ROS2 Workshop

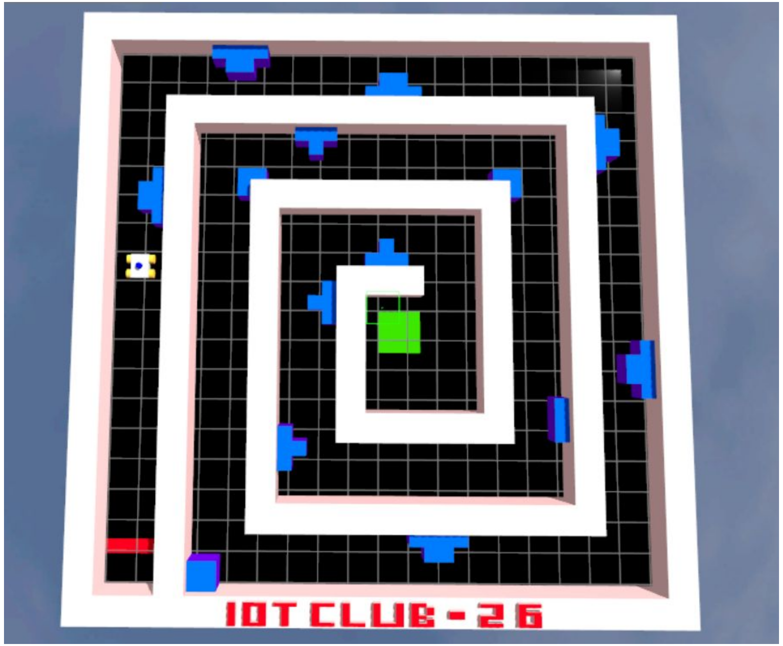
Basics to Advance

Build, connect, and control robots using ROS2!

- Learn the modern robotics middleware
- Understand communication patterns
- Work with real robots & simulation

By the End...

You'll be able to simulate your own Autonomous vehicle



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10. FINAL Simulation (Basics, Controllers and PFN algo)!!!

Introduction to Robotics

Introduction

What Is Robotics?
Robotics is the science and engineering of creating machines that can perform tasks autonomously or semi-autonomously. It integrates hardware, software, and algorithms to give machines the ability to sense, plan, and act.

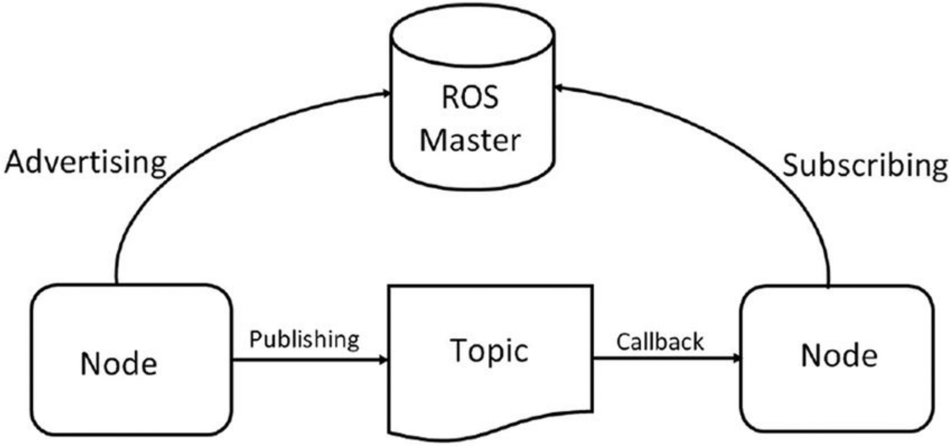
Why Learn Robotics?
Robotics allows us to solve real-world problems: automate repetitive work, explore dangerous environments, assist humans, and build future technologies like self-driving cars and service robots.

History and Architecture of ROS and ROS2

History of ROS and ROS2

ROS began in 2007 as an open-source robotics framework built for research and rapid prototyping.

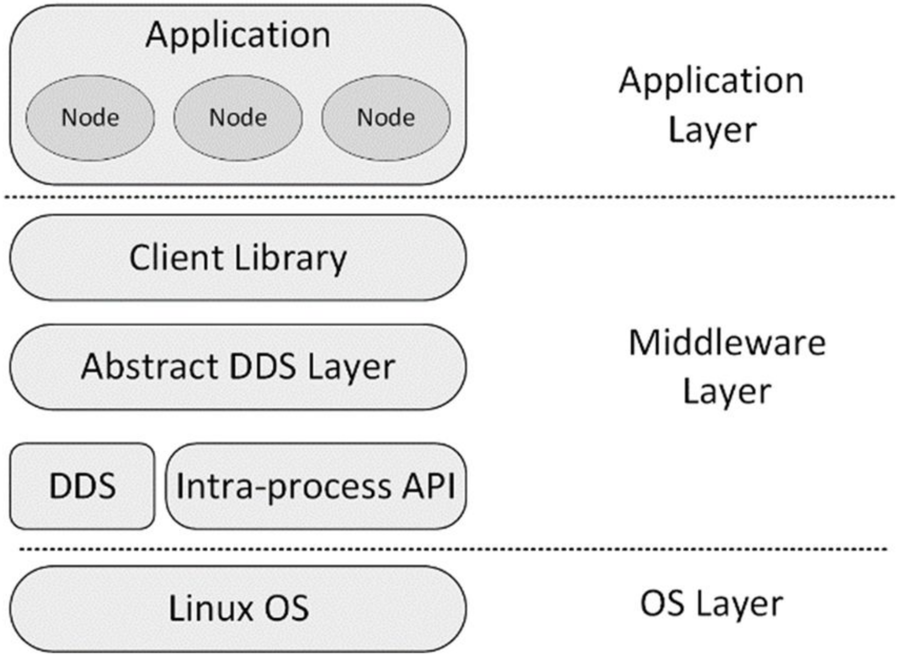
ROS1 provided a powerful foundation for modular robot software, but lacked real-time and multi-robot capabilities.



History of ROS and ROS2

ROS2, launched in 2014, evolved it into an industry-ready platform with real-time, secure, and scalable communication.

ROS2 was redesigned using DDS to deliver reliability, security, and cross-platform support.



