Realistic Character Animation

Reading

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

Modeling Realistic Motion

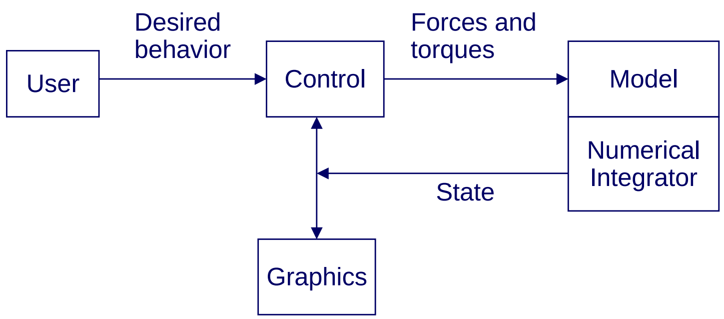
- Model muscles
- Environment forces
- Energy consumption
- Individual style

Two Approaches

- Simulate robot controllers
- Solve a large optimization that obeys laws of physics and minimized energy consumption

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

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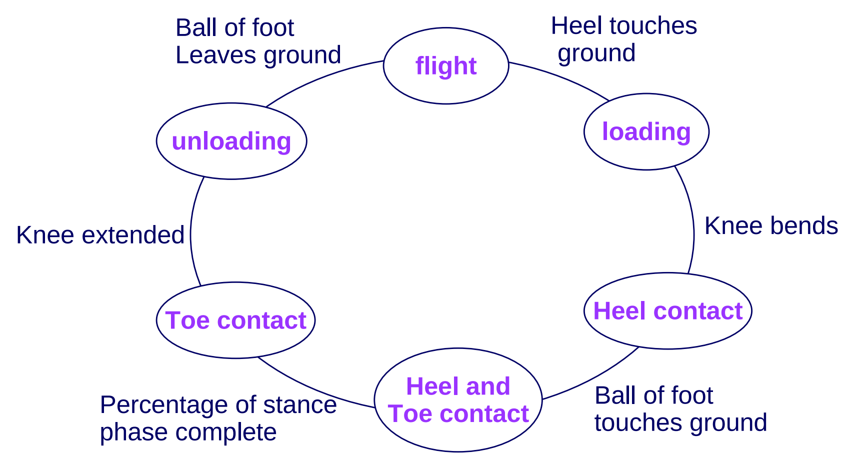
Running state machine



Hierarchy of control laws

1. State machine
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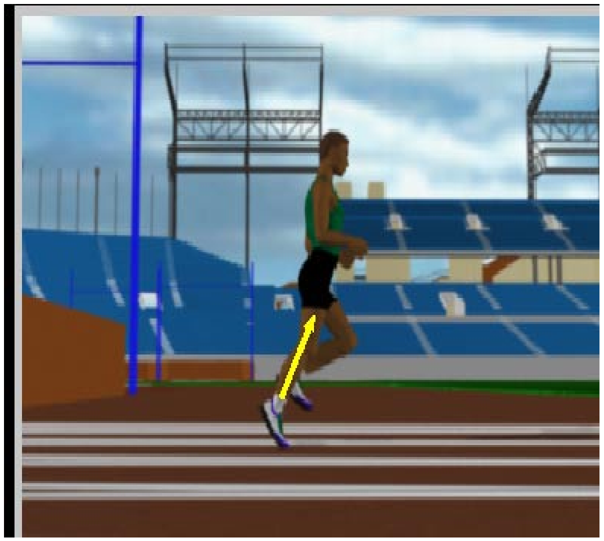
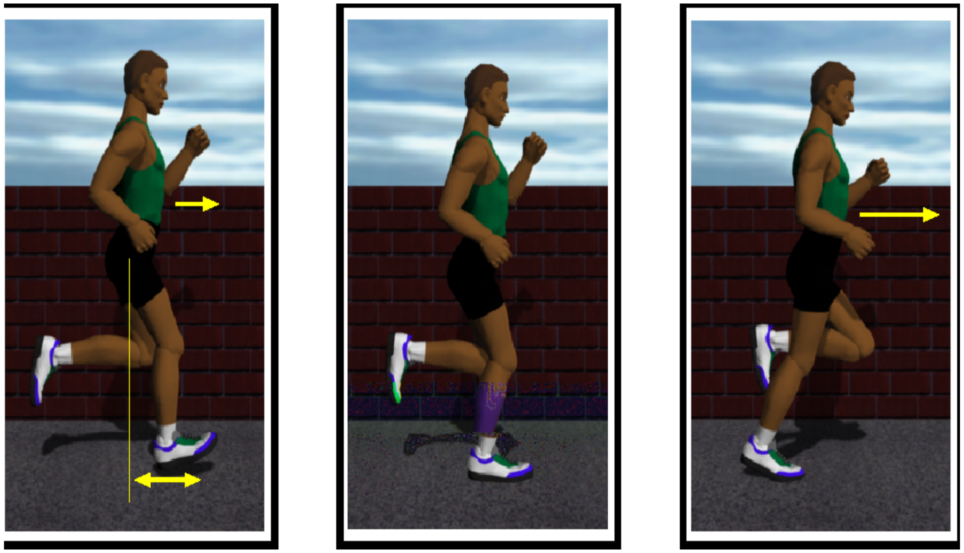
Flight duration

