Robot Autonomy Lecture Note 2.27

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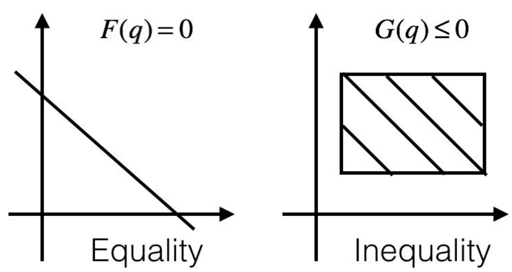
1. RRT, tRRT, RRT*

2. Planning with Constraints

In the piano mover problem we have imposed constraint:

- Find the path ζ st. $\zeta(0) = q_s$ and $\zeta(1) = q_g$ and $\zeta(t) \in C_{free}$

What we are going to do is to add a new set of constraints on this.

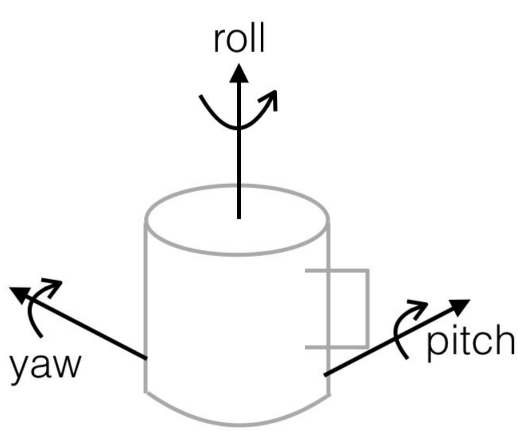


In graph representation the equality constraint could be expressed as a straight line and the inequality constraints could be expressed as a region. Some examples of the two types of constraints that we have encountered could be:

Equality: Goal configuration ($Q_g = \{q \in C_{free} | \, forward\ kinematics(q) = x_g\}$)

Inequality: DOF limit, Collision Check (inside/outside boundary)

Coffee Mug



$$\begin{bmatrix} x \\ y \\ z \\ r \\ p \\ y \end{bmatrix} = Forward\_Kinematics(q)$$

Consider the case that the robot arm moves a cup of coffee from one place to another with coffee in the mug. To avoid spilling the coffee, the constraints are:

Equality: $pitch = 0$, $yaw = 0$

Inequality: $pitch \in [p_1, p_2]$, $yaw \in [y_1, y_2]$

Taxonomy:

(1) Trajectory-wide vs Part of Trajectory

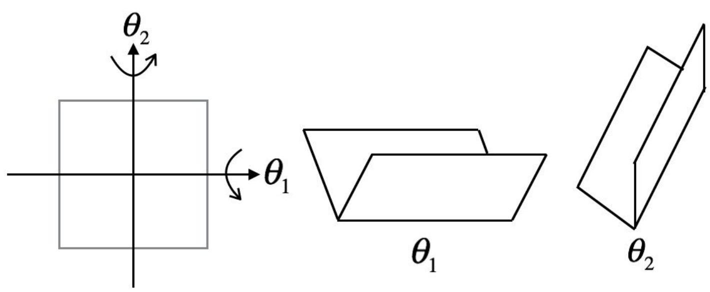
Trajectory-wide: holding the coffee mug upright

Part of Trajectory: goal constraint

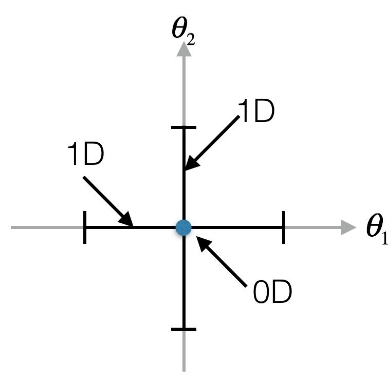
(2) Lower Dimensional

For lower dimensional constraints, we can use projection.

(3) Constraint Transition



Consider folding a paper in two directions.



If we want to fold the paper from one direction to the other, we need to go from one of the point on the axis to the origin and then go to the other axis. However, the origin is a 0-dimensional point, which means we cannot reach it with any resolution ε.

3. CBiRRT

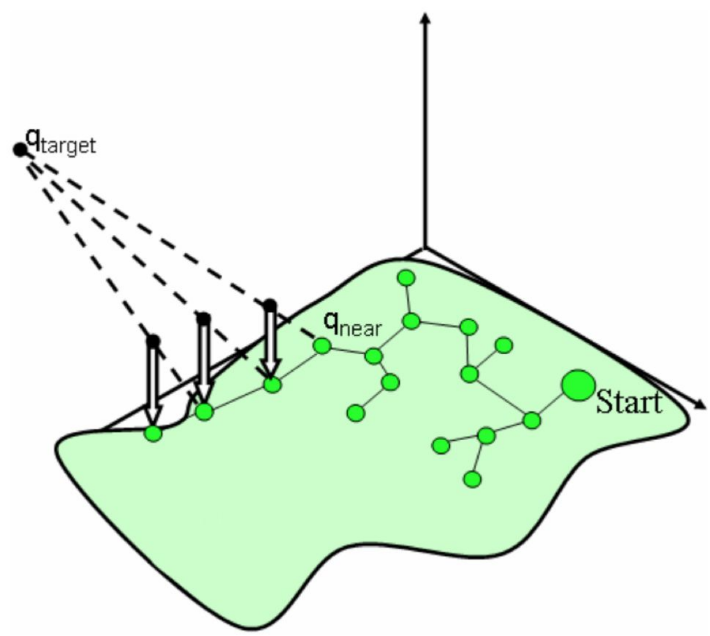
Constrained Bidirectional RRT

It grows a tree, and break down the problem into 2 piece.

1. Sampling

   If you have a full dimensional constraint(Inequality, ex: joint limits, obstacles), you can do a “rejection sampling” which means continuously sample until you reach the obstacle.
2. Extension

If you cannot do rejection sampling, just sample any point in C_{free} . Imagine the green surface in the figure in fig is the surface of the moon. We pick a distant as a sample star which is in the space and try to move forward to the star. So we jump toward that direction(extension: red arrow) and then project back on to the moon(white arrow). Repeat this after we are underneath the star. But during this process it is possible that we jump off the cliff or hit an obstacle.
Start and goal pick the same star and both jump to that star, which becomes the Bi-directional RRT on the surface.
As we explore more and more, we have to guarantee that our footstep can touch the moon.
You have projection operator to project you back to the constraint. Use gradient-descent for projection.



Iso-contour for gradient descend projection method (q)