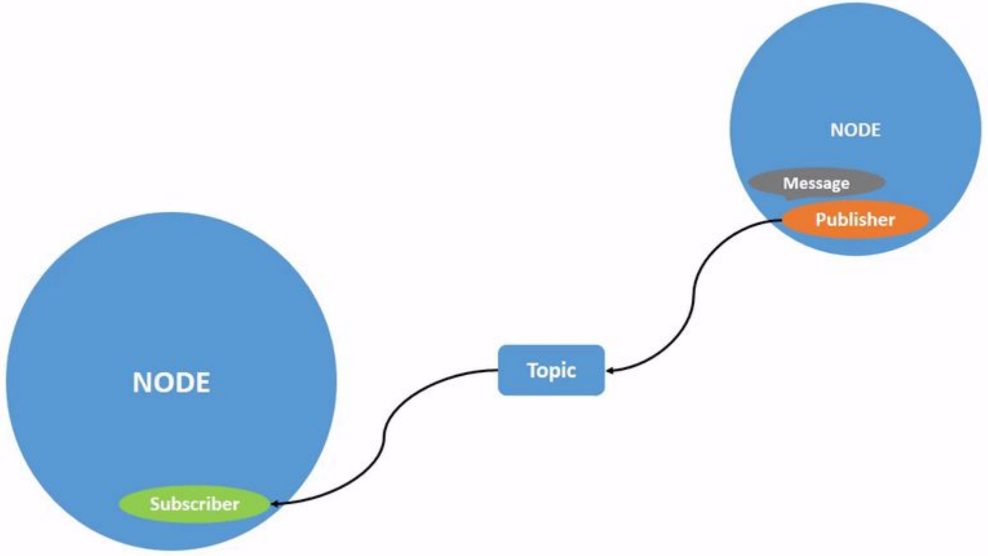
Different versions of ROS2

Components

Nodes and Topics

Nodes: Small, executable processes that perform specific tasks within a robot system.

Topics: Publish–subscribe communication channels used for sending continuous data between nodes.



Installation - Utilities & TurtleSim

Command

sudo apt update
sudo apt install terminator
echo ‘export ROS_LOCALHOST_ONLY=1’
sudo apt install ros-humble-turtlesim
sudo apt install '~nros-humble-rqt*'

Terminator
Cheat Sheet
LINUXSIMPLY

Window Management Shortcuts	
CTRL + SHIFT + T	Opens a new Terminal tab
CTRL + SHIFT + I	Opens a new Terminal window
CTRL + SHIFT + O	Split terminals Horizontally
CTRL + SHIFT + E	Split terminals Vertically
SUPER KEY + I	Spawns a new Terminator process
ALT + L	Opens layout launcher
CTRL + SHIFT + W	Closes the current terminal
CTRL+ SHIFT + Q	Closes the current window
CTRL + SHIFT + N	Minimizes the current terminal
CTRL + SHIFT + X	Maximizes the current terminal
CTRL + SHIFT + R	Resizes the current terminal
F11	Toggles window to fullscreen
CTRL + SHIFT + Z	Zooms current terminal

Navigation Shortcuts	
ALT + UP ARROW	Moves to the terminal above
ALT + DOWN ARROW	Moves to the terminal below
ALT + LEFT ARROW	Moves to the terminal left
ALT + RIGHT ARROW	Moves to the terminal right
CTRL + PAGE DOWN	Moves to next Tab
CTRL + PAGE UP	Moves to previous Tab
CTRL + TAB	Moves to next terminal
CTRL + SHIFT + TAB	Moves to the previous terminal
CTRL + SHIFT + F2	Toggles the terminal session between horizontal and vertical orientation
CTRL + SHIFT + L	Centers the viewport on the current line
SHIFT + HOME	Scrolls the viewport to the top of the terminal session
SHIFT + END	Scrolls the viewport to the bottom of the terminal session
CTRL + XX	Switches between the start of the line and the current cursor position

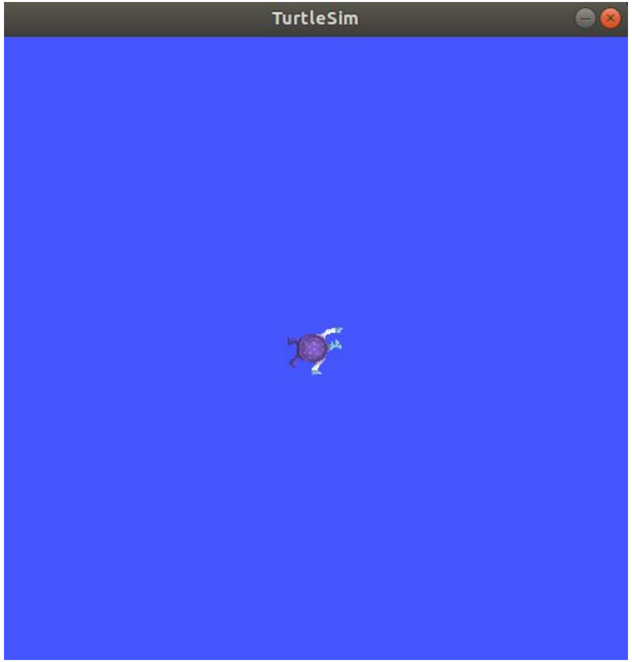
Turtlesim & CLI

Turtlesim

- Beginner-friendly ROS 2 simulator, uses a turtle to learn ROS concepts
- Helps practice topics, services, and actions and Simple way to understand robot movement, testing commands and control logic

