Addis Ababa University

(AAiT SITE)

Fundamentals of Robotics Course Project

Wheeled Robot with Robot arm, Gesture Detection and Collision Avoidance

Group Members

1.	Dawit Getahun	UGR/9220/13
2.	Metsakal Zeleke	UGR/1027/13
3.	Tewodros Berhanu	UGR/9715/13
4.	Tinsae Shemalise	UGR/6075/13
5.	Yohannes Dessie	UGR/7612/13

Table of Contents

Fundamentals of Robotics Project

Gesture Controlled Wheeled Robot with 3 DOF Arm, and Collision Avoidance

Introduction

This report provides an overview of the design and implementation of a ROS2 based robot we designed for our course project. The robot is designed to be operated via teleop using a keyboard as well as palm gestures from a laptop camera feed within the gazebo environment. The primary functionalities of the robot include controlling the wheeled base motion, simple obstacle avoidance to prevent collisions using a depth camera, and manipulation of the robotic arm using joint angles for the arm joints.

Robot Design

The robot is built upon a wheeled base platform, which serves as its primary mode of locomotion. The base is equipped with motors and wheels for omnidirectional movement, allowing the robot to navigate through various environments efficiently. Mounted at the front of the wheeled base is a depth camera, which provides real-time depth perception to the robot.

When designing the robot, we identified the different components required and designed them in separate .xacro files, which are then compiled into one .urdf file during the execution of the code. Below, we will be going over some of the main components of our design.

