Manipulation

Configurations & Grasping

Bookkeeping

- Next assignment(s)
- Projects
  - First deliverable last night
- Reading:
  - Posted to schedule tonight
- Today
  - Manipulation
  - Manipulator configuration
  - Grasping

A Talk!

UMBC CSEE Colloquium
2:00pm Friday, 2nd October
ITE325b

Programming Robotic Agents: A Multi-tasking Teleo-Reactive Approach

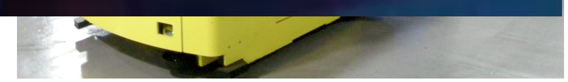
Keith Clark, Imperial College London, University of Queensland, University New South Wales
(joint work with Peter Robinson, University of Queensland)

A multi-threaded/multi-tasking message communicating robotic agent architecture in which the concurrently executing tasks are programmed in TeleoR…which extends TR in typing, knowledge representation, having task atomic procedures to control the deadlock, starvation free sharing of several robotic resources by concurrently executing tasks.

Its use is illustrated in the video at:

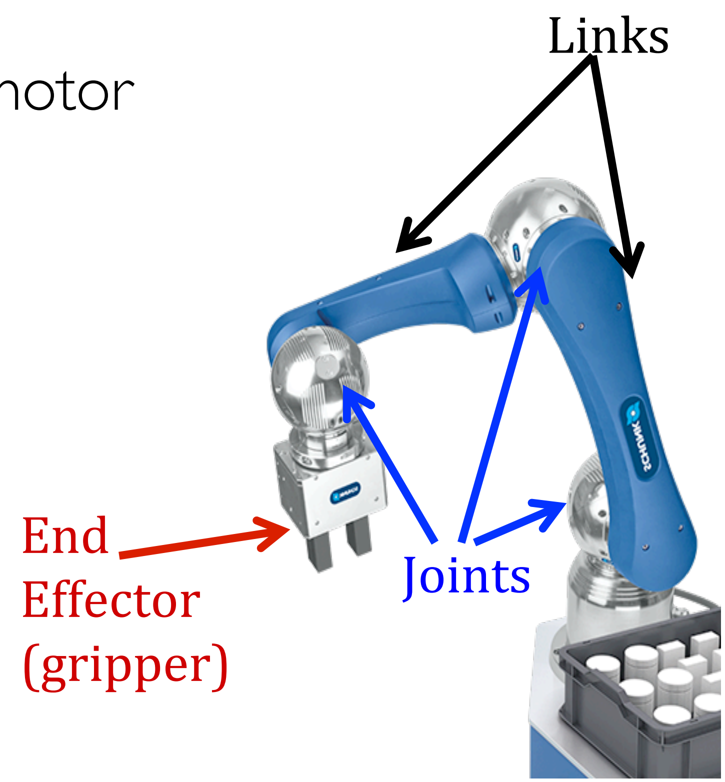
http://bit.ly/teleor

Manipulators



Terminology

- What is a manipulator?
  - Device to physically alter the world through contact
  - Modeled as a chain of *rigid links* connected by *joints*
- Actuator
  - Generates motion or force; usually a motor
- End Effector
  - Device at the end of an arm; interacts with environment
  - Grippers, tools
- Actuation
  - How are parts made to move?



