Aplicaciones de robótica de servicio en la plataforma académica Robotics Academy

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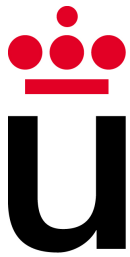
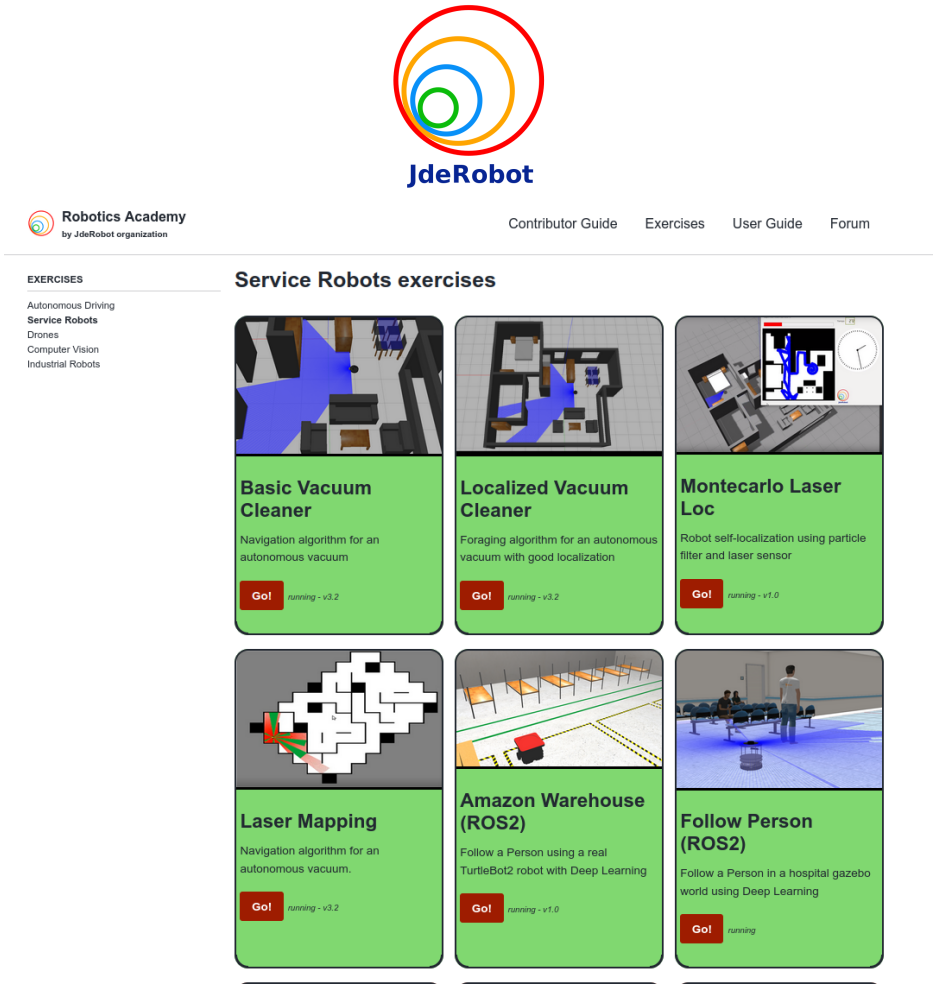


Universidad Rey Juan Carlos

Introducción

- Robótica de Servicio
  - Robótica social
  - Robótica en logística
- Robótica Educativa
  - Robotics Academy



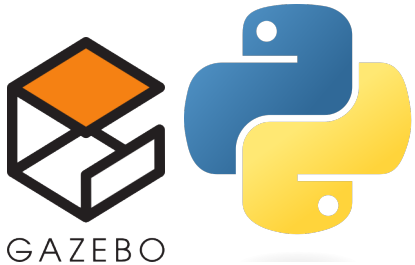
Objetivos

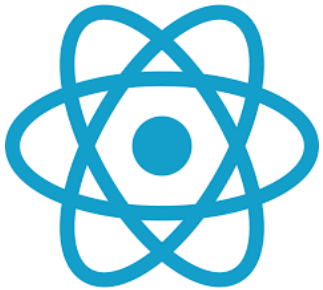
- Mejorar y ampliar la gama de ejercicios de Robotics Academy con dos ejercicios
  - Ejercicio Sigue-Persona
  - Ejercicio Almacén-Amazon

Ingredientes de los ejercicios:

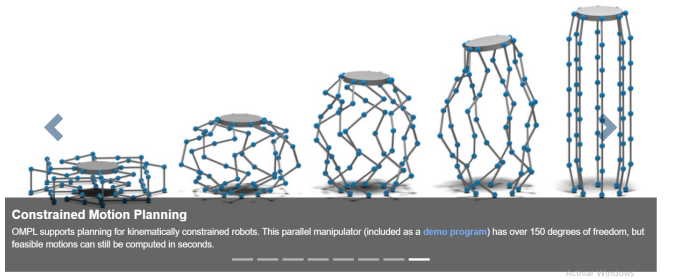
- Infraestructura
- Plantillas Python, frontend web y backend
- Solución de referencia
- Documentación de apoyo al usuario

Herramientas utilizadas



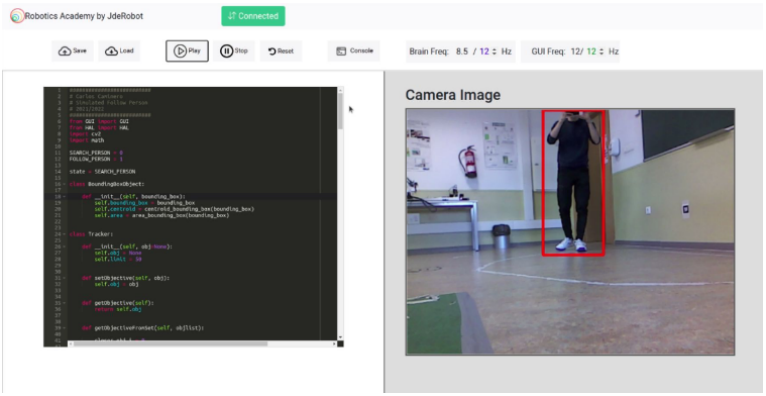


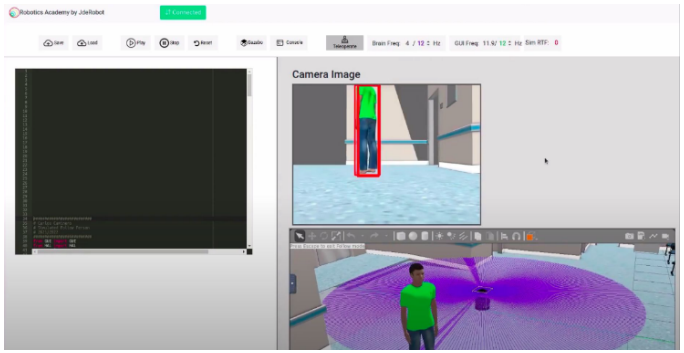
The Open Motion Planning Library



Versión antigua del ejercicio Sigue-Persona

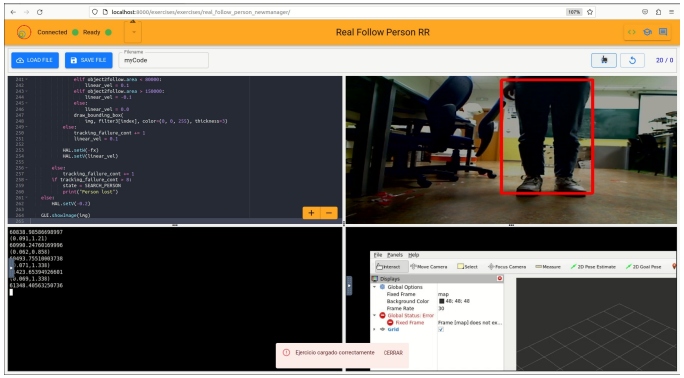
- Robotics Academy versión 4.x
- Infraestructura
  - Entorno simulado de un hospital
  - Robot TurtleBot2 en ROS 2 Foxy (simulado y real)
  - Persona simulada a seguir (autónoma o teleoperada)
- Plantillas Python
- Página web basada en plantillas JavaScript
- Solución de referencia: tracking, VFF y máquina de estados

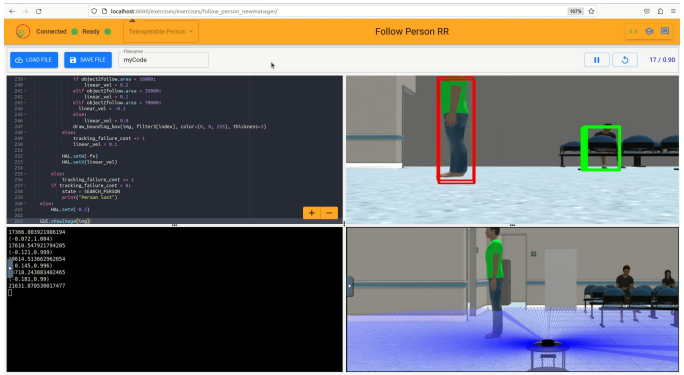




Mejoras

- Actualización del ejercicio a Robotics Academy v5.1
  - Soporte del TurtleBot2 en ROS 2 Humble
  - Reimplementación de la comunicación con el teleoperador
  - Nuevas plantillas Python
  - Nuevo diseño de la página web, plantillas React
- Mejoras en la solución de referencia: controlador PD