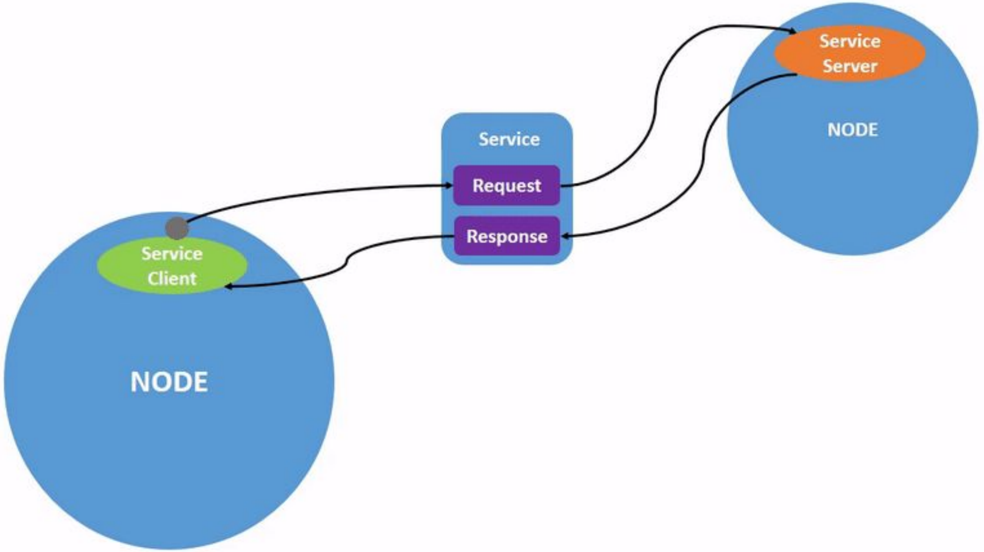
Command

ros2 run turtlesim turtlesim_node
ros2 run turtlesim turtle_teleop_key



Services

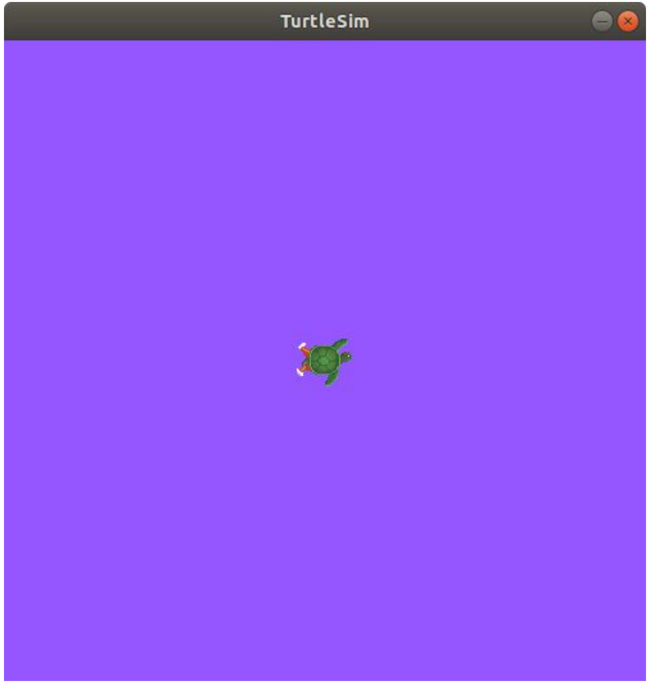
Services: Request–response communication used when a node needs to send a question and receive a direct answer.



Parameters

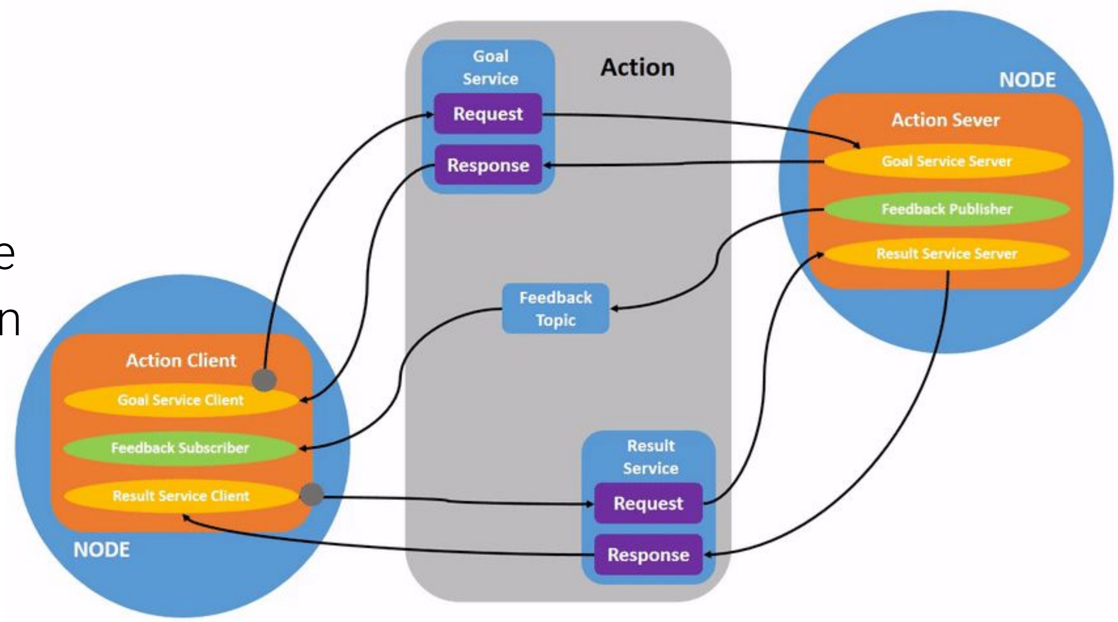
Parameters: Configurable values stored inside nodes that can be updated without changing the code.

