Grasping and manipulation in robotics

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Manipulation, grasping

Manipulation

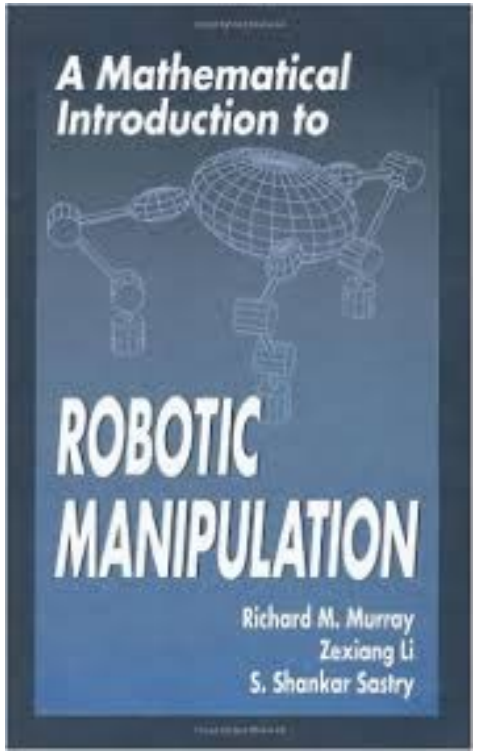
- Manipulation means interacting with the object physically, exerting forces on it in order to move or reshape it.

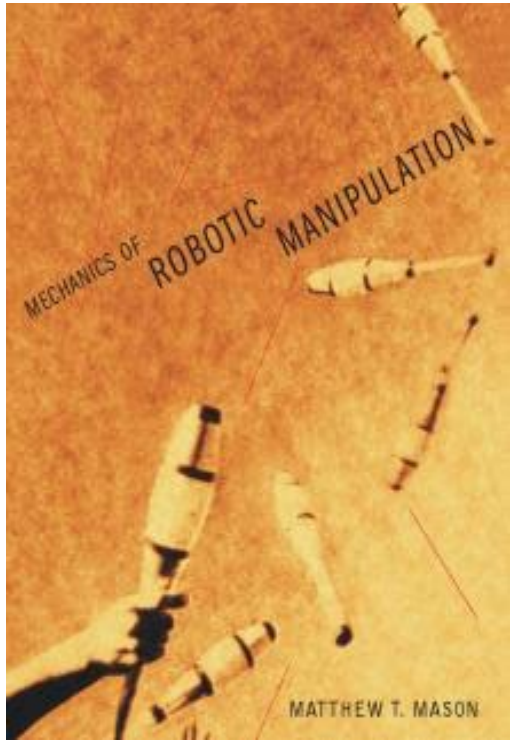
Grasping

- Merriam-Webster dictionary: “used, designed, or adapted to grasp”

Textbooks

- R.R. Murray, Li, Z., Sastry, S. S., A mathematical introduction to robotic manipulation. CRC press. Chicago, 1994.
  - http://www.cds.caltech.edu/~murray/books/MLS/pdf/mls94-complete.pdf
- M.T. Mason, Mechanics of Robotic Manipulation, MIT Press, 2001.
  - http://cognet.mit.edu/book/mechanics-of-robotic-manipulation





Robotic grasping, a complex field

- Hand design: high level (number of fingers, kinematic structure, etc.) and low-level (mechanism design, motors, materials, etc.);
- Hand control algorithms: high level (find an appropriate posture for a given task) and low-level (execute the desired posture);
- Information from sensors (tactile, vision, range sensing, etc.);
- Any pre-existing knowledge of objects shape, semantics and tasks (e.g. a cup is likely to be found on a table, should not be held upside-down, etc.);
- All of these add up to a Grasp Planning System ... and more!

Courtesy: Peter Allen, Columbia University

Mechanics of manipulation

- Contact models
- Friction
  - Coulomb's law
  - Friction cones
  - Planar single contact problems
- Grasping
  - Force- and form closure
  - Grasp synthesis and map
  - Grasp stability and quality
  - Grasp planning
- Static and quasi-static models of interaction between the manipulator and the environment.

Animals and manipulation

A dung beetle rolling a ball

A chimpanzee fishing termites

Weaverbird (snovač in Czech)

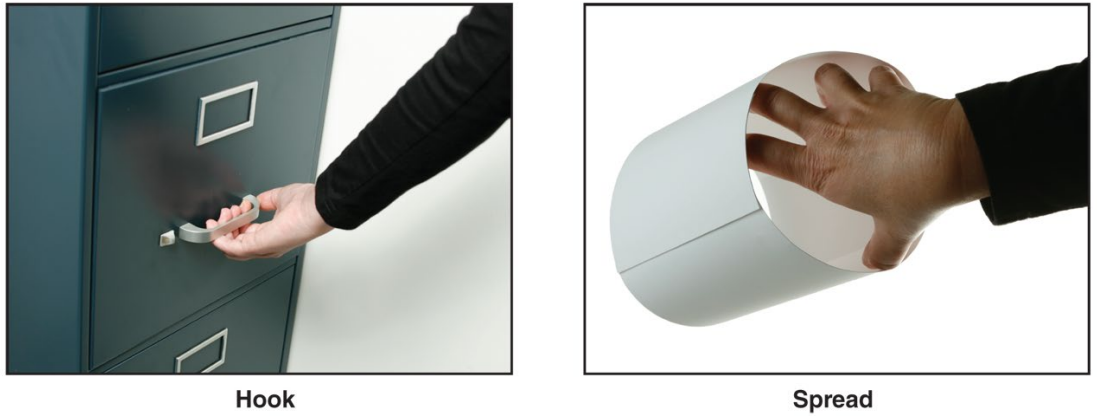
Human hand, prehensile and nonprehensile movements

