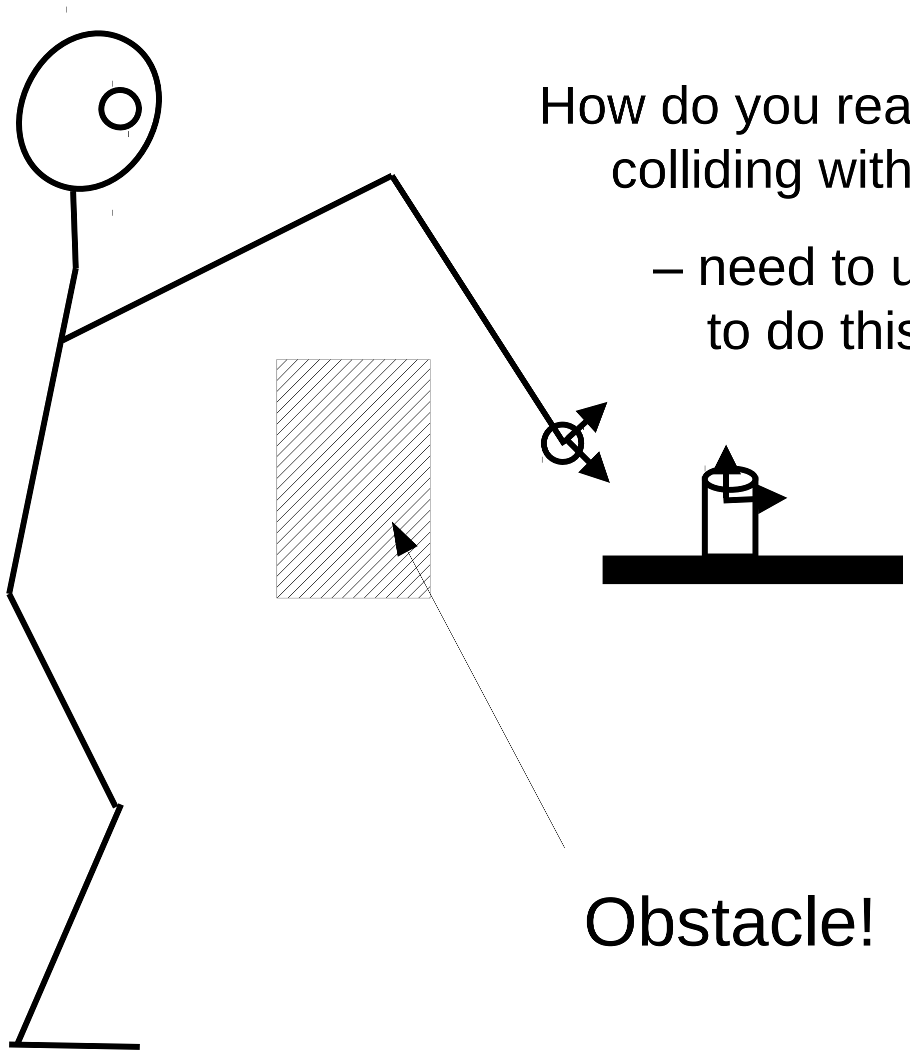
Configuration space

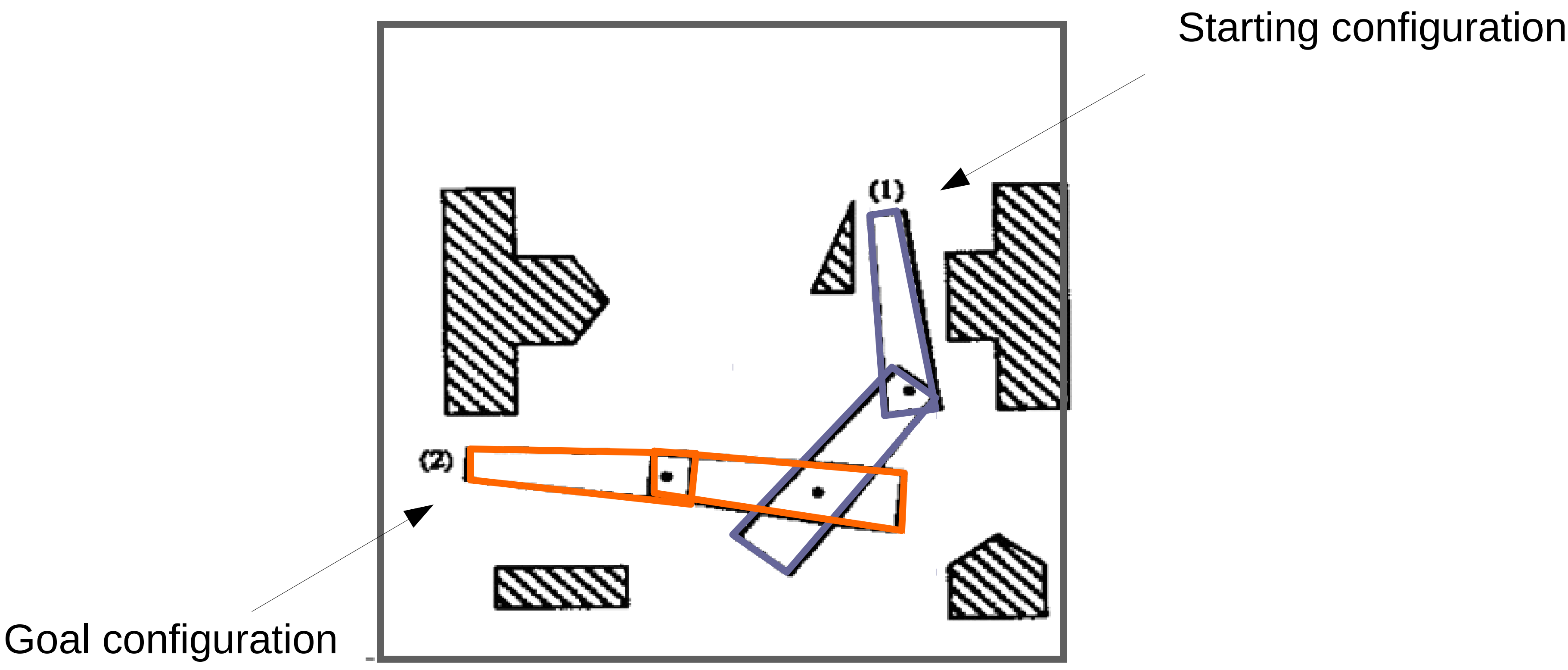
How do you reach toward something without colliding with obstacles in the environment?