Eg: `ros2 param set /turtlesim background_r 150`

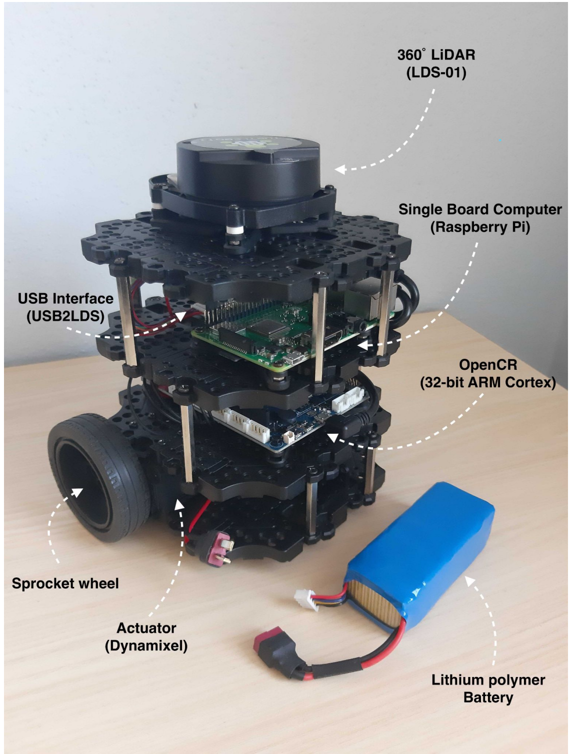


Actions

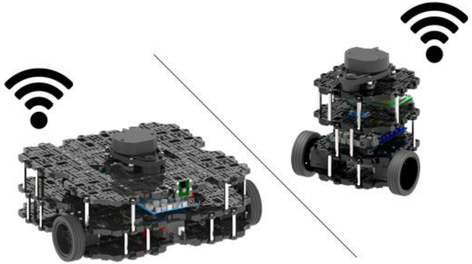
Actions: Asynchronous, long-duration tasks that provide feedback and allow cancellation (e.g., navigation goals).



Example



TurtleBot



ROS_MASTER_URI = http://IP_OF_REMOTE_PC:11311
ROS_HOSTNAME = IP_OF_TURTLEBOT

Remote PC

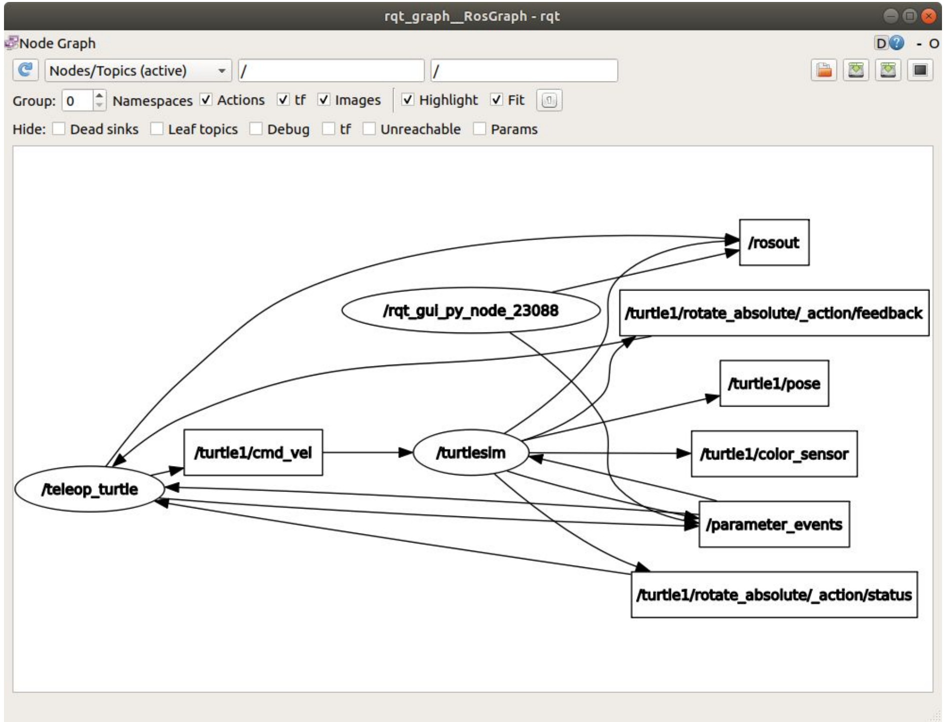
ROS_MASTER_URI = http://IP_OF_REMOTE_PC:11311
ROS_HOSTNAME = IP_OF_REMOTE_PC

* Example when ROS Master is running on the Remote PC

RQT

- GUI tool for monitoring ROS 2 systems
- Visualizes nodes, topics, and connections
- Supports plugins like rqt_graph and rqt_plot

Command - rqt



Custom Publisher & Subscriber

Custom Server & Client

Custom launch file in python (XML as well)

Workspace and Packages

Workspace: A directory structure where ROS2 packages are developed, built, and organized.

Eg:

```
mkdir -p ~/ros2_ws/src
cd ~/ros2_ws/src
```

Packages: The basic building blocks of ROS2—containing nodes, code, configuration, and launch files.

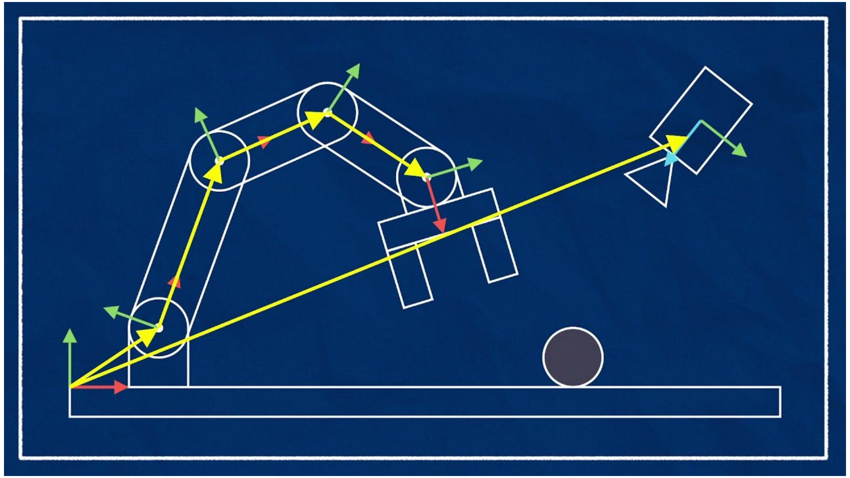
Eg:

```
ros2 pkg create --build-type ament_python <package_name>
```

Transform

Transform

- TF (Transform) manages coordinate frames in a robot system
- It tracks position & orientation between links (base, sensors, end-effector)
- Helps robots understand spatial relationships in real time
- We have TF2 library in ROS 2 for accuracy and speed



```
sudo apt install ros-humble-xacro ros-humble-joint-state-publisher-gui
```

```
ros2 run robot_state_publisher robot_state_publisher --ros-args -p robot_description:="$(xacro path/to/my/xacro/file.urdf.xacro)"
```

```
ros2 run joint_state_publisher_gui joint_state_publisher_gui
```