Prehensile movements

- Five basic prehensile

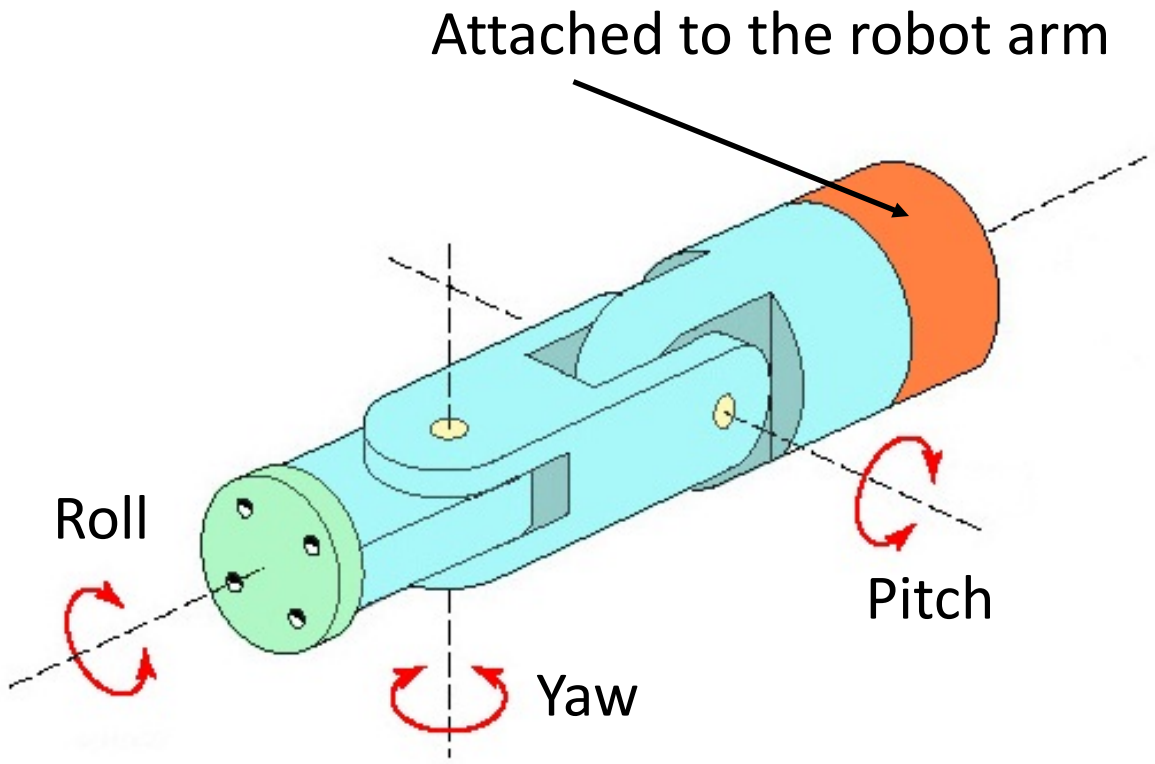
Nonprehensile movements

- Do not require finger dexterity or use of opposable thumb



Robotic wrist joint

- Has typically 3 degrees of freedom
  - ***Roll*** involves rotating the wrist about the arm axis
  - ***Pitch*** up-down rotation of the wrist
  - ***Yaw*** left-right rotation of the wrist
- The end effector is mounted on the wrist

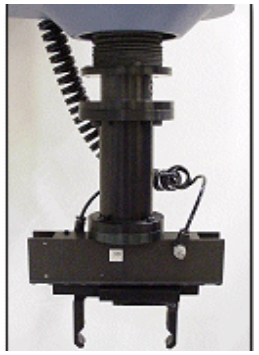


Types of end effectors

- The end effector is a device attached to the robot arm flange (wrist) enabling a general-purpose robot to perform the specific task
- Three types of end effectors
  1. **Grippers** (prehensile, chápavý zool.) grasp and manipulate objects, e. g., parts in industrial manufacturing during the work cycle
     - Structured environment
     - Reliable
     - Simple, low cost

Suction

Magnet



Parallel jaw

  2. **Hands** (prehensible)
     - Unstructured environment
     - Adaptable
     - Complex, expensive
  3. **Tools** (nonprehensile) perform a process, e. g. spray painting, welding, screw something together

