AI Robotics

Learning Objectives

- Understand the concept of a Degrees of Freedom, how they apply to multilink robots and how to compute them
- Understand the concept of configuration, task and work spaces and how they can be determined
- Understand the role constraints play in robots

Outline

- Rigid body robots are constructed by connecting bodies called links together using joints
- Links are treated as simple rigid bodies
- Joints are rotated or translated through the application of forces provided by an actuator

Common Joints

Joint Name	DOF	Notation
Revolute	1	R
Prismatic	1	P
Helical	1	H
Cylindrical	2	C
Universal	2	U
Spherical	3	S

- Configuration: The complete specification of the positions of all points of the robot
- Degrees of Freedom (dof): The minimum number of real-valued coordinates needed to represent the configuration
- Configuration Space (C-Space): The set of all possible configurations

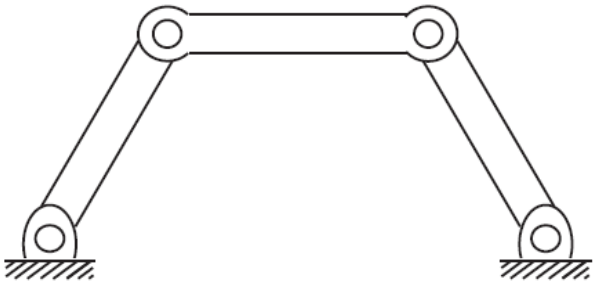
Examples

- Door on a hinge: 1 degree of freedom (angle of rotation about hinge)
- Mobile robot on a plane: 3 degrees of of freedom (x, y, θ)
- Rigid Body in 3D space: 6 degrees of freedom (3 coordinates, 3 angles) $(x, y, z, \theta, \phi, \lambda)$

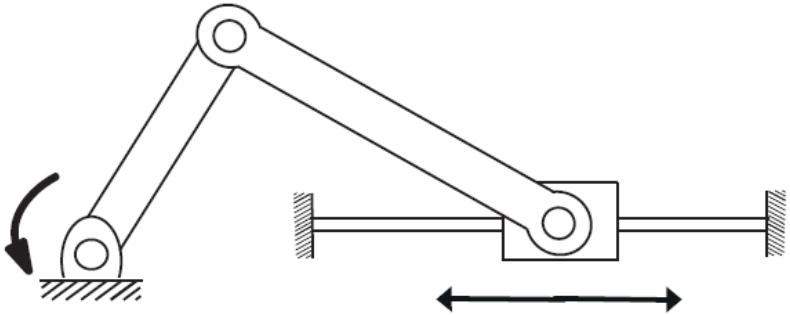
Grublers Formula

- dof = (sum of freedoms of the bodies) - number of independent constraints
- Gublers Formula: $dof = m(N - 1 - J) + \sum_{i=1}^{J} f_i$