URDF and CAD files

URDF and CAD

URDF:-

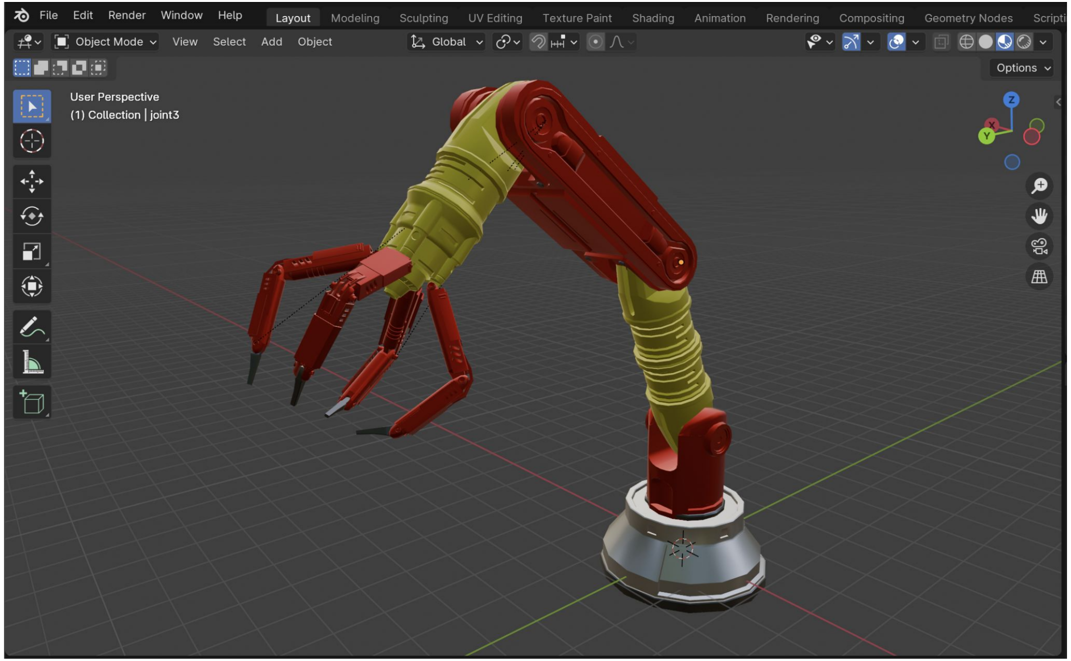
- Defines links, joints, sensors, and visuals
- Helps visualize robots in RViz and simulators
- Essential for robot modeling in ROS 2

CAD (Computer-Aided Design)

- Used to design robot parts and assemblies
- Helps ensure accurate dimensions before building
- CAD models can be converted for URDF use

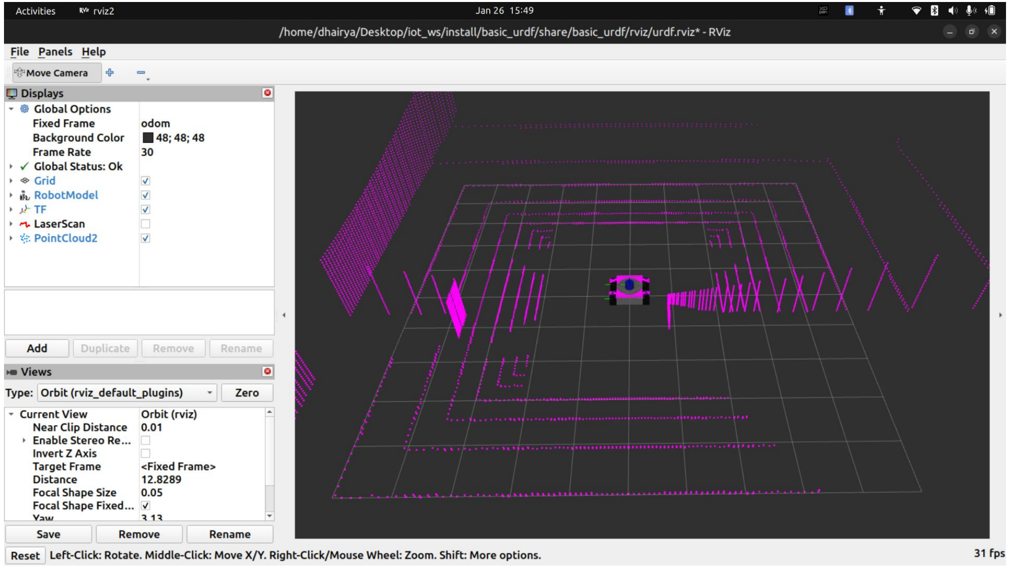
CAD softwares

Blender Example



RVIZ

- 3D visualization tool in ROS 2
- Displays robot models and sensor data
- Shows maps, paths, and TF frames
- Useful for navigation and perception