– need to understand configuration space to do this!



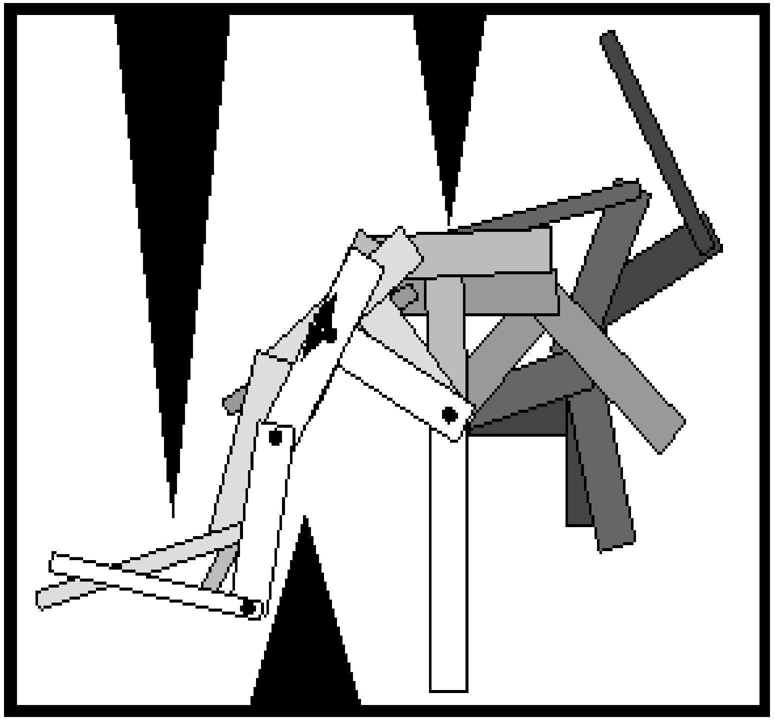
Problem we want to solve

<u>Given</u>:
– description of the robot arm (the manipulator)
– description of the obstacle environment
<u>Find</u>:
– path from start to goal that does result in a collision



Problem we want to solve

This problem statement is actually very general
– manipulators



Problem we want to solve

This problem statement is actually very general
– manipulators
– mobile robots

Approach: plan in “configuration space”

Convert the original planning problem into a planning problem for a single point.

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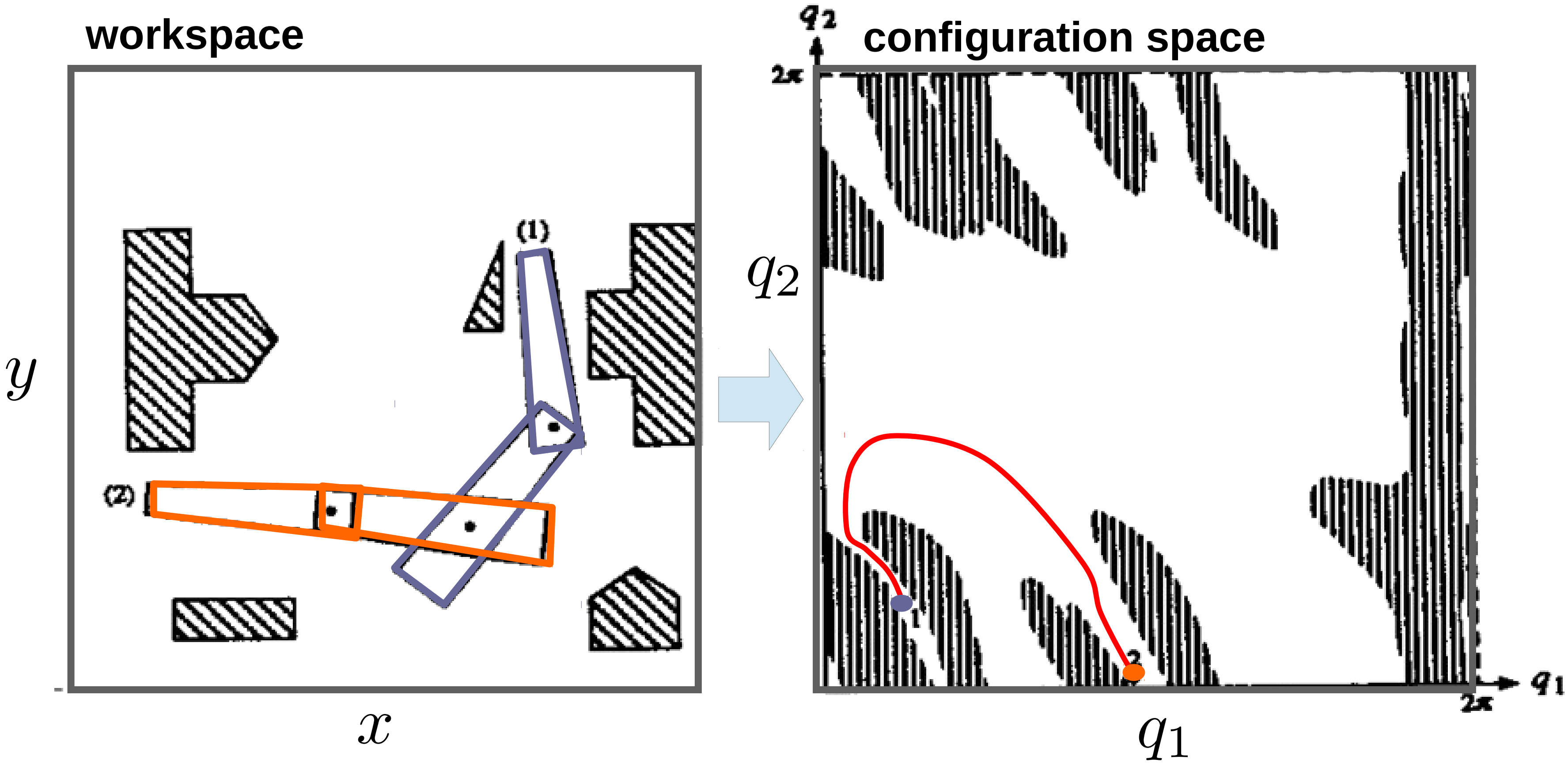
Convert the original planning problem into a planning problem for a single point.