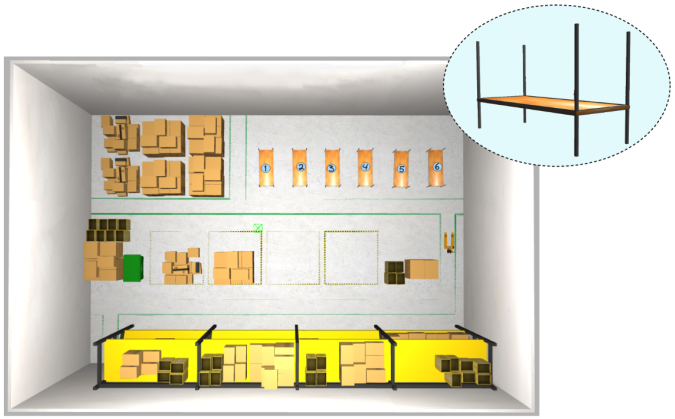




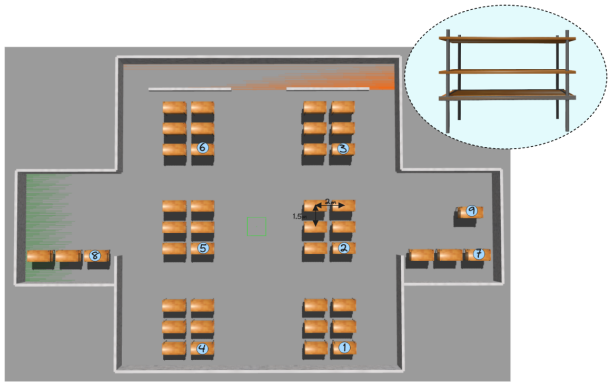
Ejecución típica en `https://youtu.be/VeRk_F9IsDM`

Infraestructura: Entorno simulado

1. Almacén pequeño



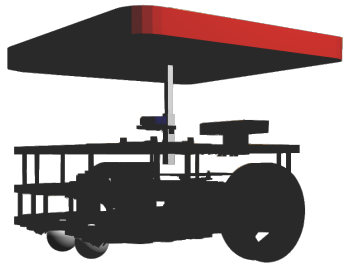
2. Almacén grande



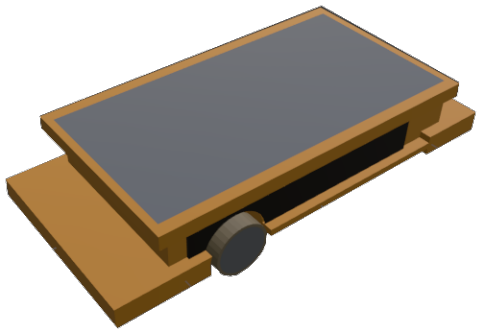
```
<?xml version='1.0' encoding='utf-8'?>
<sdf version="1.6">
  <world name="default">
    <gravity>0 0 -9.8</gravity>
    <physics default="0" name="default_physics" type="ode">
      <max_step_size>0.001</max_step_size>
      <real_time_factor>1</real_time_factor>
      <real_time_update_rate>1000</real_time_update_rate>
    </physics>

    <model name="aws_robomaker_warehouse_ShelfF_01_001">
      <include>
        <uri>model://aws_robomaker_warehouse_ShelfF_01</uri>
      </include>
      <pose frame="">-5.795143 -0.956635 0 0 0 0</pose>
    </model>

    <model name="aws_robomaker_warehouse_WallB_01_001">
      <include>
        <uri>model://aws_robomaker_warehouse_WallB_01</uri>
      </include>
      <pose frame="">0.0 0.0 0 0 0 0</pose>
    </model>

    <model name="pallet_0">
      <include>
        <uri>model://warehouse_pallet3</uri>
      </include>
      <pose frame="">3.728 0.57943 0 0 0 1.588</pose>
    </model>

  [...]
  </world>
</sdf>
```