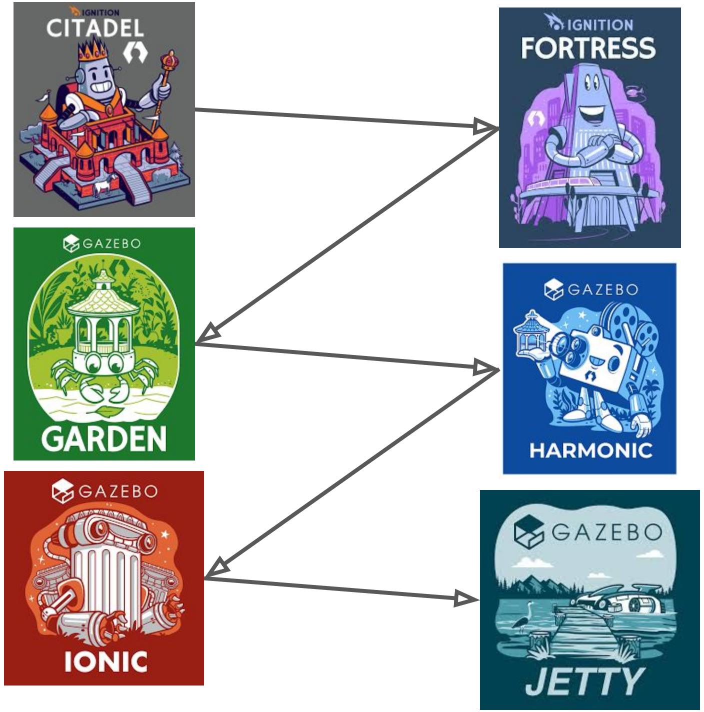


Command - rviz2

Gazebo

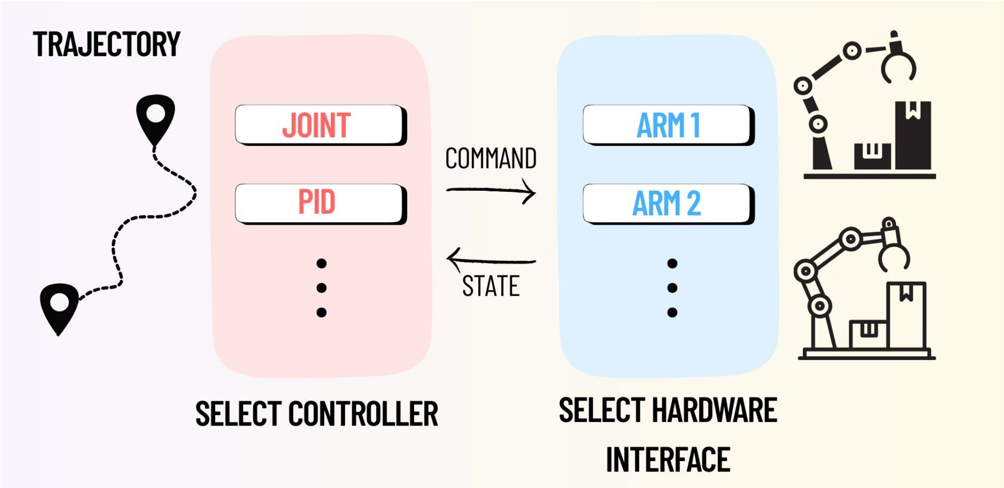
Gazebo

- 3D robot simulation environment
- Used to test robots without real hardware
- Provides realistic physics, sensors, and environments
- Saves cost and improves safety during development
- Integrates smoothly with ROS 2



Controllers

- Controllers manage robot motion and behavior
- Convert commands into motor/joint actions
- Work with hardware or simulation
- Examples: position, velocity, effort controllers



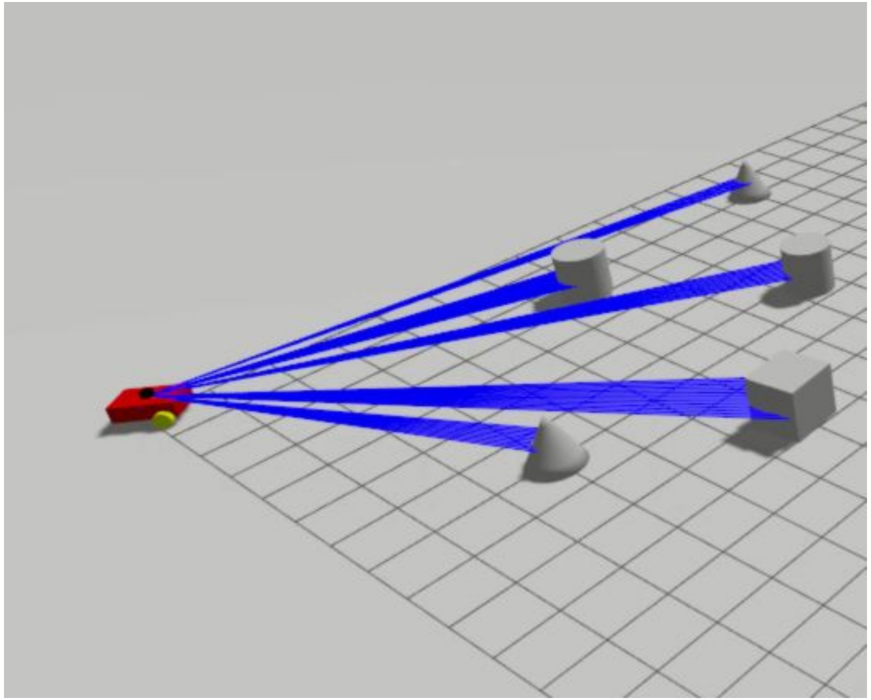
FINAL Simulation

(Basics, Controllers and Potential field navigation algo)!!!

Potential Field Algorithm

Potential Field Navigation is a reactive path-planning algorithm used in mobile robotics where:

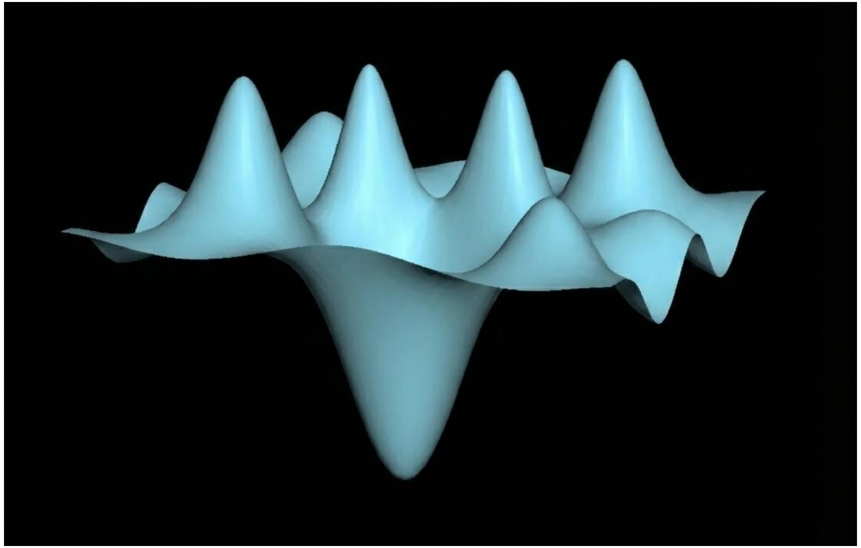
- The goal exerts an attractive force
- Obstacles exert repulsive forces
- The robot moves as if it is a particle in an artificial force field