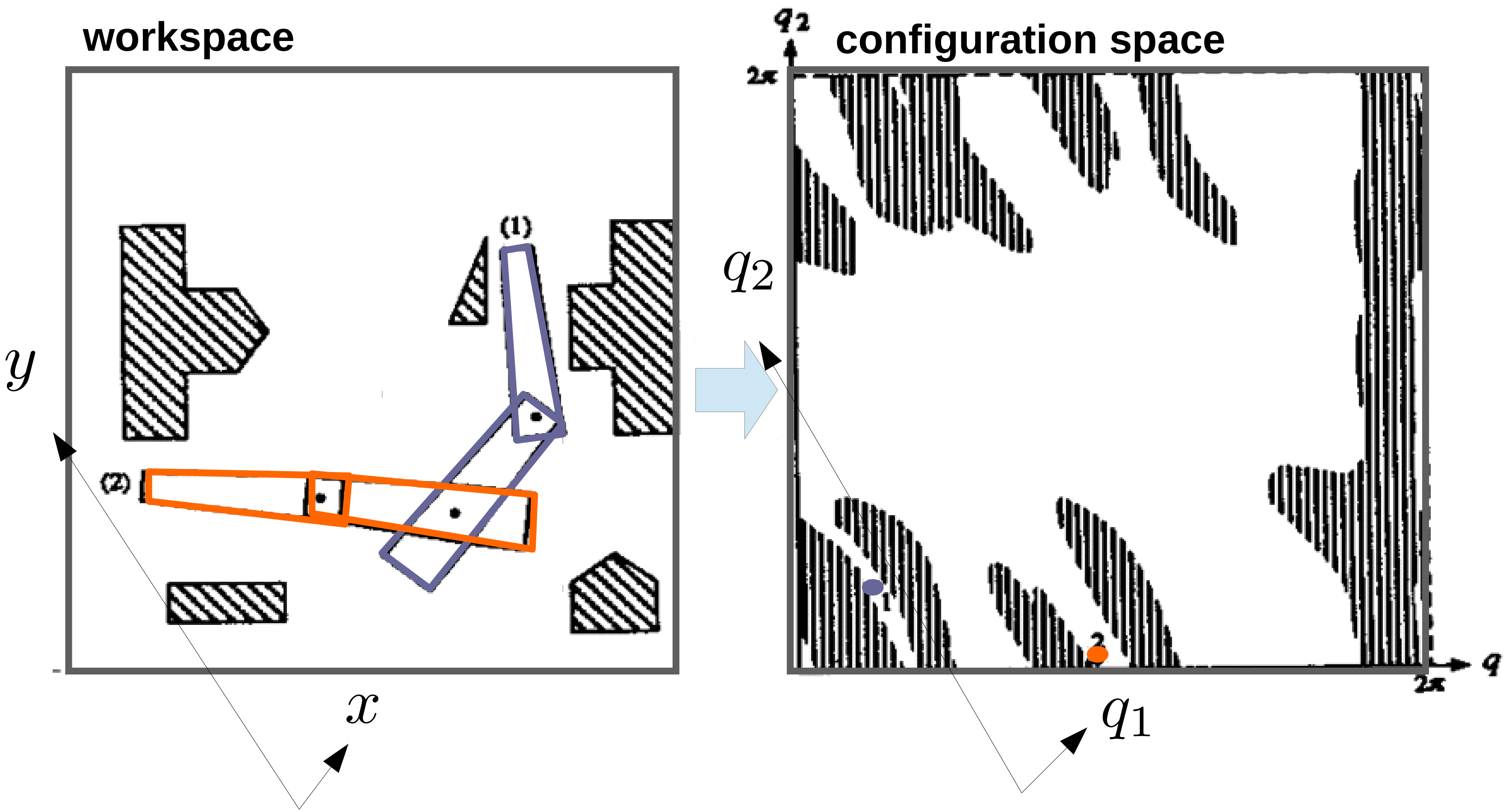


<u>Original problem</u>
– plan path for robot arm

<u>Equivalent problem:</u>
– plan path for a point

Approach: plan in “configuration space”