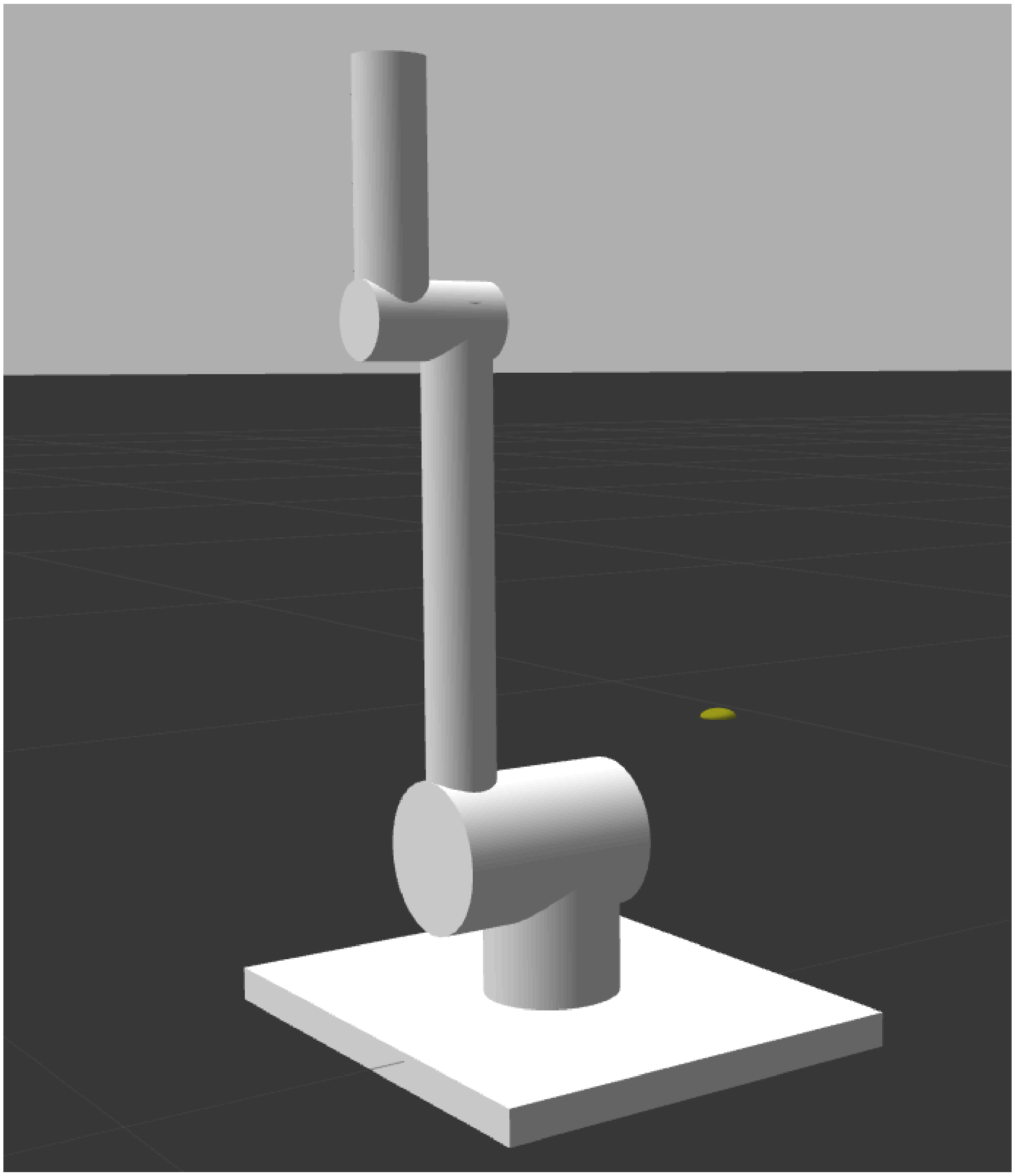
Components

Robot Arm

The robot arm has 4 main links connected by 3 joints.

- *link_0* serves as the base link of the arm, and connects to the main robot body(the wheeled base).
- *link_1* is connected to *link_0* via *joint_1* and represents the first segment of the arm. *Joint_1* is a revolute joint and it allows *link_1* to rotate about the z-axis.
- *link_2* is connected to *link_1* via *joint_2* and represents the second segment of the arm. *Joint_2* is also a revolute joint and allows *link_2* to rotate about the x-axis.
- *link_3* is connected to *link_2* via *joint_3* and represents the end effector or tool mounted on the arm. There is no gripper attached to the link however.

Beside these links and joints, the robot also consists of end_links and joints for these links, that are located at the end of links 1 and 2. Their joints are fixed. The robot arm on it's own is displayed below.



Mobile Base

The mobile base is the main base for the entire robot. It consists of the base link and 3 wheels for motion, and it is where the depth-camera and robot arms are attached as well.

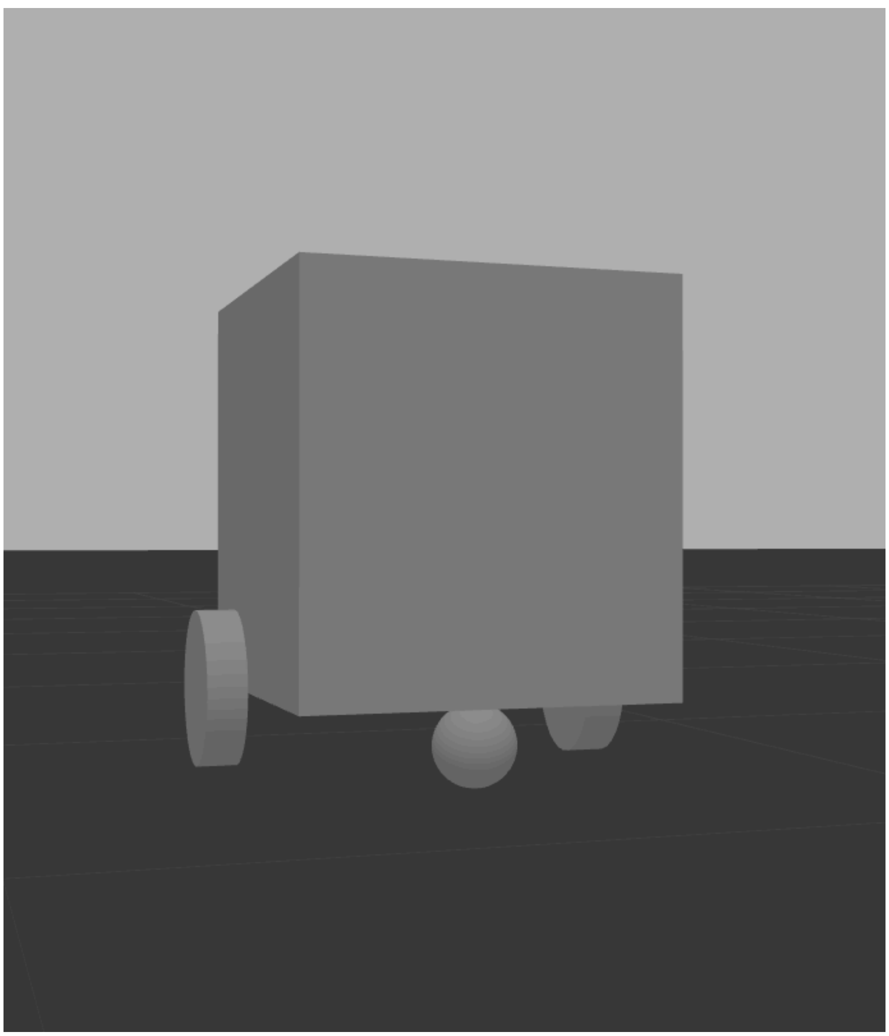
- **base_footprint**: This link represents the base of the robot. It is used here as the reference frame for the robot's movement and positioning.