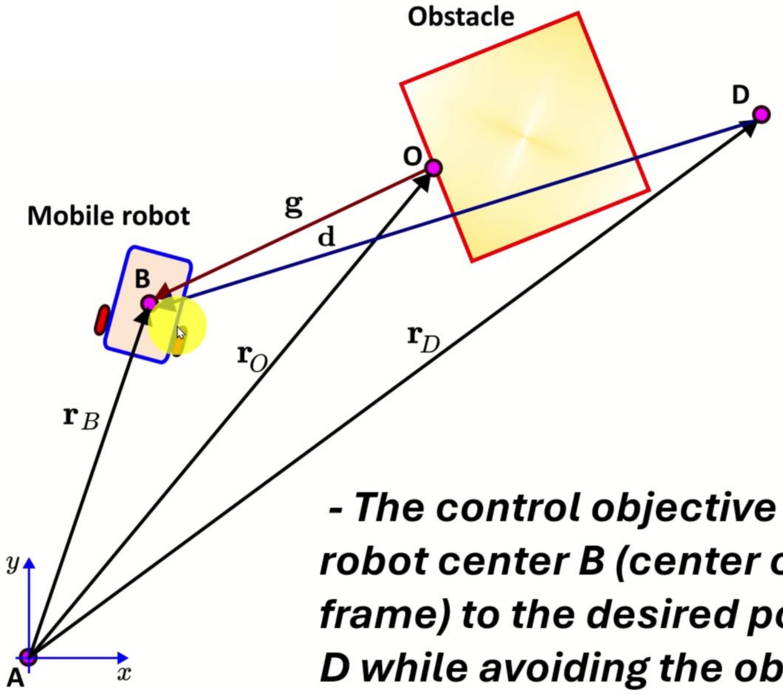
Potential Field Algorithm

Analogy:-

- Imagine the robot as a ball rolling on a surface
- The goal is a deep valley
- Obstacles are high hills
- The robot naturally rolls downhill toward the goal, avoiding hills

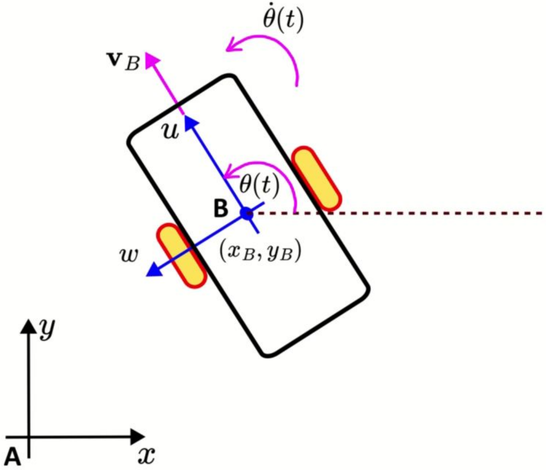


Potential Field Algorithm



- The control objective is to move the robot center B (center of the body frame) to the desired point (goal point) D while avoiding the obstacle.

Potential Field Algorithm

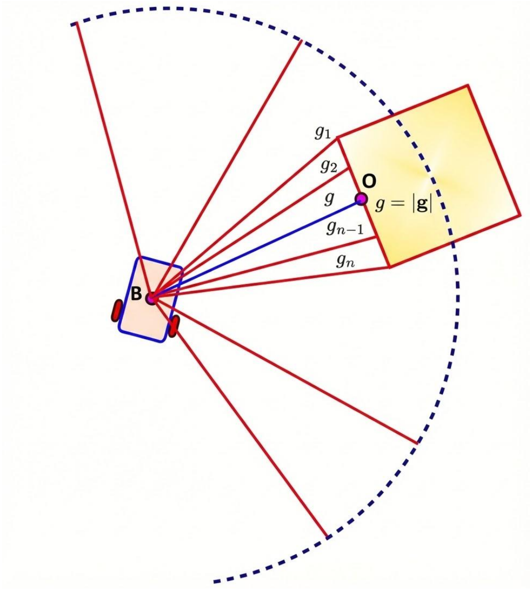


- **Position:** (x_B, y_B)
- **Orientation:** $\theta(t)$
- **Angular velocity:** $\dot{\theta}(t)$
- **Linear velocity:** $\mathbf{v}_B$
- **Body frame:** B_{uw}

- ***We assume that position*** (x_B, y_B) ***and robot orientation*** $\theta(t)$ ***are measured.***

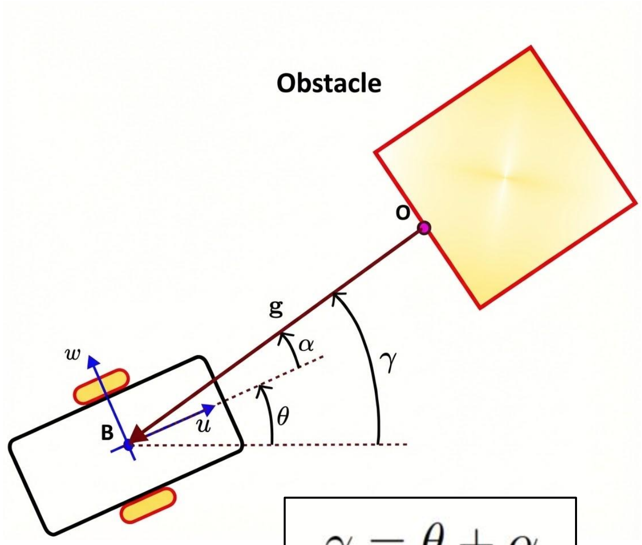
Potential Field Algorithm

- Using LiDAR, we obtain distance measurements to the obstacle from multiple scan points.



