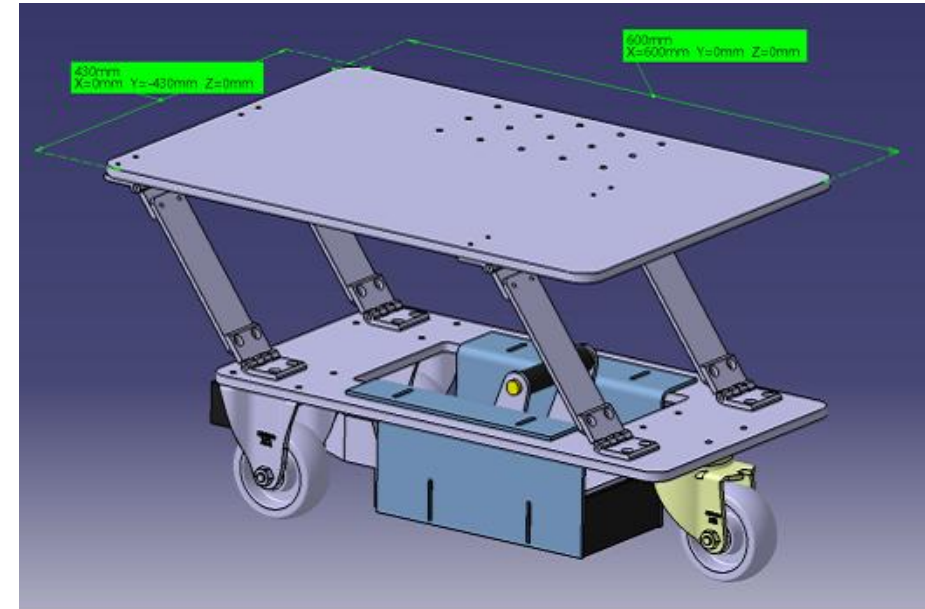
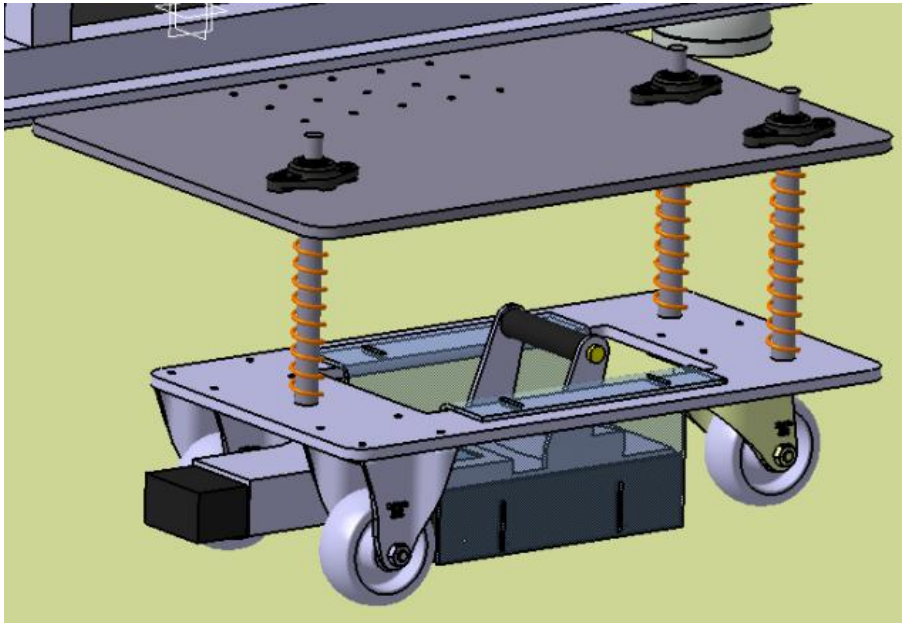
- Software:
 - BT connection.
 - Custom ROS driver.
- Hardware.
 - Very restrictive sensor placement requirements
 - 75 cm. measuring section.
 - 11 mm. max distance from floor.
 - Sensor had to be mounted externally due to required clearance.

AMR for infrastructure maintenance

Vehicle - Retroreflectometer integration

Integration of the retroreflectometer

- Early designs (cushioned).

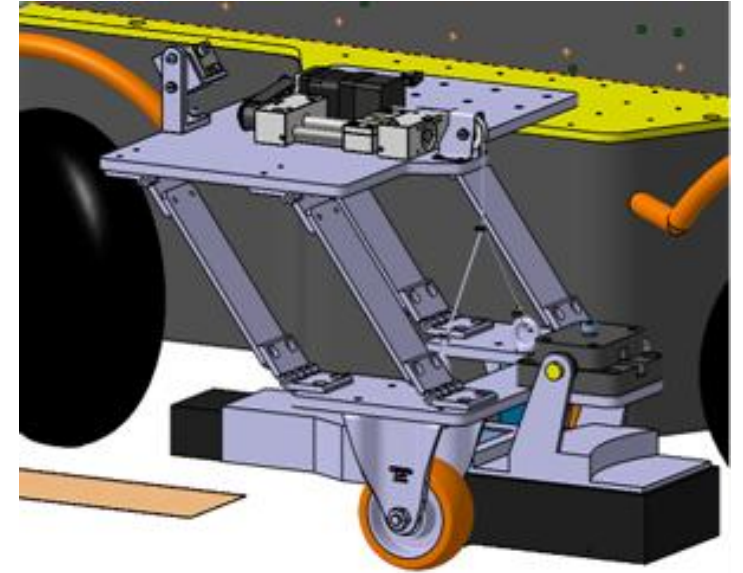


AMR for infrastructure maintenance

Vehicle - Retroreflectometer integration

Integration of the retroreflectometer

- Final design:
 - Liftable + cushioned platform.
 - Lifting mechanisms composed of pulley + spindle + NEMA stepper.
 - NEMA driver controlled via Ethernet.
 - Custom ROS driver.
 - Co-axial camera for visual servoing.
 - Resting wheels keep measuring distance and allow for low-speed movement.