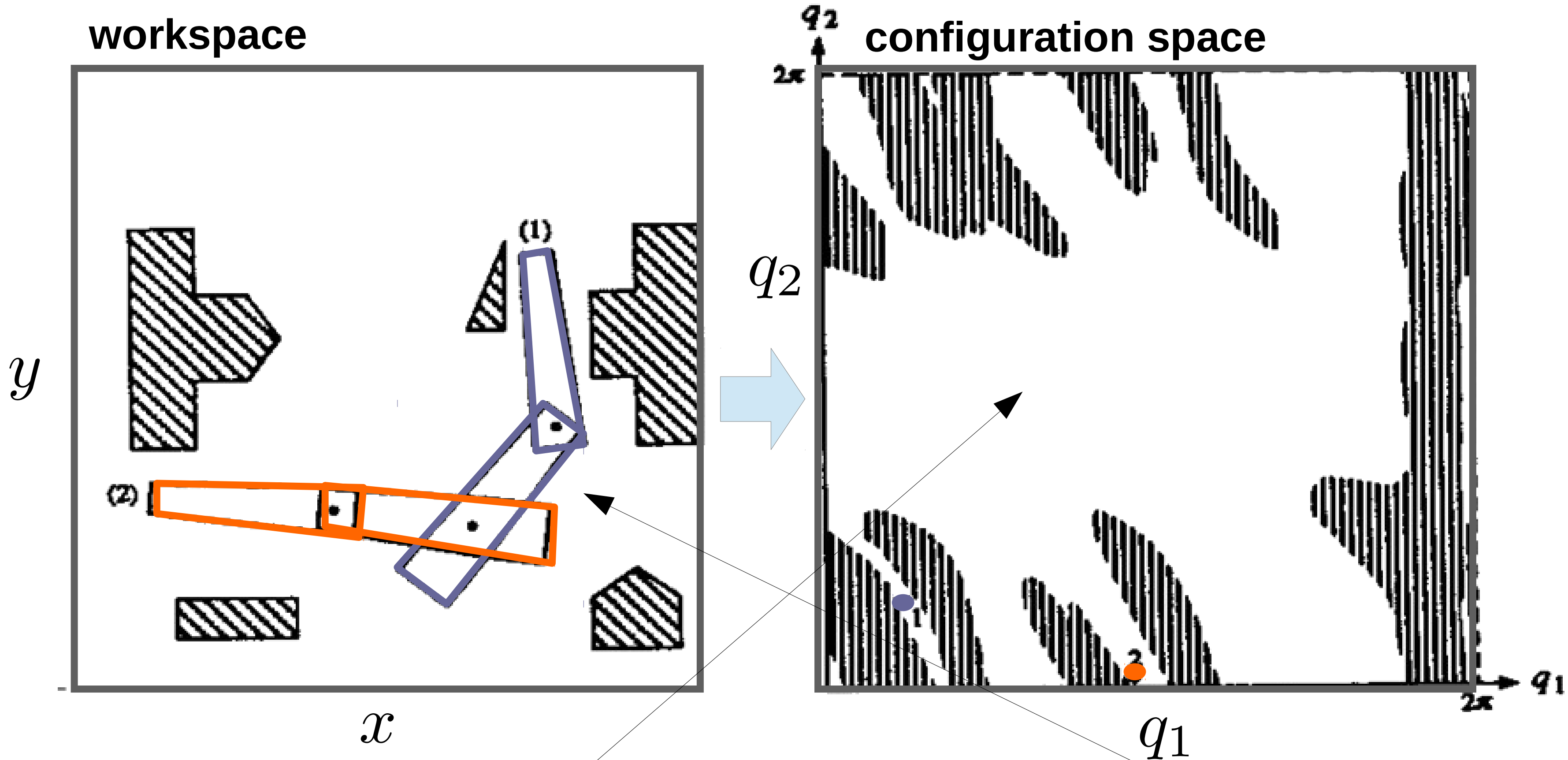
Notice the axes!



Cartesian space!

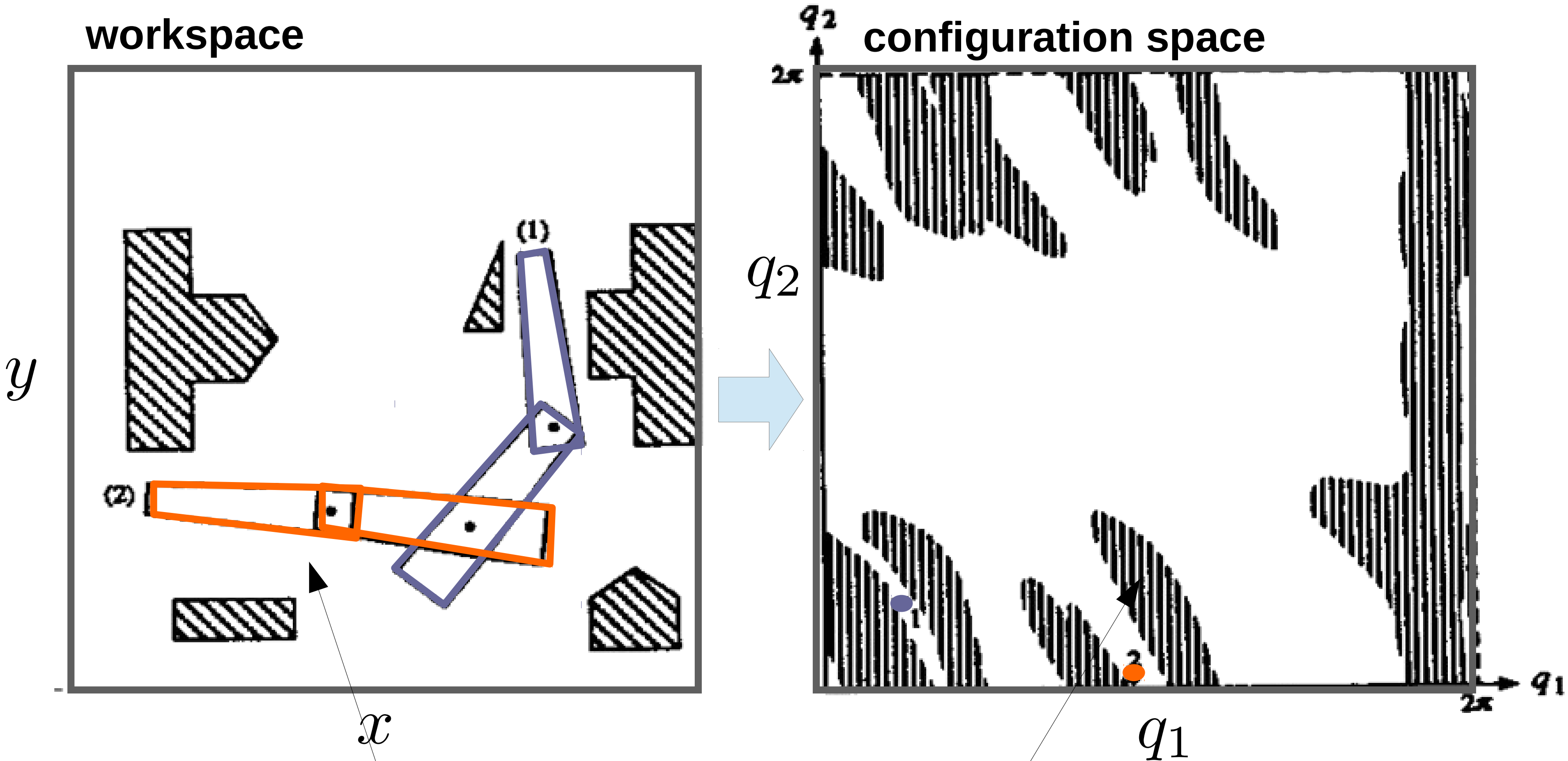
Joint angles!

