Motion-Planning Lab 1

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Part 1 – Algorithmic building blocks

Sampling

Collision detection

2.1. Assume that a link is modeled as a cylinder with a radius r, and length 10r and that all spheres have equal radii. Furthermore, assume for simplicity that the center of the link is located along the x-axis with one endpoint at (0,0,0) and the other at (10r,0,0). For the following, give the location of each sphere together with their radius in order to ensure that there are no false negatives while minimizing the number of false positives.

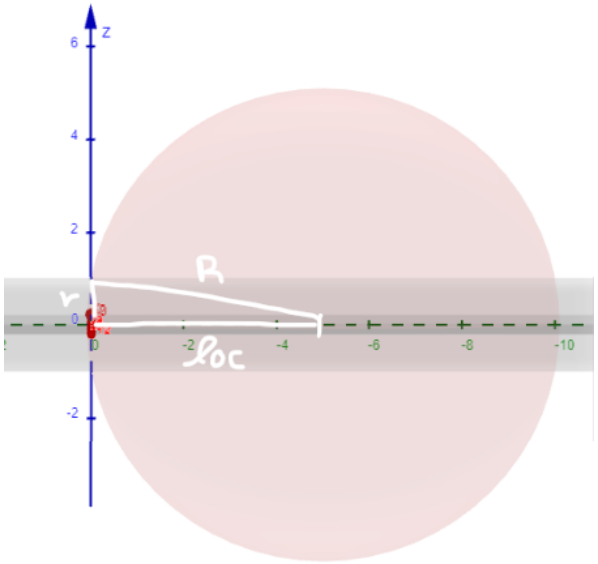
Reminder:
- False negative - the CD returns that there isn't a collision while there is in the real world.

- False positive - the CD returns that there is a collision while there isn't in the real world.

In order to make sure that there are no false negatives while minimizing the number of false positives we would set the center of the first sphere in the location:
$loc = \frac{\text{len of link}}{2\times\text{num of spheres}}$ and from there we would set the rest of the centers with spaces of twice this size until the end of the cylinder.

In addition, we would want to cover the furthest point of the link that is modeled as a cylinder with radius r.

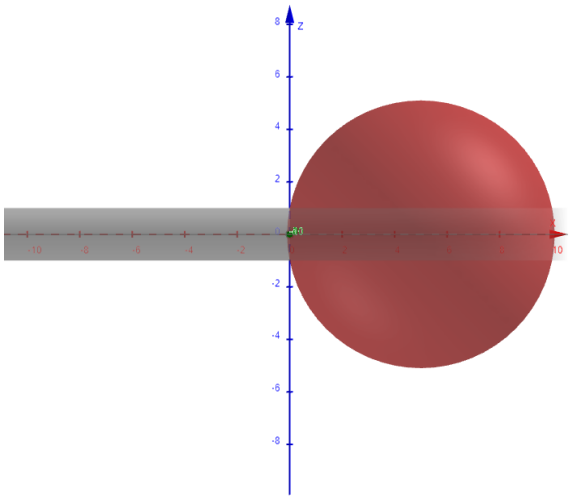
$r^2 + (loc)^2 = R^2$



This is how we calculated for each of the following cases.

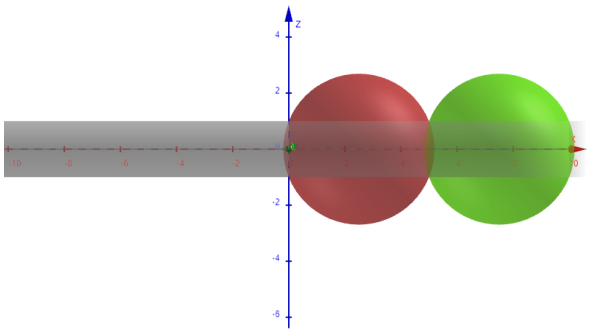
2.1.1. One sphere.

