Introduction to Computer Animation

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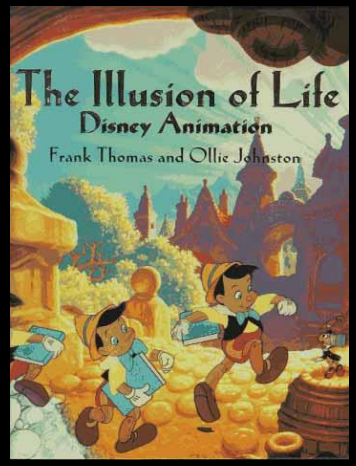
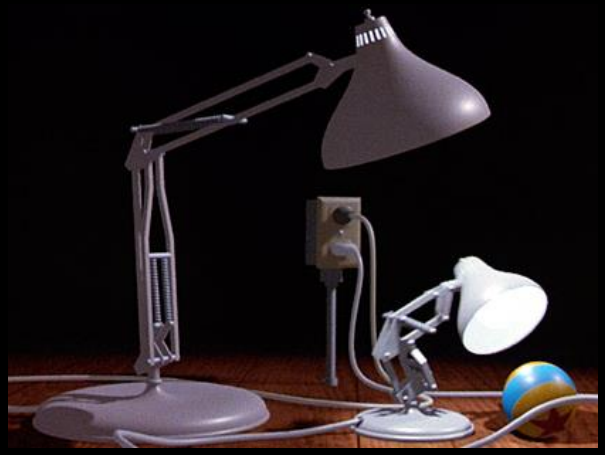
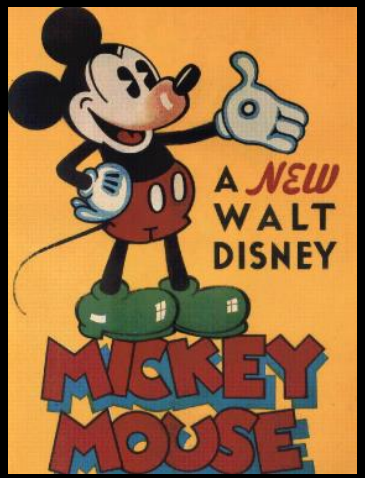
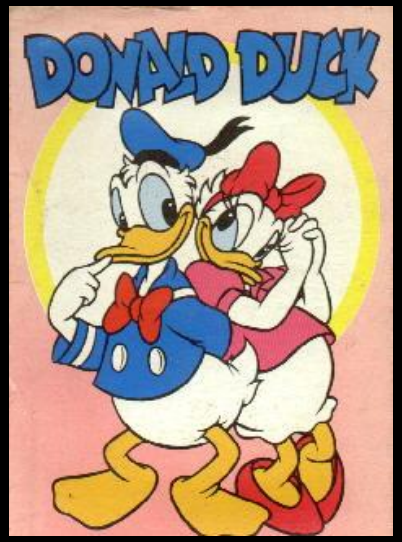




What is animation?

- Making things move
- Bring things to life
- An expressive art form
  - young but well evolved (approximately 100 years)
- Traditionally “films” or “cartoons”





