Robot Controllers in Animation

Control Systems

Where do the control laws come from?

- Observation
- Biomechanical literature
- Optimization
- Intuition

Hierarchy of control laws

1. State machine
2. Control actions
3. Low level control
Hierarchy of control laws

1. State machine
2. Control actions
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Running state machine

1. State machine
2. Control actions
3. Low level control

Flight duration

1. State machine
2. Control actions
3. Low level control
Forward Velocity

Ground speed matching

Balance: roll, pitch, yaw

Mirroring: hips and shoulders
Control laws for all states

- Neck: turn in desired facing direction
- Shoulder: mirror hip angle
- Elbow: mirror magnitude of shoulder
- Wrist: constant angle
- Waist: keep body upright

Control laws for flight phase

Active leg:
- Swing leg forward for touchdown
- Straighten knee

Idle leg:
- Mirror hip angles of active leg
- Hold knee and ankle at flight angle

Control laws for heel contact phase

Active leg:
- Pitch control with hip
- Allow ankle to extend
- Knee acts as a spring

Idle leg:
- Mirror hip angles of active leg
- Shorten knee to prevent foot contact
- Hold at flight angle

Control laws for heel/toe contact and toe contact

Active leg:
- Pitch control with hip
- Extend ankle for thrust
- Extend knee for thrust

Idle leg:
- Mirror hip angle of active leg
- Shorten knee to prevent foot contact
- Hold ankle at flight angle
Hierarchy of control laws

1. State machine
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Low level control

\[ \tau = k(\theta_d - \theta) + k_v(\dot{\theta}_d - \dot{\theta}) \]

Difference between walking and running

- Walking: double support
- Running: flight phase
- Energy transfer patterns
  - Inverted pendulum
  - Pogostick

Walking state machine

- Support (falling)
- Support (rising)
- Double support
- Correct pitch angle
- Thrust with rear leg
- Shorten swing leg
- Position swing leg
- Lengthen swing leg
- Position swing leg
- Correct pitch angle