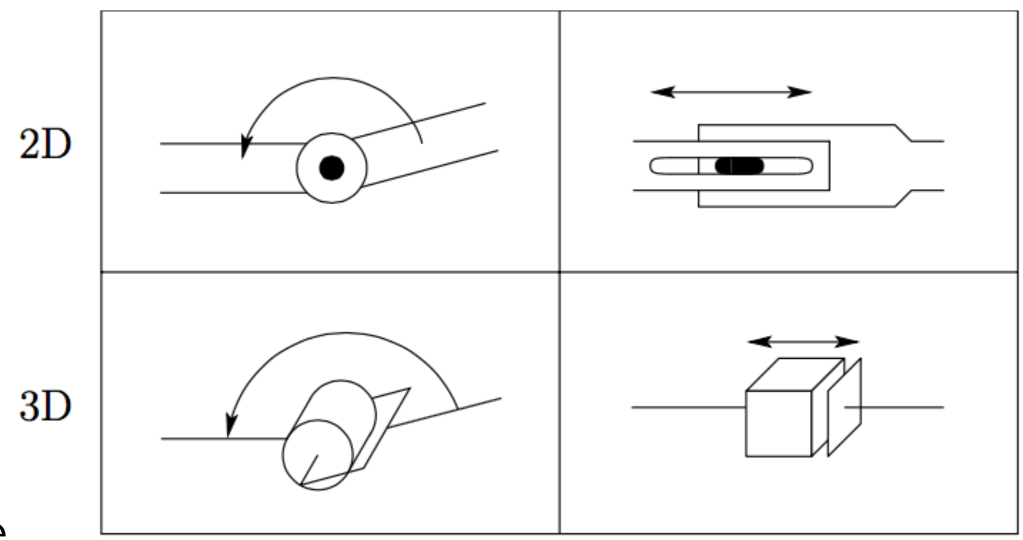
Characterizing Manipulators

- Power source (drive type: pneumatic, electric, …
  - Servoing and non-servoing / open-loop and closed loop
- Type of actuation: tendons, direct
- Configuration
  - Aka geometry, kinematic structure
  - Combinations of
    - Prismatic (linear)
    - Revolute (rotational)
- Characteristics
  - Payload
  - Working area/radius
- Application area
- Method of control

www.neobotix-robots.com/mobile-manipulator-mm-500.html

P(rismatic) & R(evolute)

- A kinematic chain of rigid links connected by joints
  - *"Kinematics is the branch of classical mechanics which describes the motion of objects and groups of objects."*
- Prismatic (denoted **P**)
  - Sliding / translational / linear; allows a linear relative motion between 2 links
- Revolute (denoted **R**)
  - Rotational; allows relative rotation between two links



Spong, Hutchinson, Vidyasagar. Robot Modeling and Control. 2006.

Joints: Denotation

- A joint represents a connection between two links
- Denotation of relative displacement between links
  - θ for revolute joint
  - d for prismatic joint
- Denotation of axis of motion
  - z_i between link i and link $i+1$
    - Axis of rotation of a revolute joint
    - Axis of translation of a prismatic joint

Spong, Hutchinson, Vidyasagar. Robot Modeling and Control. 2006.

Configuration Space

- Configuration
  - Specification of location of every point on manipulator.
- How can we specify?
  - Links are rigid
  - Base is (assumed to be) fixed
  - So if we know values for the joint variables
    - Angle for **R** joints (θ), offset for **P** joints (d)
  - We know everything!
- Manip. configuration ≡ a set of values for joint variables
- Set of all possible configurations is the *configuration space.*

Spong, Hutchinson, Vidyasagar. Robot Modeling and Control. 2006.