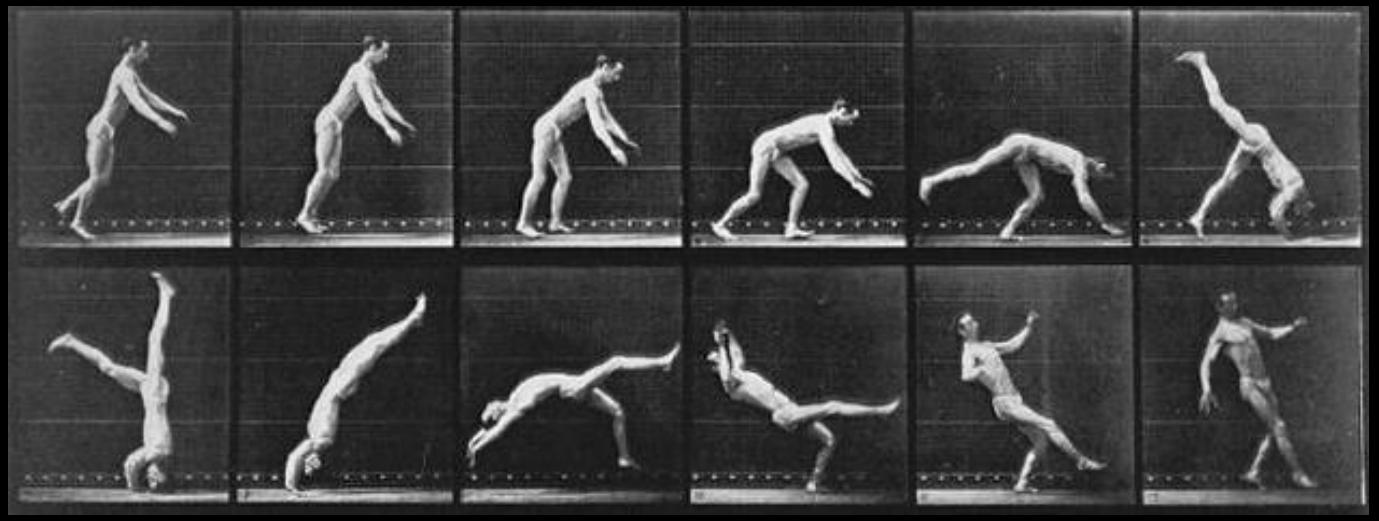
Brief History of Animation

Animation Heritage—Early Devices

- Persistence of vision
  - Shadow puppets
  - Flipbook
  - Thaumotrope (1800s)
  - Phenakistiscope (1830)
  - Zoetrope (1834)

Animation Heritage—Early Devices

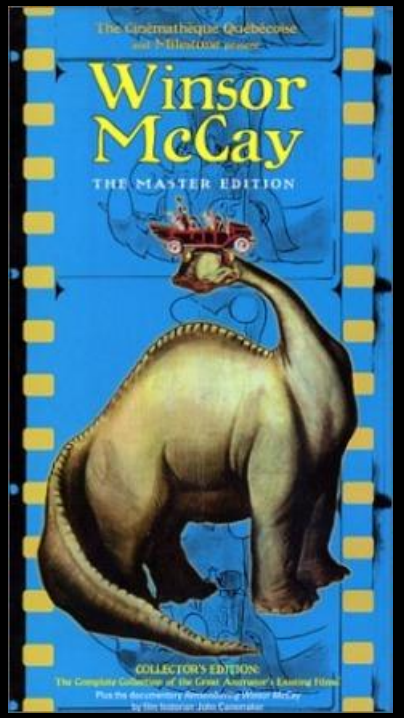
- Photograph
  - Muybridge (1885)



  - Film projector (Edison, 1891)

Early “Traditional” Animation

- First animation using a camera
  - 1896, Georges Melies, moving tables
  - 1900, J. Stuart Blackton, added smoke
- First celebrated cartoonist
  - Winsor McCay
  - Little Nemo (1911)
  - Gertie the Dinosaur (1914)

