Physics-Based Character Animation

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What determines how we move?

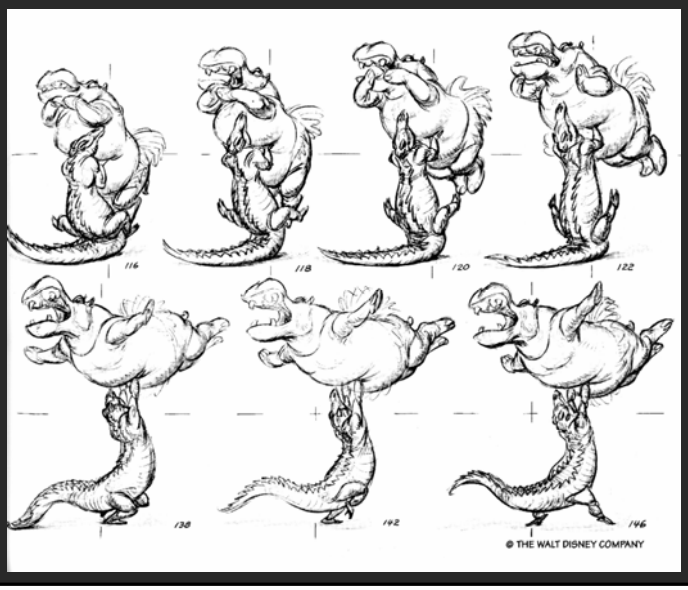
Individual Style:
Biology
Physics
Intention
Emotion
…

Can we build realistic and accurate models?

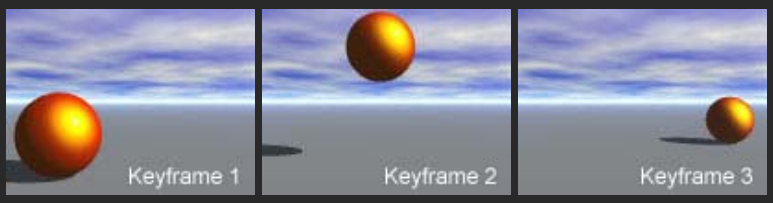
Applications

1. Computer animation
2. Computer vision
3. Biomechanics

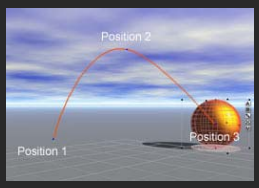
Keyframe animation



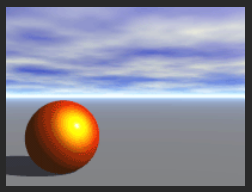
Keyframe animation



$\mathbf{q}_1$ $\mathbf{q}_2$ $\mathbf{q}_3$



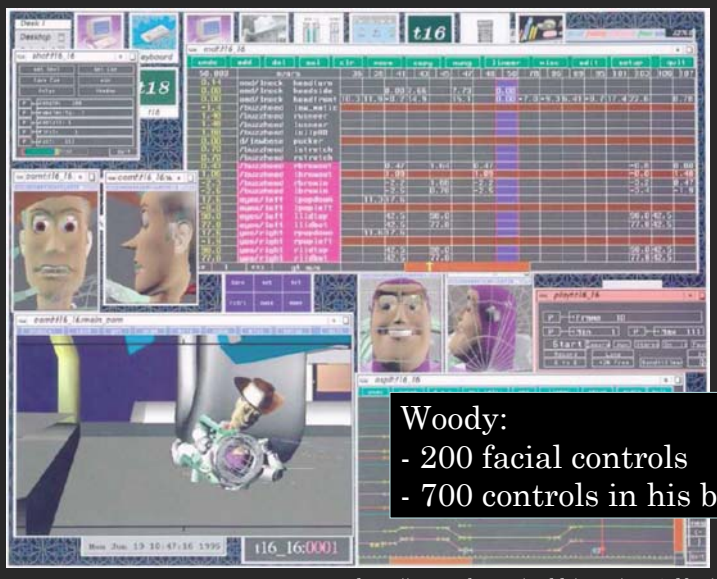
$\mathbf{q}(t)$



$\mathbf{q}(t)$

http://www.cadtutor.net/dd/bryce/anim/anim.html

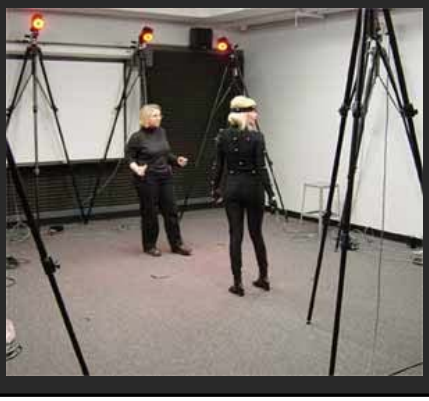
Characters are very complex



Woody:
- 200 facial controls
- 700 controls in his body

http://www.pbs.org/wgbh/nova/specialfx2/mcqueen.html

Motion capture



[Images from NYU and UW]

