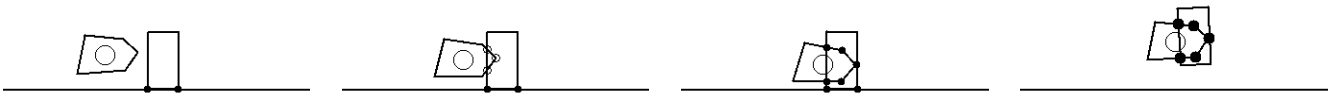
Motion Understanding

- **The Problem:** "What happened in this movie?"

- **The Approach:** Physics-based analysis of simplified scene model.
- **Example:**



  - Can is a 'passive object' (resting on table).
  - Hand is an 'active object' (moving above table).
  - Hand lifts can off table (by attaching to it).

(Overview)

Framework

Computational Perceiver (Jepson & Richards, 1991, 1993)

- **Ontology:** representation of scene properties.
  - Force-dynamic properties of simplified scene model
    (eg., ‘active’ vs. ‘passive’ objects, attached vs. contacting objects, etc.).
- **Domain theory:** constraints used to determine feasible interpretations.
  - Consistency with Newtonian mechanics.
- **Preferences:** to choose most plausible interpretation(s).

Simplifications (Base system) (Overview)

- Analysis of motion at a single point in time (relaxed later).
- Continuous motion
  (ie., no changing contact relations or collisions).
- 2D polygonal scene model.

(This base system provides a framework for an enhanced system that integrates information over time.)

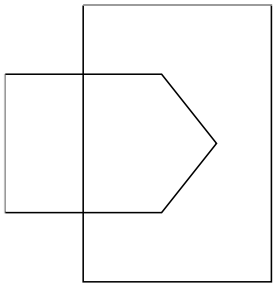
(Overview)

Representation: Kinematic Model

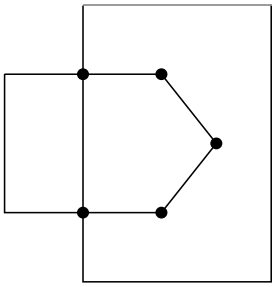
(object shapes, velocities, contact geometry)

- **Objects.**
  2D rigid polygons (made up of convex parts).

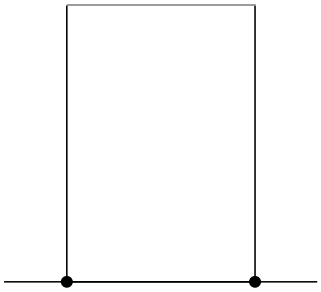
- **Contact.**
  Layered scene model with the following contact relations between objects:



Disjoint

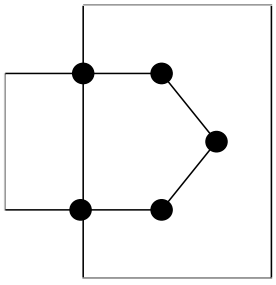


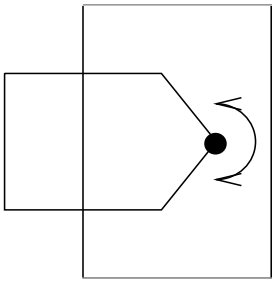
Overlap

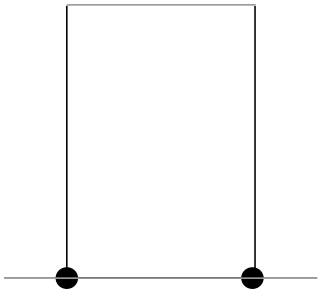


Abut

- **Attachment.**
  Model attachment by fixing contact points (analogy to *rivets*).





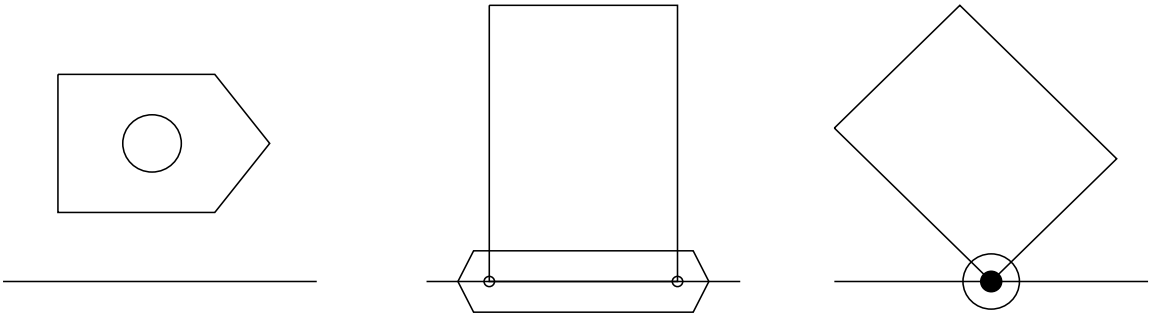


(Overview)