- **base_link**: This link represents the main body of the robot. It is visualized as a box with dimensions 0.55m x 0.45m x 0.5m. It has inertial definition and a collision geometry matching the visual geometry.

- **right_wheel_link** and **left_wheel_link**: These links represent the right and left wheels of the robot, respectively. They are visualized as cylinders with a length of 0.05m and a radius of 0.1m. Both wheel links have collision geometries matching the visual geometries and inertial definitions specifying a mass of 1.0 unit and inertia values.
- **caster_wheel_link**: This link represents a caster wheel, used for stability and support. It also allows the robot to turn in both left and right directions. It is visualized as a sphere with a radius of 0.05m.

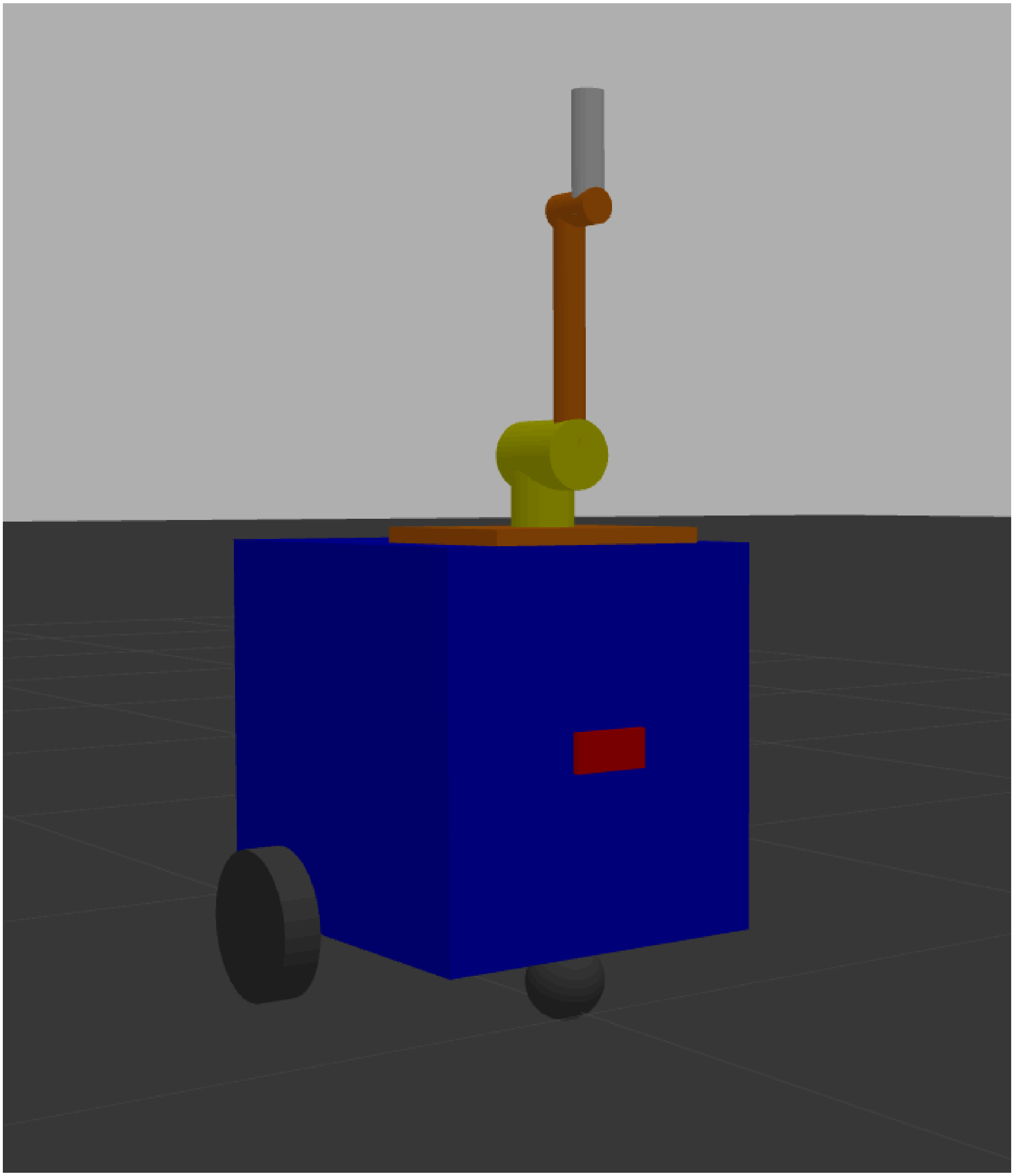
These links are connected by 4 joints specified below.