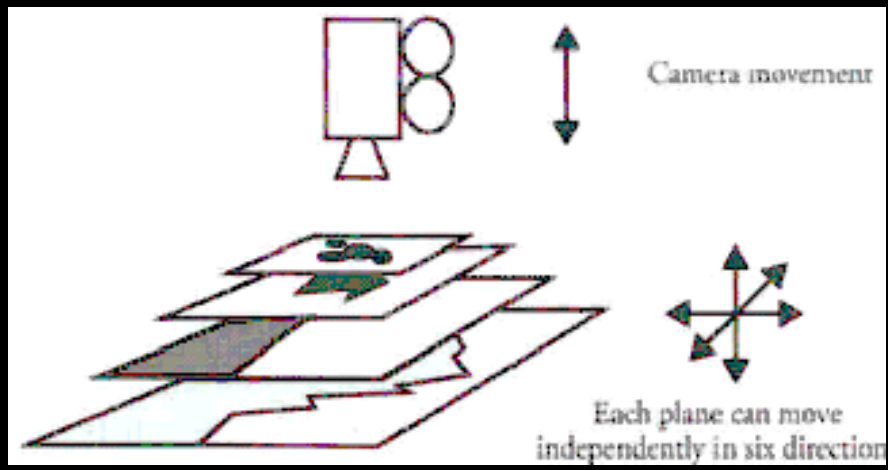


Early Technical Developments

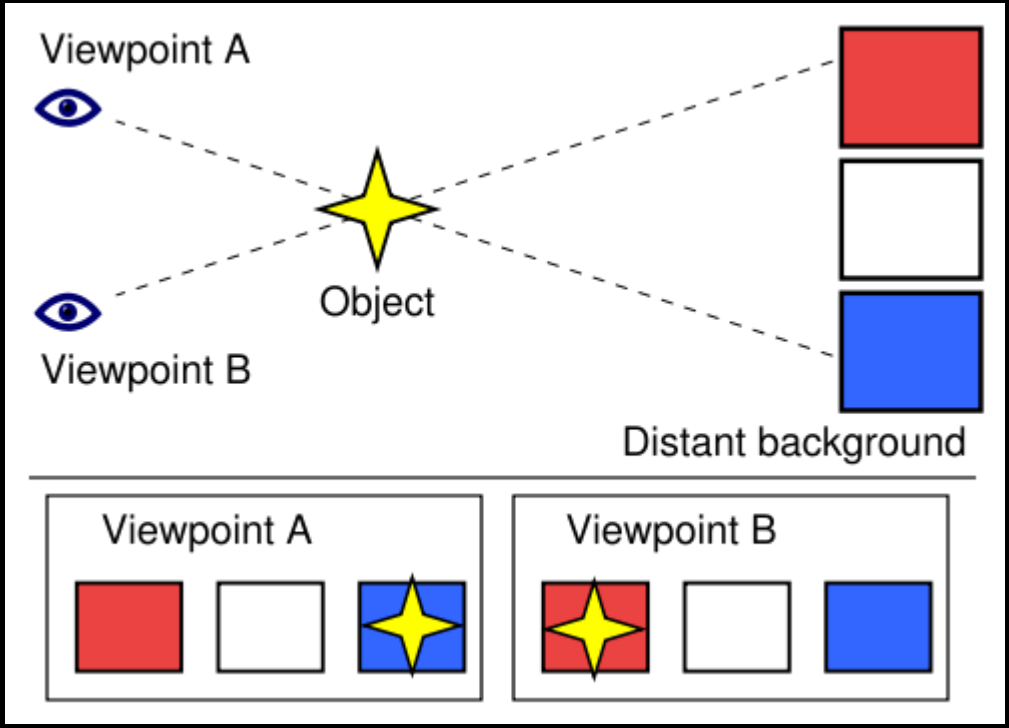
- 1910, Bray and Hurd
  - Patented translucent *cels* (formerly celluloid was used, but acetate is used now) used in layers for compositing
  - Patented gray-scale drawings
  - Patented using pegs for registration (alignment) of overlays
  - Patented the use of large background drawings and panning camera

Disney

- Advanced animation more than anyone else
- First to have sound in 1928, Steamboat Willie
- First to use storyboards
- First to attempt realism
- Invented multiplane camera
  - Creating illusion of depth
  - Zooming
  - Parallax
  - Motion blur



Side note: Parallax



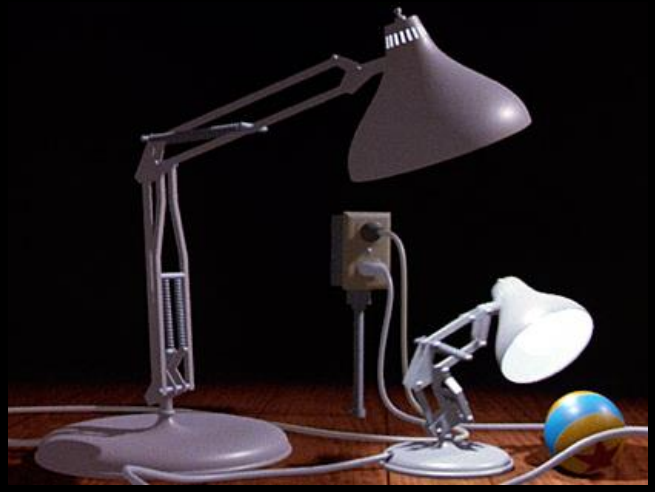

ANIMATION IN
THE 1930's
Pure Hardwork

Disney's Multiplane Camera

Computer Animation Techniques

Computer Animation

- Uses computer algorithms and techniques to produce animation
- Brings new meaning to animation
  - Interactive (games, virtual reality, education tools)
  - Mix into live action (digital special effects)
  - Part of digital production

