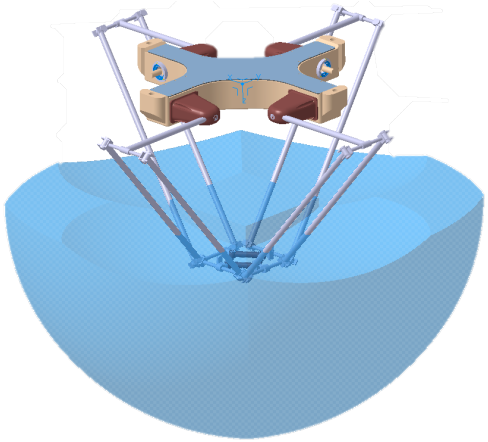
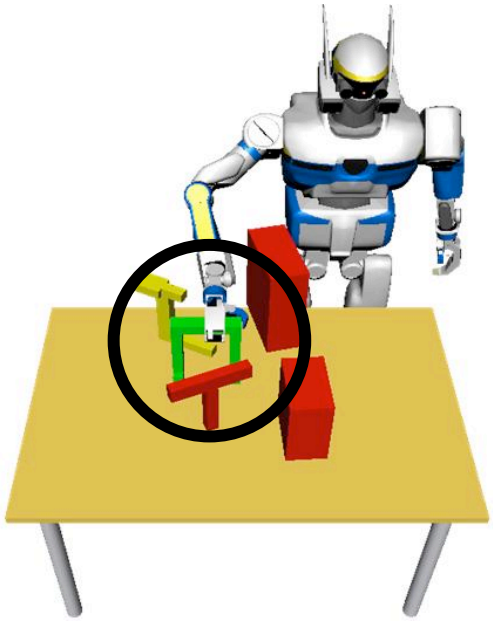
Manipulation – *Grasping*
Actuators – *20,000 feet*





Bookkeeping

- Assignment, plan draft ← discussion next few slides
- Class participation
  - Relatively low weight, small and coarse-graine
  - Designed to let you know if you have a prob
- Upcoming
  - Project final draft due tomorrow (7th Oct.)
  - Assignment 2 posted tonight (21st Oct.)
- Quiz 2: **Blackboard**
  - Posted Friday, due Monday night (http://tiny.cc/bb-quizzes)
- Reading: [KINEMATICS]

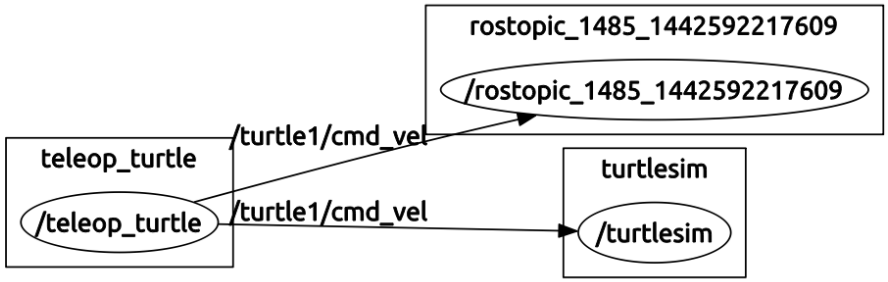
Ask questions, attend talks, answer questions, post Q's or A's, post random interesting stuff, …

Should be able to knock out fairly quickly unless you're missing research

Assignment 1: Tutorials

- Intermediate 4: Nisha will cover Tuesday
  - for various cases
- 6b: `rqt_graph` , not `rqt_plot`

Keep up on Piazza!



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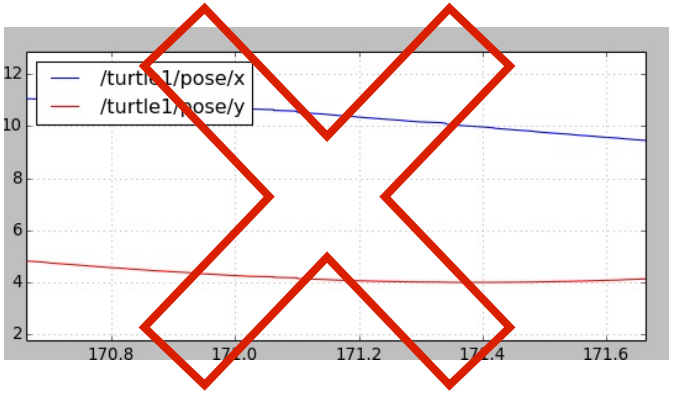


- Intermediate 4: missing `/chatter` topic:

```
ros-user@ROS:~$ rostopic list
/chatter
/rosout
```

Assignment 1: Writeups

- Writeup

> 1. A writeup of the process. This should be **a PDF file** 300-500 words, containing:
>
> - How, on what, and using what media you did Step 1. (Which choice in Step 1, what computer
> - The names of anyone who helped you (in the class or not) with Step 1, and a little about how/
> - The names of anyone *you* helped, and a little about how/with what.
> - Approximately how much time you spent on each step of the process took.
> - The things you found hardest and any errors/problems you ran into.

  - If you didn't give/receive help, please say so
  - Not everyone gave times for non-setup steps
    - Common enough that I only took off a point.

- General notes
  - Put name on things
  - Check file types

Plans: Common Problems

- Does it answer: Where are **you** putting your effort, starting now?
- Where is work concentrated?
- Goals **and subgoals**
  - Subgoals are *specific* and *testable*
  - Stretch goals: what might you get to, or want to get to if you had more time?
  - Simplification: how would you demo without this working?

Point of plan:

decide and describe what you are going to do.