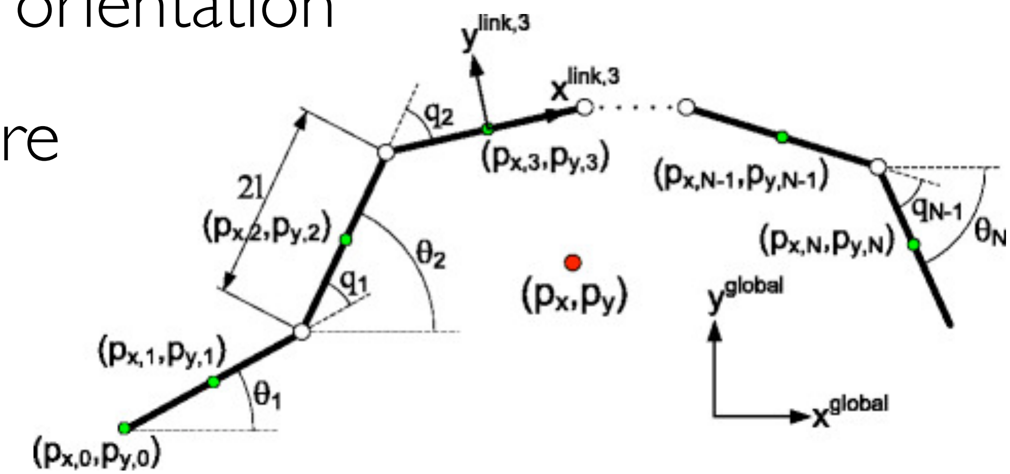
DoFs for Manipulation

- A system has n DoFs if exactly n parameters are required to completely specify the configuration.
- For a manipulator:
  - Configuration can be specified by n joint parameters, so
  - # of DoFs = dimension of the configuration space
  - So, # number of joints determines DoFs
- Rigid object in 3D space has six parameters
  - 3 positioning (x, y, z), 3 orientation (roll, pitch and yaw angles)
- DoFs < 6 $\Rightarrow$ arm cannot reach every point in workspace with arbitrary orientation.

Spong, Hutchinson, Vidyasagar. Robot Modeling and Control. 2006.

Notes on DoFs

- DoFs < 6 $\Rightarrow$ arm cannot reach every point in workspace with arbitrary orientation
- Sometimes you need more
  - E.g., dealing with obstacles
- DoFs > 6 is kinematically redundant



- Difficulty of control problem as # DoFs grows?
  - Increases *rapidly* with the number of links
    - Every 2 links need a joint
  - Control $\underset{\sim}{\propto}$ 1/Maneuverability

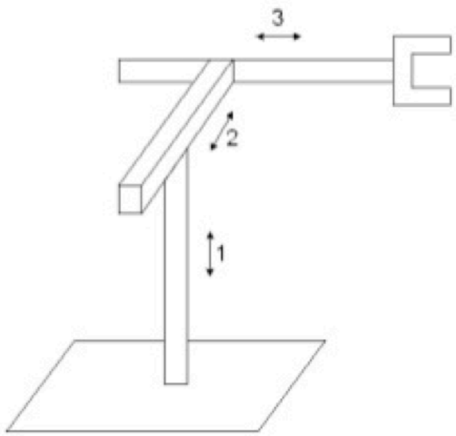
Spong, Hutchinson, Vidyasagar. Robot Modeling and Control. 2006.
Ehsan Rezapour. Pettersen, Gravdahl, Liljebäck, Kelasidi. Robotics and Biomimetics. 2014.

Common Configurations

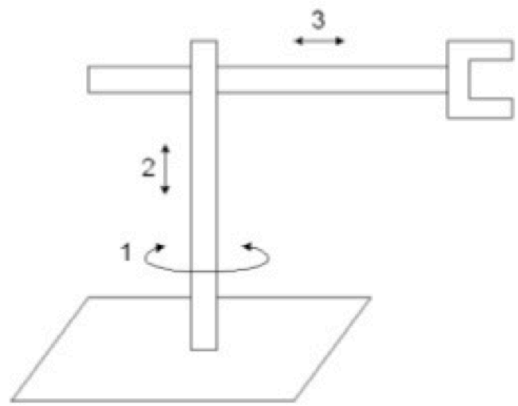
- Geometry / kinetic (mechanical) structure
- Labeled by type of first three joints
  - The wrist is described separately.
- 8 possible arrangements
  - Three joints, two possibilities each
  - Only 4 combinations are common (RRP used twice)
- RRR: articulated
- RRP: spherical
- RRP: SCARA
- RPP: Cylindrical
- PPP: Cartesian

Spong, Hutchinson, Vidyasagar. Robot Modeling and Control. 2006.
Hanz Richter, Mechanical Engineering, Cleveland State University