Desired: position/orientation vs. dynamics

Move the end effector to a desired position/orientation

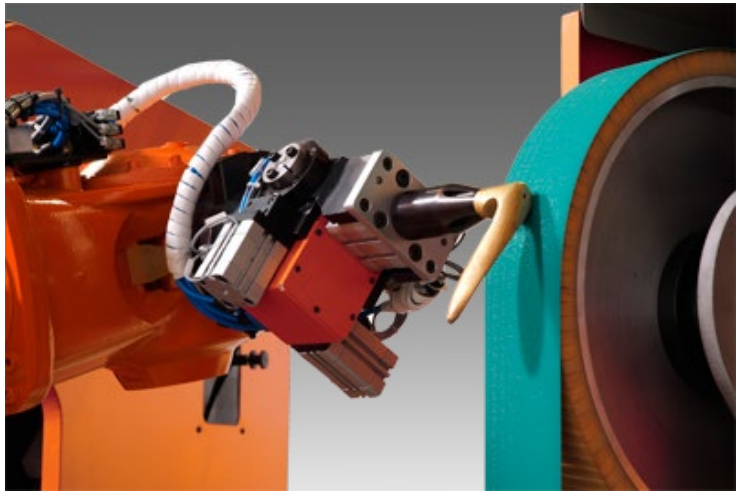
Typical operations

- Pick and place
- Assembly
- Stacking and loading

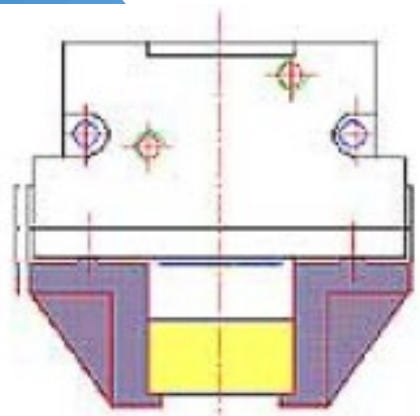
Move the end effector with a desired dynamics (having a force/torque feedback is needed in some cases)

Typical operations

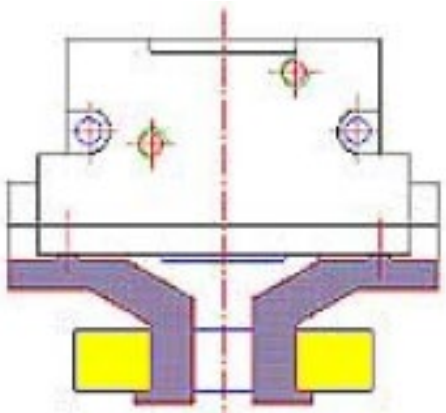
- Cutting, machining, grinding, …
- Painting
- Scanning areas



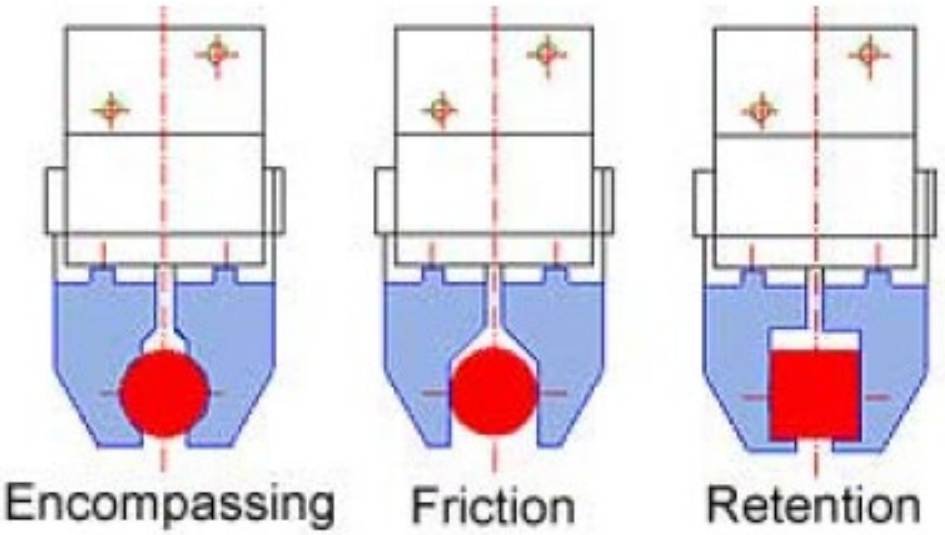
Mechanical grippers



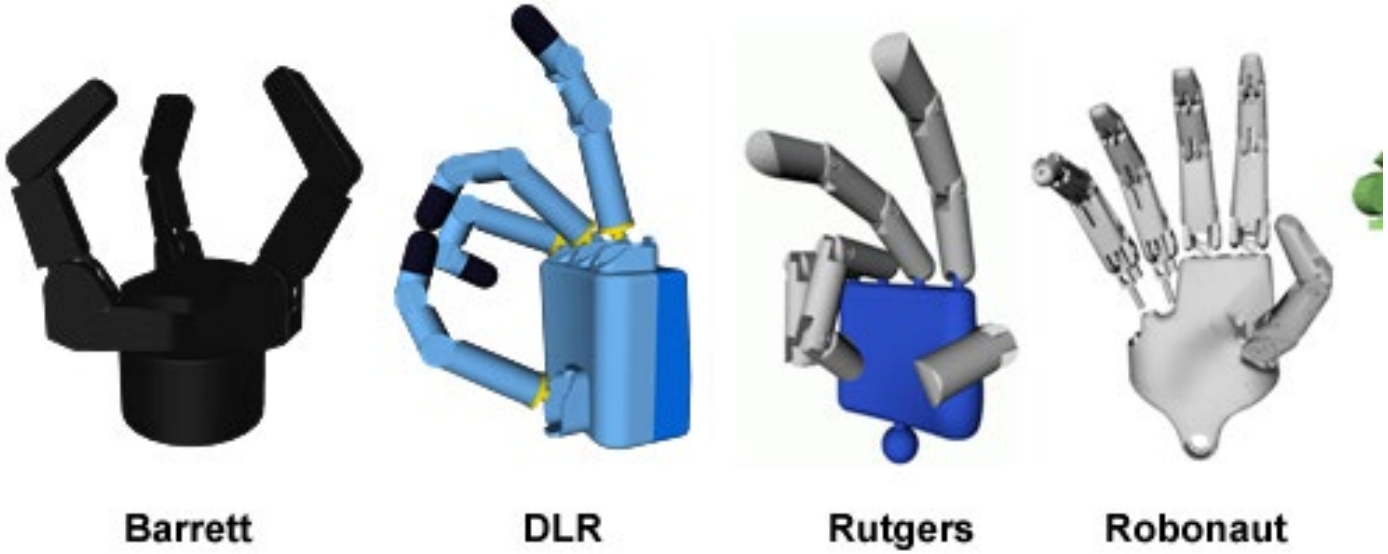
External Grip
(Closed)