2. Human detection using vision (4 weeks)

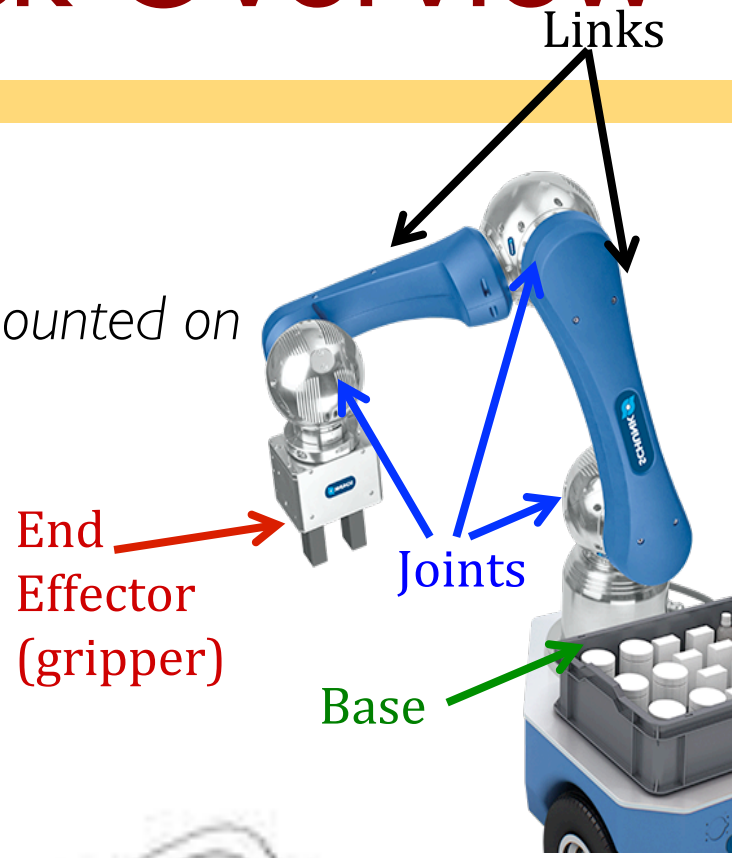
a. Take video stream of hallways with people and save (for development).
b. Use OpenCV on non-Pi computer on test stream.
c. Show using OpenCV to detect people in images (using HOG).
d. Initial simplification: let the human controller do the people-spotting.
e. Stretch goal: stream composite video from camera in real-time.

Project Plans: Schedule

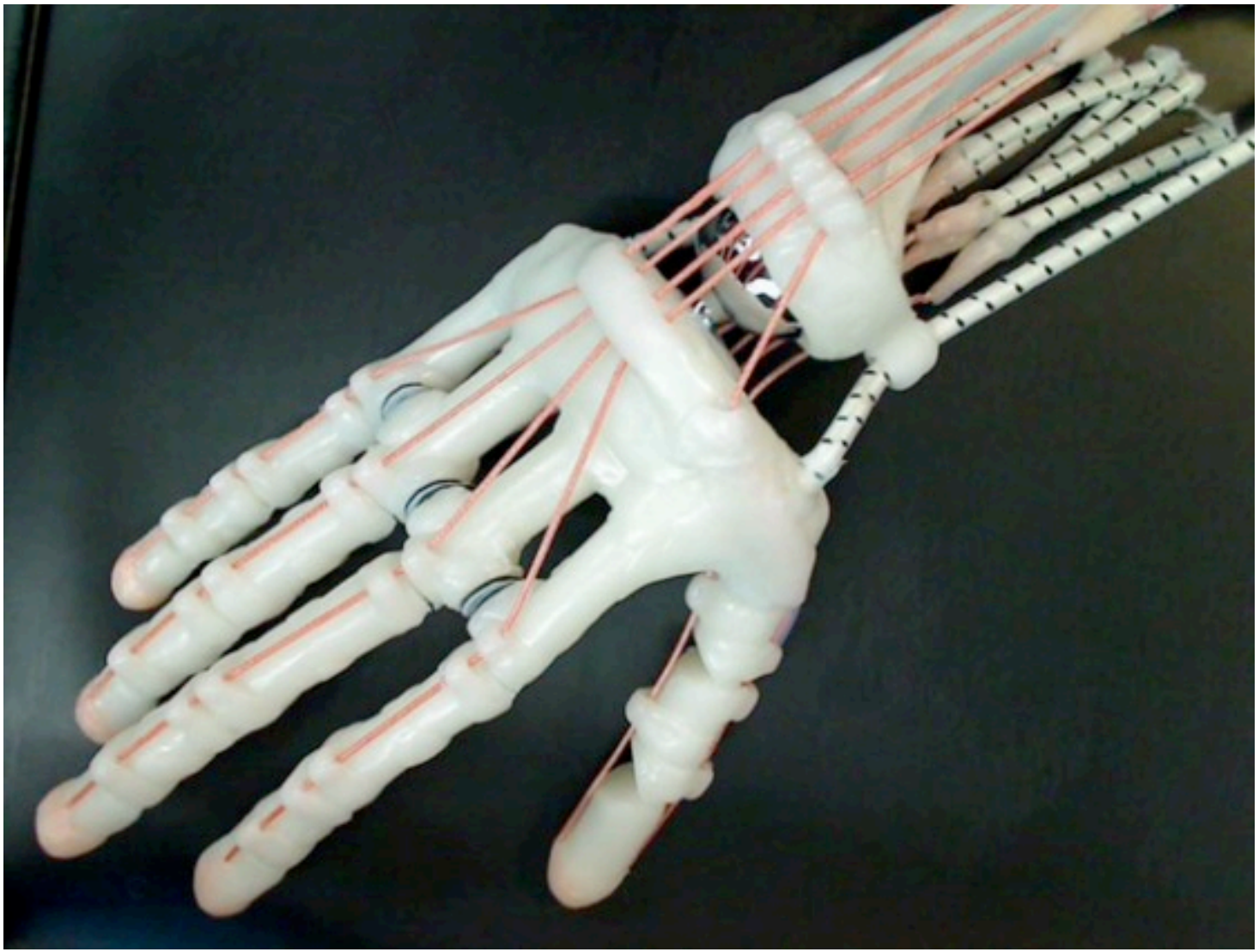
- Goal: on 10/14, 10/28, 11/11, 11/24, 12/1, and 12/8, we have a clearly defined check: are things on track?
  - If not, that's when we know to meet and replan.
- They should be:
  - Detailed
    - "Ubuntu running on raspberry pi", not "software integrated"
  - Testable / demonstrable
    - "Programming robot underway" is not testable
    - Possible tests: demo; writeup or architecture diagram; screenshots; …
- Shopping list – give links!
  - If you don't know what works best or what exactly you want, start Googling.