Motion capture

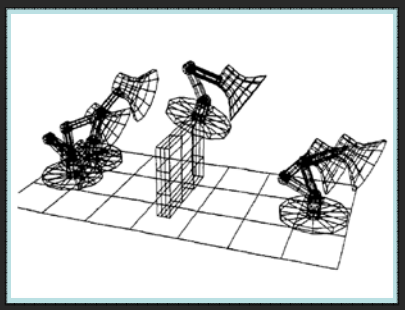
Problems

1. Very labor intensive
2. Mocap is inexpressive
3. Don't work in real-time (e.g. for games)

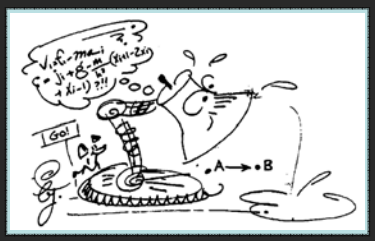
Physics-Based Animation

- Spacetime optimization
- Motion editing
- Real-time control

Spacetime Animation



Witkin and Kass, SIGGRAPH 88



Laura Green

Animals

- Bird flight

High-energy motions

Fang video

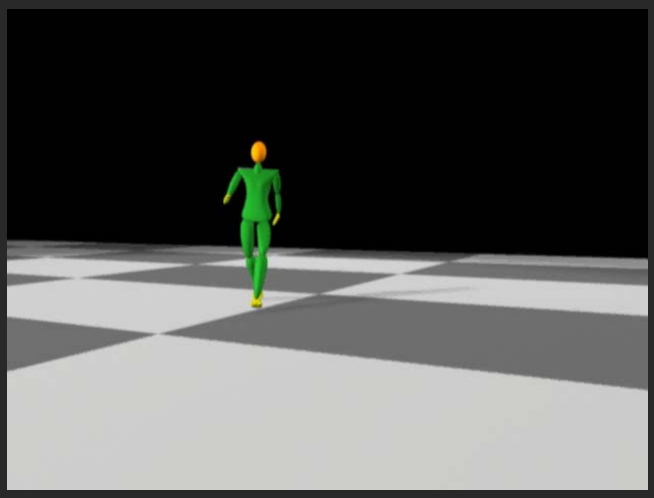
1.1. State of the art and contributions

The literature on modeling human motion is too broad for us to review here. However, we provide a brief synopsis of alternative approaches that can guide the reader to place our contribution into context.

Computer graphics and physical simulations:. generative approaches to realistic human motion synthesis include designing controllers driving physical simulations of the body dynamics [15, 12] and constrained optimization [33, 27]. In simulations contact forces are modeled with stiff springs, knowing the ground. This solution is not appropriate for vision applications, because these models cannot be efficiently "learned" (they contain parameters that cannot be identified from data, hence are not "observable").

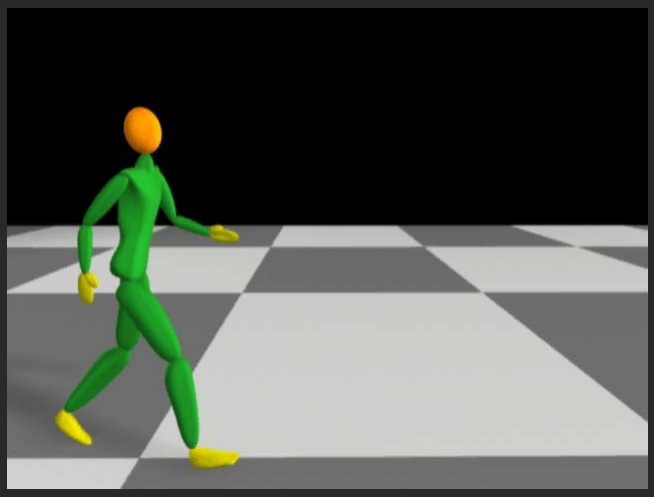
Bissacco, CVPR 2006

Physics-based motion style



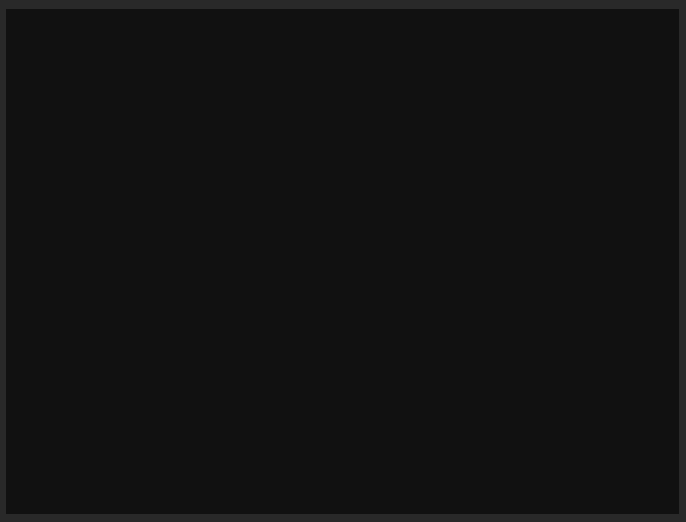
[Liu et al. 2005]