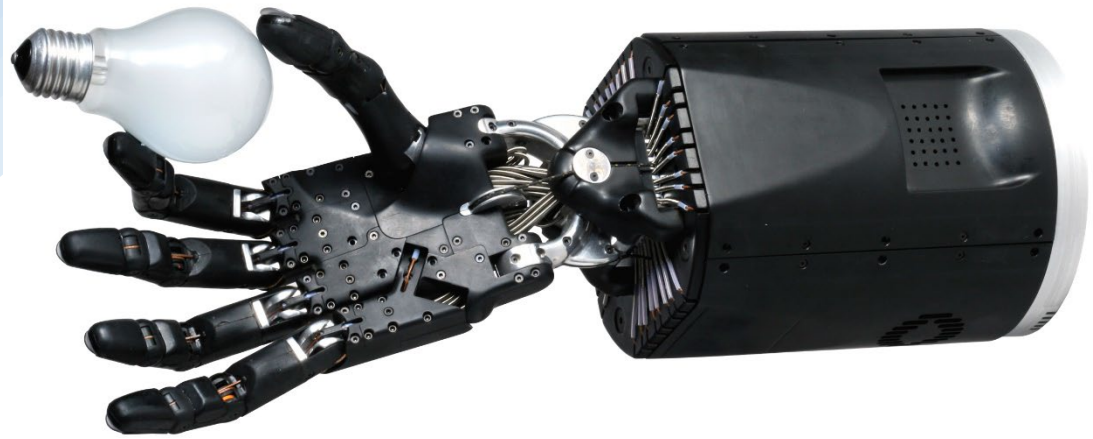


Internal Grip
(open)