Manipulation: Quick Overview

- Links, joints, base, end effectors
  - Base is *base of arm*, not *thing arm is mounted on*
- Actuator
  - Generates motion or force
  - Usually a motor
- Actuation
  - How are parts made to move?
    - Example: tendon-driven
  - Not 1:1 with actuators

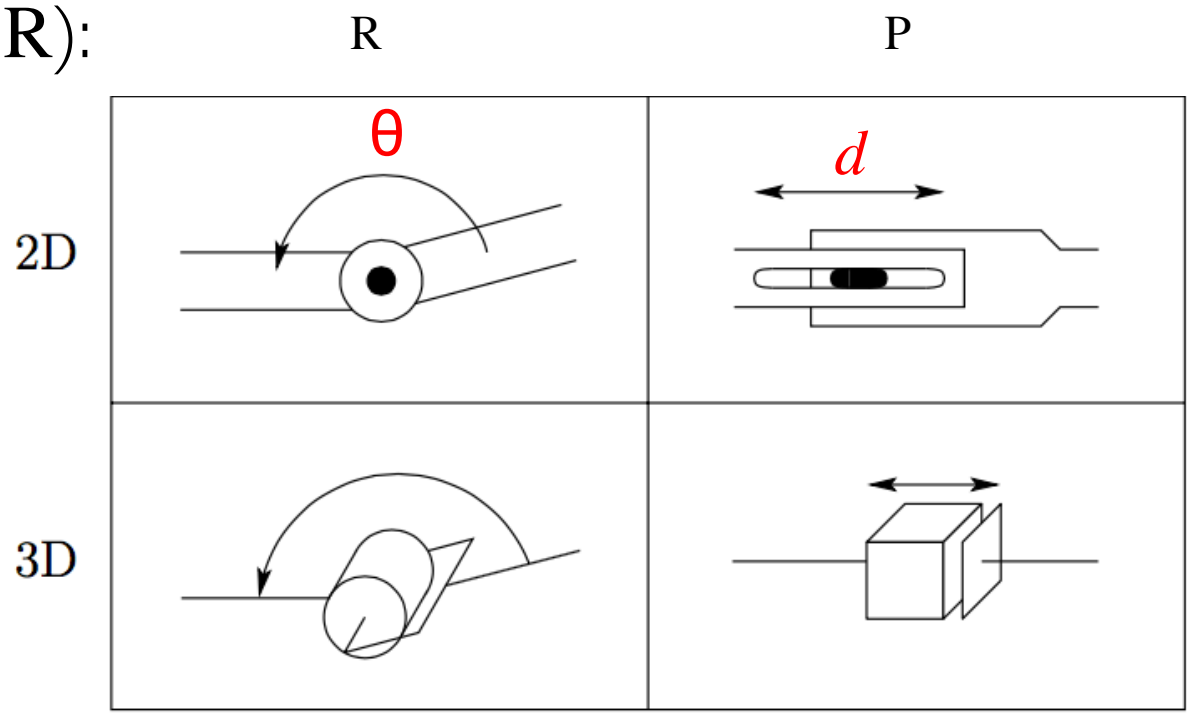


Manipulation: Quick Overview



Joints, P(rismatic) & R(evolute)

- *Prismatic* (denoted **P**): sliding / translational / linear; allows a linear relative motion between 2 links
- *Revolute* (denoted **R**): Rotational; allows relative rotation between two links
- Combinations of these describe arm *configuration*

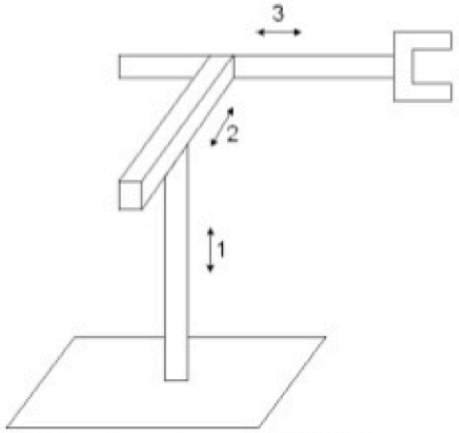


- All possible configurations = *configuration space*

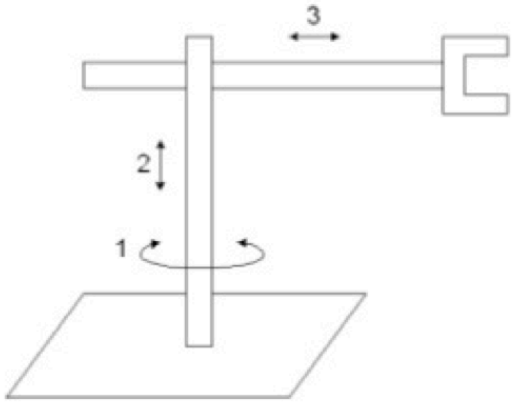
Spong, Hutchinson, Vidyasagar. Robot Modeling and Control. 2006.

Configurations

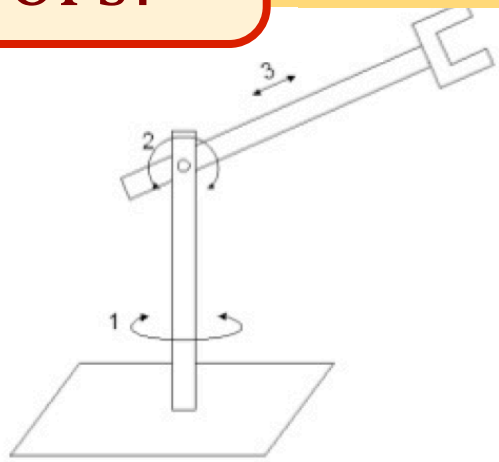
How many DOFs?