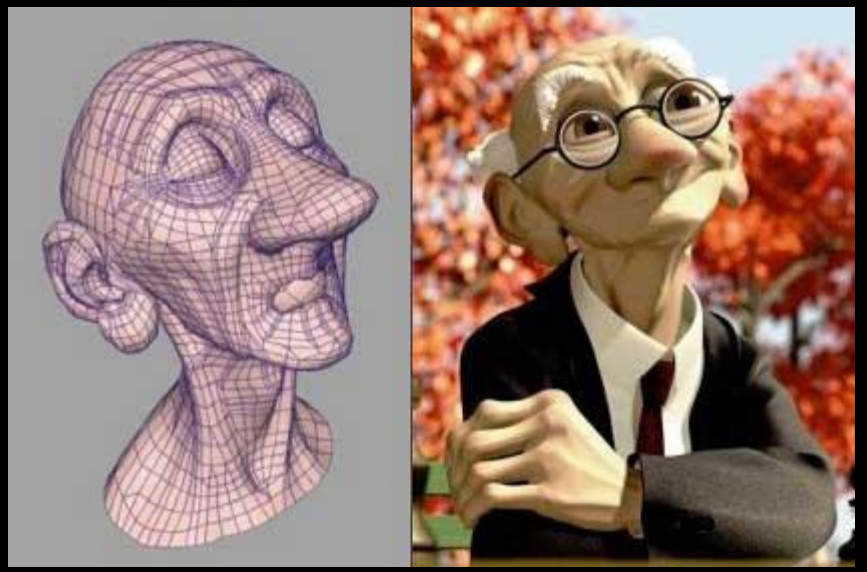


Luxo Jr. (Pixar, 1986)

Digital Production Pipeline

- Story
- Storyboards
- Visual development
- Character design
- Scene layout
- Modeling
- Animation
- Shading and texturing
- Lighting
- Rendering
- Post production

CoCo



Toy Story

- First full-length CG film

How Pixar's 'Toy Story 4' Was Animated

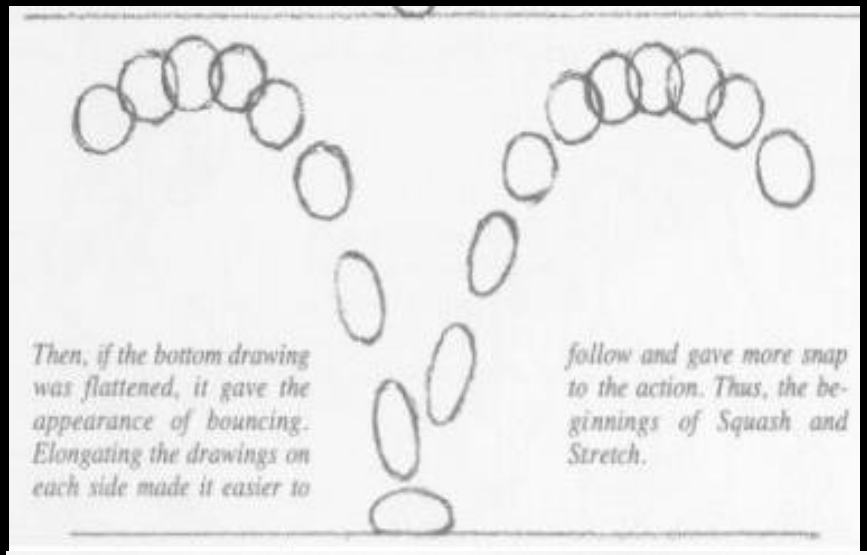
Computer Animation Techniques

- Keyframing
- Skeletal Animation
  - Kinematics
  - Motion capture
  - Motion editing
- Dynamics and Simulation
- Behavior Animation