Robot hands



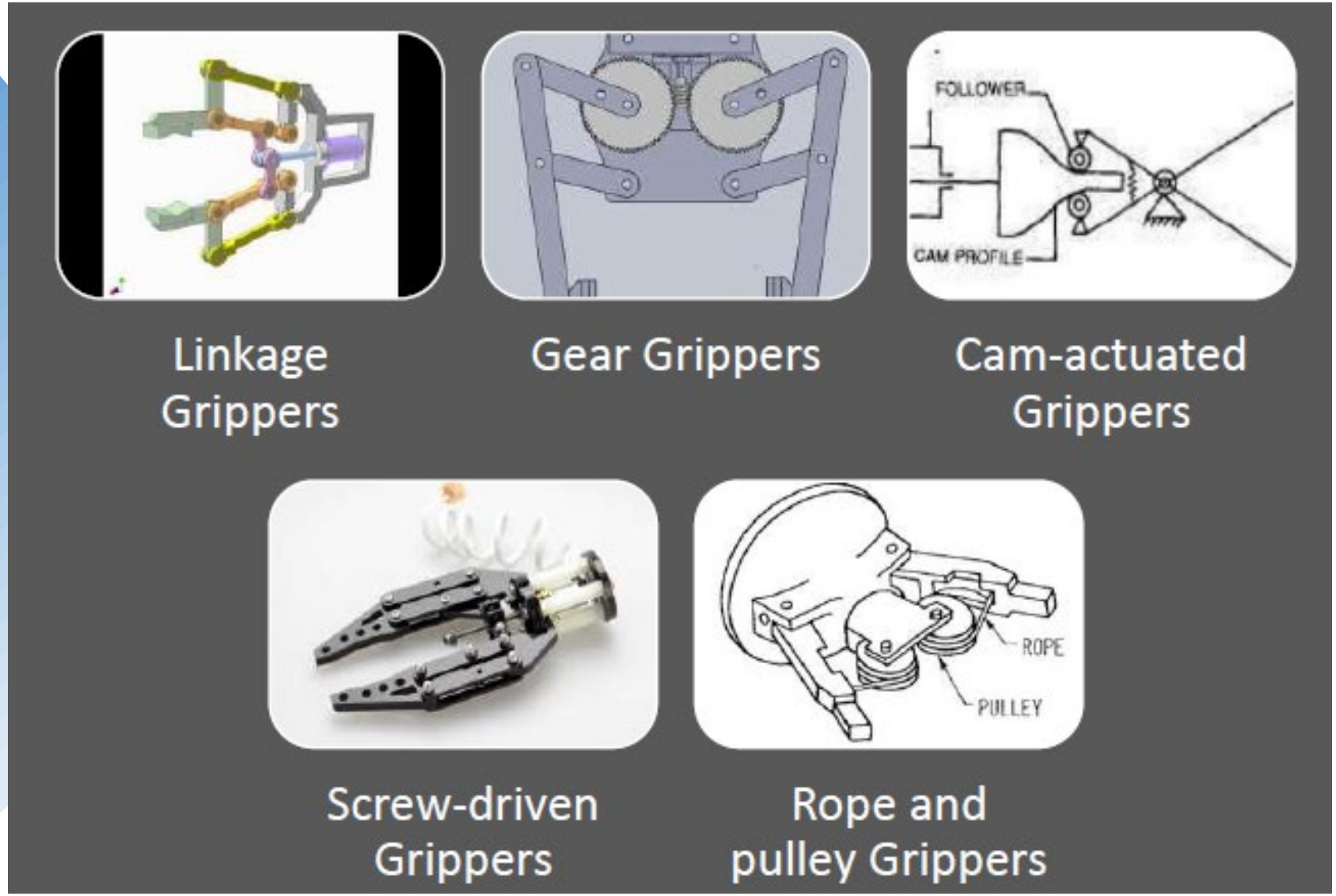


Grippers classification

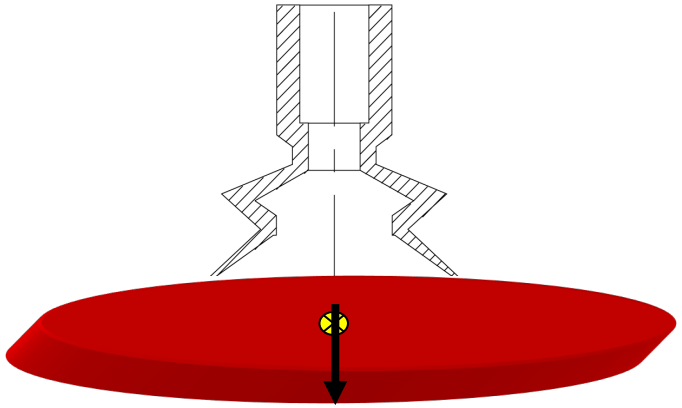
Gripper End Effectors			
Gripper Type	**Gripper Configuration**	**Gripper Movement**	**Internal/External Gripping**
Mechanical finger	Two-finger Three-finger Four-finger	Parallel or angular	Internal and external
Collet	Round Square Hexagonal	360° clamping contact	Internal and external
Vacuum	One or more suction cups	Vacuum/suction	External
Electromechanical	Permanent magnet Electromagnet	Magnetic attraction	External