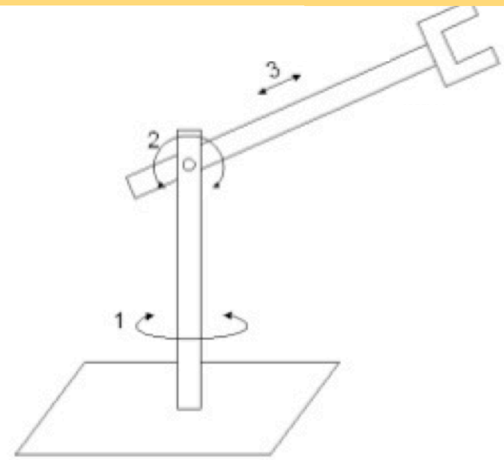
Configurations



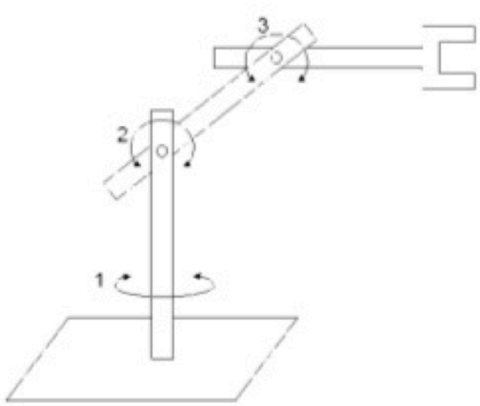
Cartesian: PPP



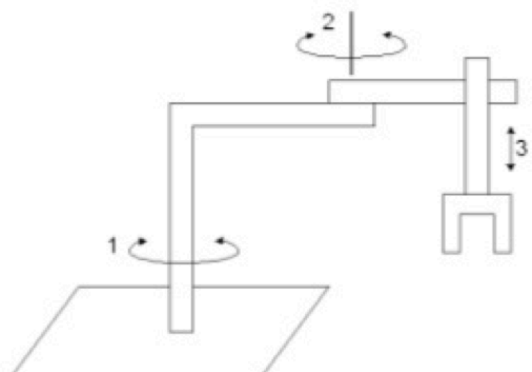
Cylindrical: RPP



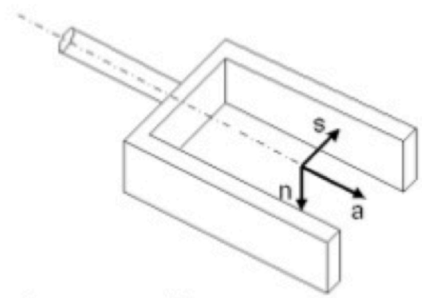
Spherical: RRP



Articulated: RRR



SCARA: RRP



Hand coordinate:

n: normal vector; **s**: sliding vector;

