Robotics Lab Technical Project
Robotic Warehouse
Year 2025/2026

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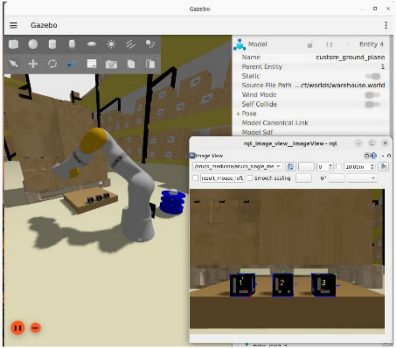
Github: https://github.com/Federica2103/RL_2025_Technical_Project.git

PROBLEM DESCRIPTION AND SIMULATION

This project simulates a Smart Logistics scenario driven by the cooperation between an industrial manipulator and a mobile robot. The objective is to automate the entire sorting pipeline: from visual recognition and manipulation (using **KUKA-IIWA**) to autonomous transport and delivery into specific storage zones (via **FRA2MO**).

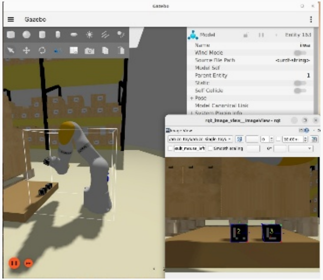


STEP 1: START

The KUKA-IIWA recognizes the contents of the 3 boxes using the camera located at its base

https://youtu.be/8iSqM_rtfP8

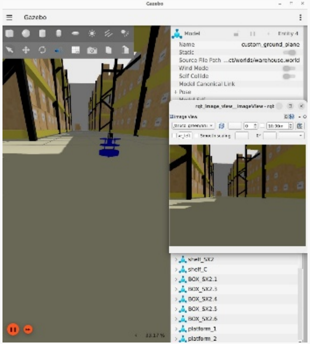
PROBLEM DESCRIPTION AND SIMULATION



STEP 2: DELIVERY TO FRA2MO

The KUKA-IIWA picks up the correct package and follows a trajectory to release it onto the FRA2MO robot

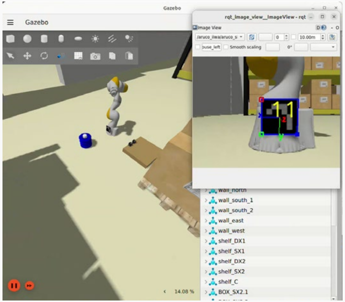
https://youtu.be/necuYC4s-zM



STEP 3: PACKAGE TRANSPORT

FRA2MO transports the package to the designated delivery area.

https://youtu.be/WLTPP42qvi0



STEP 4: FRA2MO RETURNS TO IIWA

After delivery, FRA2MO returns to the IIWA's location to pick up the next box.

https://youtu.be/_fZaoxsYo1o

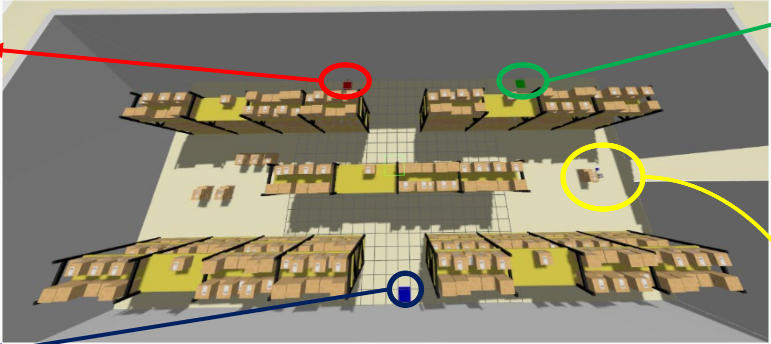
The cycle is repeated three times to process all three packages

Full Simulation Video: https://youtu.be/kCA5HvhDavQ

SIMULATION SETUP: WORLD

Medicine drop-off area

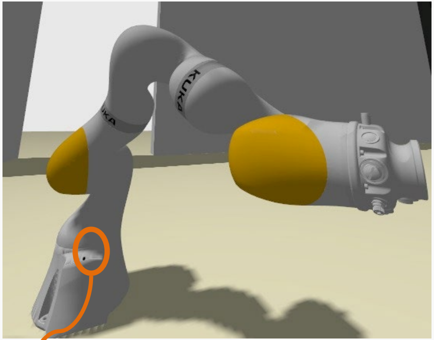
Toys drop-off area



Clothes drop-off area

Most of the models used in this simulation were imported from the official Gazebo libraries