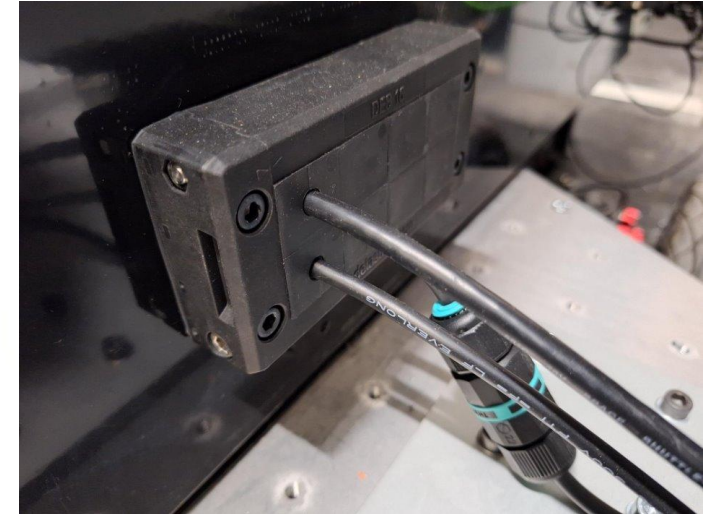
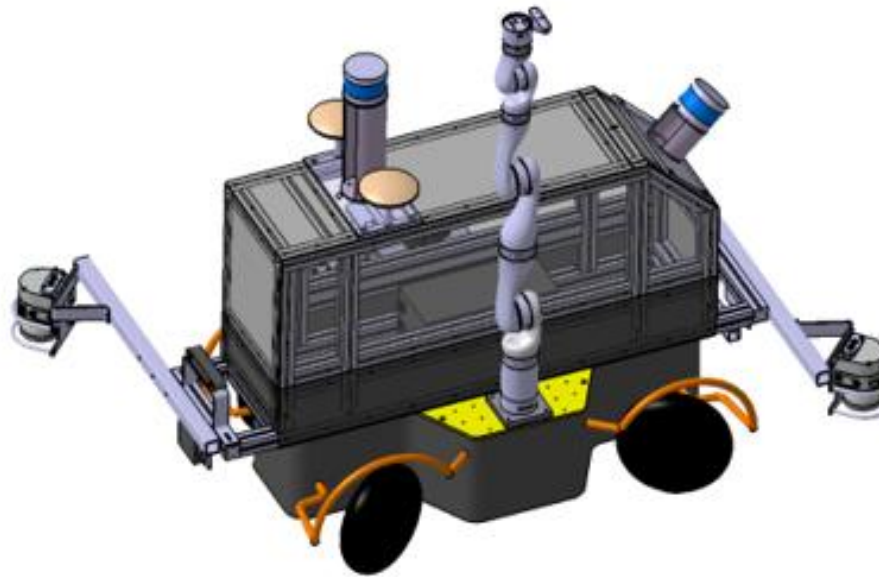
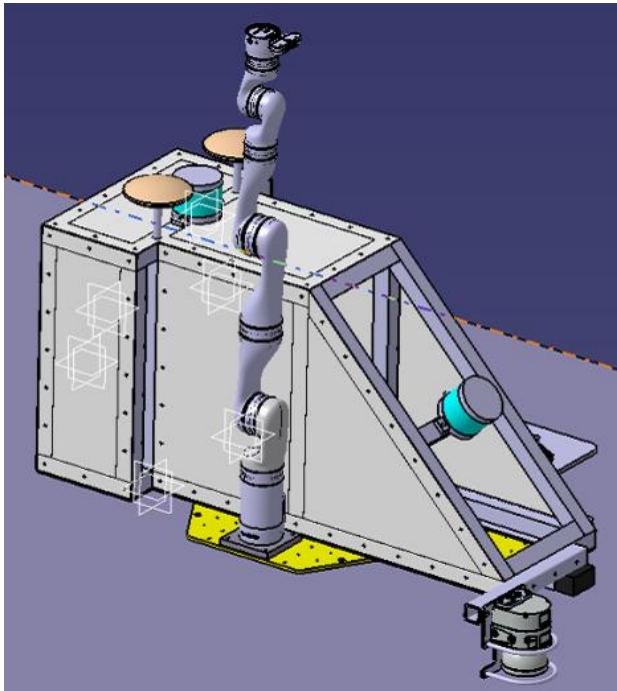
AMR for infrastructure maintenance

Vehicle - All-weather bodywork

- Offer protection to at least light rain.
- Enough space to hold all the equipment.
- Suitable placement for all the sensors.
- Easy access to the interior for maintenance.
- Must be removable “as a block” from the base platform.
- Weight / material cost balance.
- Provision enough space for mounting an optional lightweight arm like the Kinova Gen3.

