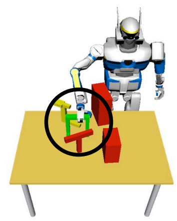
Gripping, Grasping, and Chaining





Kinematic Chains

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- Kinematic Models: links, joints, base
  - A kinematic model describes how a system can move in the world – e.., "this joint rotates, moving that link"
- Manipulator links from a chain
- Serial or parallel (mostly)
  - Sequence of end-to-end links *or*
  - Multiple links connect to single joint
- Proximal Link: closest to the base
- Distal Link: farthest from the base
  - Base is where attaches to the world

Kinematic Chains

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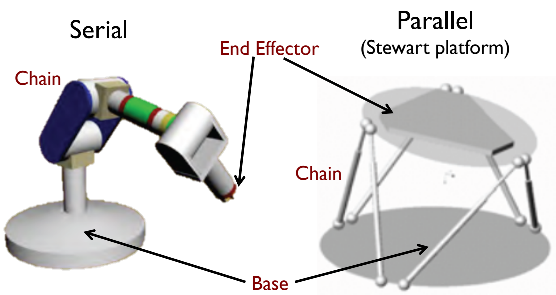
Multiple links and joints are called a *kinematic chain.*



web.cecs.pdx.edu/~mperkows/CLASS_479/2013%20lectures/2012-1819.%20Various%20Problems%20-%20Manipulation.pptx

Serial vs. Parallel Linkages

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Serial Linkages

- Serial chain of links and joints
  - Large workspace
  - Low stiffness
  - Cumulative errors from link to link
- Proximal links carry the weight and load of distal links
- Actuation of proximal joints affects distal links
- Limited load-carrying capability at the end effector

Serial vs. Parallel Linkages

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Parallel Linkages

- End plate directly actuated by multiple links and joints
- More restrictive workspace
- Common link-joint configuration
  - This can serve as Pick-and-Place Robot
- Light construction
- Stiffness
- High load-carrying capacity

Parallel Linkage Robot

https://www.youtube.com/watch?v=lIPPvG1rQos

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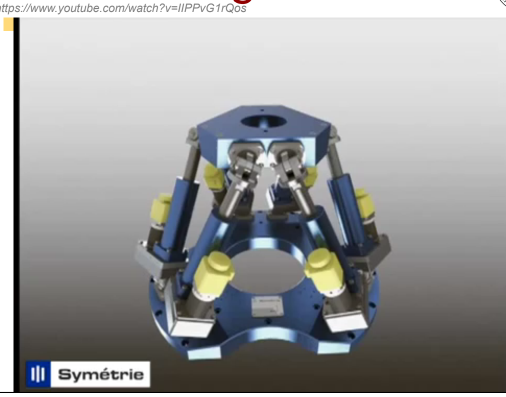

Grippers

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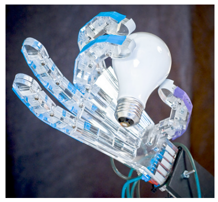
- Five categories of robot grippers:
  - Impactive
    - Jaws or claws which physically grasp (grasping) by direct impact upon the object
  - Ingressive
    - Pins, needles or hackles penetrate surface
      - Textile, carbon and fiberglass handling
  - Astrictive
    - Suction forces applied to surface
    - 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

Underactuation

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- If a robot has as many actuators as DoFs, it is *holonomic* (fully actuated)
- Otherwise, it is *underactuated*
- Don't always need full actuation!
  - Try bending just the last knuckle.