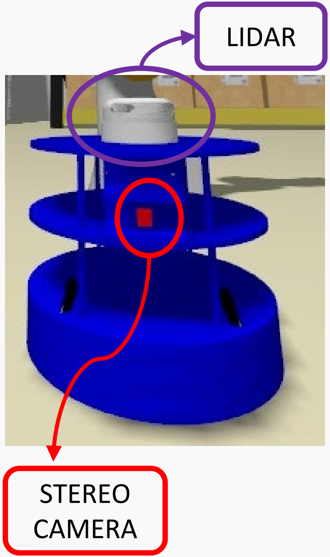
SIMULATION SETUP: IIWA ROBOT



high-resolution camera (1280x960) mounted on the base link (link_0)

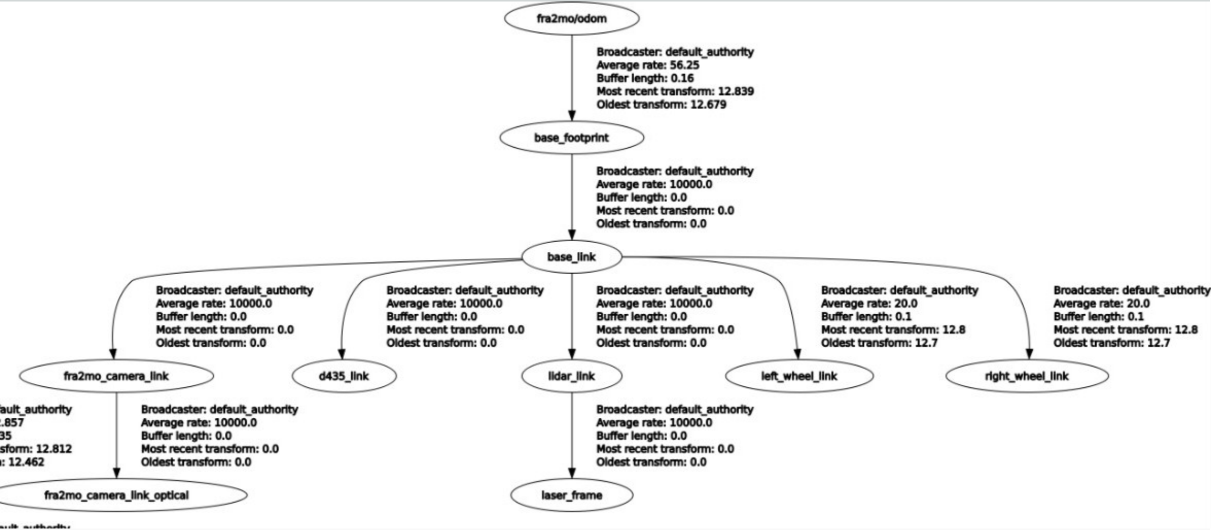
- The manipulation subsystem relies on the **KUKA LBR iiwa 14 R820**, a redundant **7-DOF** industrial robot defined via **Xacro macros**.
- The robot is equipped with a **camera sensor** to perform object detection and classification using **ArUco tags**, allowing it to identify and distinguish between different package types such as medicine, toys, or clothes.
- Regarding the actuation, the robot's motion is governed by a **ROS-based Velocity Controller**.
- Furthermore, the grasping mechanism is simulated using the **ignition-gazebo-detachable-joint-system plugin**, which dynamically creates a kinematic link between the robot's flange and the target package to ensure a stable and reliable handover to the **FRA2MO** mobile platform.

SIMULATION SETUP: FRA2MO ROBOT



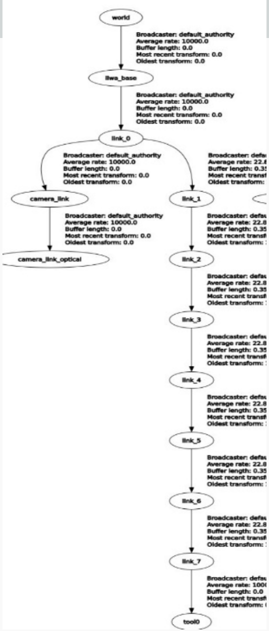
- The second robot in the multi-robot system is **FRA2MO**, an autonomous differential drive mobile platform designed for smart logistics tasks.
- Its physical structure is characterized by a blue cylindrical chassis with two **main wheels** and a supportive **caster**, providing the agility required to navigate warehouse environments.
- For environmental perception and navigation, the robot is equipped with a GPU-based **Lidar sensor** offering a wide horizontal field of view and a 10-meter range, alongside an RGB **camera** for visual feedback.
- The robot's operational logic is governed by a custom Task Manager node that orchestrates high-level navigation goals through **nav2** and performs precise **visual docking** maneuvers using ArUco tag detection.
- Furthermore, physical package handling is achieved via the ignition-gazebo-**detachable-joint**-system plugin, which allows FRA2MO to securely transport and autonomously drop off specific cargos at their designated storage areas.