- **base_joint**: A fixed joint connecting the base_footprint to the base_link.
- **base_right_wheel_joint** and **base_left_wheel_joint**: Continuous joints connecting the base_link to the right_wheel_link and left_wheel_link, respectively. These joints allow rotation about the y-axis to allow the entire link to turn left/right and have origins and axes defining the positions and orientations of the wheels relative to the base_link.
- **base_caster_wheel_joint**: Another fixed joint connecting the base_link to the caster_wheel_link, with an origin offset along the x-axis and z-axis.



Full Robot Design

Overall, combining the arm, the wheeled base and the depth camera, we have the final design displayed below.



The red rectangle in the front of the wheeled base is the depth-camera.

Functionalities and Features

Control Mechanisms

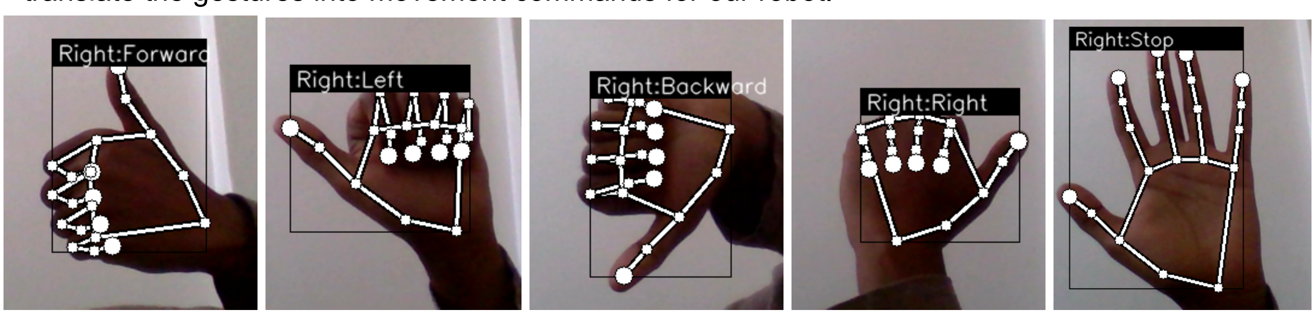
The robot's control mechanisms are implemented using ROS2 nodes, which facilitate communication between different components of the system. The following nodes are utilized:

Teleoperation

The teleoperation functionality is facilitated by the teleop_twist_keyboard package, a widely-used ROS2 package specifically designed for teleoperating mobile robots using keyboard inputs. This node translates keyboard commands into Twist messages, containing linear and angular velocities, enabling intuitive control of the wheeled base's motion.
The wheeled base of the robot can also respond to this form of control and subscribes to the *cmd_vel* topic as well.Users can easily maneuver the robot in various directions by pressing designated keys, allowing for efficient navigation in diverse environments.