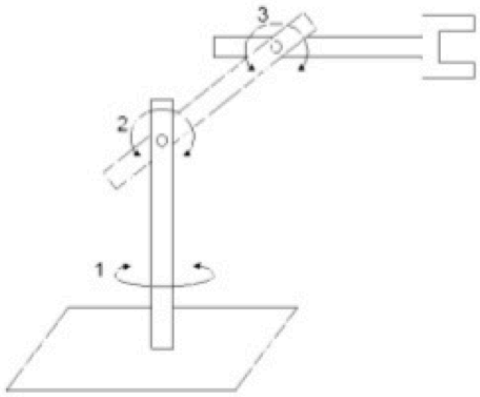
Cartesian: PPP



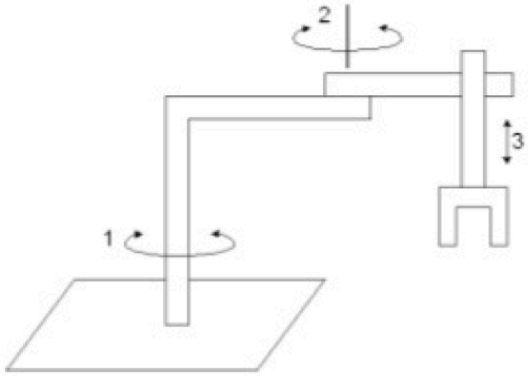
Cylindrical: RPP



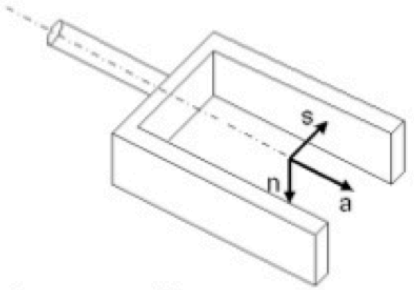
Spherical: RRP



Articulated: RRR



SCARA: RRP

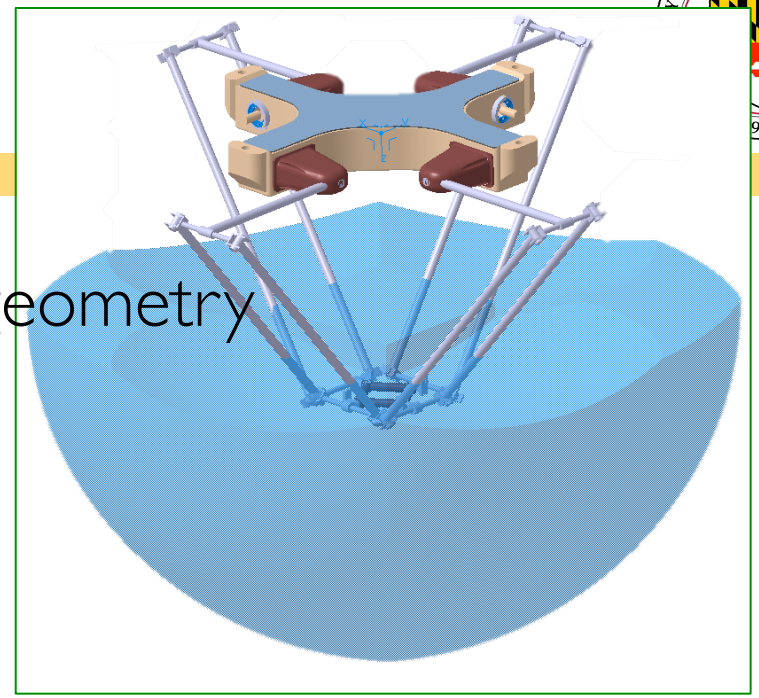


Hand coordinate:

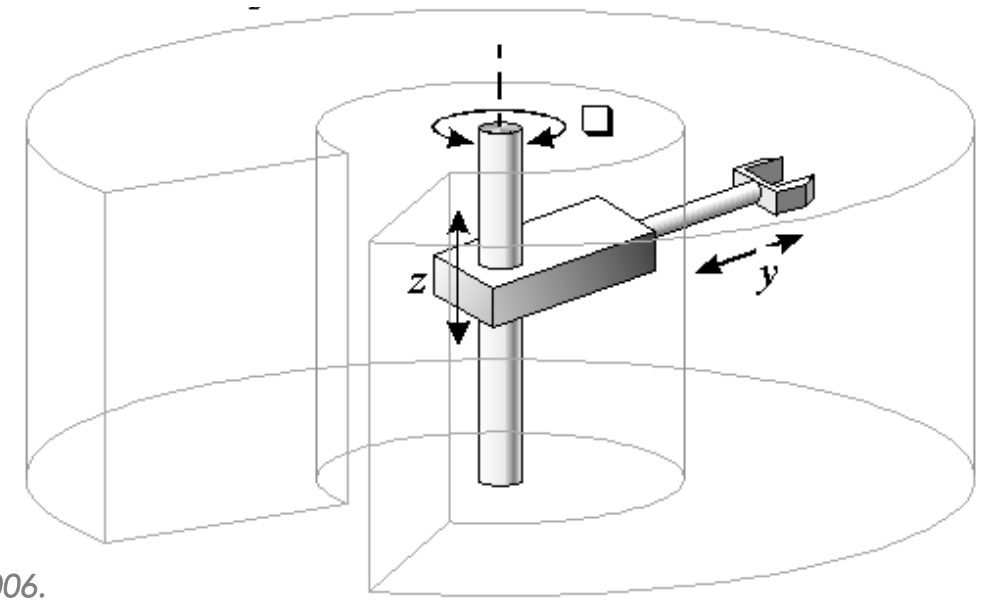
n: normal vector; **s**: sliding vector;

a: approach vector

Workspaces



- Configuration only provides geometry
- Workspace
  - Set of all possible *positions* of end effector
- Dexterous workspace
  - Set of points where end effector can be any orientation



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

Manifolds and Motion

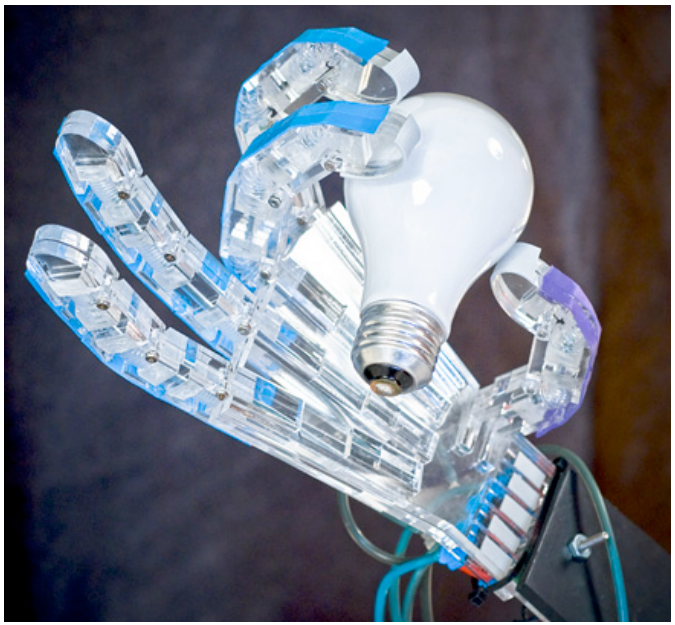
- Manifold: the surface an end effector can trace out
- Motion: point-to-point or manifold following