Approach: plan in “configuration space”



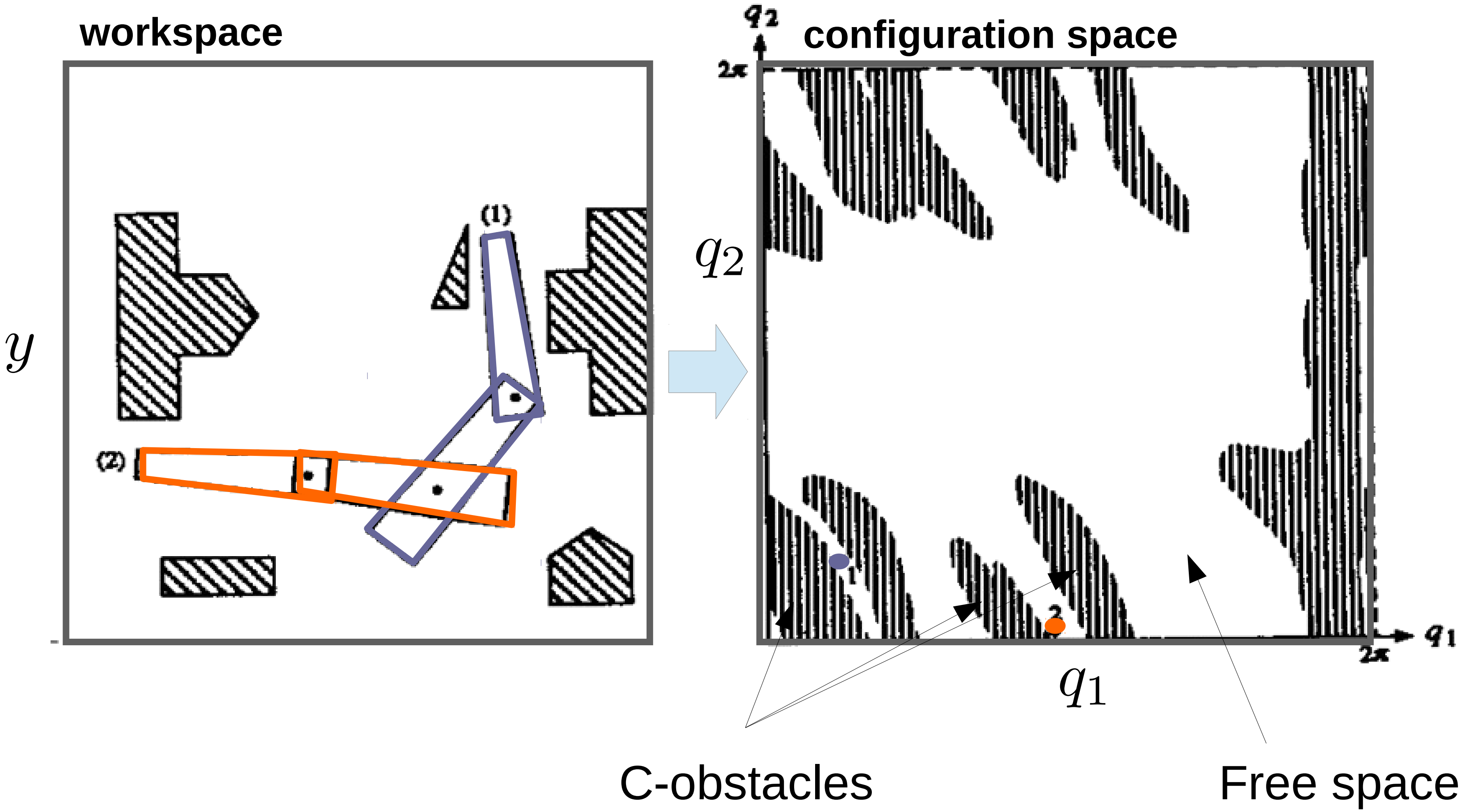
Every point here corresponds to a single robot configuration here

Approach: plan in "configuration space"



Every point that intersects an obstacle here corresponds to an arm configuration that intersects an obstacle

