Manipulation: Mechanisms, Grasping and Inverse Kinematics

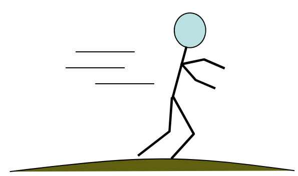
RSS Lectures 14 & 15

Monday / Wednesday, 31 March / 2 April 2014

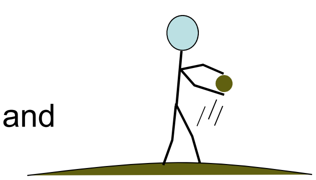
Prof. Seth Teller

Mobility / Manipulation Duality

- Mobility:
  - Earth is fixed
  - Legs apply forces to earth
  - Reaction forces move body



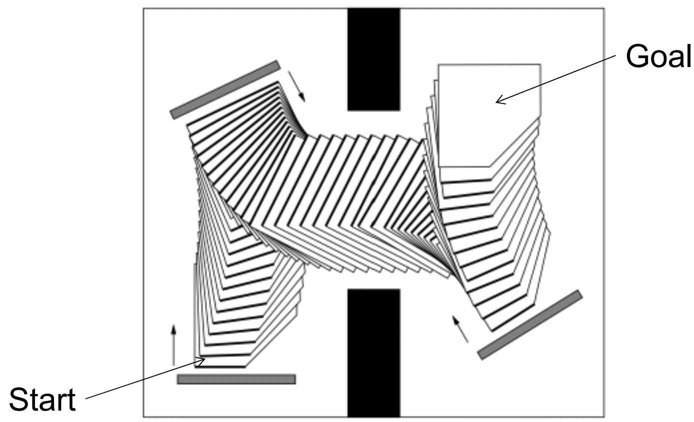
- Manipulation:
  - Body is fixed to earth
  - Arms apply forces to manipuland
  - Forces move manipuland



- Goal of Field: Mobile Manipulation
  - Use of *coordinated whole-body motion* to effect desired manipulation of manipuland, environment
  - Examples: Lifting a sandbag, throwing a baseball, shoveling snow, replacing a ceiling smoke detector

Manipulation by Pushing

- Stable push:
  - Motions that keep object in *line* contact w/ manipulator

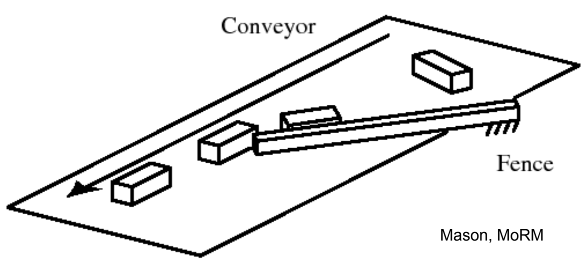


Northwestern

  - Motion planning, but with additional constraints

Fixturing

- Use of designed pegs, surfaces, prior knowledge of manipuland geometry to achieve desired pose

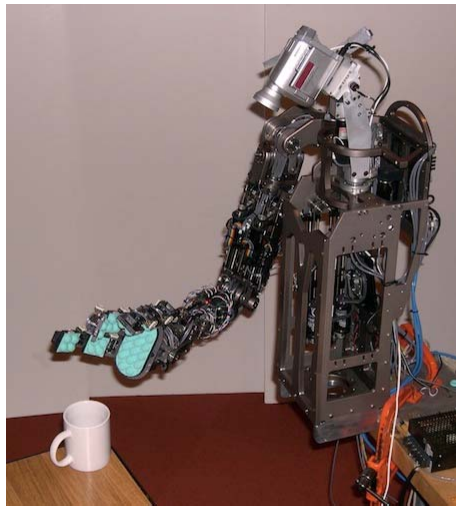


Mason, MoRM

- Goldberg's "part squeezer" (Try it!)