location: (0, 0, 5r)
radius: $\sqrt{26}r$



2.1.2. Two spheres.

location$_1$: (0, 0, 2.5r), location$_2$: (0, 0, 7.5r)
radius: $\sqrt{\frac{29}{4}}r$

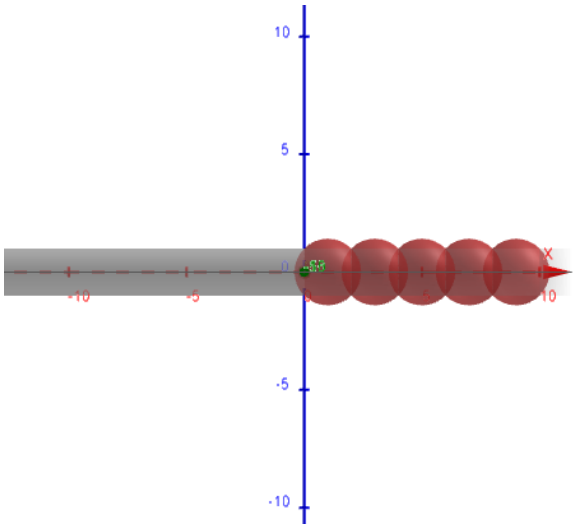


is

2.1.3. Five spheres.

location$_1$: (0, 0, 1r), location$_2$: (0, 0, 3r), location$_3$: (0, 0, 5r), location$_4$: (0, 0, 7r), location$_5$: (0, 0, 9r)

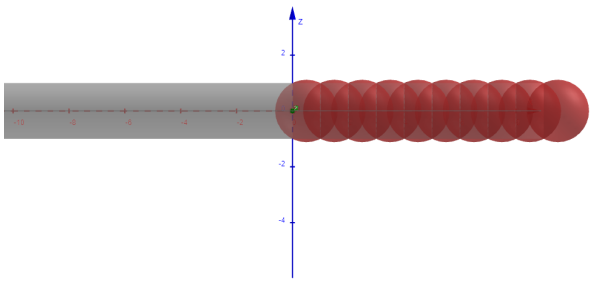
radius: $\sqrt{2}r$



2.1.4. Ten spheres.

location$_1$: (0, 0, 0.5r), location$_2$: (0, 0, 1.5r), location$_3$: (0, 0, 2.5r), location$_4$: (0, 0, 3.5r), location$_5$: (0, 0, 4.5r), location$_6$: (0, 0, 5.5r), location$_7$: (0, 0, 6.5r), location$_8$: (0, 0, 7.5r), location$_9$: (0, 0, 8.5r), location$_1$0: (0, 0, 9.5r)

radius: $\sqrt{\frac{5}{4}}r$



2.2. Discuss in general terms the tradeoff and effect of the number of spheres and their radius.

Answer: As the number of spheres increases the accuracy increases (less false positives) but it means that there are more spheres to check in each link, meaning bigger time complexity. As the number of spheres decreases the accuracy decreases (more false positives) as well but it means that there are less spheres to check in each link, meaning smaller time complexity.

2.3. Visualization of the configuration [-0.694, -1.376, -2.212, -1.122, 1.570, -2.26][in radians] for inflation-factor = 1, 2, 3:

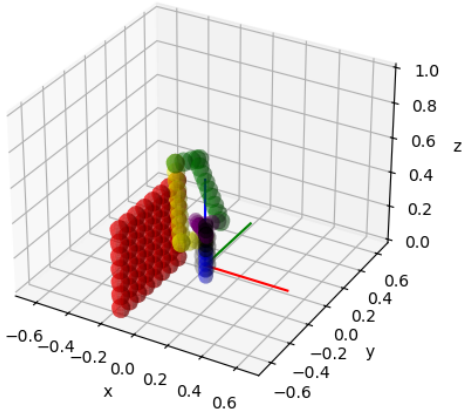


Figure 1: inflation factor = 1

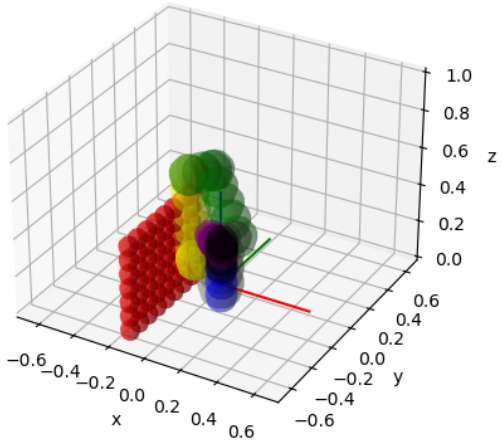


Figure 2: inflation factor = 2

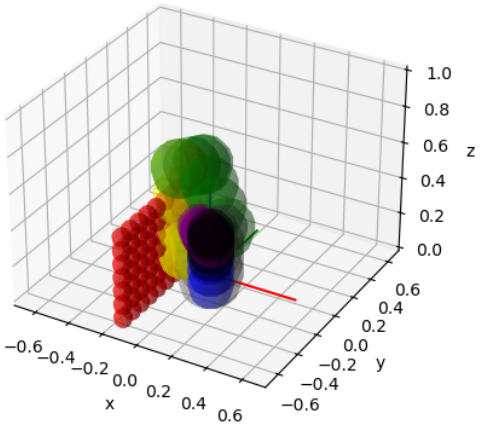


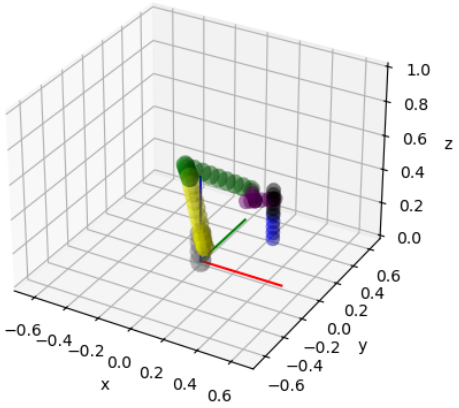
Figure 3: inflation factor = 3

3.1. Examples of:

(i) Configuration which is collision free:

configuration (in rad): [0.694, -1.376, -2.212, -1.122, 1.570, -2.26]

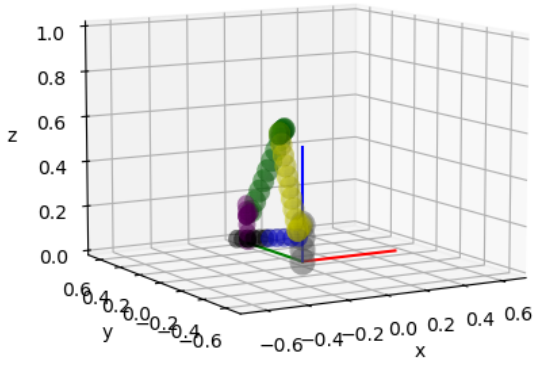
snapshot:



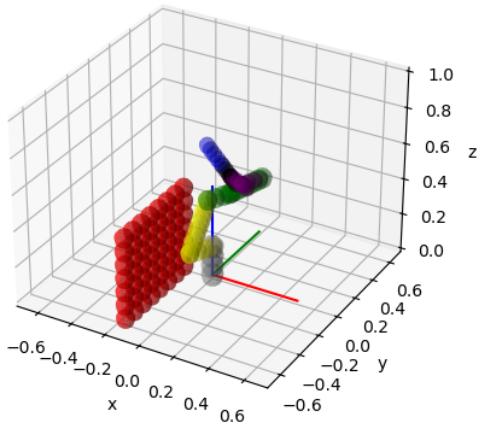
(ii) Configuration which is in collision:

configuration (in rad): [-0.694, -1.376, 2.55, -1.122, -1.570, 2.26]