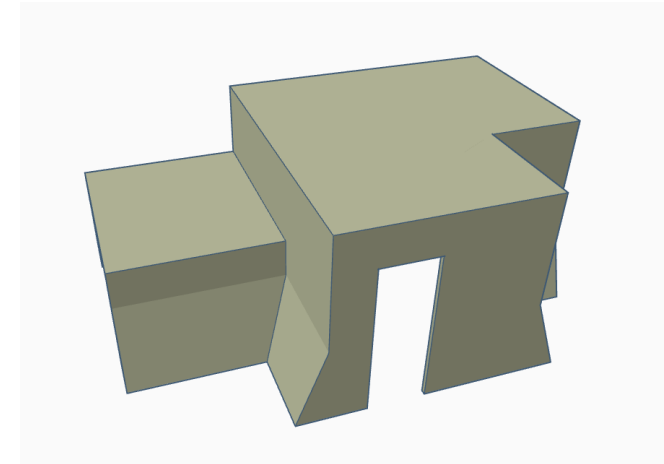
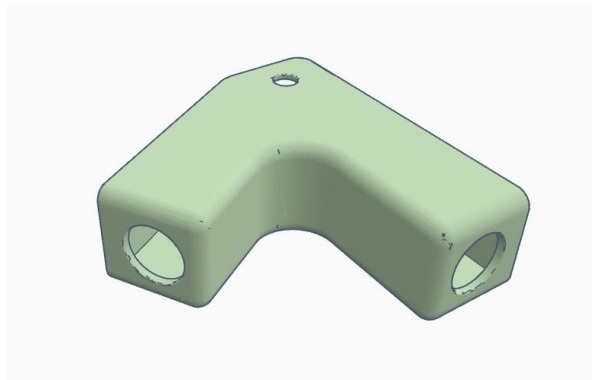
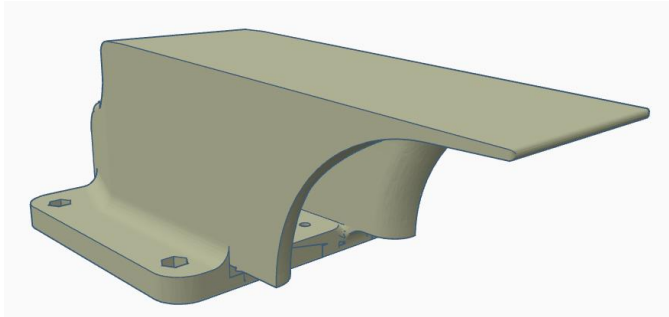
AMR for infrastructure maintenance