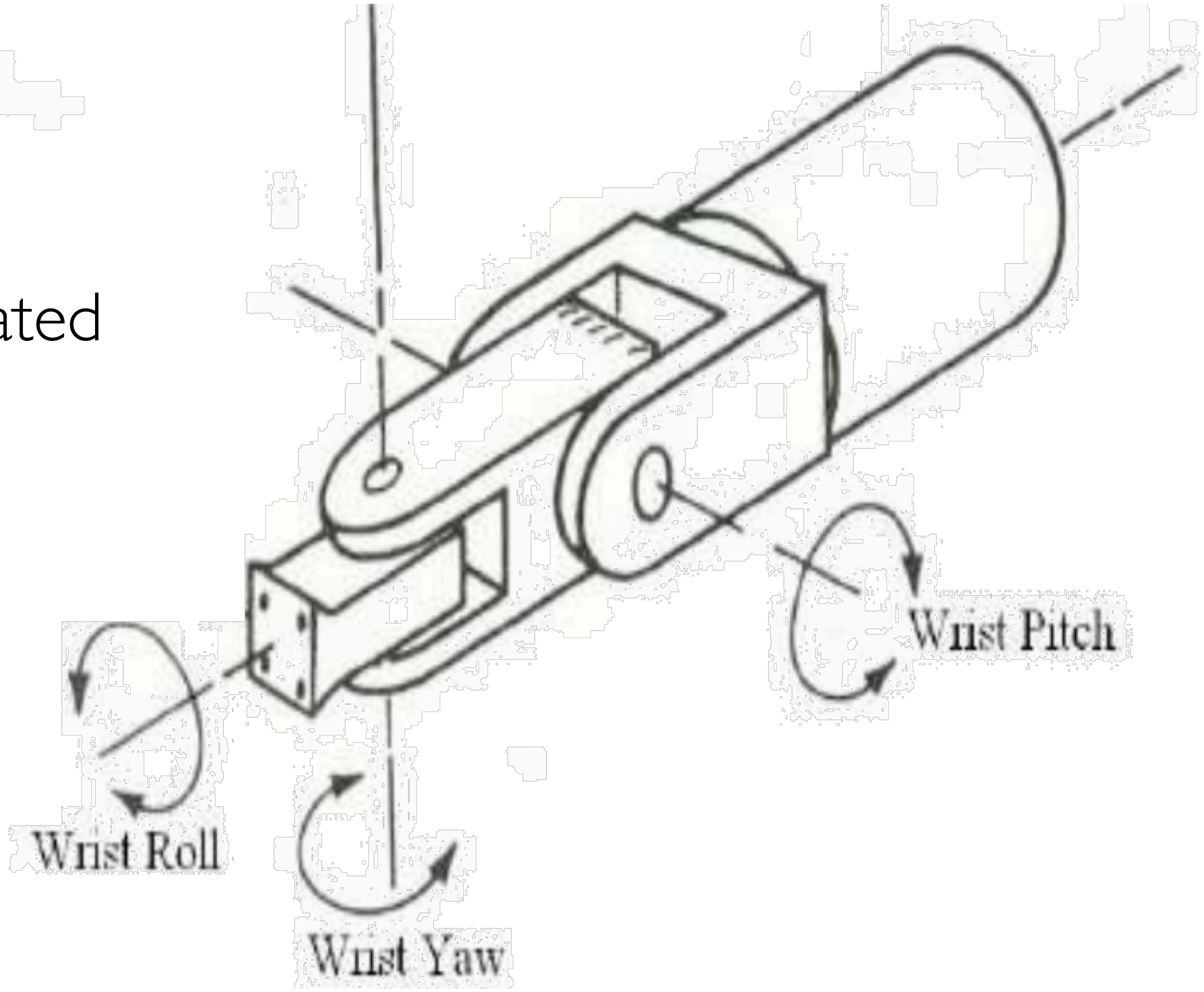
a: approach vector