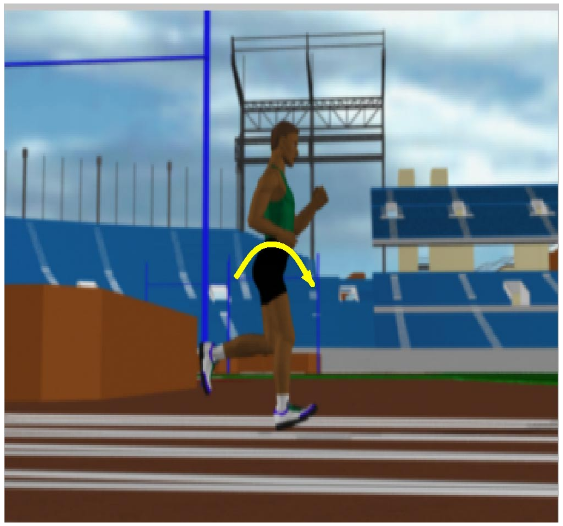


Forward Velocity

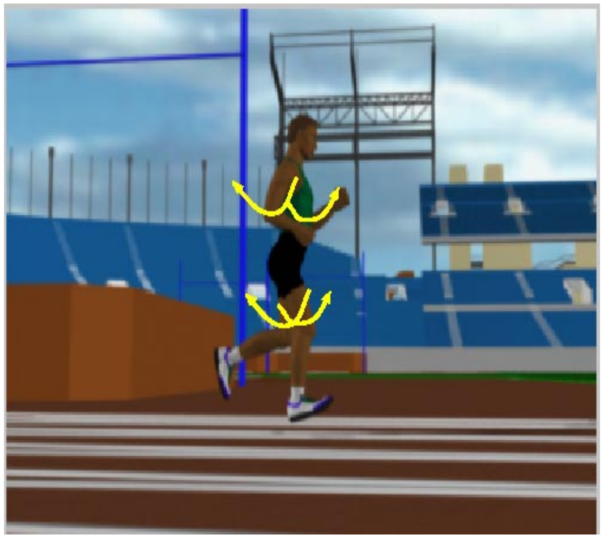


Ground speed matching

Balance: roll, pitch, yaw



Mirroring: hips and shoulders



Control laws for all states

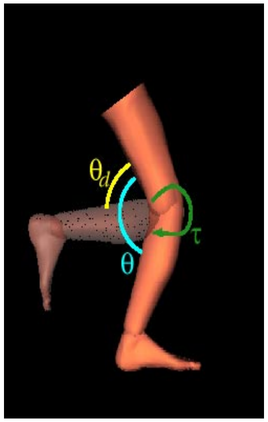
Neck: turn in desired facing direction
Shoulder: mirror hip angle
Elbow: mirror magnitude of shoulder
Wrist: constant angle
Waist: keep body upright