Vehicle - All-weather bodywork



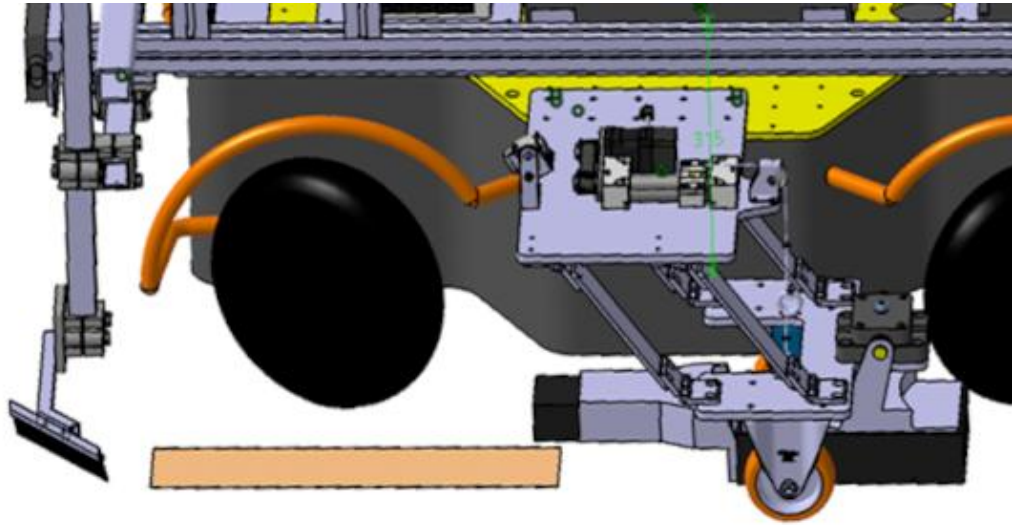
AMR for infrastructure maintenance

Vehicle - All-weather bodywork



AMR for infrastructure maintenance

Vehicle - All-weather bodywork



AMR for infrastructure maintenance

Vehicle - All-weather bodywork



AMR for infrastructure maintenance

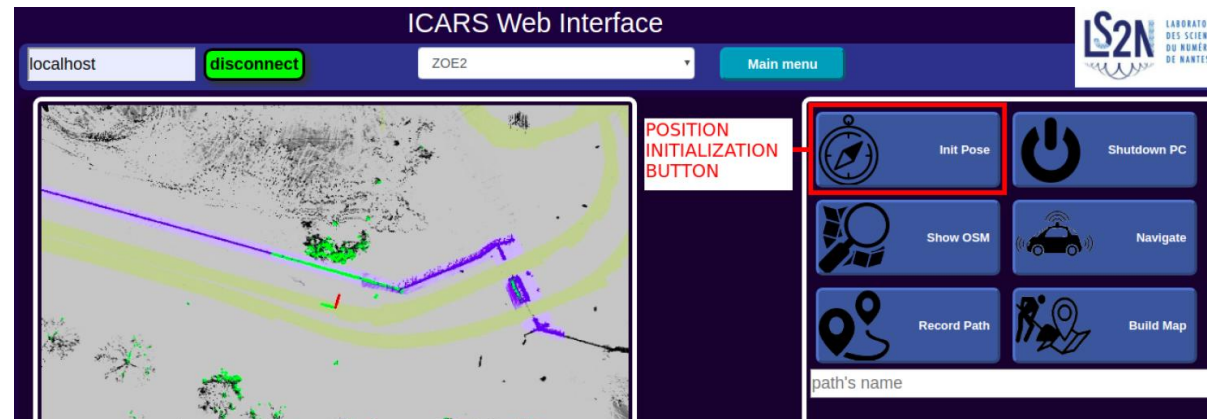
Autonomous capabilities – Outdoor navigation

- Outdoor localization:
 - Integration of other off-the-shelf navigation solutions.
 - Third party 2.5D navigation suite (LS2N ICARs).
 - Custom 3D navigation suite.
 - Pure GPS navigation.
 - System set-up to easily switch between systems.
 - UTM to AMR localization provided by GPS+inertial fusion (robot_localization using EKF).

AMR for infrastructure maintenance

Autonomous capabilities – Outdoor navigation

- 2.5D navigation suite (LS2N ICARS)
 - Commercial solution from the Laboratoire des Sciences du Numérique de Nantes (LS2N)
 - 3D LiDAR + GPS + IMU.
 - « Flatten » 3D scans to create 2D geo-localised maps.
 - Deployed previously in other projects.



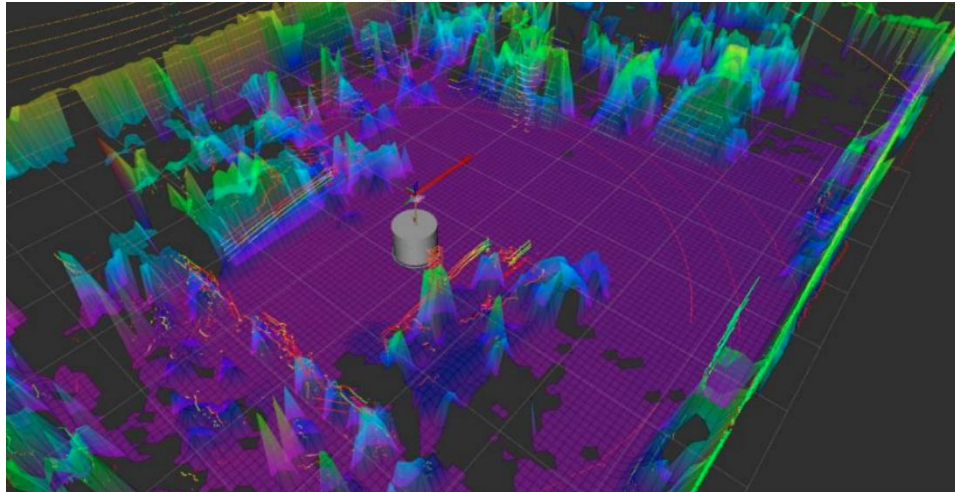
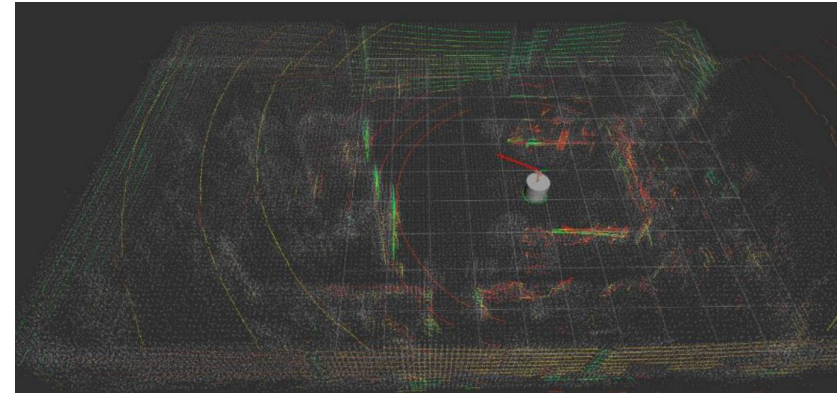
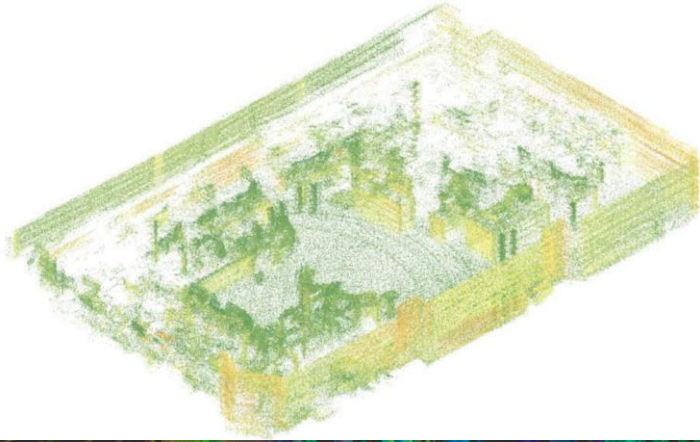
AMR for infrastructure maintenance