Infraestructura: Robots simulado

1. Robot logístico holonómico

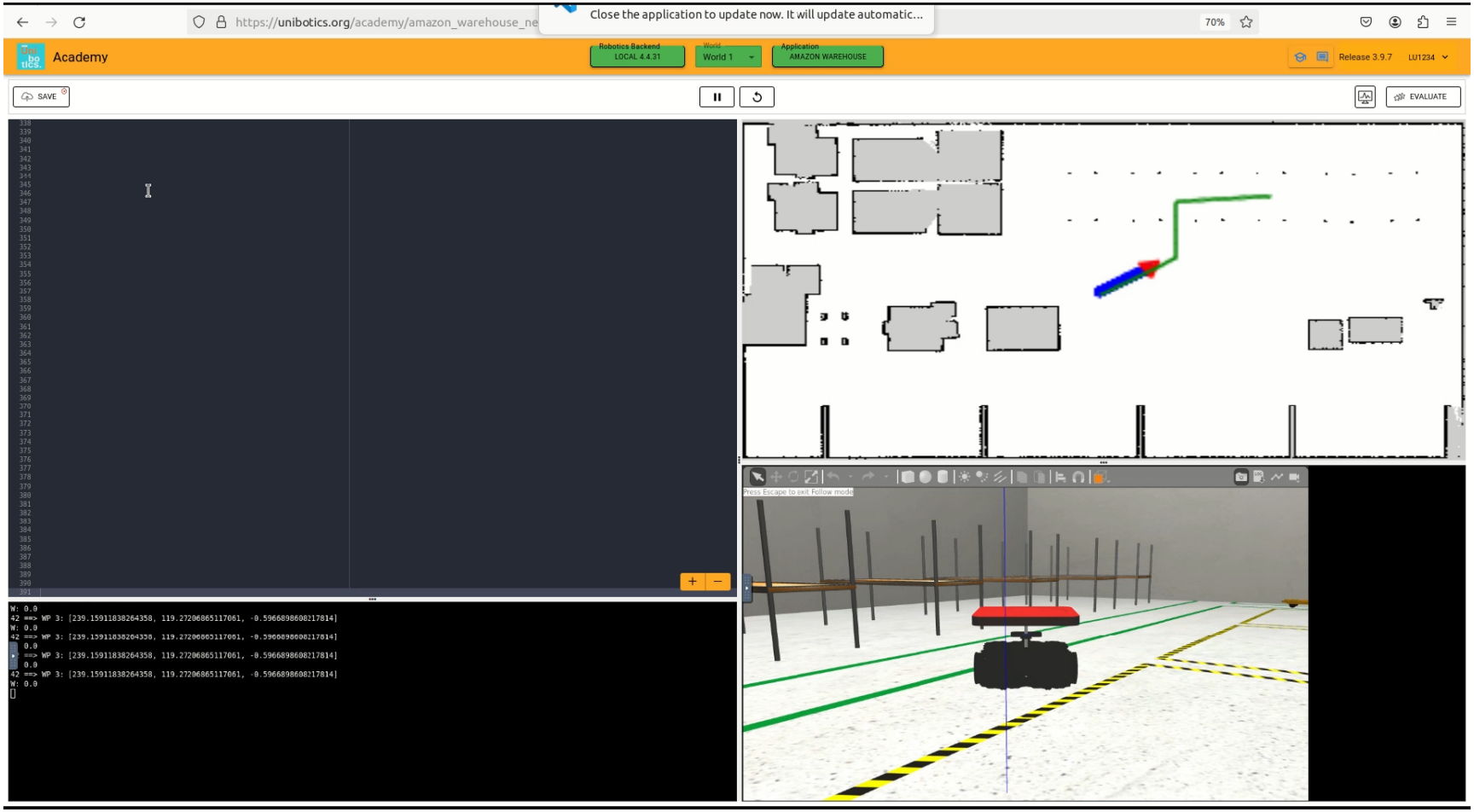


2. Robot logístico Ackermann



```xml
<?xml version="1.0"?>
<sdf version="1.5">
  <model name="ackermann_logistic_robot">
    <pose>0 0 0.0 0 0 0</pose>
    <link name='base_link' />
    <joint name='chassis_link_joint' type='fixed'>
      <pose>0.0 0.0 0.0 0 0 0</pose>
      <parent>base_link</parent>
      <child>chassis_link</child>
    </joint>
    <link name='chassis_link'>
      <inertial>
        <pose>1e-06 0.07307 0.65096 0 -0 0</pose>
        <mass>1580</mass>
        <inertia>
          [...]
        </inertia>
      </inertial>
      <collision name='chassis_link_fixed_joint_lump__chassis_link_collision'>
        <pose>0 0 0.0 0 -0 0</pose>
        <geometry>
          <mesh>
            <scale>0.5 0.5 0.5</scale>
            <uri>model://ackermann_logistic_robot/meshes/chassis.dae</uri>
          </mesh>
        </geometry>
        <surface>
          [...]
        </surface>
      </collision>
      <visual name='chassis_link_fixed_joint_lump__chassis_link_visual'>
        <pose>0 0 0.0 0 -0 0</pose>
        <geometry>
          <mesh>
            <scale>0.5 0.5 0.5</scale>
            <uri>model://ackermann_logistic_robot/meshes/chassis.dae</uri>
          </mesh>
        </geometry>
      </visual>
      <self_collide>1</self_collide>
    </link>
    [...]
    </model>
</sdf>
```