Gesture Detection

To provide an alternative control interface, a custom node is implemented for gesture detection using the laptop camera feed. Using a hand recognition library obtained [online](), this node analyzes the camera feed to detect predefined palm gestures. The online library we used has functionality to detect palm gestures and has a setting that allows training of custom commands, so we used that and trained the model with a few gestures we found to be somewhat comfortable to perform. We then updated the model and integrated it with our custom node to translate the gestures into movement commands for our robot.



Upon detection, the gestures are interpreted as commands for controlling the robot's movement or manipulation.

Wheeled Base Movement

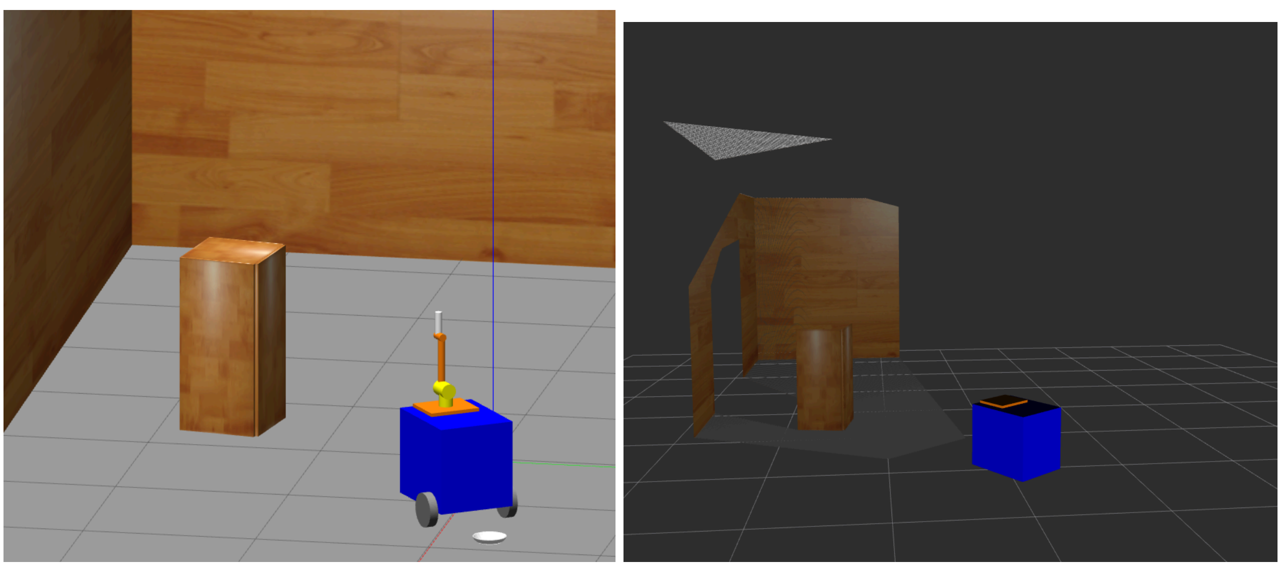
This node receives motion commands from either the teleoperation node or the gesture detection node and translates them into motor control signals for the wheeled base, enabling smooth and precise movement.