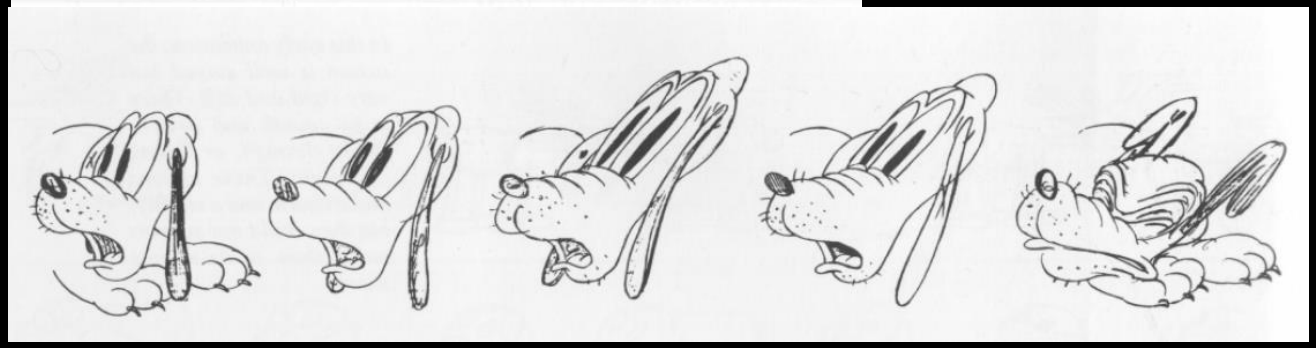
Keyframing

Keyframing

Specify only the important frames, interpolate the frames in-between



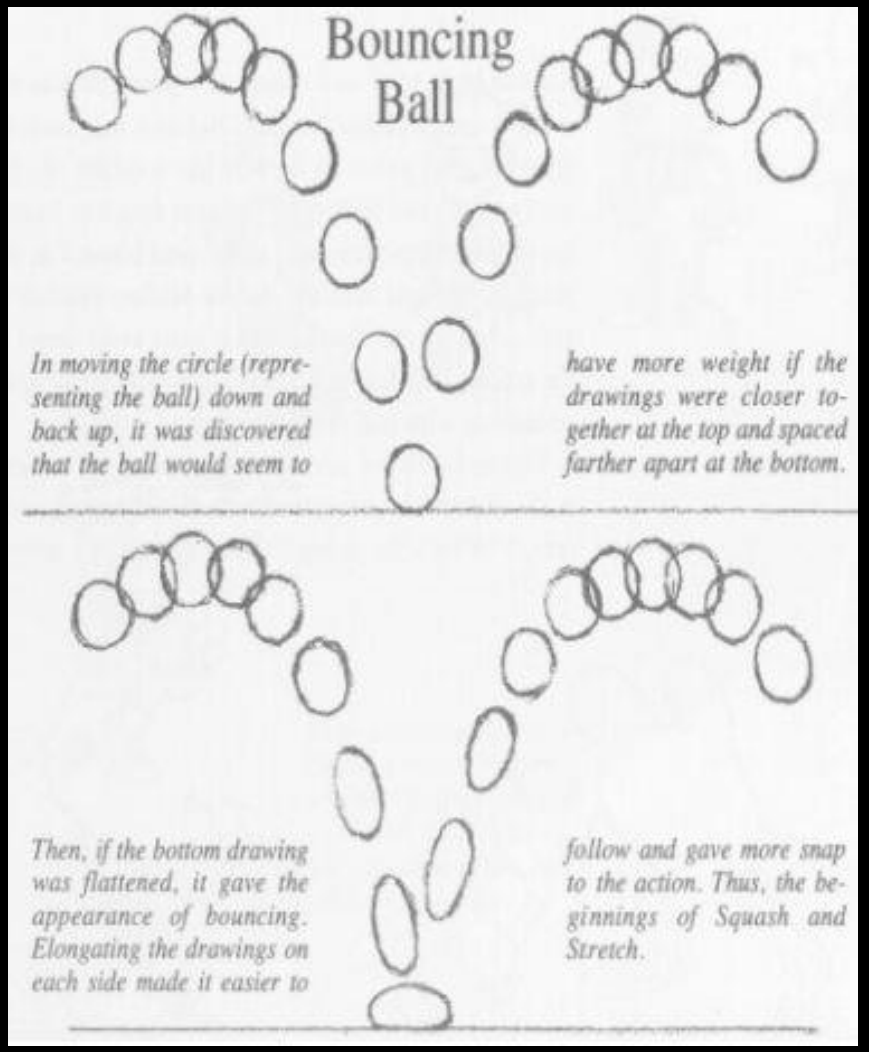
What and how to interpolate is important