Página Web


Close the application to update now. It will update automatic...
https://unibotics.org/academy/amazon_warehouse_ne
Academy
Robotics Backend
LOCAL 4.4.31
World
World 1
Application
AMAZON WAREHOUSE
Release 3.9.7
SAVE
EVALUATE

Página Web

```
{% extends "react_frontend/exercise_base.html" %}
{% load react_component %}

{% block exercise_header %}
{% endblock %}

{% block react-content %}
    {% if deployment %}
        {% react_component exercise/amazon_warehouse_newmanager/AmazonWarehouseRR %}
            {% react_component components/containers/MaterialBox id="exercise-container" %}
            {% react_component components/common/MainAppBar exerciseName="Amazon Warehouse" url="https://jderobot.github.io/RoboticsAcademy/exercises/MobileRobots/amazon_warehouse/"%}
            {% react_component RA_links/WorldSelectorRA %} {% end_react_component %}
            {% end_react_component %}
            {% react_component components/containers/MaterialBox id="content" %}
                {% react_component components/containers/MaterialBox id="content-exercise" %}
                    {% react_component components/containers/ExerciseControl %}{% end_react_component %}
                    {% react_component components/containers/FlexContainer row %}
                    {% react_component components/containers/FlexContainer console %}
                    {% react_component components/editors/AceEditorRobot %}{% end_react_component %}
                        {% react_component components/visualizers/VncConsoleViewer%}{% end_react_component %}
                        {% end_react_component%}
                        {% react_component components/containers/FlexContainer%}
                            {% react_component exercise/amazon_warehouse_newmanager/SpecificAmazonWarehouse %}{% end_react_component %}
                            {% react_component components/visualizers/GazeboViewer%}{% end_react_component %}
                        {% end_react_component %}
                {% end_react_component %}
            {% end_react_component %}
            {% react_component components/message-system/Loading %}{% end_react_component %}
            {% react_component components/message-system/Alert %}{% end_react_component %}
{% end_react_component %}
{% end_react_component %}
    {% end_react_component %}
    {% else %}
        {% react_component exercise/amazon_warehouse_newmanager/AmazonWarehouseRR %}
            {% react_component components/wrappers/MaterialBox id="exercise-container" %}
                {% react_component components/layout_components/MainAppBar exerciseName="Amazon Warehouse" url="https://jderobot.github.io/RoboticsAcademy/exercises/MobileRobots/amazon_warehouse/"%}
                {% react_component components/visualizers/WorldSelector %} {% end_react_component %}
                {% end_react_component %}
            {% react_component components/wrappers/MaterialBox id="content" %}
                {% react_component components/wrappers/MaterialBox id="content-exercise" %}
                    {% react_component components/layout_components/ExerciseControl %}{% end_react_component %}
                    {% react_component components/wrappers/FlexContainer row %}
                    {% react_component components/wrappers/FlexContainer console %}
                    {% react_component components/editors/AceEditorRobot %}{% end_react_component %}
                    {% react_component components/visualizers/ConsoleViewer%}{% end_react_component %}
                        {% end_react_component%}
                        {% react_component components/wrappers/FlexContainer%}
                            {% react_component exercise/amazon_warehouse_newmanager/SpecificAmazonWarehouse %}{% end_react_component %}
                            {% react_component components/visualizers/GazeboViewer%}{% end_react_component %}
                        {% end_react_component %}
                {% end_react_component %}
            {% end_react_component %}
            {% react_component components/message_system/Loading %}{% end_react_component %}
            {% react_component components/message_system/Alert %}{% end_react_component %}
    {% end_react_component %}
    {% end_react_component %}
    {% end_react_component %}
    {% endif %}
{% endblock %}
```