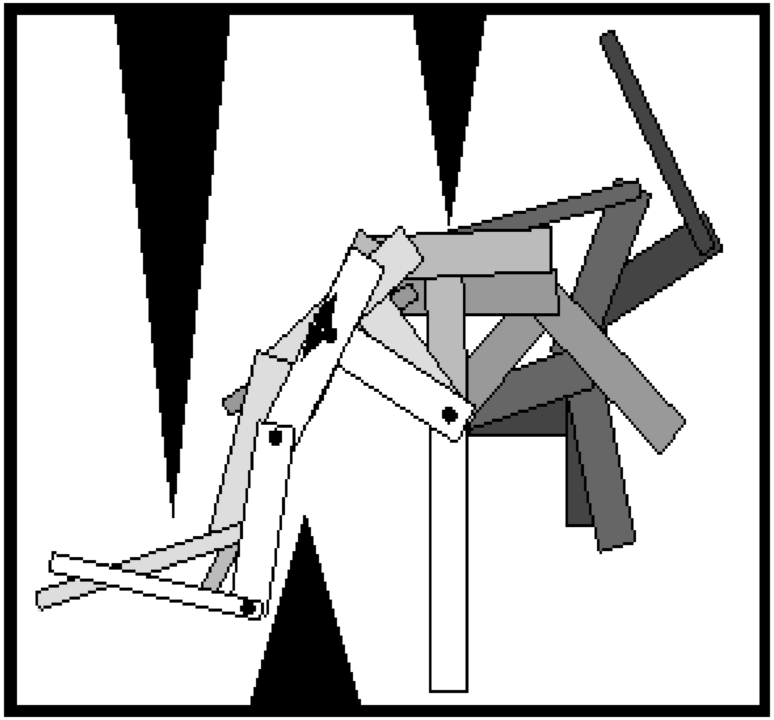
Approach: plan in "configuration space"



Configuration space

The dimension of a configuration space is the minimum number of parameters needed to specify the configuration of the robot completely.

– also called the number of “degrees of freedom” (DOFs)



Dimension = 3

Configuration space

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Dimension = ?

Topology of configuration space

<u>What is topology?</u>

– the properties of space that are preserved under continuous deformations, such as stretching and bending, but not tearing or gluing

The topology of this mug is a torus

Topology of configuration space

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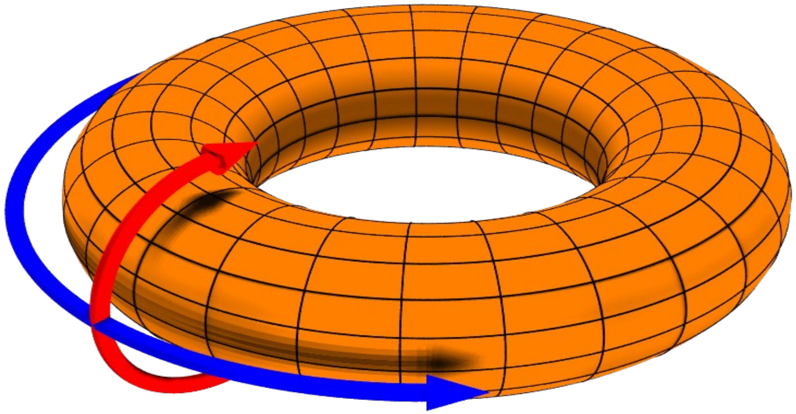

Torus: $C = S^1 \times S^1$

Topology of configuration space

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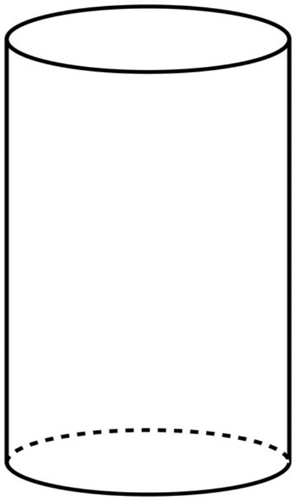

Cylinder: $C = R^2 \times S^1$

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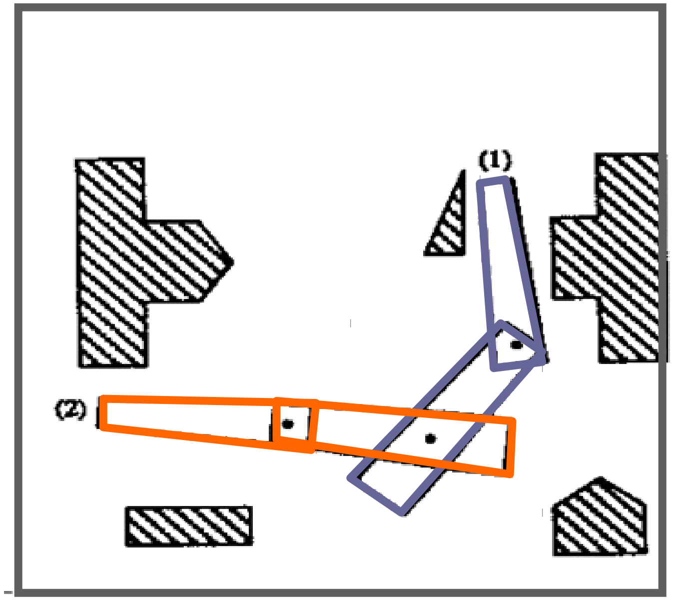

Configuration space: $C = ?$

Topology of configuration space

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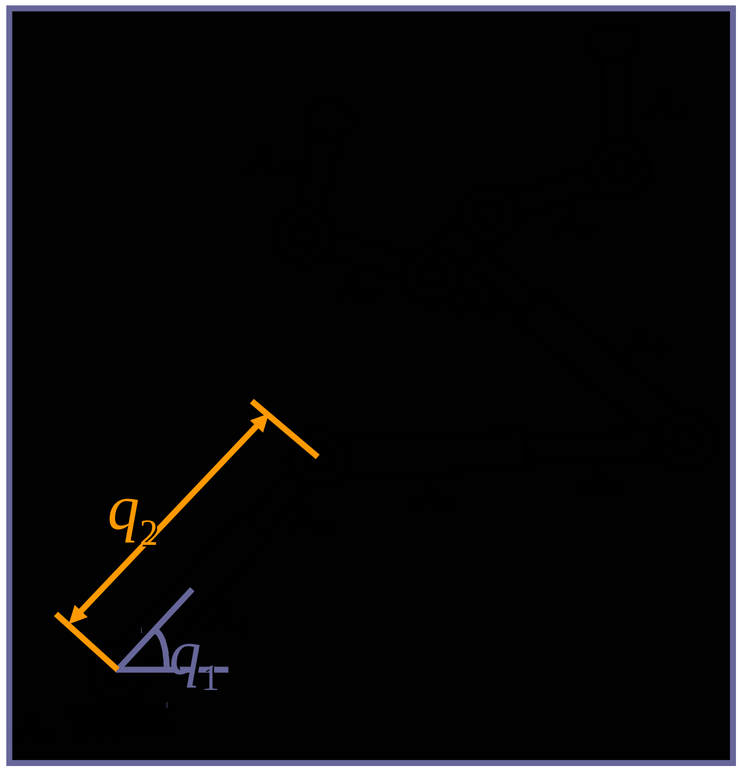