www.iri.upc.edu/research/webprojects/cuikweb/aims.php
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 physically grasp by direct impact upon the object
  - Ingressive
    - Pins, needles or hackles penetrate surface
      - Textile, carbon and glass fibre handling
  - Astrictive
    - Suction forces applied to surface
    - Vacuum, magneto- or electroadhesion
  - Kontugutive / Contigutive
    - Requiring direct contact for adhesion
    - Glue, surface tension or freezing

grasping



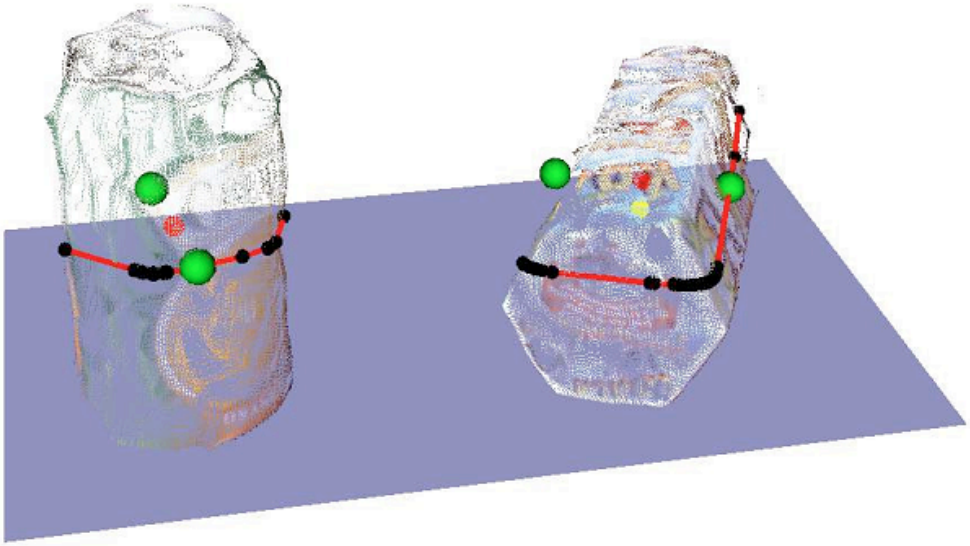
Monkman, Hesse, Steinmann, Schunk. Robot Grippers. 2007.
news.nationalgeographic.com/news/2009/05/090505-robot-hand-picture.html

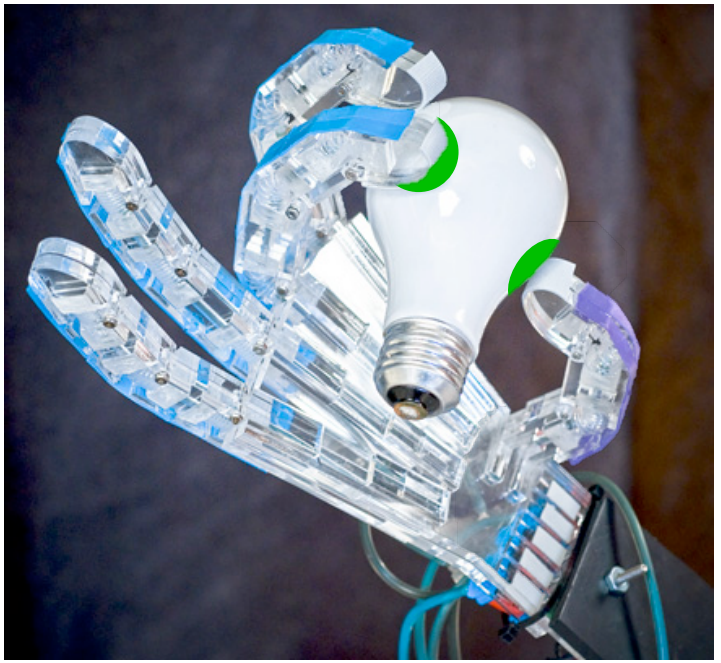
Universal Gripper: Video

- https://www.youtube.com/watch?v=0d4f8fEysf8

Grasps

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

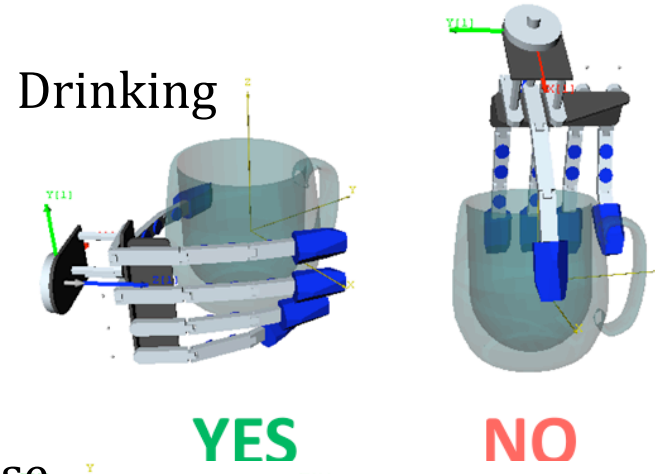


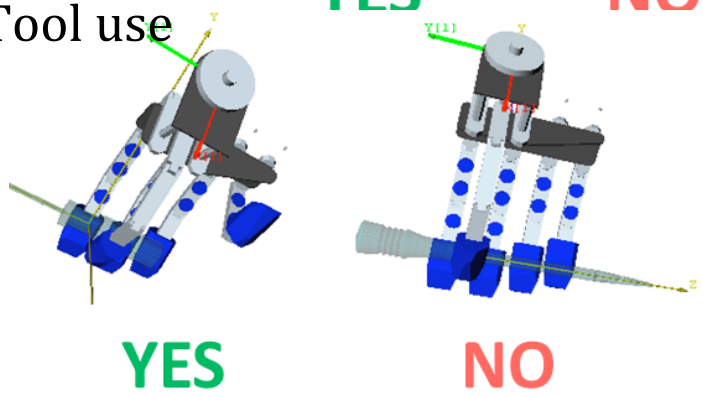


www.intechopen.com/books/robot-arms/robotic-grasping-of-unknown-objects1
news.nationalgeographic.com/news/2009/05/090505-robot-hand-picture.html