Soft-finger Manipulation

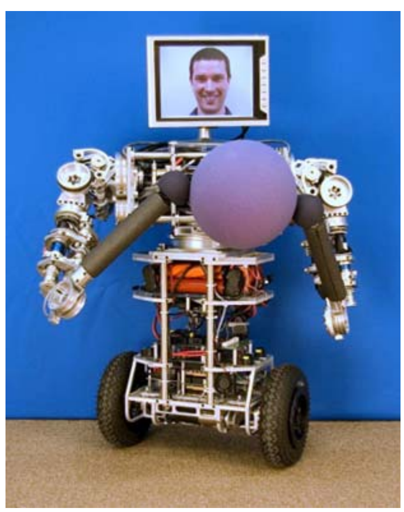
- Can exploit visual/tactile sensing & feedback



Obrero / MIT

Mobile, Two-handed Manipulation

- Challenges: mass distribution; uncertainty



uBot / UMass Amherst

End Effectors

- The component that usually comes into intentional contact with the manipuland
- Often attached interchangeably to robot arm
  - … like a human hand picking up a specialized tool
- Many designs (here ordered roughly by time)

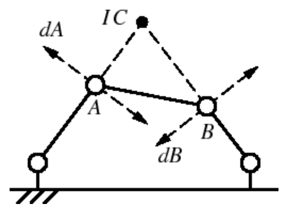
Manipulation Challenges

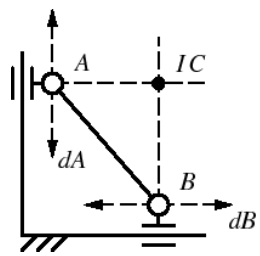
CMU robot "Herb" (Home Exploring Robot Butler, also after Herb Simon)

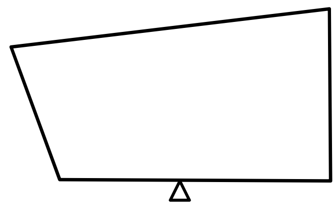
How can the robot *perceive* the object's type and pose?
How can the robot *reach for* the object?
How can the robot *grasp* the object?
How can the robot *move* the object where desired?
… Today we'll focus on grasping.

Mechanism Analysis

- Given some set of constraints, how can the motion of an object be characterized?
  - Rotating links
  - Sliding links
  - Point contacts



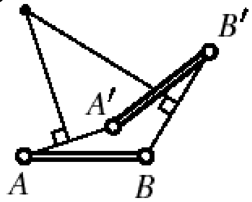




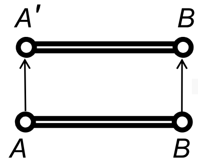
Figures from Mason, MoRM

Rotation Center (RC)

- Consider *finite* planar displacement of rigid object
  - Some point in the plane is left fixed by displacement
  - This point is called the "rotation center" (RC)
- What if the displacement is a pure translation?
  - Where is the RC?

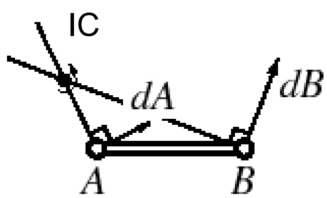


Mason, MoRM

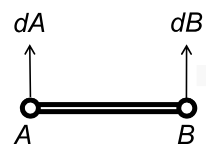


Instantaneous Center (IC):

- Consider a *differential* displacement (i.e. velocity)
  - Displacement still has a fixed point; where is it?
- What if the displacement is a pure translation?
  - Where can the IC lie?