Configuration space: $C = ?$

Paths in c-space

A path is a function from the unit interval onto configuration space:

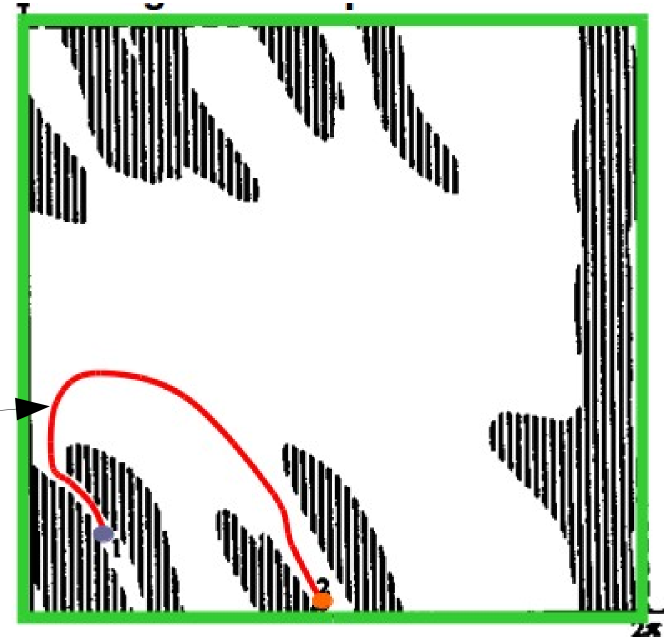
$$\tau : [0, 1] \rightarrow C$$

$\tau(0)$ = start of path

$\tau(1)$ = end of path

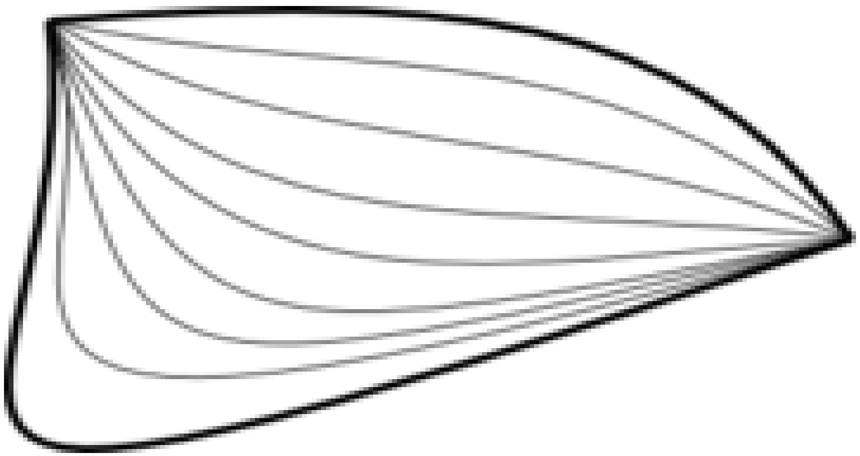
$\tau(0.5)$ = somewhere in between...

A path



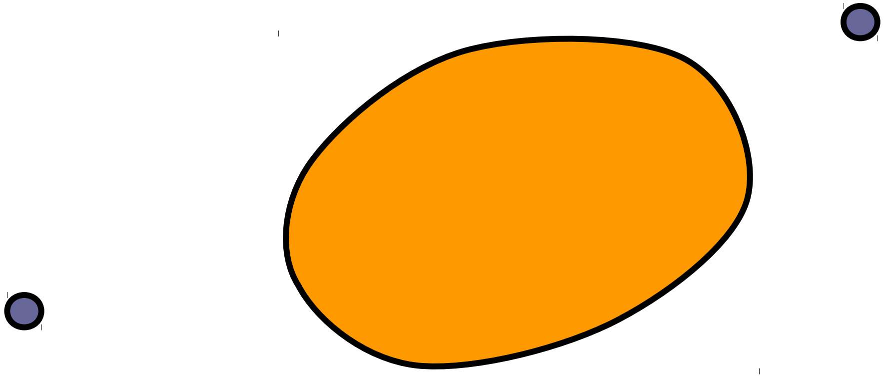
Homotopic paths

Two paths are homotopic if it is possible to continuously deform one into the other



Homotopic paths

How many homotopic paths are their between these two points?



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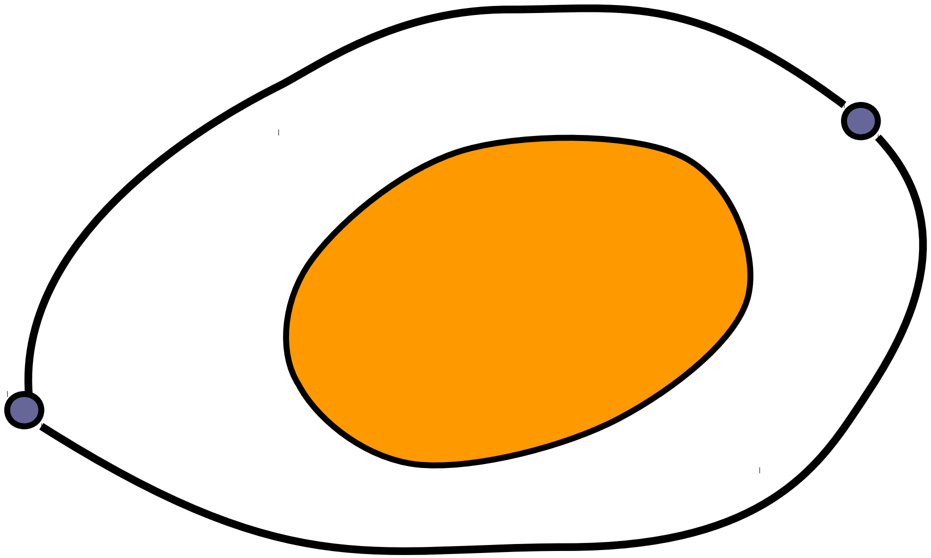