Underactuated Gripper

https://www.youtube.com/watch?v=XuvCLXavd5s

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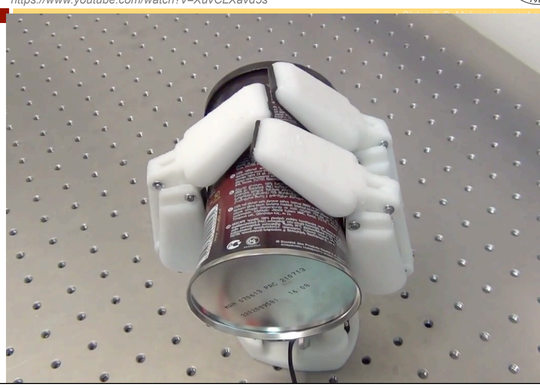

Grasps

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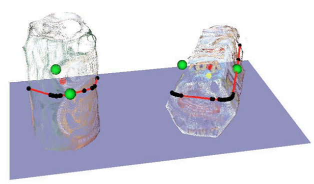
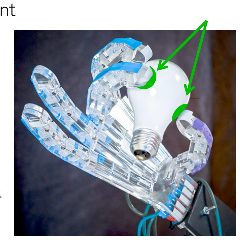
- Grasp:
  - A set of contact points on an object's surface
  - Goal: constrain object's movement





www.intechopen.com/books/robot-arms/robotic-grasping-of-unknown-objects1
news.nationalgeographic.com/news/2009/05/090505-robot-hand-picture.html

Grasps

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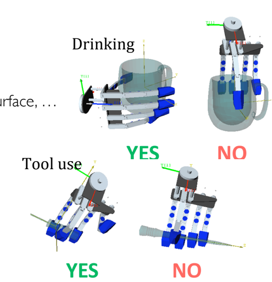
- Grasps vary by:
  - Hand (gripper)
  - Object being grasped
    - Topology, topography, mass, surface, …
  - Type of motion desired
- For each hand or hand/object pair:
  - Where to grasp it?
  - How hard?
  - Then what?
- Additional constraints (e.g., don't spill)



www.madry.pro
León, Morales, Sancho-Bru. Robot Grasping Foundations. 2013

The Grasping Problem

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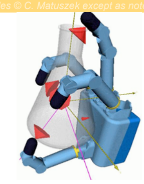
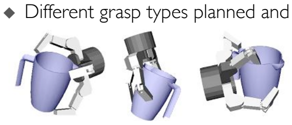
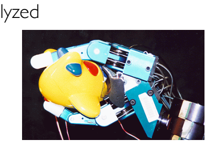
- Grasps are not obvious (easy to calculate)
  - Any given object has arbitrary contact points
  - Hand has geometry constraints, etc.
- Synthesized trial-and-error
  - For a hand/object pair:
  - Different grasp types planned and analyzed







- Real trial and error

www.cs.columbia.edu/~cmatei/graspit/
www.programmingvision.com/research.html
www.cc.gatech.edu/gvu/people/faculty/nancy.pollard/grasp.html

Grasp Planning

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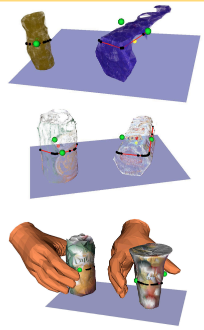
- Grasp synthesis: Find suitable set of contacts, given
  - Object model
  - Constraints on allowable contacts
- Grasp points are determined
  - Mostly assume point contacts
  - Larger areas usually discretized
  - Contact model defines the force the manipulator exerts on contact areas
- Grasp analysis
  - Is that grasp stable?



León, Morales, Sancho-Bru. Robot Grasping Foundations. 2013.
www.intechopen.com/books/robot-arms/robotic-grasping-of-unknown-objects1

Current Research Questions

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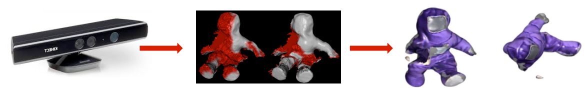
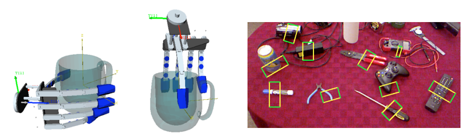
- How do you get the object model?



- What are the constraints?



www.madry.pro
www.cs.washington.edu/robotics/3d-in-hand

Types of Motion

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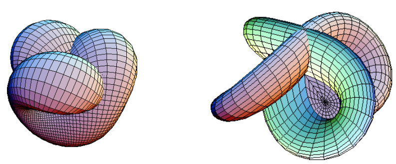
- Point to point
- Path-following
  - Manifold: the surface an end effector can trace out



- So how do we actuate grasping?