Autonomous capabilities – Outdoor navigation

- Custom 3D navigation suite.
 - 3D navigation suite compiled by TECNALIA in previous EC projects (ODIN, CLEANDEM).
 - Opportunity for testing in different environment.
 - Mapping module: LIO-SAM.
 - Localization module: HDL_Localization.
 - Planning: Grid maps + transitivity estimation + ROS stack.

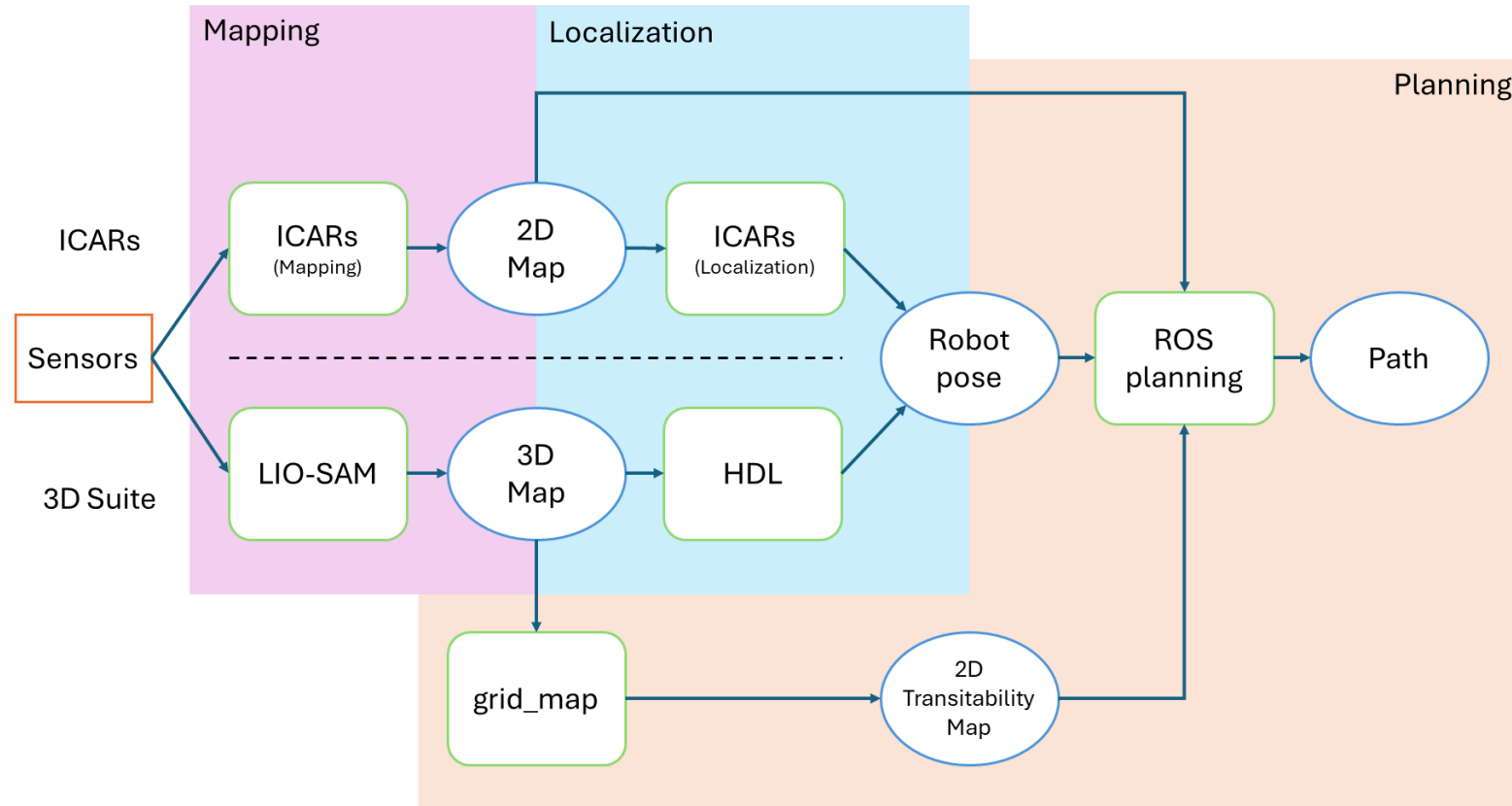
AMR for infrastructure maintenance

Autonomous capabilities – Outdoor navigation



AMR for infrastructure maintenance

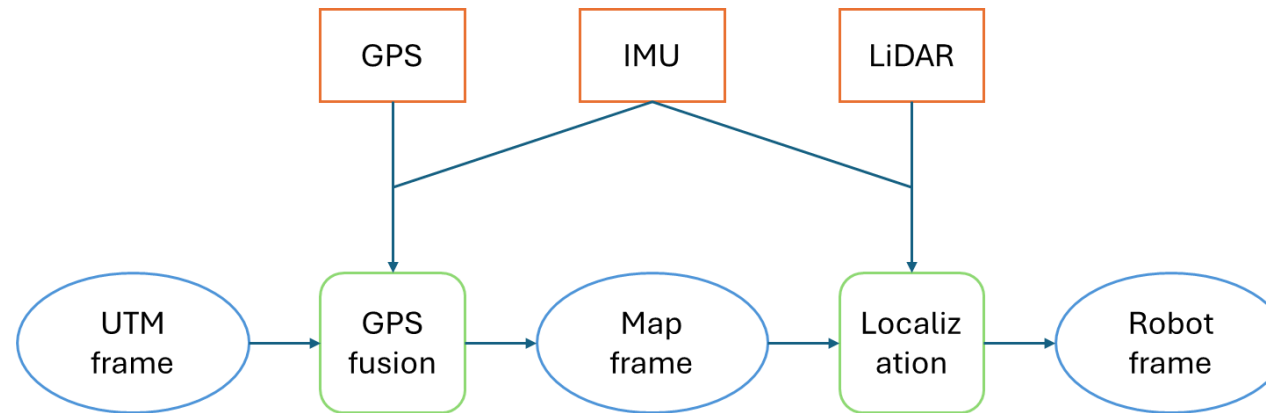
Autonomous capabilities – Outdoor navigation