"The Illusion of Life"

What is a key?

- For a bouncing ball
  - 3D Positions
  - Orientation?
  - Squishedness?



What is a key?

- For characters?
  - 3D Position and orientation
  - Joint angles of the skeleton
  - Facial features
  - Hair/fur?
  - Clothing?
- Scene components?
  - Camera
  - Lights
  - Snow

Frozen (Pixar, 2013)

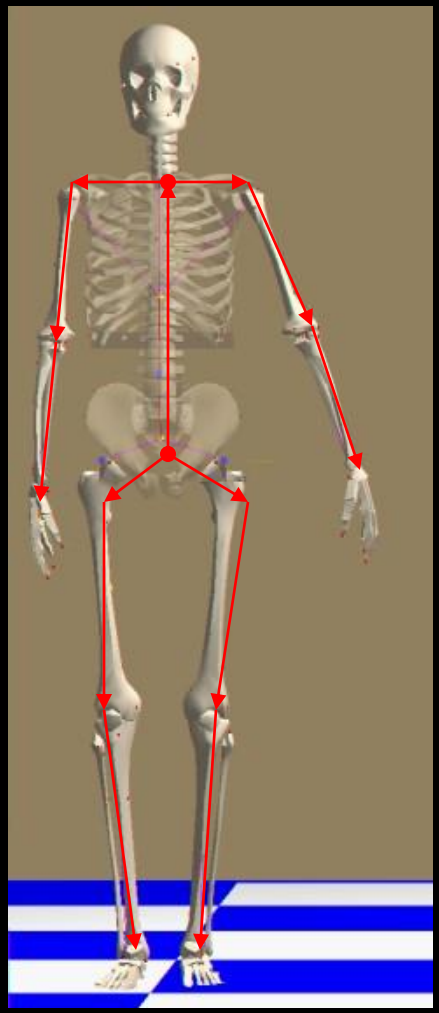
Example: Keys in Pixar Characters

Skeletal Animation

Kinematics

The study or specification of motion, independent of the underlying physics that created the motion

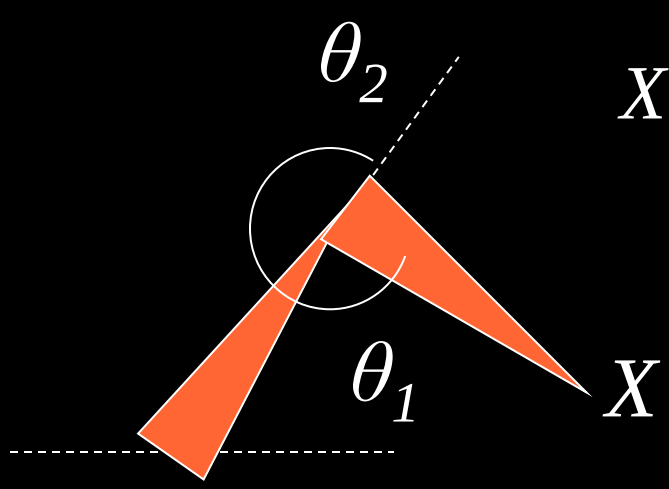
Articulated Figure:
A figure made up of a series of links (bones) connected at joints