System architecture: TF Tree

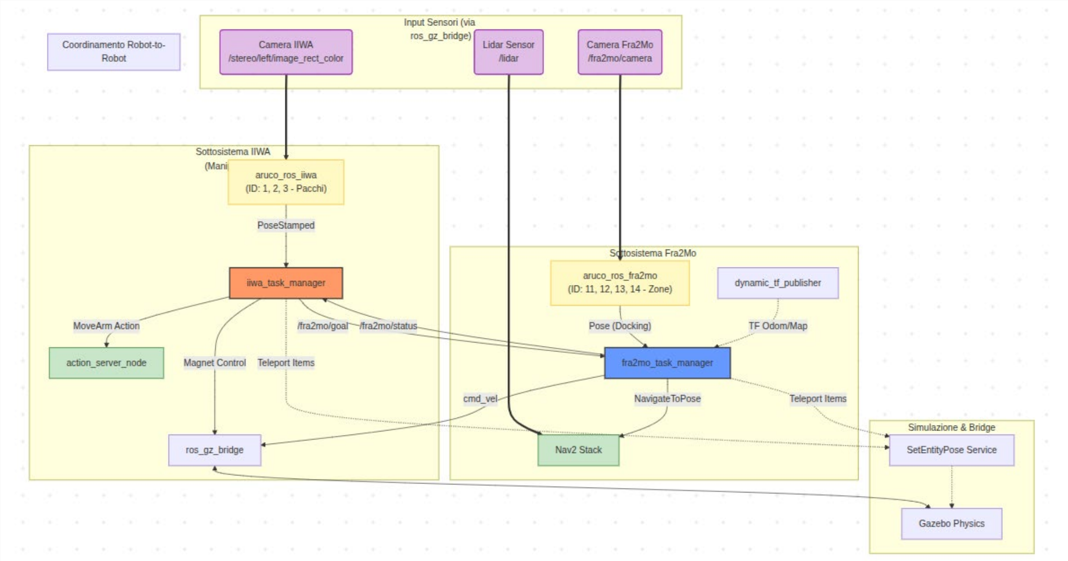


System architecture: TF Tree

- This diagram represents the hierarchical structure of coordinate frames within the system.
- It defines the spatial relationships between the global **world** frame and the local frames of both robots.
- The left branch details the **KUKA iiwa** kinematic chain (from link_0 to link_7 and the camera), while the right branch shows the **FRA2MO** structure, including the odometry frame, wheels, Lidar, and camera links.
- This tree is fundamental for transforming sensor data into a shared coordinate system for cooperative tasks.



System architecture: Nodes interconnection



System architecture: Nodes interconnection

- The system architecture is designed around two main control nodes: the **iiwa_task_manager** and the **fra2mo_task_manager**, which handle picking and logistics respectively.

- The process begins with the IIWA arm identifying target parcels—medicine, toys, or clothes—using a camera that detects **Aruco markers** with IDs 1, 2, and 3. Once the iiwa_task_manager confirms detection, it communicates with a KDL-based **action server** to execute a sequence of movements including approach, pick, and lift. During the "PICK_DOWN" phase, the system triggers a magnetic gripper through detachable joint topics in the simulation and uses the SetEntityPose service to ensure the parcel is correctly attached to the end-effector. After loading the parcel onto the mobile platform, the IIWA robot communicates the mission details to the mobile robot via the /fra2mo/goal topic.

- The Fra2Mo robot, managed by its own task manager, then utilizes the Nav2 stack and Lidar data to navigate **autonomousl**y toward the designated delivery zones. As it nears its target, the robot transitions from global navigation to a visual **docking mode**, where it identifies Aruco markers with IDs 11 through 14 to achieve precise alignment with the delivery bays. Once the delivery is finalized, the parcel is detached, and Fra2Mo returns to its home position, notifying the IIWA arm that it is ready for the next task through the /fra2mo/status topic.

- The entire simulation environment is synchronized through the **ros_gz_bridge**, which manages the exchange of sensor data, joint commands, and clock information between ROS 2 and the Gazebo engine.

GRAZIE PER L’ATTENZIONE