Example: Output



[Liu et al. 2005]

Motion editing



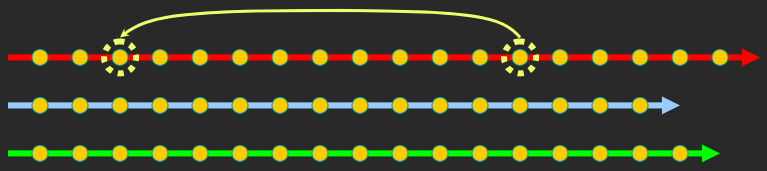
Momentum-based parameterization

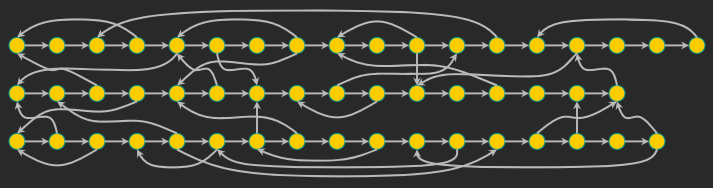
Controller-based animation

Hodgins video

Motion graphs

Input: raw motion capture





"Motion graph"

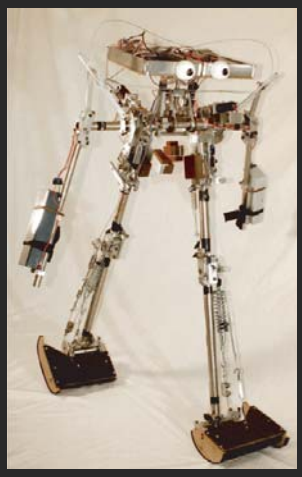
Demo

Rag-doll simulation

Walking robots

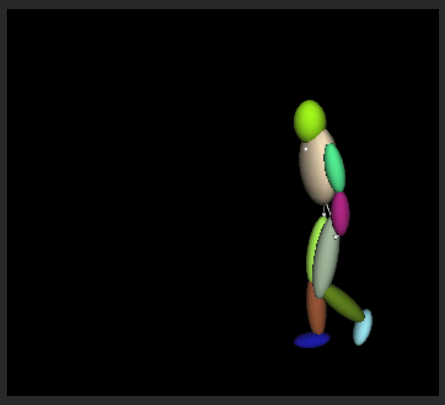
All joints actively actuated

Walking robots



Collins et al, *Science* 2005

Monocular tracking



Goals of this course

1. Understand mechanics
2. How can we build better models of motion?
3. How can we apply these models to animation, vision, etc.?

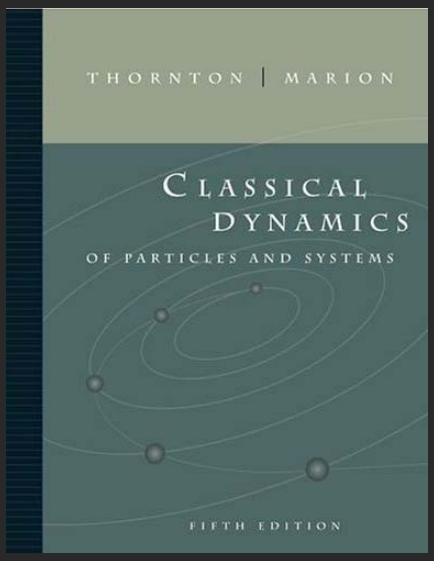
Outline of this course

- Lectures (first few weeks or so)
- Paper reading and discussion
- Assignments

Lecture topics

1. Newton's laws; forces and energies
2. Ordinary Differential Equations
3. Numerical Integration
4. Calculus of variations
5. Lagrangian Dynamics
6. Rigid body simulation
7. Numerical Optimization

Textbook



Presentation and Discussion

- 10 minutes presentation, 20 minutes discussion
- Presenter meet with me beforehand
- Whiteboard only
- Reaction reports/discussion questions required before class
- More on this later

Assignments (tentative)

1. Written problems and 1D numerical solver
2. Inverse kinematics
3. Real-time rigid-body implementation
4. Open-ended (implementation or research project)