Actuation: Characteristics

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- Continuous rotation: revolute joint that spins 360°
  - Most joints have a smaller range of motion
- Underactuated system (vs. fully actuated): has fewer actuators than DoFs
  - Some joints can't be controlled directly
  - Most common example: fingertips
- Back-driveable: can be moved by an external force without damage
  - Some kinds of actuation will break if you move them around in space

Actuators: Motors

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- Motor (usually a simple DC motor)
  - You put in power and it spins; increase and it goes faster
- Servo: usually, motor + encoder + plus controller
  - Sometimes:
    - Geared
    - Limited to 180°
    - Non-backdriveable
  - This is somewhat fuzzy!
- Stepper motor: Spins to specific rotations
  - As a product of how it is designed

Motors writ (very) broad

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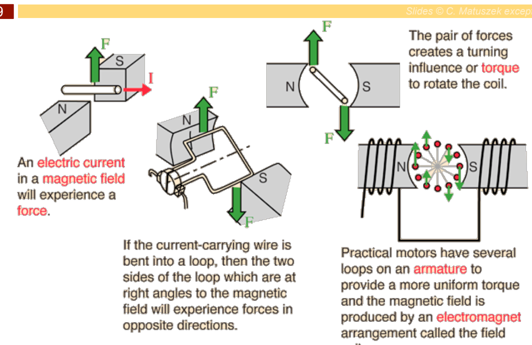

http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/mothow.html

Actuators: Tendons

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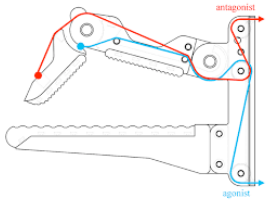
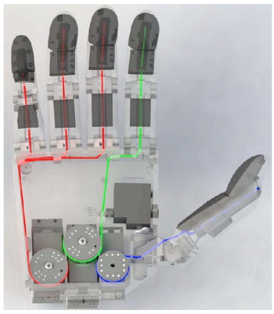
- String/cords across joints through holder; pulling cords opens/closes joints





- Note underactuation!

Kappassov, Zhanat et al, ICMA 2013
Ma, Raymond et al, Advances in reconfigurable mechanisms and robots II, 2016

Actuators: Tendon-Driven

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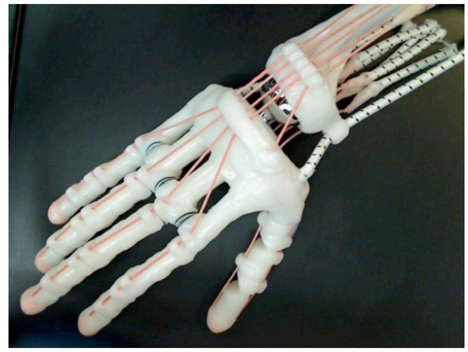

Hydraulics

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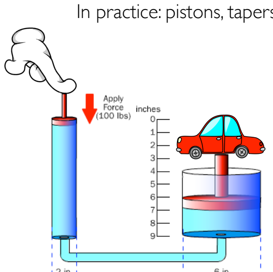
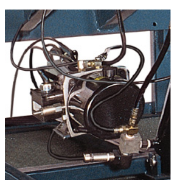
- Hydraulics: Force multiplication using incompressible liquid
  In practice: pistons, tapers, …





Hydraulic Motor

http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/mothow.html

Pneumatics

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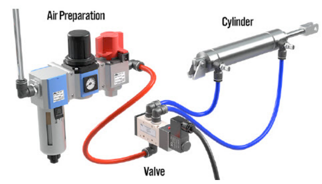
- Use compressed air to generate energy.
  - Quick to respond
  - Not ideal under high pressures



- Piston style
  - Generate linear force by acting on a piston
  - Convert linear force to torque (if needed)
- Diaphragm style
  - Rubber diaphragm and stem in circular housing
  - Good for valves requiring shorter travel

https://library.automationdirect.com/why-use-pneumatics/