Goodheart-Willcox Publisher

Gripper mechanisms



Vacuum grippers aka suction cups

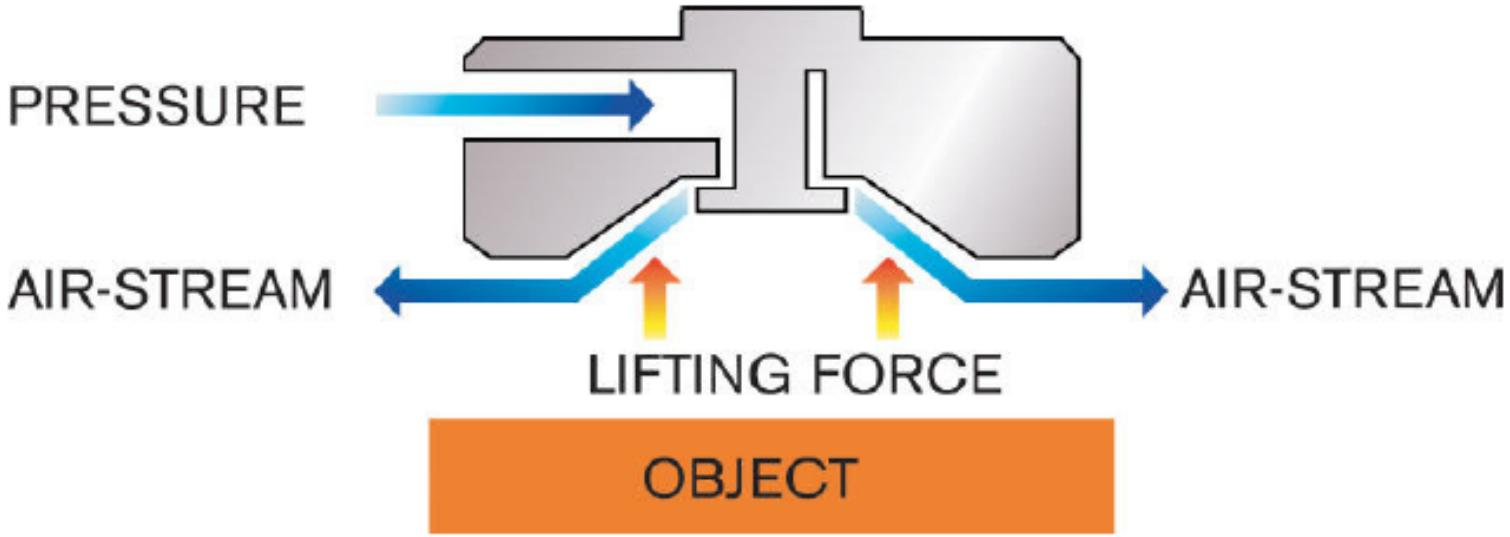


Small to medium objects

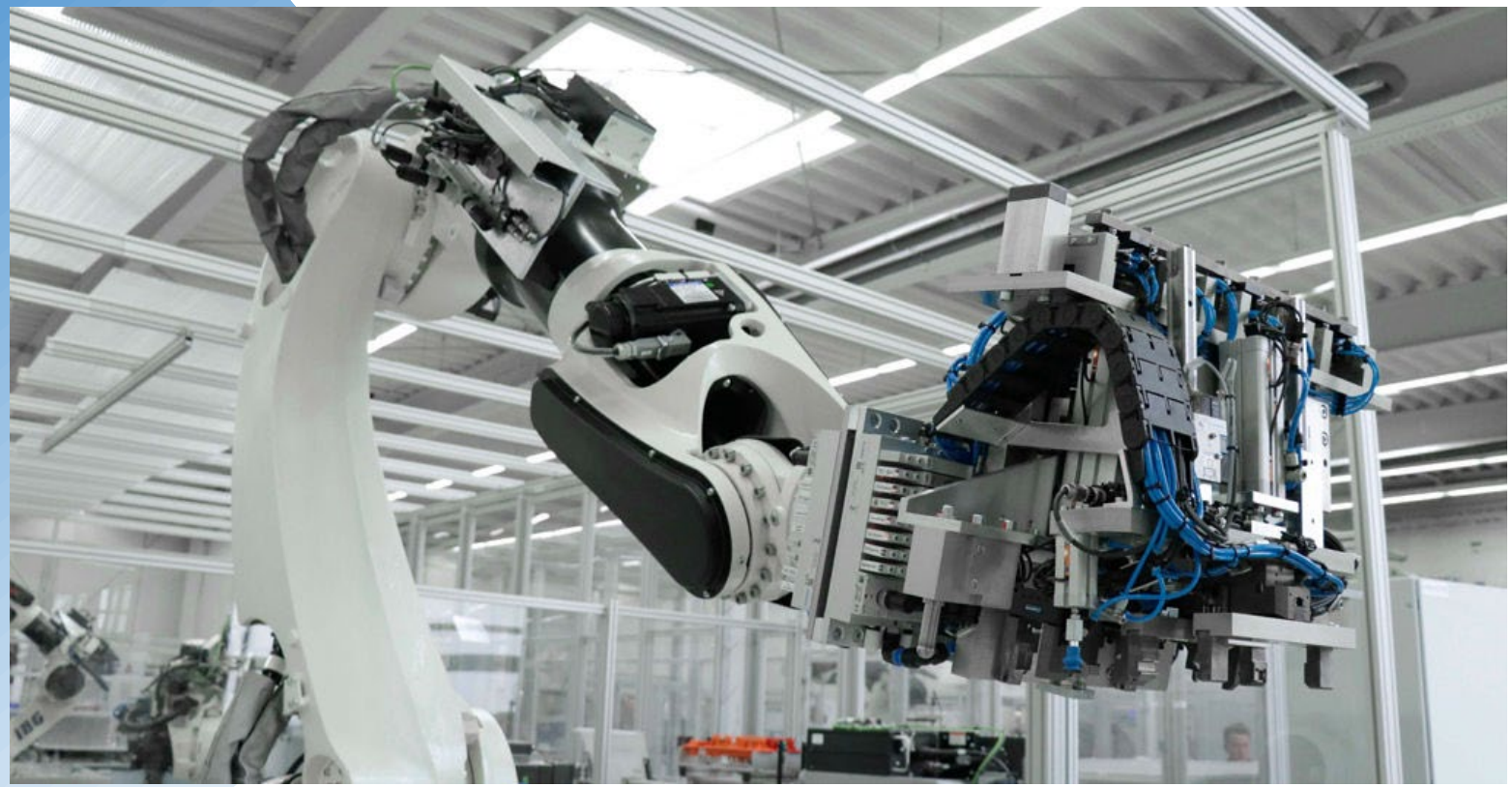
Large, heavy objects

Vacuum grippers applications

Negative pressure, Bernoulli, non-contact

