ME454 Midterm exam

2022.04.17

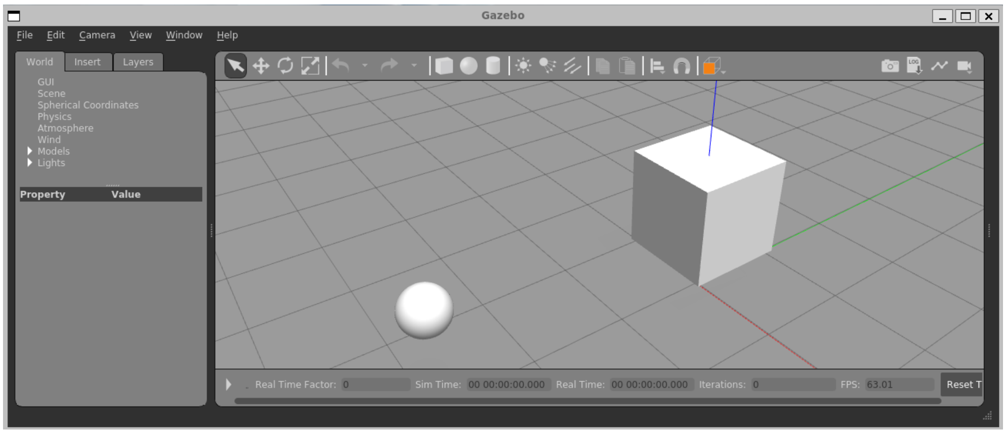
Start : 11:59 AM, April 17th, End : 11:59 AM, April 18th

In this midterm exam, students are evaluated for creating a ROS 2 package of two objects and for understanding the dynamics of rigid body collision. Perform a simulation to throw a sphere toward a cube. Observe the physical quantities of the two objects.

- Use the given “midterm.world” .
- Create a ROS 2 package using “ros2 pkg create” command as below

```
midterm
- worlds
    - midterm.world
- urdf
    - empty
- src
    - empty
- launch
    - empty
- include
    - empty
```

- The midterm.world loads libgazebo_ros_state plugin and sets the gravity to zero. Do not modify it.
- The ODE dynamics solver is the default solver of gazebo classic. Do not modify it.



(1) Make unit_cube.urdf for a cube and unit_sphere.urdf for a sphere. Use the properties below.

Put the two files in the urdf folder of the package. **(15 points)**

- Cube properties: size 1.0 m, 1.0 m, 1.0 m, mass 10 kg, inertia ixx=1.667, iyy=1.667, izz=1.667 (unit in kg m^2)

- Sphere properties: radius 0.2 m, mass 1 kg, inertia ixx=0.016, iyy=0.016, izz=0.016 (unit in kg m^2)

- Use the following code to set the collision properties of the objects (append the code at the end of and before </robot> in the urdf file.

```
<gazebo reference="base_link">
    <collision name='base_link_collision'>
        <surface>
            <friction>
                <ode>
                    <mu>0.9</mu>
                    <mu2>0.9</mu2>
                    <fdir1>0 0 0</fdir1>
                </ode>
            </friction>
            <contact>
                <ode>
                    <kp>1e+13</kp>
                    <kd>1</kd>
                    <max_vel>10.0</max_vel>
                </ode>
            </contact>
            <bounce>
                <restitution_coefficient>1.0</restitution_coefficient>
                <threshold>0.0</threshold>
            </bounce>
        </surface>
    </collision>
</gazebo>
```

(2) Make a launch file “midterm_launch.xml” and put it in “launch” folder. **(20 points)**

- It starts gazebo and loads midterm.world.

- It loads unit_cube.urdf and sets the cube at x=0.0 m, y=0.0 m, and z=1.0 m.

- It loads unit_sphere.urdf and sets the sphere at x=0.3 m, y=-3.0 m, and z=1.3 m.

- It loads the node in problem (3).

* In gazebo, Z-axis is the vertical axis

- Run rqt_graph and capture a screenshot of the graphs of nodes and topics when the system is launched.

(3) Make a node application in this package. **(30 points)**

- It subscribes the kinematics of objects in gazebo and broadcasts the following physical quantities to the topic channels

Physical quantity	Topic channel name	Message type
Linear momentum of the sphere	sphere_linear_momentum	geometry_msgs/Vector3
Angular momentum of the sphere around the world origin	sphere_angular_momentum	geometry_msgs/Vector3
Kinetic energy of the sphere	sphere_kinetic_energy	std_msgs/Float32
Linear momentum of the cube	cube_linear_momentum	geometry_msgs/Vector3
Angular momentum of the cube around the world origin	cube_angular_momentum	geometry_msgs/Vector3
Kinetic energy of the cube	cube_kinetic_energy	std_msgs/Float32
Combined linear momentum of the cube and sphere	combined_linear_momentum	geometry_msgs/Vector3
Combined angular momentum of the cube and sphere around the world origin	combined_angular_momentum	geometry_msgs/Vector3
Combined kinetic energy of the cube and sphere	combined_kinetic_energy	std_msgs/Float32

(4) Throw the sphere toward the cube using a gazebo service call. **(5 points)**

- Initial velocity of the sphere: linear [0, 1, 0] m/s, angular [0, 0, 0] rad/s

- Initial velocity of the cube: linear [0, 0, 0] m/s, angular [0, 0, 0] rad/s

- What are the commands to do it in the command line?

* You can pause gazebo before sending these commands to gazebo, and then press play button in gazebo to observe simulation

(5) Monitor the topics in (3) with rqt topic monitor and plot plugins after throwing the sphere using the commands in (4). **(10 points)**

- Capture the graphs of following physical quantities with the rqt from the start of sphere throwing up to 4 seconds exactly.

- Capture 1. Linear momentum

  Linear momentum along x – cube x, sphere x, and combined x

  Linear momentum along y – cube y, sphere y, and combined y

  Linear momentum along z – cube z, sphere z, and combined z

- Capture 2. Angular momentum

  Angular momentum along x – cube x, sphere x, and combined x

  Angular momentum along y – cube y, sphere y, and combined y

  Angular momentum along z – cube z, sphere z, and combined z

- Capture 3. Kinetic energies of the cube, sphere and combined.

(6) Change the restitution coefficients of the cube and sphere to 0.5 and repeat (5). **(10 points)**

(7) Discuss conservations of the momentums and energies of the combined system (cube and sphere) in (5) and (6). **(8 points)**

(8) QAIST question: Suggest a project that you want students to do with ROS 2 for final exam if you were a professor. It should include multiple rigid bodies. Students with good answers will receive small gifts from the school. **(2 points)**

* Do not use any external libraries.

Zip the following items and upload it to KLMS by NOON, April 18th.

- An image of signed honor code
- Your ROS package that can be compiled using colcon build.
- A Powerpoint file that contains
  - Explanation to run the simulation with your package. TA will test your package by following your explanation.

- A screenshot of rqt_graph in (2)
- Commands in (4)
- Graphs captured in (5) and (6)
- Discussion for (7)
- QAIST question for (8)
- A video (mp4 format) of the simulation captured in (5) and (6). Use the video recording button in Gazebo.

You cannot upload it to KLMS after the deadline. Upload it early. There is no late submission.

Contact TA (sbs0323@kaist.ac.kr) before 11 AM, April 18th if you have a problem in uploading to KLMS.