Realistic Character Animation

Modeling Realistic Motion
- Model muscles
- Environment forces
- Energy consumption
- Individual style

Reading
- Jessica Hodgins, et.al, Animating Human Athletics, SIGGRAPH ’95
- Zoran Popović, Changing Physics for Character Animation, SIGGRAPH ‘00

Two Approaches
- Simulate robot controllers
- Solve a large optimization that obeys laws of physics and minimized energy consumption
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
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Running state machine

Flight duration
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

Hierarchy of control laws

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

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
Spacetime Optimization

Captured Motion

- Works well only for small deformations
- No high-level editing constructs

High Level Control

- Get a limp walk by making one leg stiff
- Reduce gravity to get a “moon walk”
- Change the position and timing of foot placements
- Make a “quiet” run by reducing the floor impact forces
The New Approach

- Transform existing motion
- Spacetime constraints formulation
- Simplified character representation
- Get the best of both worlds:
  - Expressiveness of captured data
  - Controllability of the spacetime model

Outline

- Complex Model
- Simplified Model
- Motion Library
- Final motion
- Reconstruction
- Transformed spacetime motion

Outline

- Original motion
- Final motion
- Reconstruction
- Simplified Model

Outline

- Simplified Kinematics
- Human Run
- Human Jump
Motion Synthesis As Constrained Optimization

- Body, muscle and force DOFs: q(t)
- Constraints:
  - Pose \( C_p \)
  - Mechanical \( C_m \)
  - Dynamics \( C_d \)
- Objective \( E(q(t)) \)

Outline

- Transformed spacetime motion
- Spacetime motion model
- Spacetime Editing

Spacetime Editing

- Change pose and environment constraints
  - Foot placement and timing
  - Introduce a new obstacle
- Change the objective function
  - Minimize floor impact forces
  - Make dynamic balance more important
**Spacetime Editing**

- Change explicit character parameters
  - Short leg
  - Redistribute mass
  - Modify muscle characteristic
  - Gravity

**Example: Human Run**

- Original model has 59 DOFs
- Simplified model has 19 DOFs
- Optimizations are done on one gait cycle
- Each optimization completes within 2 minutes

**Example: Human Broad Jump**

- Original model has 59 DOFs
- Simplified model has 11 DOFs
- Entire upper body reduced to a mass point
- No joint angle DOFs
Hopper

Prismatic Joint