Robot Arm Control Nodes

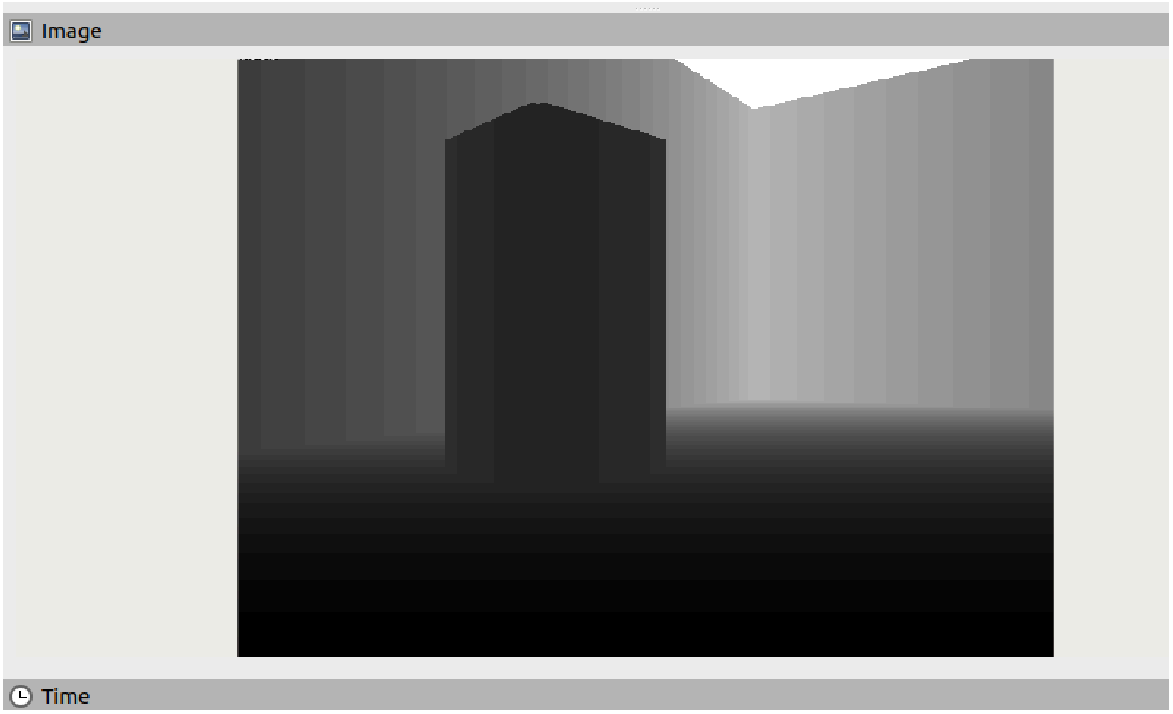
Two nodes are dedicated to controlling the robotic arm, the trajectory_publisher and trajectory_subscriber nodes. The subscriber node receives a message on a custom topic */movement/cmd_joint_angles* of a custom type that we defined, building on one of the assignments given to us in class. The message is a set of 3 joint angles that allow us to configure the robot arm through its 3 joints in different ways. The *trajectory_subscriber* node then converts these into a *JointTrajectory* message that moves the robot arm.
The *trajectory_publisher* node lets the user input the three angles from the terminal, and publish it to the */movement/cmd_joint_angles* topic for the subscriber node.

Obstacle Avoidance

In this node, the robot uses the sensor(depth camera) to prevent collisions of the robot. The depth camera data is processed by this node to detect obstacles in front of the robot. If an obstacle is detected within a predefined range, the node sends signals to halt the forward movement of the wheeled base, preventing collisions or damage to the robot base, camera or arm.
Let's visualize the depth-camera using rviz2.



In the pictures above, first we have the robot's position and environment in Gazebo. On the right we have its visualization in Rviz2, using PointCloud2 to show the camera feed from the depth camera. What it exactly sees is also shown below.



We use this to calculate the distance of the robot from the object in front of it, and stop it if it gets too close. The robot will also not be able to make any forward movements once it's within this range.

Running the program

Prerequisites

The program has quite a few dependencies, so they first need to be installed.

- Install Tensorflow

```
ros2_ws$ pip install tensorflow
```

- Cv2

```
ros2_ws$ pip install opencv-contrib-python
```

- Joint state publisher

```
ros2_ws$ sudo apt install ros-humble-joint-state-publisher
```

- Controller Manager

```
ros2_ws$ sudo apt install ros-humble-ros2-control
ros2_ws$ sudo apt install ros-humble-ros2-controllers
```

```
ros2_ws$ sudo apt install ros-humble-gazebo-ros-pkgs
```

After the python dependencies have been installed, navigate to the directory containing the packages and ensure all required packages are present and the directory structure looks like this.

```
.
└── src/
    ├── gesture_controlled_robot_py/
    │   ├── .
    │   ├── .
    │   ├── gesture_controlled_robot_py/
    │   │   └── hand_gesture_recognition_mediapipe
    │   ├── .
    │   └── .
    └── three_joint_angles/
```