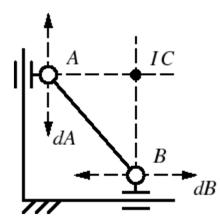


Mason, MoRM

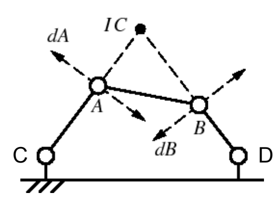


Use of IC for Mechanism Analysis

- Example four-bar linkage:
  - Base link
  - Two sliding+rotating links A, B
  - Coupler link connecting AB



- Example four-bar linkage:
  - Base link
  - Four rotating links A, B, C, D
  - Coupler link connecting AB

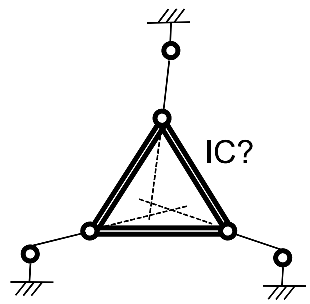


- Constraints on A, B dictate coupler motion
- IC completely determined; characterizes linkage

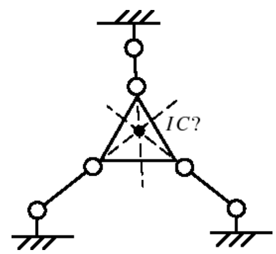
Figures from Mason, MoRM

IC for Mechanism Analysis (cont.)

- Consider this mechanism:
  - IC is



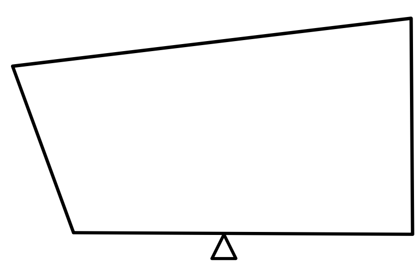
- Another possibility:
  - “False instantaneous center”



Mason, MoRM

Unilateral constraints

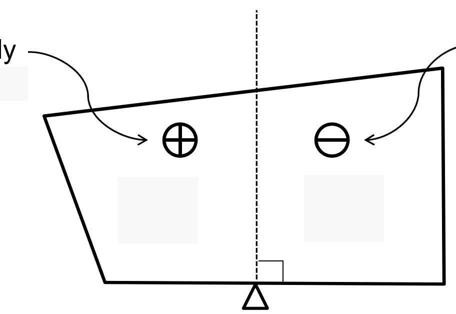
- Point contact with boundary of manipuland
- Manipuland cannot *violate* constraint (but it can *separate* from it: thus “unilateral”)



- How does this point contact constrain the possible motions of the manipuland?

Reuleaux's method (1876)

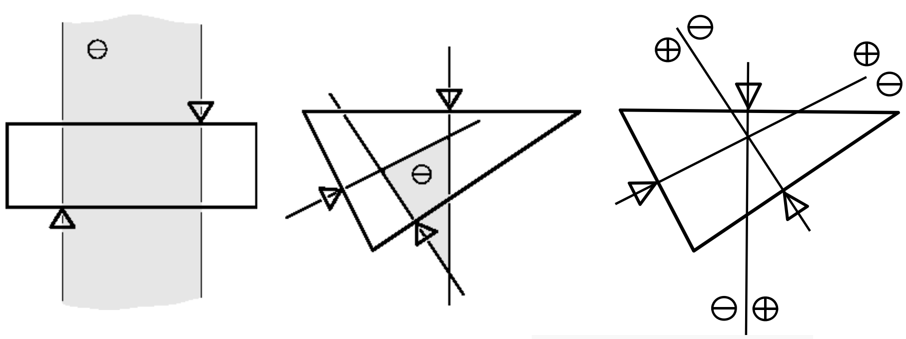
- Each unilateral constraint partitions space of ICs into regions left, right and on *line of contact normal*



- Why is the "line of contact normal" key to analysis?
  - Along it, differential rotation of either sign is possible (for now, we are assuming frictionless point contacts)

Reuleaux's method (cont.)

1. Construct line of   for each contact
2. Label plane regions as   w.r.t. this constraint



3. Each remaining region with
   is a locus of possible instantaneous centers

→ Can the IC locus become *empty*? If so, how?