Plantillas Python

1. HAL API
   - setV(), setW()
   - getPose3d()
   - getSimTime()
   - lift(), putdown()
2. GUI API
   - showPath()
   - getMap()

```python
import rclpy
import sys
import cv2
import threading

from interfaces.motors import PublisherMotors
from interfaces.pose3d import ListenerPose3d
from interfaces.laser import ListenerLaser
from interfaces.platform_controller import PlatformCommandListener
from interfaces.platform_publisher import PublisherPlatform

# Hardware Abstraction Layer
class HAL:
    def __init__(self):
        rclpy.init(args=sys.argv)
        rclpy.create_node('HAL')

        self.motors = PublisherMotors("/amazon_robot/cmd_vel", 4, 0.3)
        self.pose3d = ListenerPose3d("/amazon_robot/odom")
        self.laser = ListenerLaser("/amazon_robot/scan")
        self.platform_listener = PlatformCommandListener()
        self.platform_pub = PublisherPlatform("/send_effort")

        # Spin nodes so that subscription callbacks lift topic data
        executor = rclpy.executors.MultiThreadedExecutor()
        executor.add_node(self.pose3d)
        executor.add_node(self.laser)
        executor.add_node(self.platform_listener)
        executor_thread = threading.Thread(target=executor.spin, daemon=True)
        executor_thread.start()

    @classmethod
    def initRobot(cls):
        new_instance = cls()
        return new_instance

    def getPose3d(self):
        return self.pose3d.getPose3d()

    def getLaserData(self):
        return self.laser.getLaserData()

    def setV(self, velocity):
        self.motors.sendV(velocity)

    def setW(self, velocity):
        self.motors.sendW(velocity)

    def lift(self):
        self.platform_pub.lift()

    def putdown(self):
        self.platform_pub.putdown()
```

Soluciones referencia

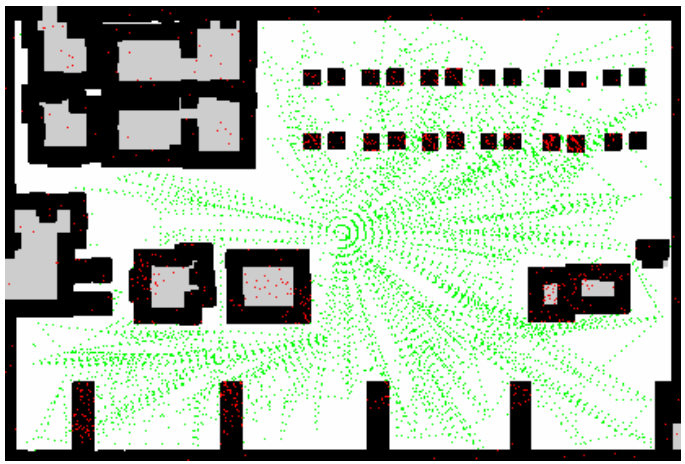
1. Planificación espacial con robot holonómico y geometría "circular"
2. Planificación espacial con robot holonómico y geometría "rectangular"
3. Planificación basado en controles con robot Ackermann

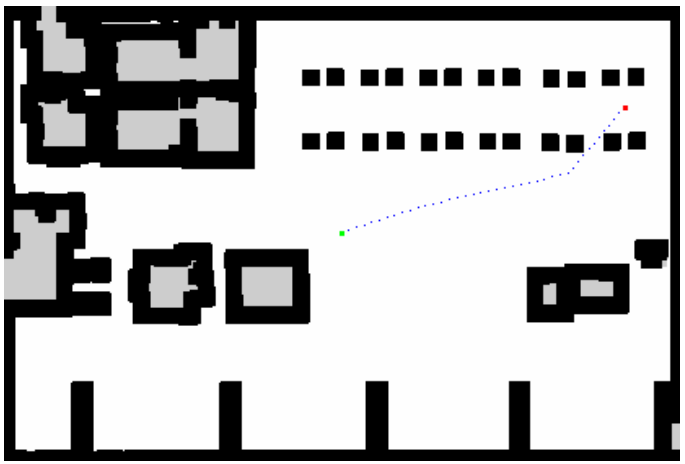
Soluciones referencia

- Fases
  - Planificación de la ruta con OMPL:
    - Espacio de estados (y espacio de controles)
    - Criterio de validación de estados
    - Estado inicial y estado final
    - Planificador (y objetivo de optimización)
    - Resolución del problema $\rightarrow$ lista de *waypoints*
  - Ejecución de la ruta
- Máquina de estados

Soluciones referencia

1. Planificación espacial con robot holonómico y geometría "circular"
   - *RealVectorStateSpace*, (x, y)
   - *PathLengthOptimizationObjective* → Ruta óptima





   - Indexado por posición → recorriendo secuencia (x, y)