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

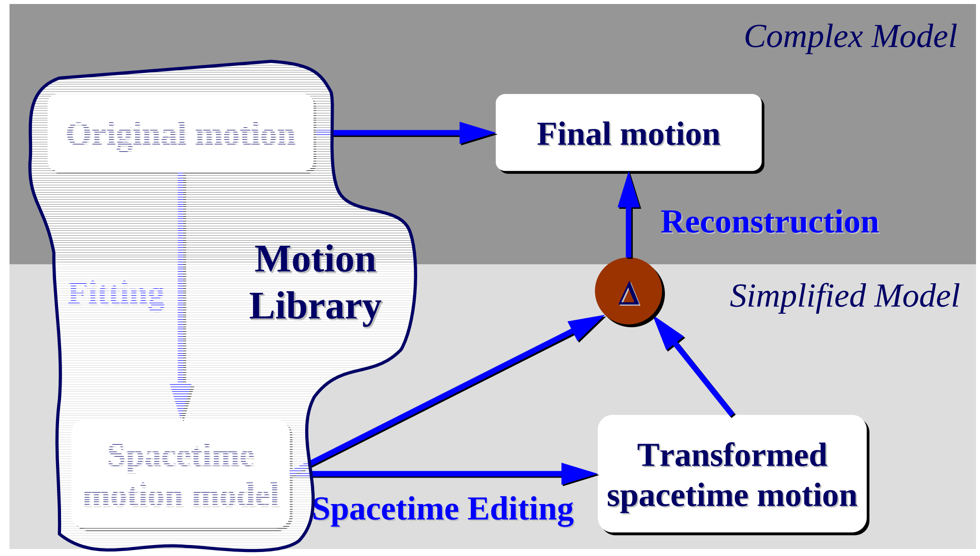
High Level Control

- 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

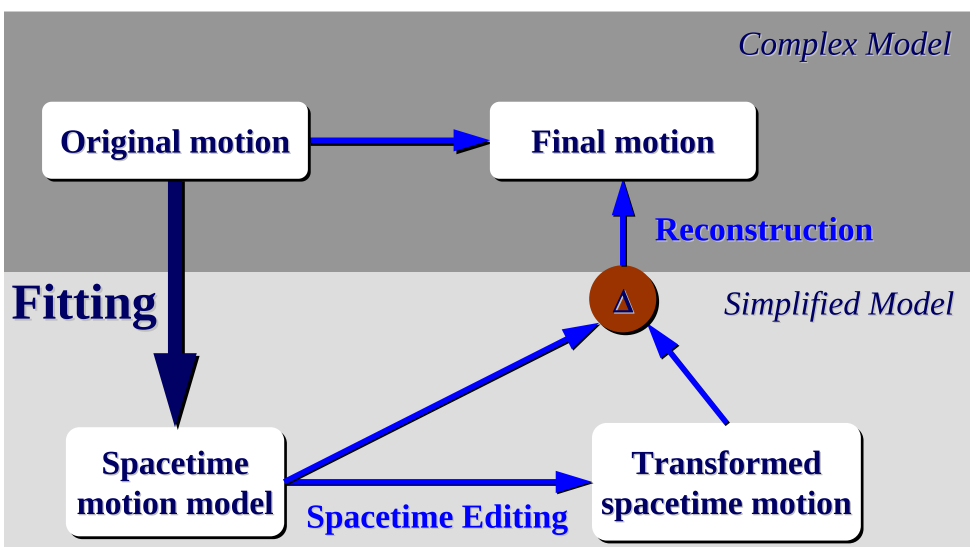
The New Approach

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

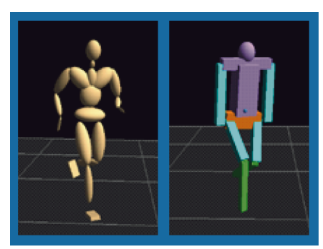
Outline



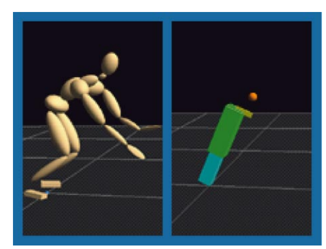
Outline



Simplified Kinematics



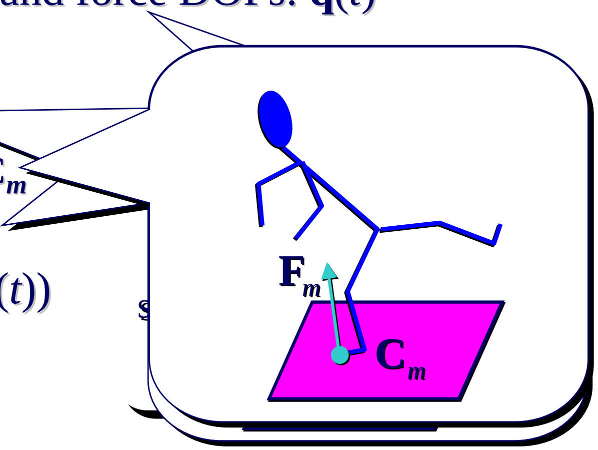
Human Run



Human Jump