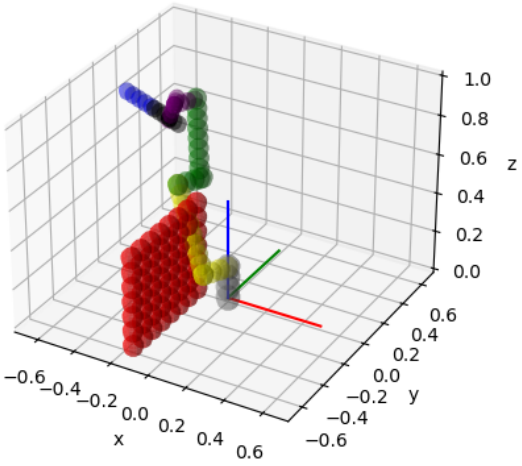
snapshot:



3.2. Examples of: (i) one configuration which is collision free:
configuration (in rad): [-0.5, -2, -0.5, 1, 1, -1]
snapshot:



(ii) one configuration that is in collision with the obstacle.
configuration (in rad): [-0.5, -1, -0.5, 1, 1, -1]
snapshot:



4.

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For self.resolution of 0.1 the number of intermediate configuration that were checked is: 13, and the local planner returns False

For self.resolution of 0.2 the number of intermediate configuration that were checked is: 7, and the local planner returns False

For self.resolution of 0.3 the number of intermediate configuration that were checked is: 5, and the local planner returns False

For self.resolution of 0.4 the number of intermediate configuration that were checked is: 4, and the local planner returns False

For self.resolution of 0.5 the number of intermediate configuration that were checked is: 3, and the local planner returns False

For self.resolution of 0.6 the number of intermediate configuration that were checked is: 3, and the local planner returns False

For self.resolution of 0.7 the number of intermediate configuration that were checked is: 2, and the local planner returns True

For self.resolution of 0.8 the number of intermediate configuration that were checked is: 2, and the local planner returns True

For self.resolution of 0.9 the number of intermediate configuration that were checked is: 2, and the local planner returns True

For self.resolution of 1 the number of intermediate configuration that were checked is: 2, and the local planner returns True
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As can be seen, for resolution=0.6 the local planner returns False and 3 intermediate configurations were checked. And for resolution=0.7 the local planner returns True and 2 intermediate configurations were checked.