Grasps

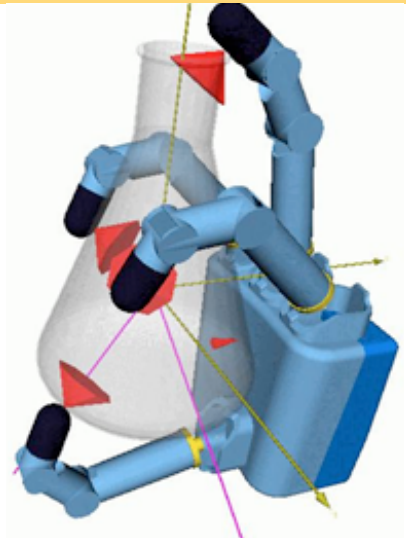
- Grasps vary by:
  - Hand (gripper)
  - Object being grasped
    - Topology, topography, mass, surface, …
  - Type of motion desired
- For each hand or hand/object pair:
  - Where to grasp it?
  - How hard?
  - Then what?
- Additional constraints (e.g., don't spill)



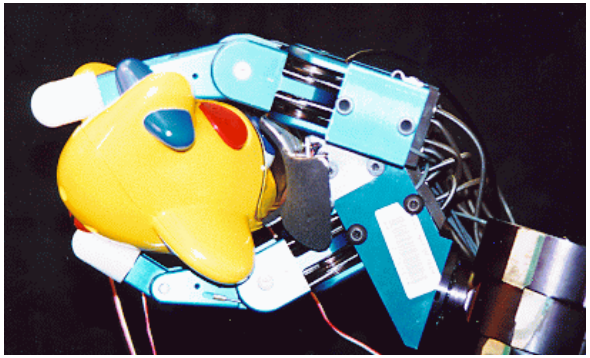


León, Morales, Sancho-Bru. Robot Grasping Foundations. 2013

The Grasping Problem



- 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

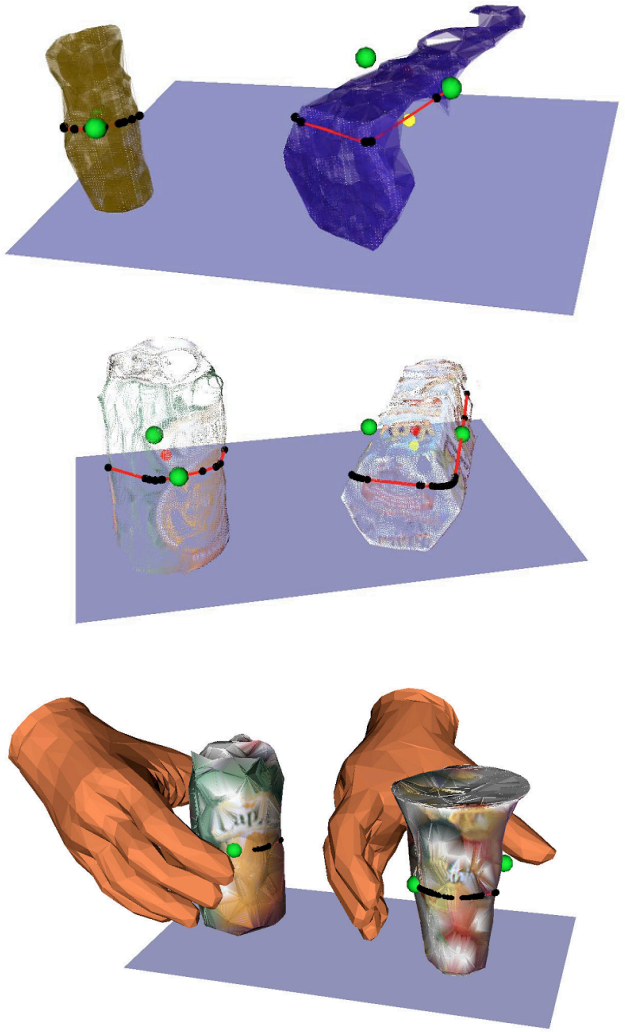


- Real trial and error

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

Grasp Planning

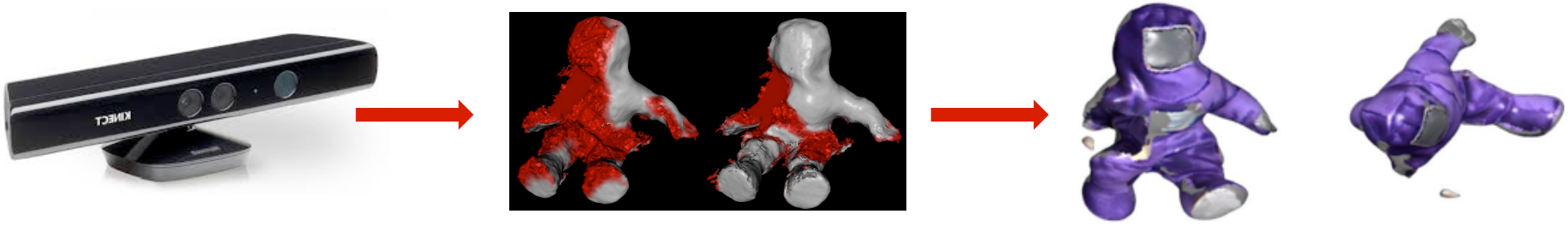
- **Grasp synthesis:** Find suitable set of contacts, given
  - Object model
  - Constraints on allowable contacts
- **Grasp points** are determined
  - Mostly assume point **contacts**
  - Larger areas usually discretized
  - **Contact model** defines the force the manipulator exerts on contact areas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