Representation: Dynamic Model

(object masses, accelerations, forces)

- **Masses**
  - **Mass.** Variable mass; assumed to be positive (and bounded above).
  - **Center of gravity.** Taken to be center of object.
  - **Inertia.** Constrained by mass and bounds on mass distribution.
- **Forces**
  - **Gravity** acts on all objects.
  - **Contact forces.** normal forces, tangential forces (friction).
- **Ground plane:** used to represent table.
- **Motors** (Our assertions about ‘active’ objects.)



BodyMotor LinearMotor AngularMotor

(Overview)

Interpretation

Definition: An *interpretation* is an unambiguous assignment of the terms in our representation:

- contact and attachment relations between objects,
- all force-generators (*motors*) in the scene.

(Overview)

Feasible Interpretations

Definition: An interpretation is *feasible* if the motion of the objects is consistent with the physics-based model.

Testing Feasibility by 'Force-balancing'

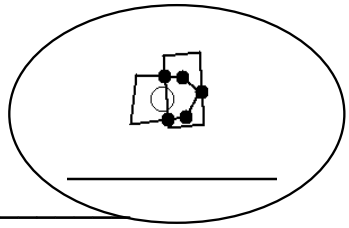
- For each object, sum forces due to gravity, contact with other objects, and forces due to motors.
- masses are variable (constrained to be positive).
- solution must explain observed accelerations according to Newtonian mechanics.
- formulate as *constraint satisfaction problem*.
  (Reduces to *linear programming* in our case)

Sample inferences:

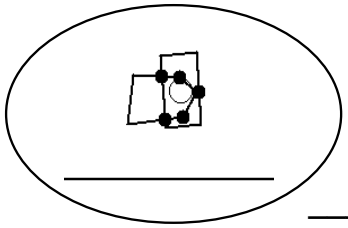
- 'passive' objects: must be *supported* (otherwise *falling*).
- non-attached objects: can 'push' but not 'pull'.

(Overview)

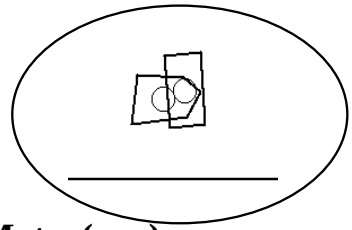
Example: Feasible Interpretations



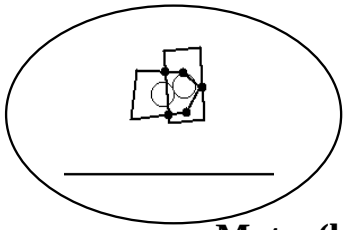
Motor(hand),_____
Attach(hand,can)
Contact(hand,can)



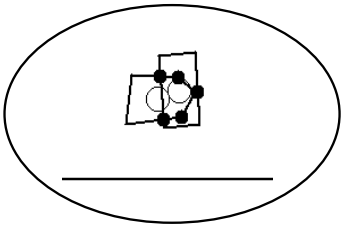
_____,Motor(can)
Attach(hand, can)
Contact(hand, can)



Motor(hand), Motor(can)
_____
_____



Motor(hand), Motor(can)
_____
Contact(hand,can)



Motor(hand), Motor(can)
Attach(hand,can)
Contact(hand,can)

Observation: trivial interpretations can always be found by adding extra motors!

(Overview)

Preferred Interpretations

- **Preferences:**

  Minimize set of motors:

  – $P_{bm} : \neg \textsc{BodyMotor}(o) \succ \textsc{BodyMotor}(o)$;

  – $P_{lm} : \neg \textsc{LinearMotor}(o_1, o_2) \succ \textsc{LinearMotor}(o_1, o_2)$;

  – $P_{am} : \neg \textsc{AngularMotor}(o_1, o_2) \succ \textsc{AngularMotor}(o_1, o_2)$.

  Minimize set of attachments:

  – $P_a(o_1, o_2) : \neg \textsc{Attach}(o_1, o_2) \succ \textsc{Attach}(o_1, o_2)$,

  Indifferent to contacts:

  – $P_c(o_1, o_2) : \neg \textsc{Contact}(o_1, o_2) \sim \textsc{Contact}(o_1, o_2)$,

- **Priorities on preferences:**

  – $\{P_{bm}, P_{lm}, P_{am}\} > P_a > P_c$

Key observation: Preferred models defined by *prioritized subset ordering*. (This is a special case of *circumscription* (McCarthy, 1980).)

(Overview)

Preference Ordering

- hand lifts can.
- can lifts hand.