The last package, *three_joint_angles,* is our custom message type and is also **required** as it is needed for the robot arm movement functionality (it's also provided with the source code).
Next, we need to build the package.
Again, **BOTH packages are required** for the project, and both need to be built together.

```
xetho@xetho-G3-3579:~/ros2_ws$ colcon build
[1.738s] WARNING:colcon.colcon_ros.prefix_path.ament:The path '/home/xetho/ros2_
ws/install/simple_robot_description' in the environment variable AMENT_PREFIX_PA
TH doesn't exist
Starting >>> gesture_controlled_robot_py
Starting >>> three_joint_angles
Finished <<< three_joint_angles [2.47s]
--- stderr: gesture_controlled_robot_py
/usr/lib/python3/dist-packages/setuptools/command/install.py:34: SetuptoolsDepre
cationWarning: setup.py install is deprecated. Use build and pip and other stand
ards-based tools.
  warnings.warn(
---
Finished <<< gesture_controlled_robot_py [4.31s]

Summary: 2 packages finished [5.70s]
```

Starting the program

To start the program, run the launch file with the command:

```
ros2_ws$ ros2 launch gesture_controlled_robot_py gazebo.launch.py
```

This will launch the gazebo simulator, and the various different nodes. Since we are also using tensorflow during this, this process might take some time, especially launching the laptop camera.

Running the Teleop for the robot base(wheeled base)

The following will run the Teleop and allow the wheeled base to be controlled by keyboard inputs

```
ros2_ws$ ros2 run teleop_twist_keyboard teleop_twist_keyboard
```

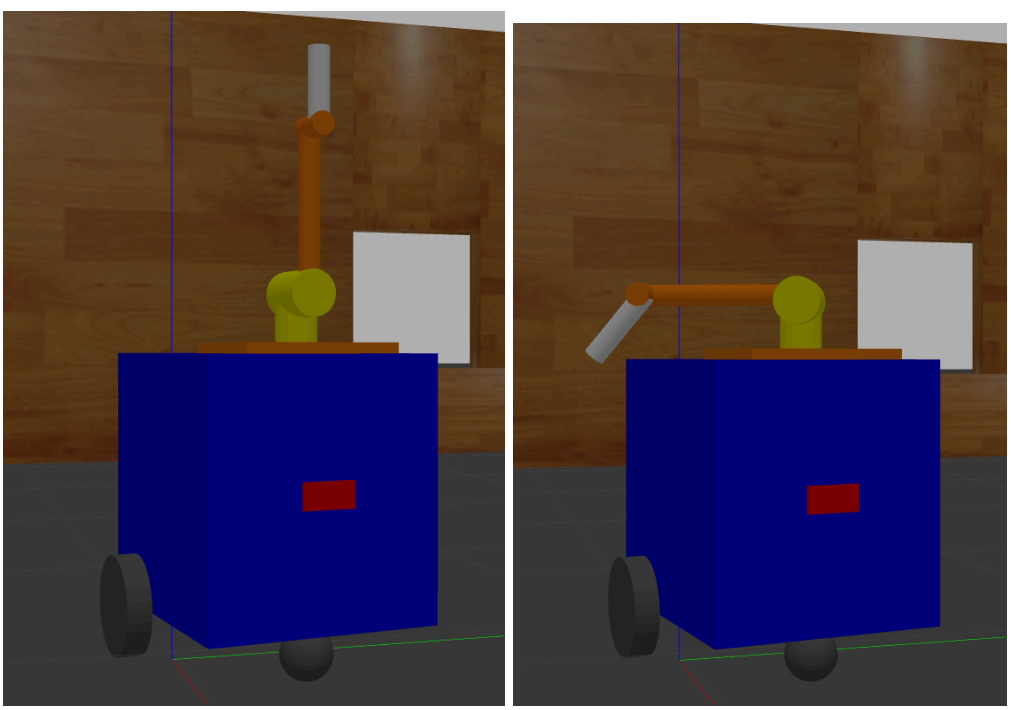
Moving the Robot Arm

To move the robot arm, we need to run the publisher node in a separate terminal and input the three desired angles for the three joints. Run the node with the command:

```
ros2_ws$ ros2 run gesture_controlled_robot_py trajectory_publisher
```

Then, input the three desired angles for the robot arm

```
Enter the three joint angles space separated:
-30 90 50
```



Summary

In this document, we have outlined the design of our robot and its functionalities implemented with ros2 and gazebo. The robot design is made of several components, and we saw the designs of the **robot arm**, **the wheeled base**, and **the depth-camera** and its image-feed. The functionality of the robot includes **Palm Gesture and Teleop controls for movement**, **movement of the robot arm** with joint angles and **collision avoidance** using the depth camera.