Soluciones referencia

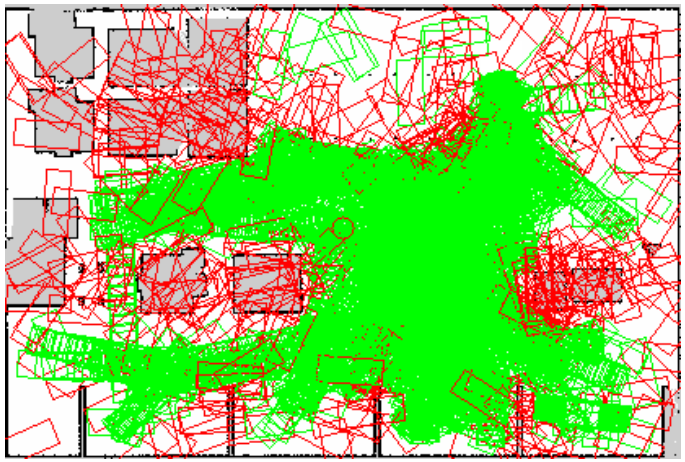
1. Planificación espacial con robot holonómico y geometría "circular"

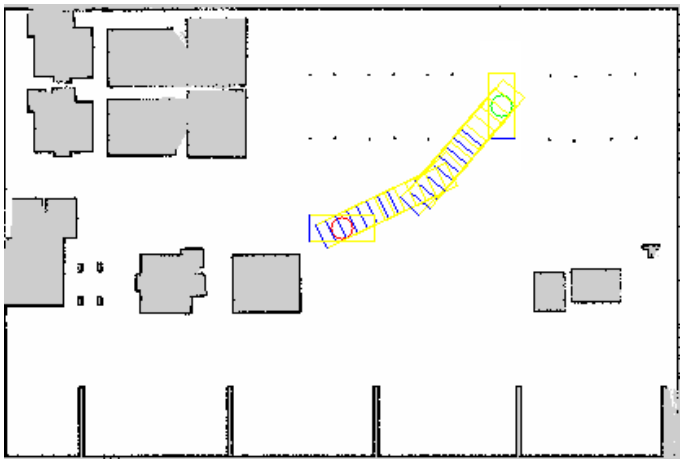
```
1   def isStateValid(state):
2       w = min(int(state[0]), MAP_WIDTH - 1)
3       h = min(int(state[1]), MAP_HEIGHT - 1)
4
5       c = eroded_map[h, w]
6       free = c[0] * 255 > 250 and c[1] * 255 > 250 and c[2] * 255 > 250
7       return free
```

Ejecución típica en `https://youtu.be/EVt9vYqEoDg`

Soluciones referencia

2. Planificación espacial con robot holonómico y geometría "rectangular"
   - *DubinsStateSpace*, (x, y, yaw)
   - *PathLengthOptimizationObjective* → Ruta óptima





   - Indexado por posición → recorriendo secuencia (x, y)

Soluciones referencia

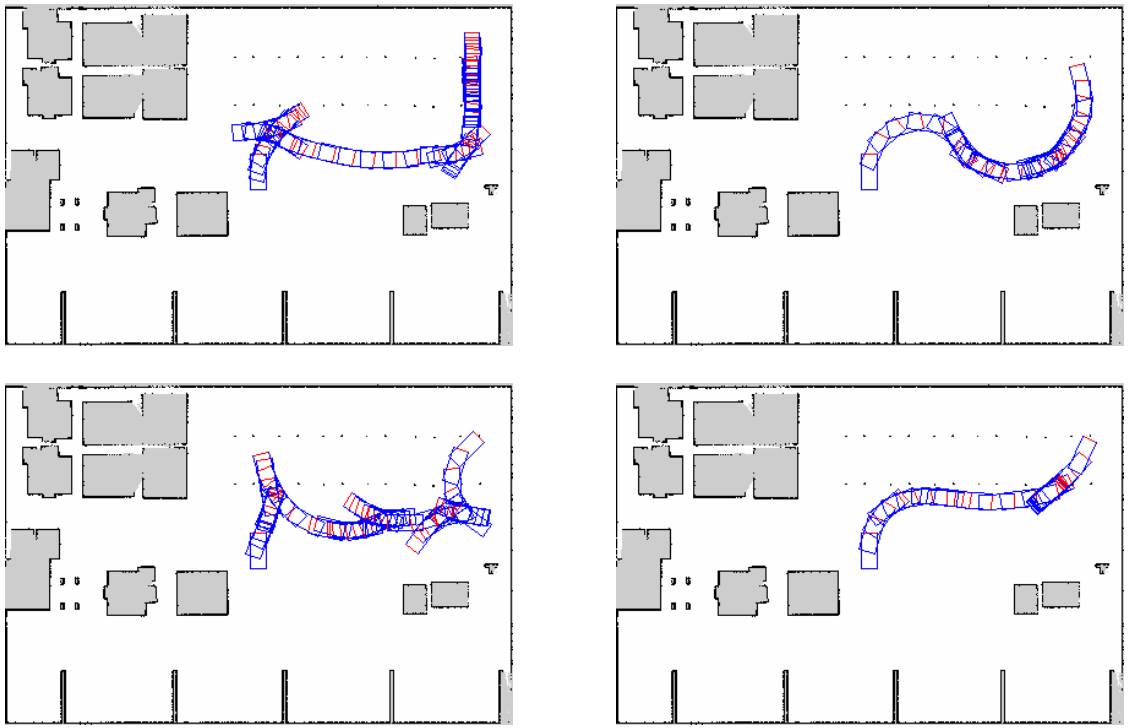
2. Planificación espacial con robot holonómico y geometría "rectangular"

```
1   def isStateValid(state):
2       w = min(int(state.getX()), MAP_WIDTH - 1)
3       h = min(int(state.getY()), MAP_HEIGHT - 1)
4       yaw = state.getYaw()
5
6       for x in range(-robotw, robotw, 1):
7           for y in range(-robotl, robotl, 1):
8               newx, newy = rotationMatrix(x, y, w, h, yaw)
9               if 0 < newx < MAP_WIDTH and 0 < newy < MAP_HEIGHT:
10                  c = mapImg[newy, newx]
11                  free = c[0] * 255 > 250 and c[1] * 255 > 250 and c[2] * 255 > 250
12              else:
13                  free = False
14              if not free:
15                  break
16          if not free:
17              break
18      return free
```