AMR for infrastructure maintenance

Autonomous capabilities – Outdoor navigation

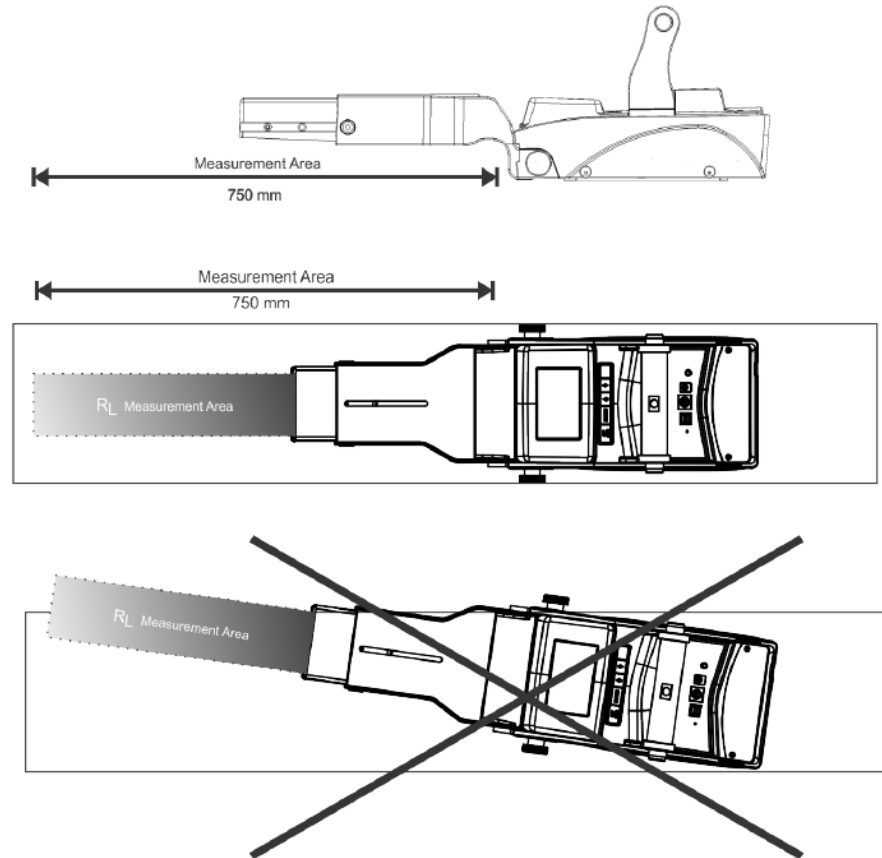
- GPS fusion
 - DT works on UTM, while AMR work on local map.
 - UTM → Map transformation required.
 - GPS integration using robot_localization.



AMR for infrastructure maintenance

Autonomous capabilities – Horizontal signs detection and sampling

- Tight requirements for accurate measurements.
 - Correct alignment.
 - Enough clearance in front of sensor.
- AMR must detect and align correctly the sensor over the line:
 - Detect the line.
 - Drive itself to correct position.