Potential Field Algorithm

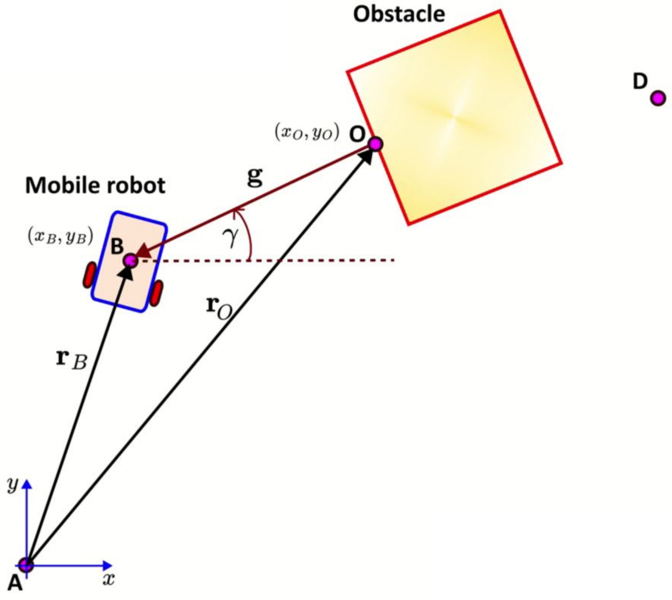
- For each scan point, the corresponding angle is computed with respect to the robot's body frame.
- These angles are then transformed into the global (inertial) frame by adding the relative orientation between the body frame and the global frame.



$$\gamma = \theta + \alpha$$

Potential Field Algorithm

- Using these values we can estimate the points on the obstacle w.r.t. global frame.
- And later we can calculate the resultant artificial force exerted by the surrounding on our robot.



Potential Field Algorithm

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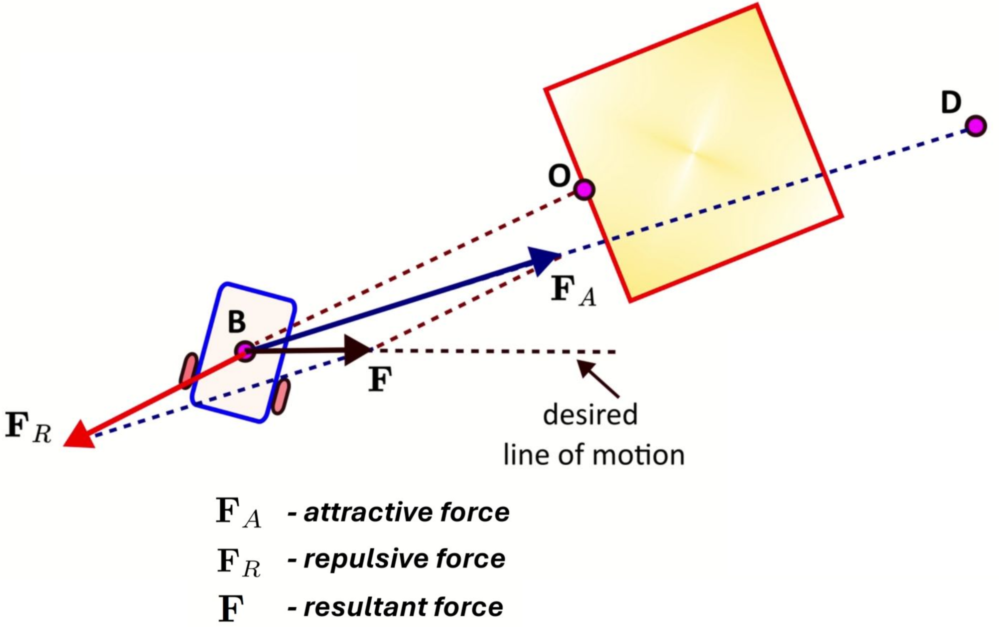
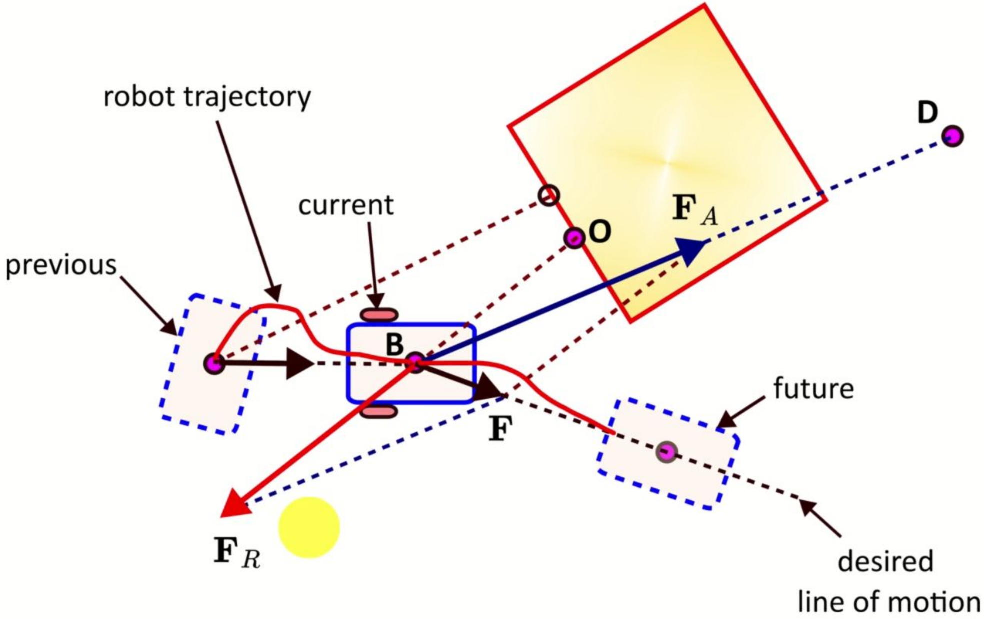


Potential Field Algorithm

- We repeat these steps again and again to get desired path which avoids the obstacle.



Potential Field Algorithm

Key Notes:

- The Attractive force is applicable throughout the navigation.

$$U_{att}(q) = \frac{1}{2} k_{att} \| q - q_{goal} \|^2$$

- The Repulsive force is only exerted when the robot is within certain distance of the obstacle.

$$U_{rep}(q) = \begin{cases} \frac{1}{2} k_{rep} \left(\frac{1}{d(q)} - \frac{1}{d_0} \right)^2 & d(q) \leq d_0 \\ 0 & d(q) > d_0 \end{cases}$$

Let’s move onto the code!!!

Thank U
for your time!!!