Forward Kinematics

Given the character's state, calculate its pose

$$X = f(\theta)$$

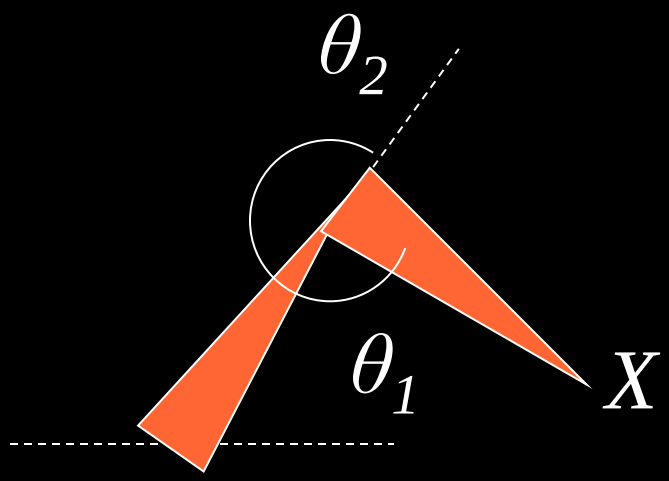


$$X = \begin{bmatrix} l_1 \cos\theta_1 + l_2 \cos(\theta_1 + \theta_2) \\ l_1 \sin\theta_1 + l_2 \sin(\theta_1 + \theta_2) \end{bmatrix}$$