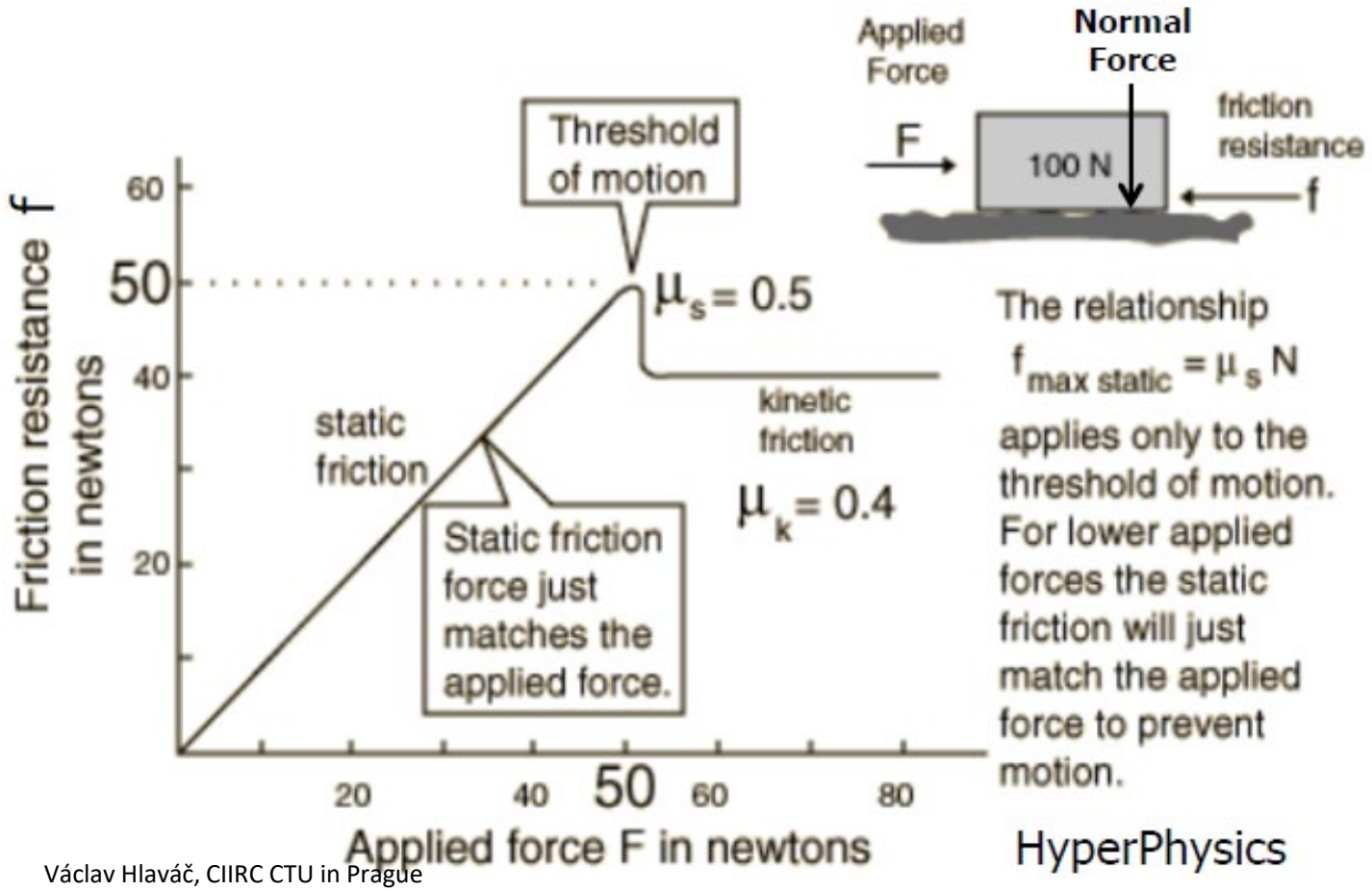


Special purpose gripper



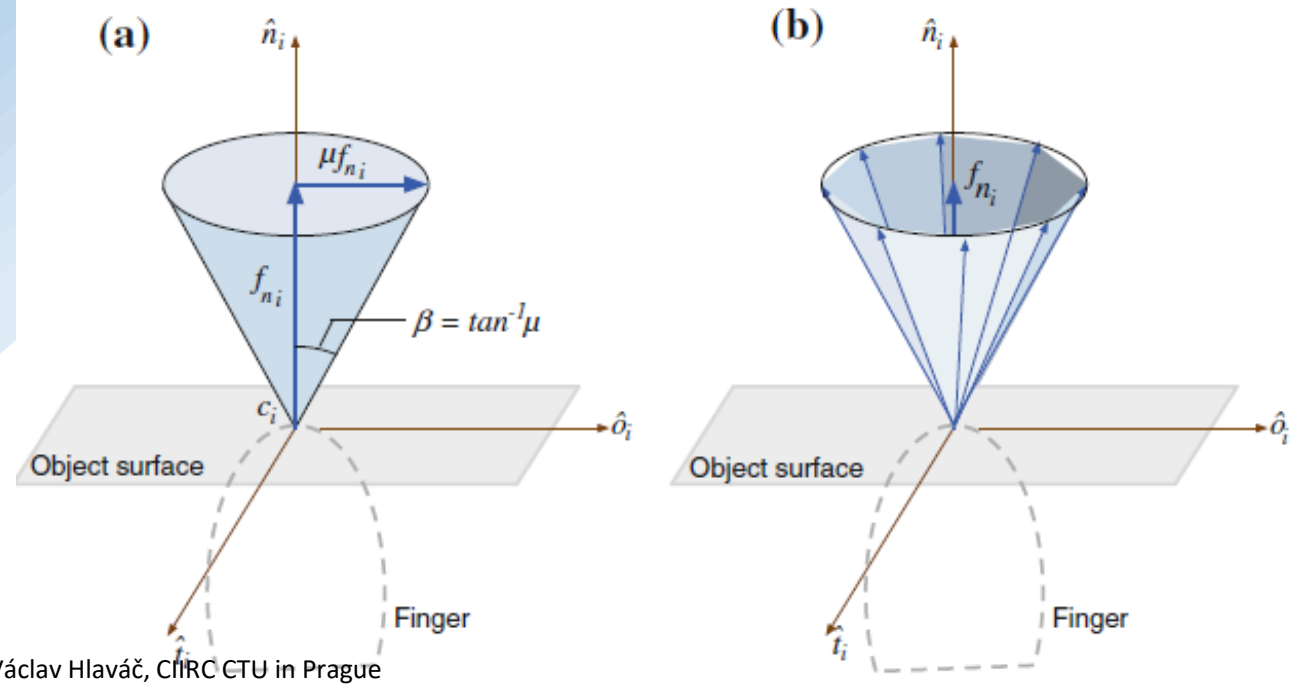
Kinetic and static friction (aka stiction)

- $F_f \leq \mu_s \cdot F_n$ (at rest), μ_s is the coefficient of static friction
- $F_{f \leq \mu_k} \cdot F_n$ (moving), μ_k is the coefficient of kinetic friction