AMR for infrastructure maintenance

Autonomous capabilities – Horizontal signs detection and sampling

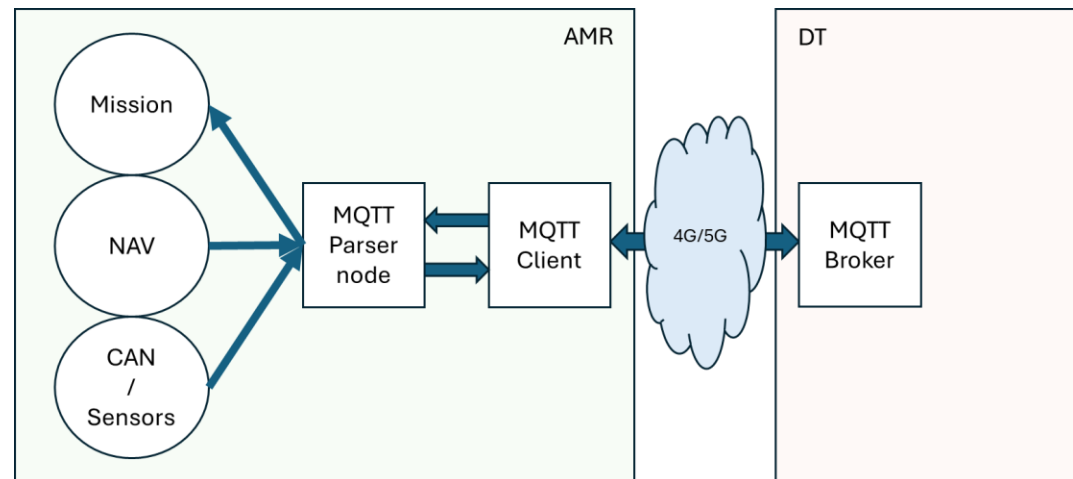
- Line detection:
 - Images from co-axial mounted camera.
 - Image preprocessing (resize, grayscale, Gaussian blur, background extraction).
 - Sign extraction (contour detection, approximation by polygonal shapes and bounding box extraction).
 - Output:
 - Base point (distance to centre)
 - Direction vector.
- Visual servoing steering.
 - PID minimising angle and distance.



AMR for infrastructure maintenance

DT communications

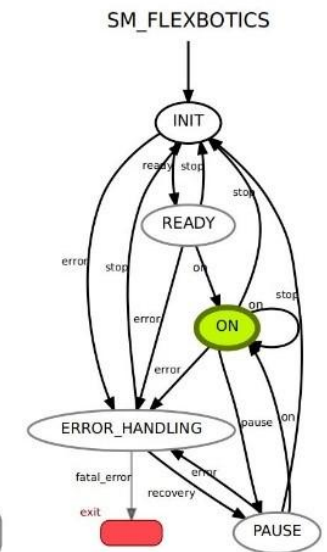
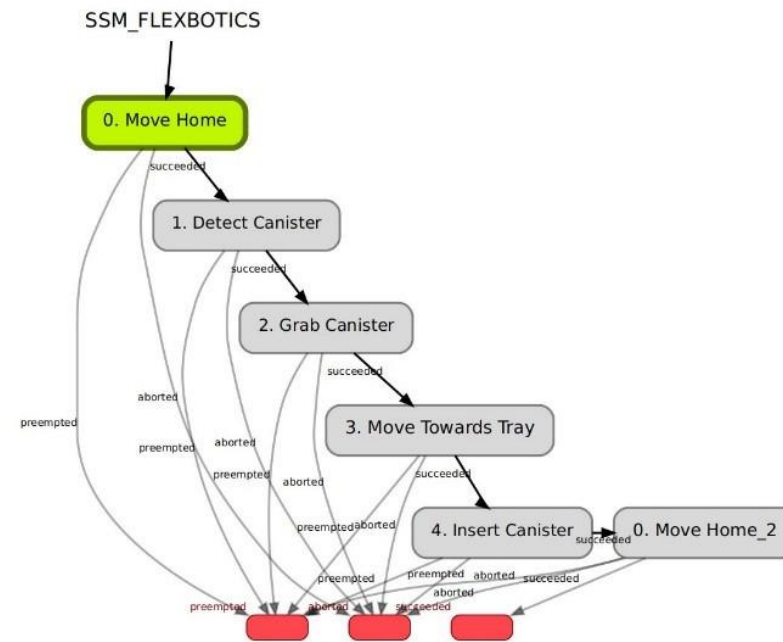
- MQTT messages through 4G connection.
- Four messages defined:
 - <CommandMessage>: List of waypoints (UTM).
 - <CommandReturnMessage>: ACK from the AMR, mission result.
 - <StateMessage>: Cyclic message reporting the status of the AMR.
 - <DeviceMeasurement>: Result of each retroreflectometer measurement.



AMR for infrastructure maintenance

Mission management

- Missions managed using TECNALIA's Flexbotics Execution Manager (FEM).
- Missions defined as yaml files.
 - States.
 - Transitions between states.
- One State Machine used for managing the process.
- One Smach State Machine to manage the execution of the mission.