Motion Synthesis As Constrained Optimization

- Body, muscle and force DOFs: $\mathbf{q}(t)$
- Constraints:
  - Pose $\mathbf{C}_p$
  - Mechanical $\mathbf{C}_m$
  - Dynamics $\mathbf{C}_d$
- Objective $E(\mathbf{q}(t))$



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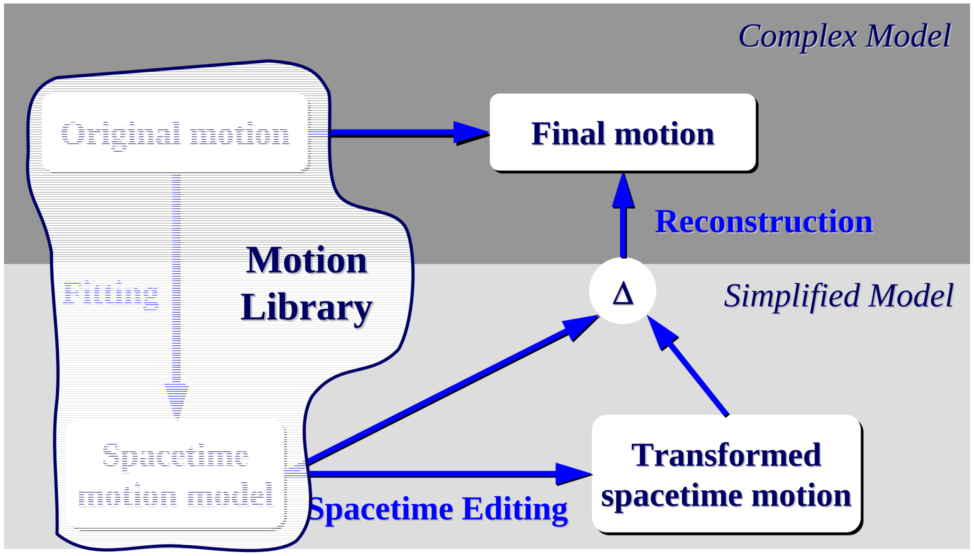

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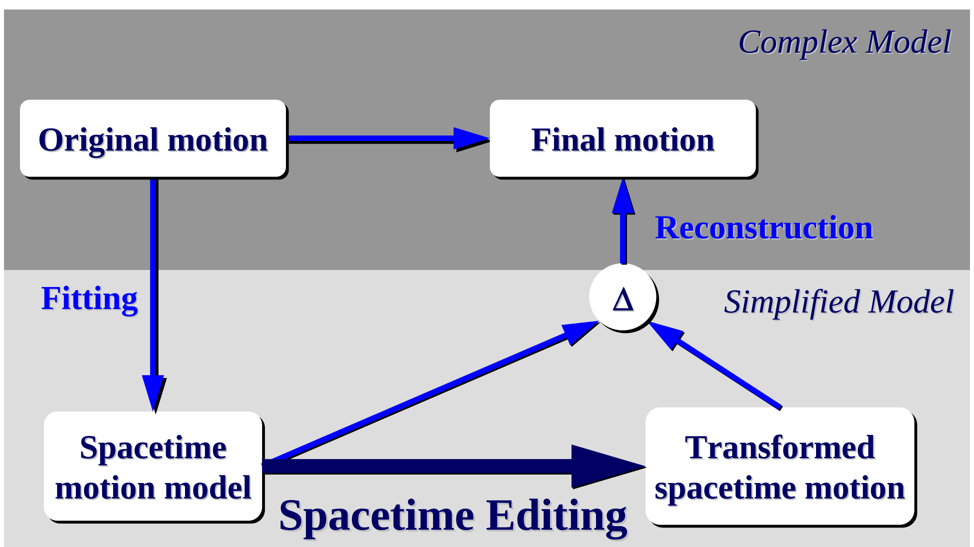

Spacetime Editing

- 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