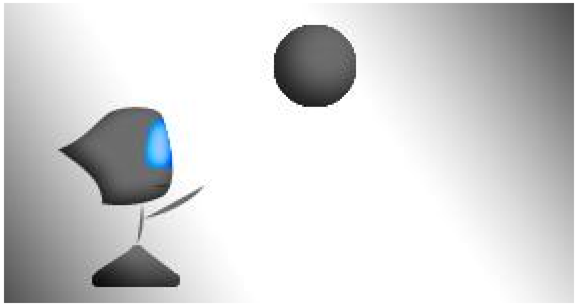


Robots Playing Catch

Brandon Tolsch

Brandon Tolsch

Robots Playing Catch

- Two robots throwing a ball through the air
- Free to move around on the ground
- Pass back and forth forever
- Never drop the ball

Brandon Tolsch

Robots Playing Catch

Brandon Tolsch

Robots Playing Catch

- Robots: modeled as circles
  - Both collision and catching boundary
  - Constant acceleration
  - In plane z = 0
- Ball: modeled as point
  - Travels without air resistance
  - Should not go below z = 0

Brandon Tolsch

Robots Playing Catch

- Safety
  - Ball never goes below z = 0
  - No collisions
- Efficiency
  - Minimal power use
  - Target location optimality
  - Application dependent
- Liveness
  - One doesn’t hold ball forever
  - Robots don’t stand still
  - Also application dependent

$$b_z(t) = 0 \rightarrow (IR_A(t) \vee IR_B(t))$$

$$(A_x - B_x)^2 + (A_y - B_y)^2 \geq (2r)^2$$

Brandon Tolsch

Robots Playing Catch

- Simplifications and Stepping Stones
  - Cannon adjustments
    - Vertical angle, rotation, power
  - Robot motion
    - Stationary, 1D, 2D linear, 2D free
  - Motion timing
    - Motion before pass, after pass

Brandon Tolsch

Robots Playing Catch

- Stationary case already poses problem
  - Evolution domain constraint

$$(IR_A(t) \rightarrow b_z(t) \geq 0) \wedge (IR_B(t) \rightarrow b_z(t) \geq 0)$$

  - Solution

$$b_z(t) = v_0 \sin(\theta)t - \frac{1}{2}gt^2$$

  - Condition to restrict solution

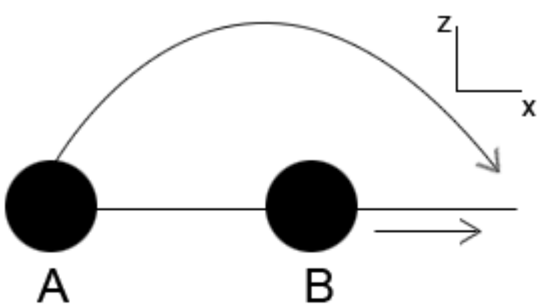
$$\forall t(t > t_c \rightarrow \exists s(s \leq t \wedge \neg((IR_A(s) \rightarrow b_z(s) \geq 0) \wedge (IR_B(s) \rightarrow b_z(s) \geq 0))))$$

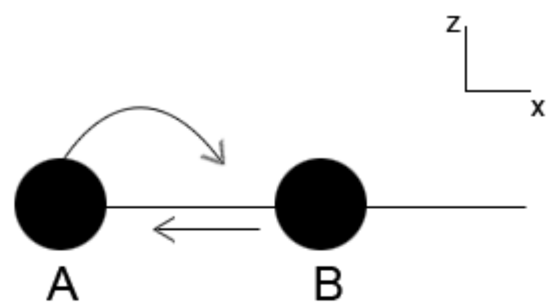
  - Solution: change model

Brandon Tolsch

Robots Playing Catch

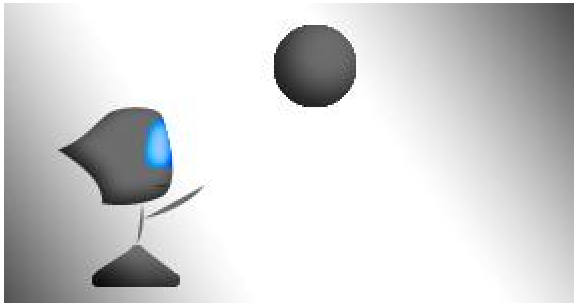
- One-dimensional motion





Brandon Tolsch

Robots Playing Catch



- Domain constraints can cause trouble
- One-dimensional passing is safe
- Efficiency is application dependent