Configuration Example

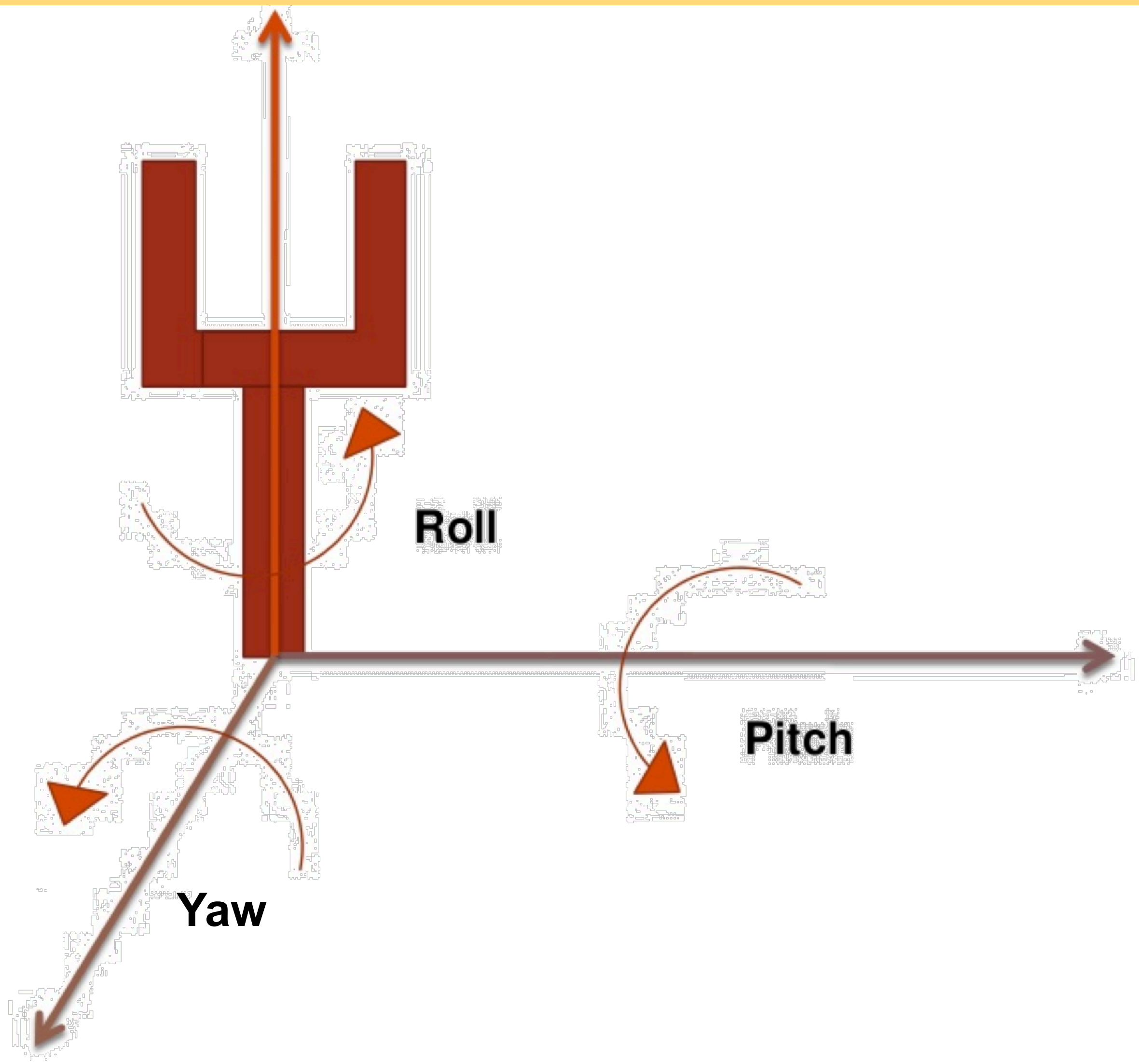
- So this is?