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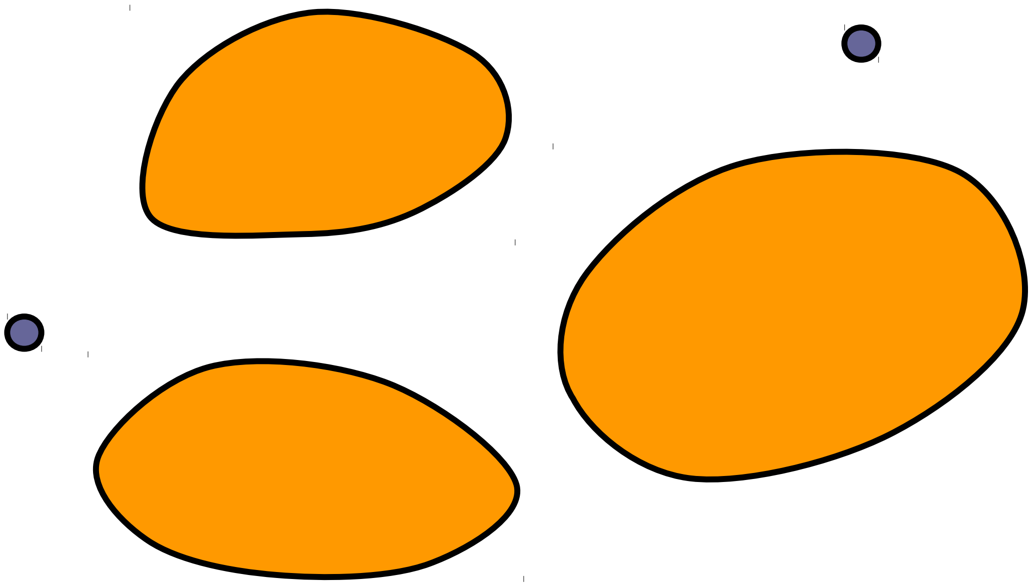

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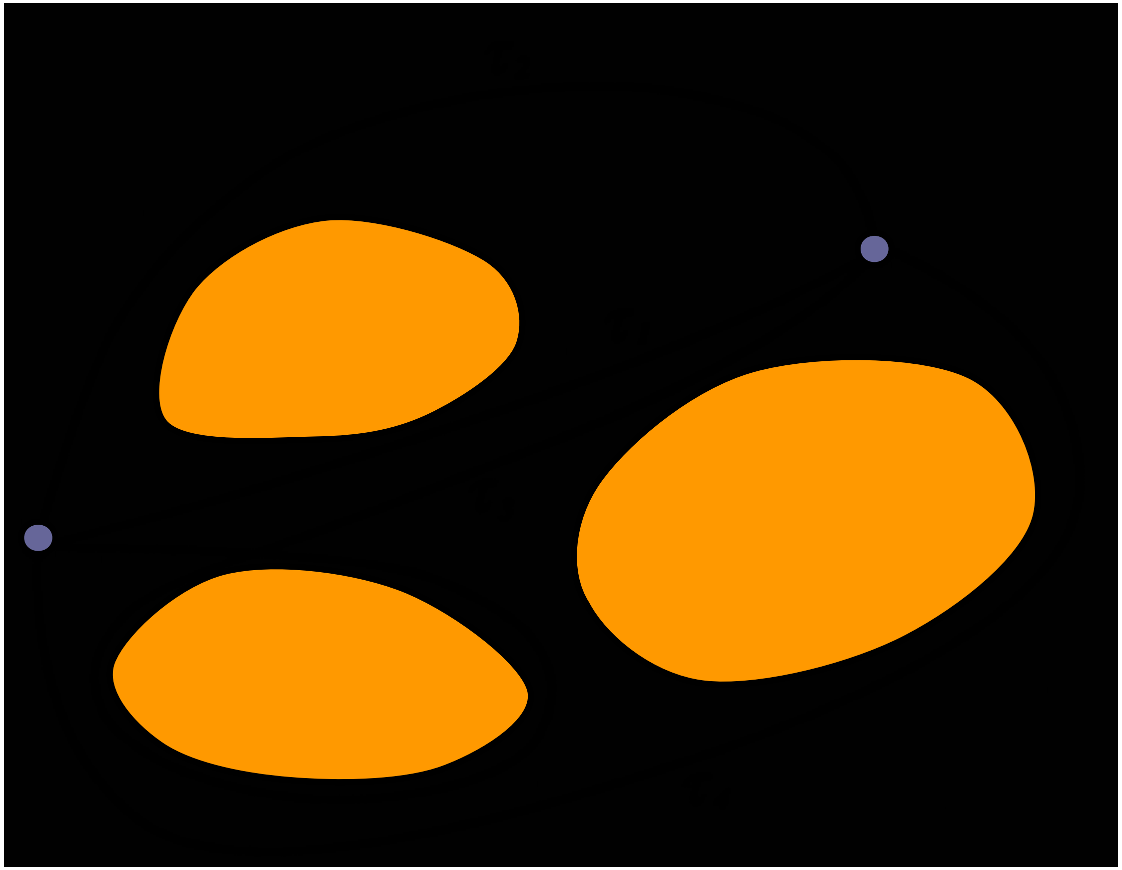

Connectedness of c-space

C is connected if every two configurations can be connected by a path.

C is simply-connected if any two paths connecting the same endpoints are homotopic.

Otherwise C is multiply-connected.