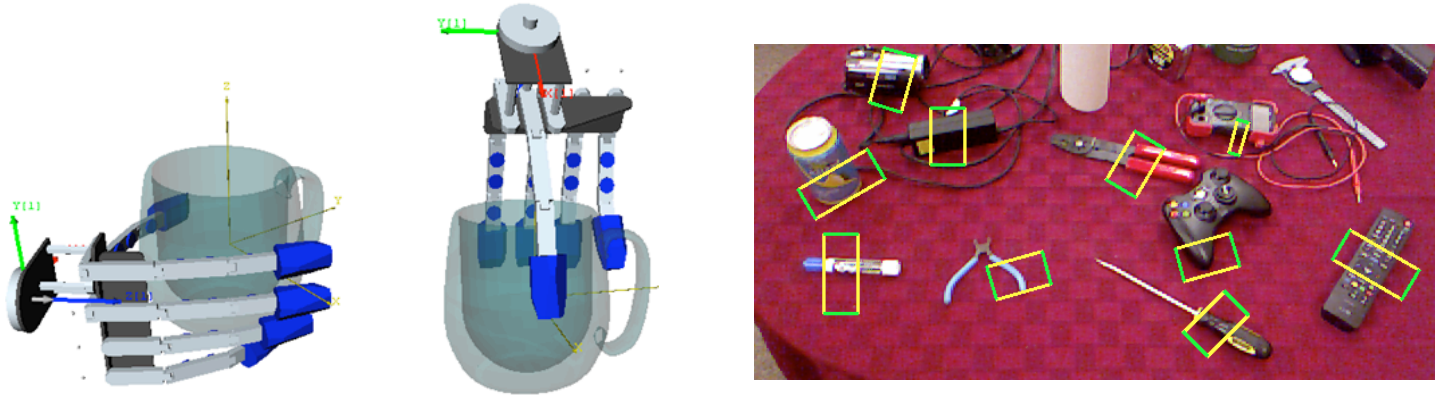
León, Morales, Sancho-Bru. Robot Grasping Foundations. 2013.
www.intechopen.com/books/robot-arms/robotic-grasping-of-unknown-objects1

Ongoing Research

- How do you get the object model?



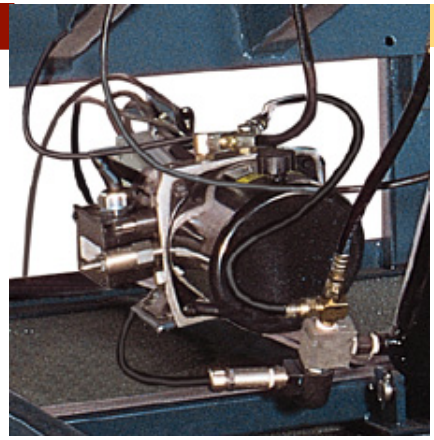
- What are the constraints?



- Background knowledge, mathematical modeling, …

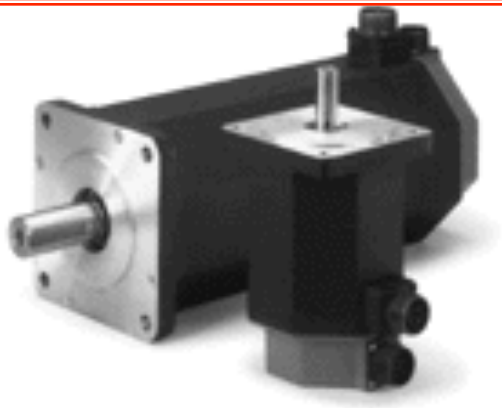
www.madry.pro
www.cs.washington.edu/robotics/3d-in-hand

Actuators



Hydraulic Motor

Pneumatic Cylinder



Stepper Motor

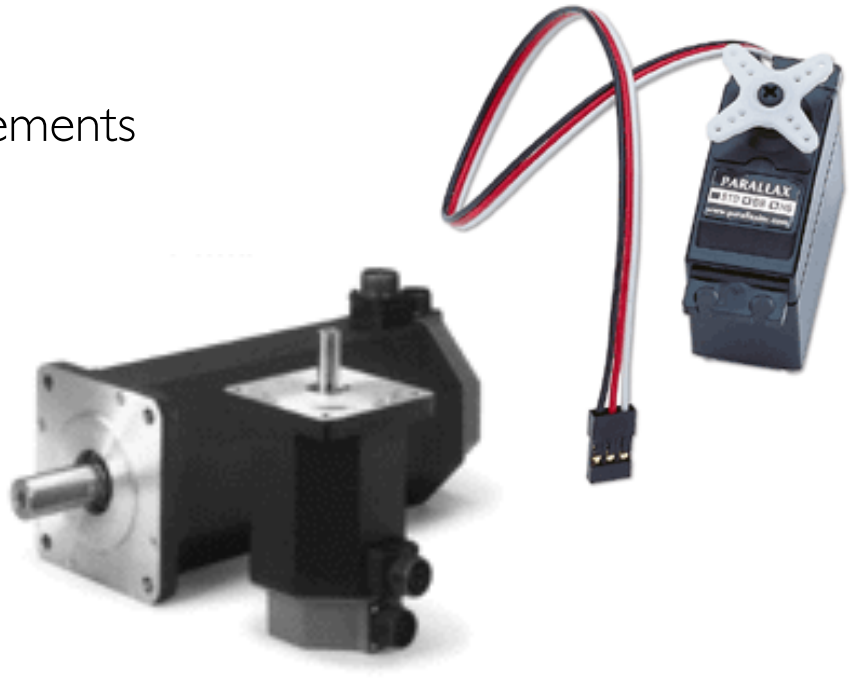
Pneumatic Motor

DC Motor

Servo Motor

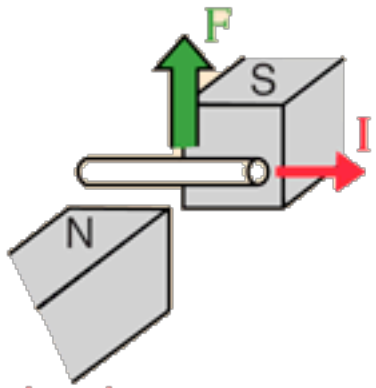
When Do We Use…

- Most common: combinations of different motors
  - Stepper motor
    - Subdivides a rotation into 4-10 increments
    - Open Loop
  - Servo Motor
    - Subdivides a rotation arbitrarily
    - Closed Loop
    - AC servo, brushless DC servo, brushed DC servo

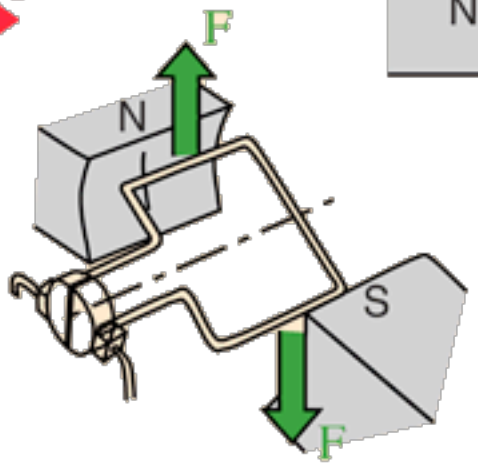


- What is a motor?
  - Basic idea: electricity goes in, rotation happens.
  - Rotation is really useful!