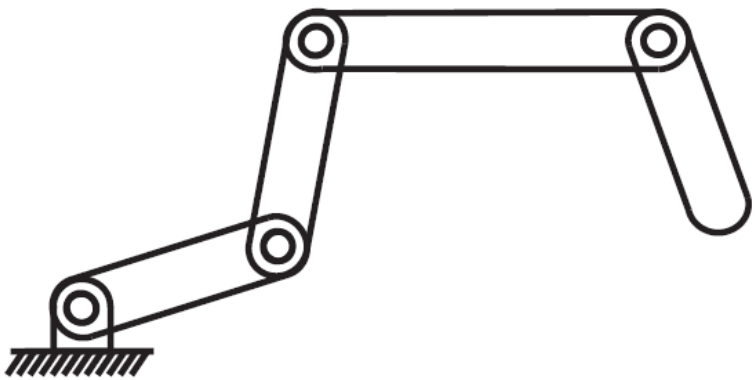
Example: Four-Bar Linkage



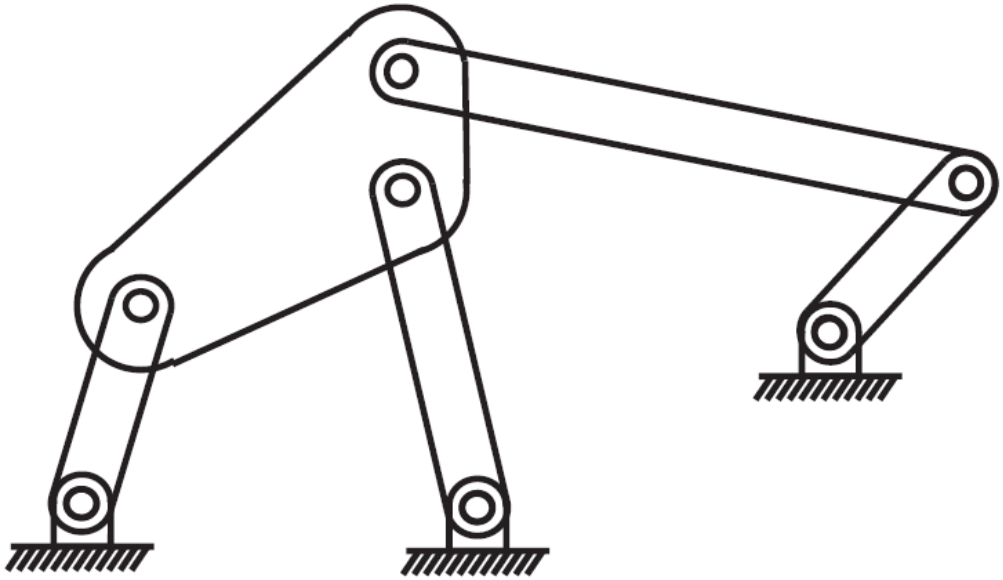
Example: Slider Crank



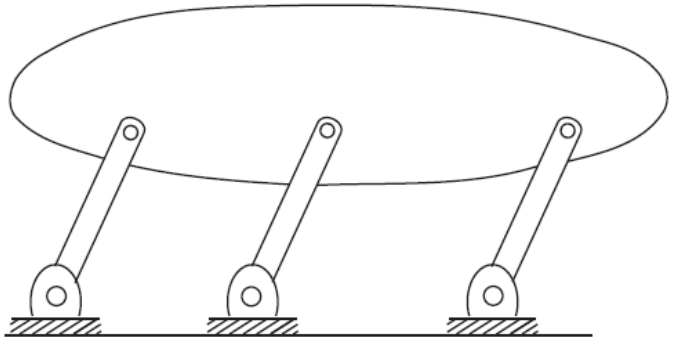
Example: K-Link Planar Serial Chain



Example: Stephenson six-bar linkage



Example: Parallelogram linkage



- What went wrong? Not all links are independent (try remove the middle link and solve)

Outline

- The shape of a configuration space can be described by its topology
- Two spaces are topologically equivalent if one can be transformed into the other without cutting or gluing
- Topologically distinct 1D spaces:
  - Circle
  - Line
  - Closed Interval

- Configuration spaces can be described as a product of multiple lower dimensional spaces
- A rigid body can be written as $R^2 \times S^1$
- 2R Robot can be described as $S^1 \times S^1$

Outline

- A given configuration space can be represented in multiple ways
- Representations can be split into two categories Implicit and Explicit
- Implicit representation: An n-dimensional space embedded in a higher dimensional Euclidean space with constraints
- Explicit Representation: Represents the space with the same number of coordinates and the dimension of the space

Explicit

- Uses the minimum number of coordinates to describe the space
- Explicit representations are susceptible to singularities
- Minimum number of coordinates needed to represent a point on the surface of a sphere is 2
- This can be latitude and longitude

Implicit

- An n-dimensional space embedded in a higher dimensional Euclidean space with constraints
- Consider the surface of a sphere

Task and Work Spaces

- Taskspace: The space in which the robots task can be expressed
- Workspace: The configurations that the end-effector can reach
- The workspace is separate to the configuration space. E.g. multiple points in the C-Space may correspond to a single point in the workspace

Summary

- Introduced the concept of Configuration, Task and Work Spaces
- Configuration space is the minimum number of real values coordinates which describe every position of the robot
- Implicit representations are robust against singularities

- Next Lecture
  - Describing rigid body motion