5. Notice: We were told that we should calculate false positive and not false negative as was written in the assignment.

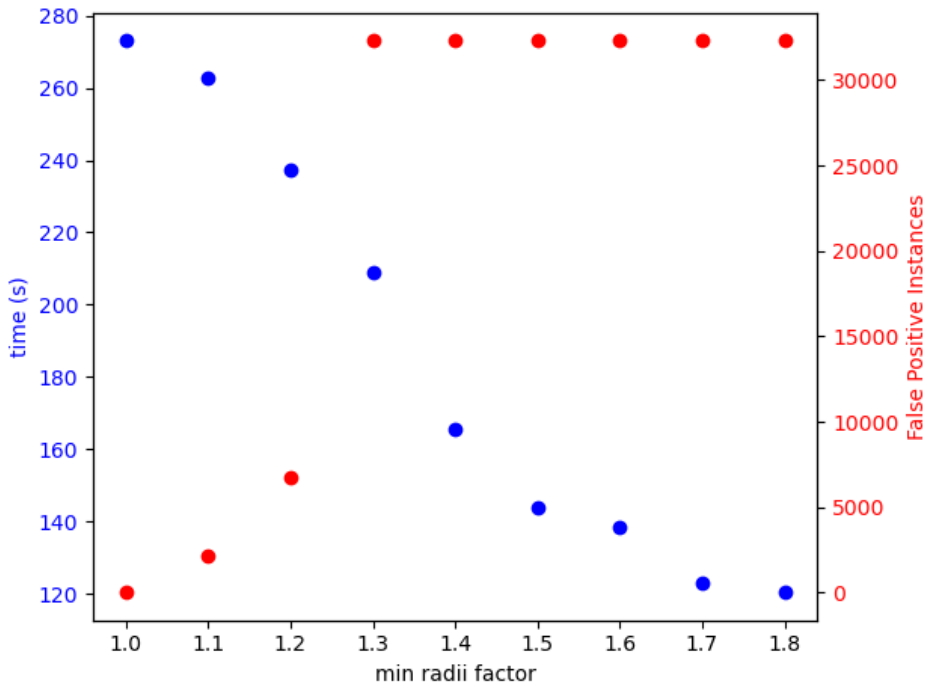

Figure 4: First Plot - without the assumption that there is collision between the wrist links

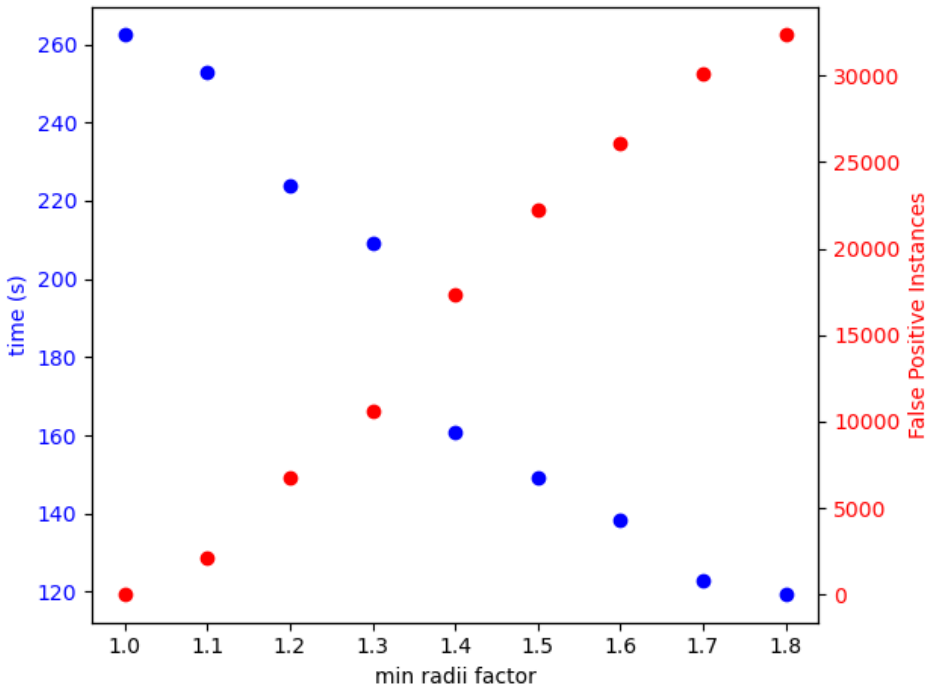

Figure 5: Second Plot - with the assumption that there is collision between the wrist links

Assumptions in Collision Detection

After observing issues with collision detection we made the following assumption:

1. Adjacent Links Collision: Based on empirical observations and mechanical analysis, it was noted that adjacent links in the UR5 robotic manipulator design are inherently structured to avoid collision during movement. Consequently, collision detection between adjacent links was excluded from the collision detection algorithm.

And after observing issues with collision detection performance when utilizing inflation factors above 1.3 which resulted in a higher incidence of false positive collisions during testing, we made the following assumption:

2. Wrist Links Collision: Further examination revealed that the last three parts of the wrist assembly ('wrist_1_link', 'wrist_2_link', and 'wrist_3_link') are mechanically designed to prevent collisions with each other. As a result, collision detection between these components was considered redundant and was consequently omitted from the collision detection process.

Therefore, these assumptions were adopted and you can see the results when only the first assumption was made in the first plot while on the second plot you can see the results when the the two assumptions were made. The code that we have submitted is without the second assumption because we are not sure that it is absolutely correct.