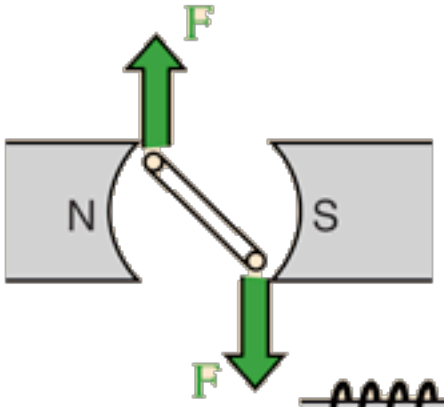
Motors writ (very) broad



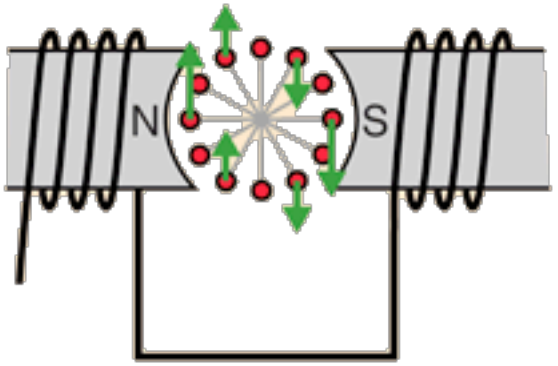
An electric current in a magnetic field will experience a force.



If the current-carrying wire is bent into a loop, then the two sides of the loop which are at right angles to the magnetic field will experience forces in opposite directions.



The pair of forces creates a turning influence or torque to rotate the coil.



Practical motors have several loops on an armature to provide a more uniform torque and the magnetic field is produced by an electromagnet arrangement called the field coils.

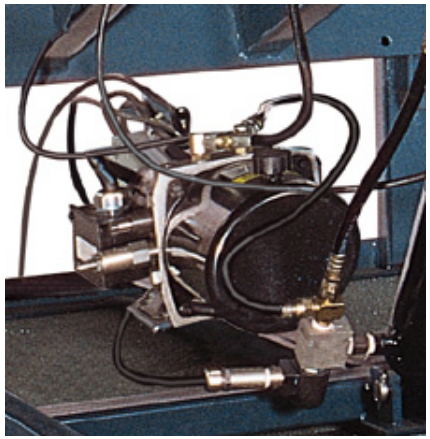
http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/mothow.html

Other Choices

- Hydraulic/pneumatic
  - Heavy loads, high speeds
  - Sometimes hard to control (esp. pneumatic)
  - Doesn't produce sparks

Pneumatic Motor

Pneumatic Cylinder

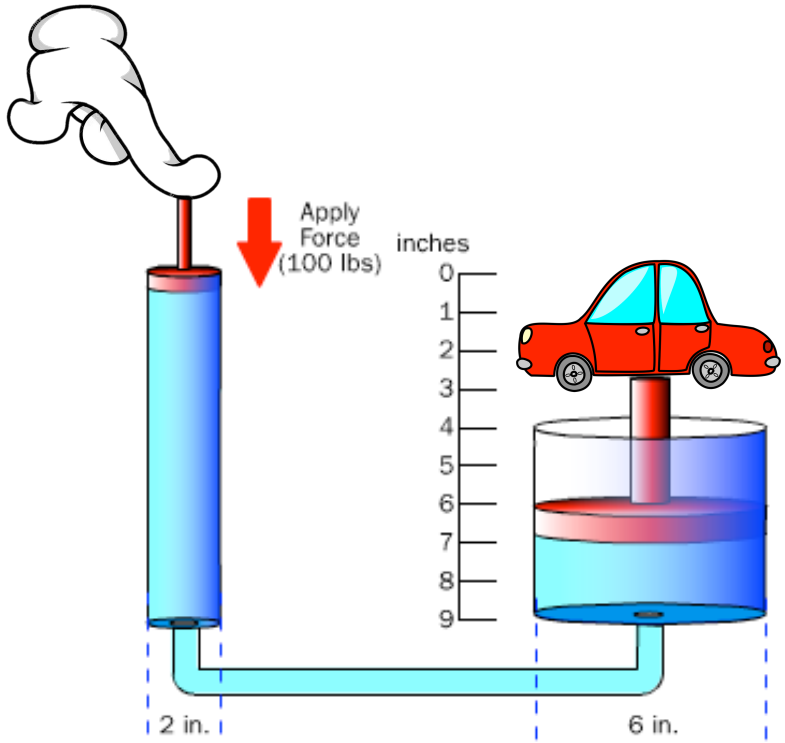


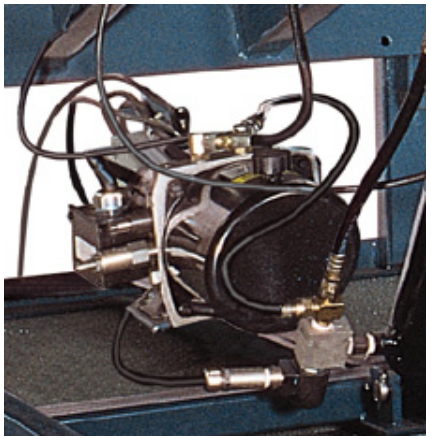
Hydraulic Motor

Hydraulics

- Hydraulics: Force multiplication using incompressible liquid

  In practice: pistons, tapers, …





Hydraulic Motor

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

Pneumatics

- Use compressed air to generate energy.
  - Quick to respond
  - Not ideal under high pressures
    - Why?
- Piston style
  - Generate linear force by acting on a piston
  - Then convert linear force to torque (if needed)
- Diaphragm style
  - Rubber diaphragm and stem in circular housing
  - Good for valces requiring shorter travel