AMR for infrastructure maintenance

Mission management

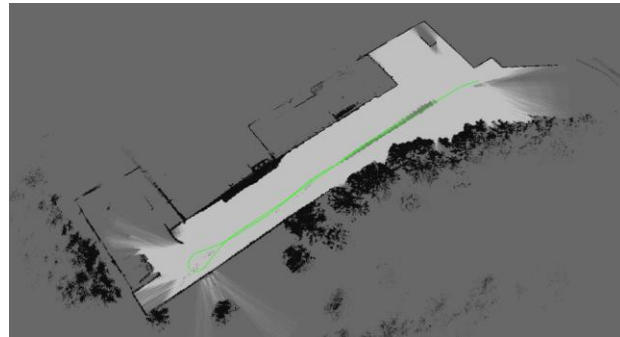
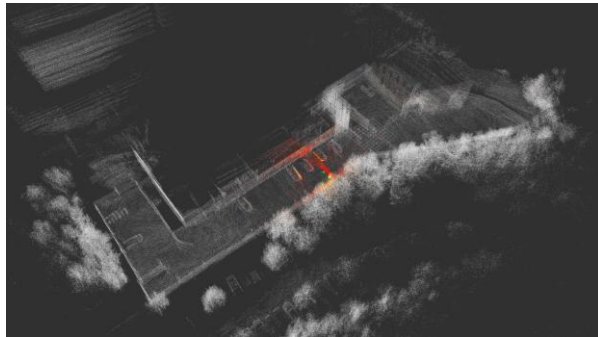
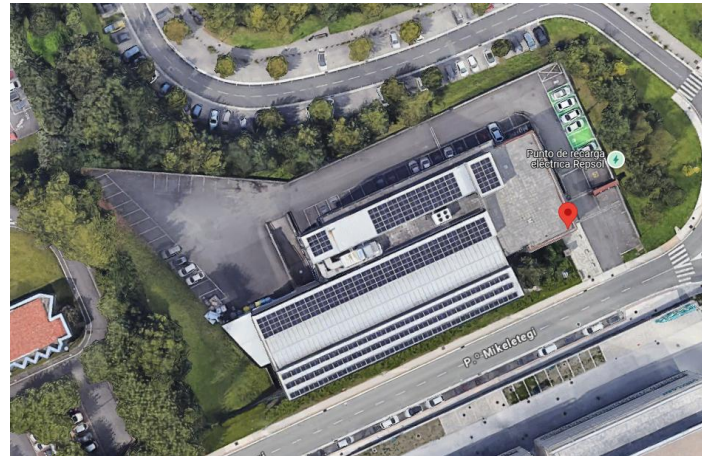
```
!Sequence
params:
  waypoints: !Link mission_waypoints
states:
- !Action
  name: NAV_TO_WAYPOINT_0
  action_name: "/planck/move_base"
  action_spec: move_base_msgs.MoveBaseAction
  params:
    target_pose: !Link waypoints[0]
  result: goal_result
- !Decision
  name: CHECK_GOAL_RESULT
  rules:
    line_alignment: !Link goal_result.success == 1
    mission_error: otherwise
- !Action
  name: LINE_ALIGNMENT_ACTION
  action_name: "/planck/LineAlignAction"
  action_spec: actionlib.TestAction
  result: alignment_result
- !Decision
  name: CHECK_ALIGNMENT_RESULT
  rules:
    retro_measurement: !Link alignment_result.success == 1
    mission_error: otherwise
```

```
- !Service
  name: RETRO_MEASUREMENT
  service_name:
/easylux_mini_sensor/easylux_measurement_service
  service_spec: easylux_mini_msgs.srv.TakeMeasurement
  result: measurement_result
- !Decision
  name: CHECK_MEASUREMENT_RESULT
  rules:
    NAV_TO_WAYPOINT_1: !Link measurement_result.success == 1
    mission_error: otherwise
- !Action
  name: NAV_TO_WAYPOINT_1
  action_name: "/planck/move_base"
  action_spec: move_base_msgs.MoveBaseAction
  params:
    target_pose: !Link waypoints[1]
  result: goal_result

...
```

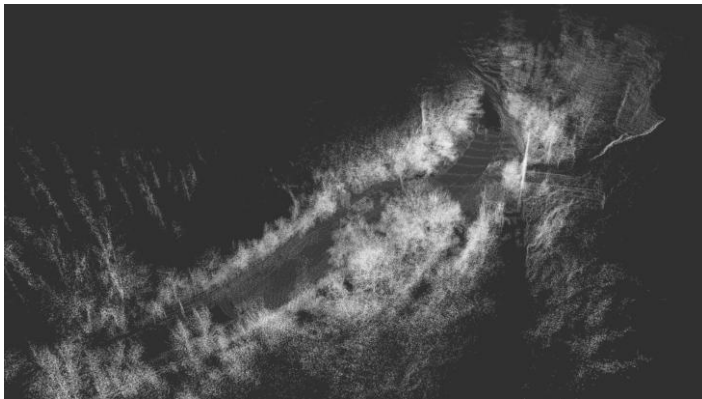
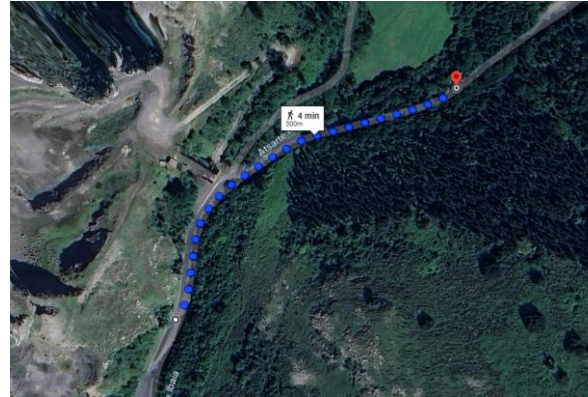
AMR for infrastructure maintenance

Field tests – TECNALIA (Donostia-San Sebastián, Spain)



AMR for infrastructure maintenance

Field tests – Abadiño (Spain)



AMR for infrastructure maintenance

Field tests – L'Aquila (Italy) – Final demonstrator