  RRR

  Articulated

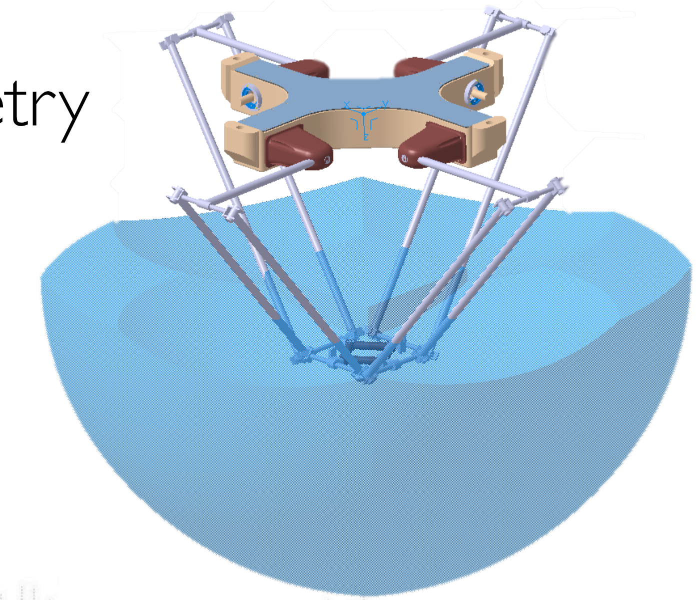


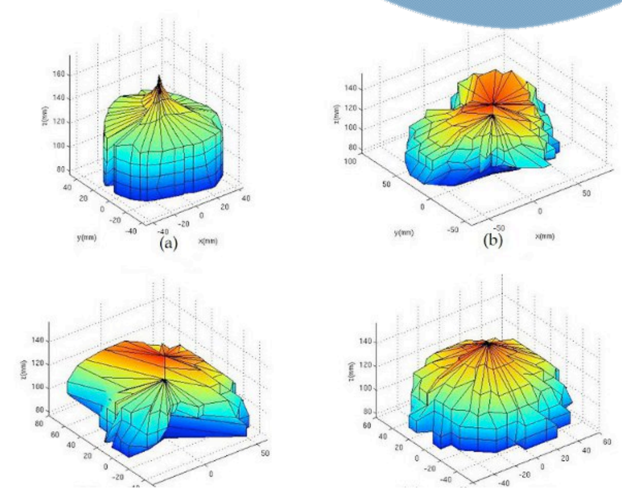
RPY Again: Wrist Example



Workspaces

- Configuration only provides geometry
- Workspace
  - Set of all possible positions of end effector
  - In practice, these can be complex
- Dexterous workspace
  - Set of points where end effector can be any orientation
  - Subset of workspace

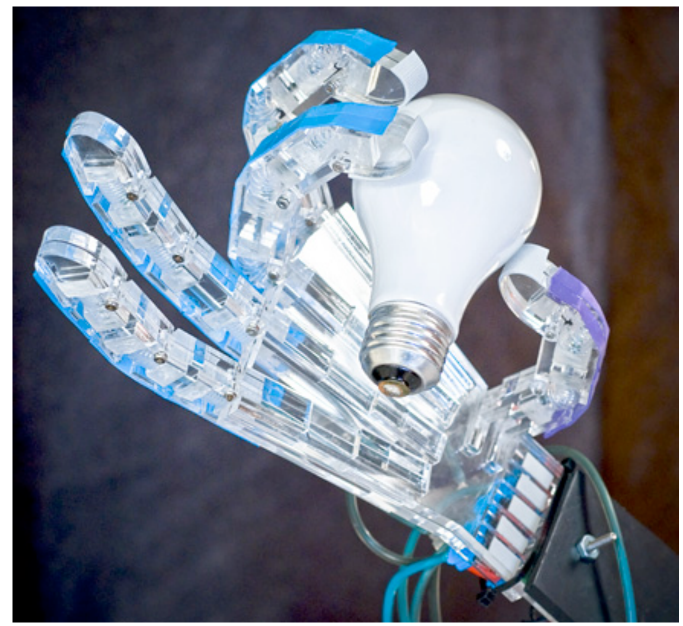




Spong, Hutchinson, Vidyasagar. Robot Modeling and Control. 2006.
engineerjau.wordpress.com/2013/07/07/on-the-basis-of-workspaces-of-robotic-manipulators-part-1

Grippers

- Four categories of robot grippers:
  - Impactive
    - Jaws or claws which $\underbrace{\text{physically grasp}}$ grasping by direct impact upon the object
  - Ingressive
    - Pins, needles or hackles penetrate surface
      - Textile, carbon and fiberglass handling
  - Astrictive
    - Suction forces applied to surface
    - Vacuum, magneto- or electroadhesion
  - Kontugutive / Contigutive
    - Requiring direct contact for adhesion
    - Glue, surface tension or freezing



Monkman, Hesse, Steinmann, Schunk. Robot Grippers. 2007.
news.nationalgeographic.com/news/2009/05/090505-robot-hand-picture.html