Ejecución típica en `https://youtu.be/-2D90I-wZKs`

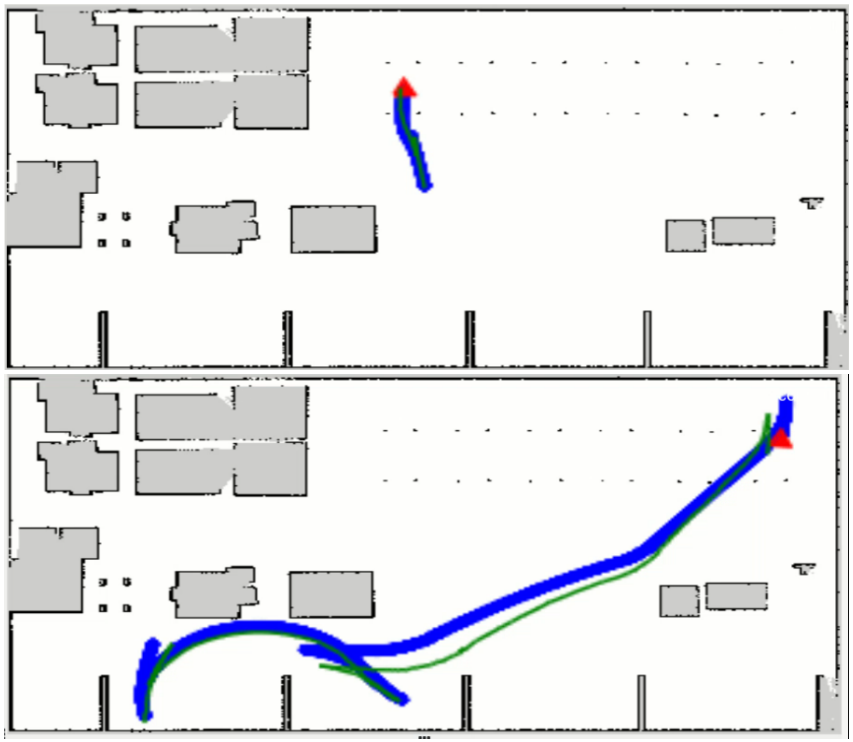
Soluciones referencia

3. Planificación basado en controles con robot Ackermann
   - OMPL app: *setEnviromentMesh()*, *setRobotMesh()*
   - *KinematicCarPlanning*: *SE2StateSpace*, (x, y, yaw) + *control space*,(v, w, duration)
   - Ruta aproximada → Ruta subóptima



Soluciones referencia

3. Planificación basado en controles con robot Ackermann
   - Indexado en el tiempo → recorriendo secuencia (v, w, duration)



Ejecución típica en `https://www.youtube.com/0P04S80mn30`

Conclusiones: objetivos cumplidos

- Actualización del ejercicio Sigue-Persona a RA v5.1
- Creación de un nuevo ejercicio Almacén-Amazon

Conclusiones: líneas futuras

- Mejoras en la solución
- TurtleBot2 + Almacén-Amazon

Gracias por su atención