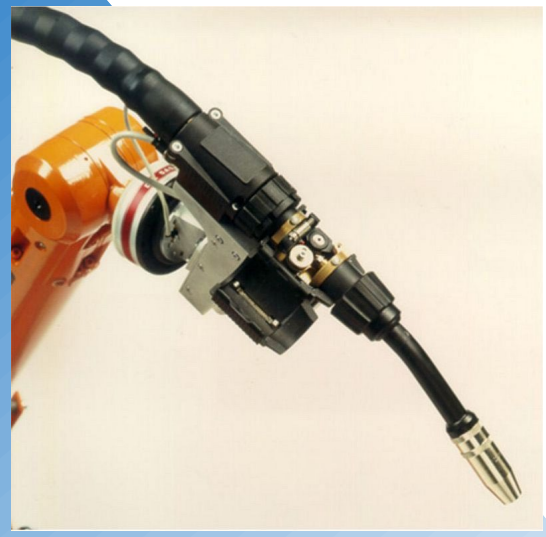


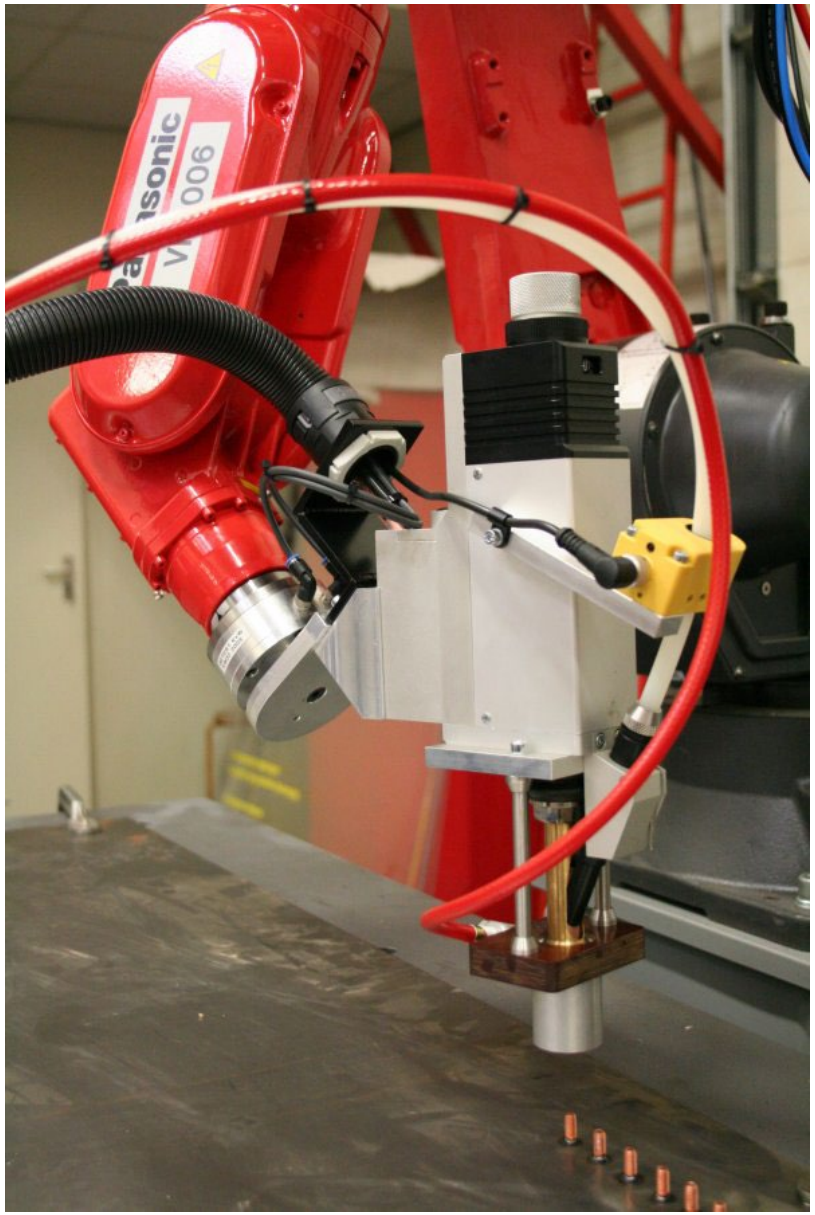
Friction cones

- Friction at a contact point allows forces in directions other than the contact normal
- COF, μ, is determined by the contacting materials
- Estimate friction cone as convex sum of a force vectors on the boundary assuming a unit normal force, $\|\mathbf{f}\| = 1\,,\ \mathbf{f} = \sum_{j=1}^{m} \alpha_j\ \mathbf{f}_j$



Tools: welding

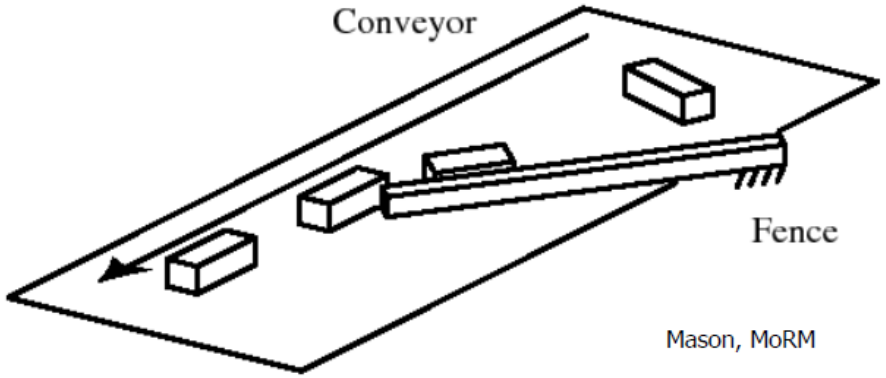




Peripherals: Part feeding

Many methods for presenting product to robot:

- Loose (bulk)
- Accumulated (conveyor)
- Random (conveyor)
- Trays
- Magazines
- Taped Reels
- Carrier Strip



Fixturing

Vibrating bowl feeding