Inverse Kinematics

Given the character's pose, calculate its state

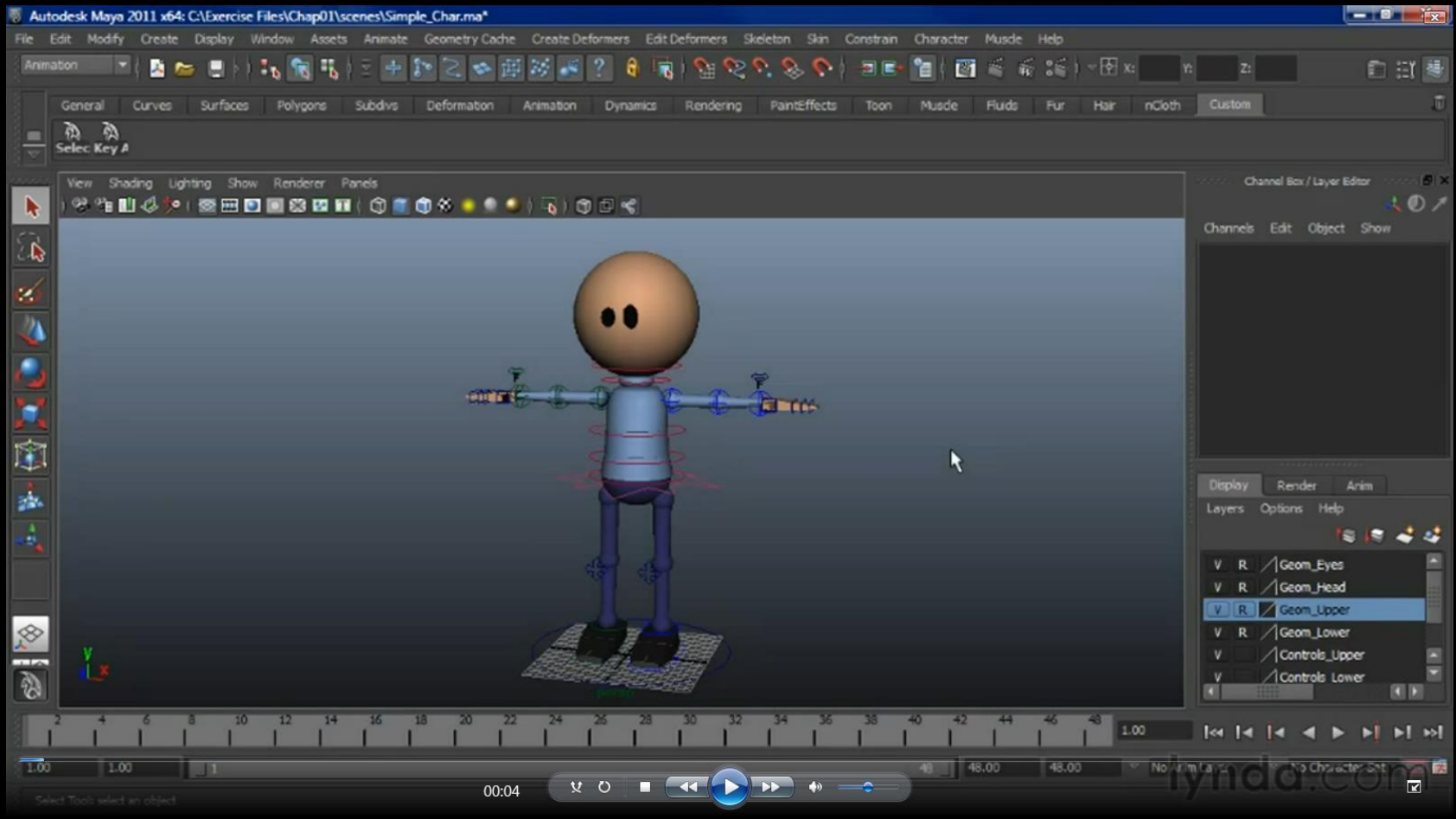
$$\theta = f^{-1}(X)$$



$$\theta = \begin{bmatrix} \dfrac{-(l_2 \sin\theta_2)x + (l_1 + l_2\cos\theta_2)y}{(l_2 \sin\theta_2)y + (l_1 + l_2\cos\theta_2)x} \\ \cos^{-1}\dfrac{(x^2 + y^2 - l_1^2 - l_2^2)}{2l_1 l_2} \end{bmatrix}$$

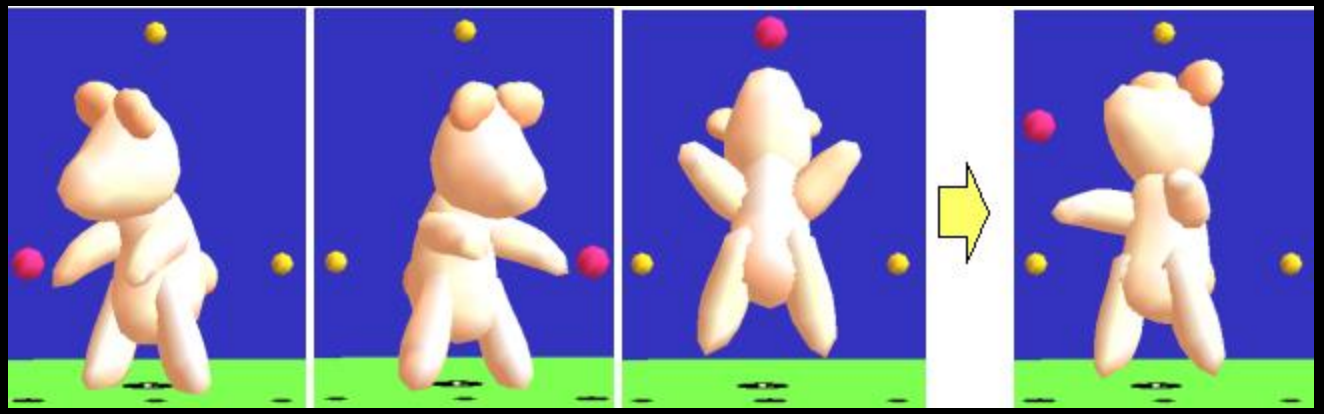
Example: Forward Kinematics

- Maya tutorial



Example: Inverse Kinematics & Keyframing

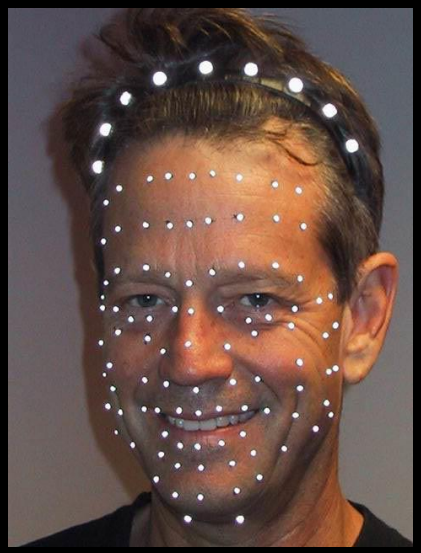
- Takeo Igarashi, Tomer Moscovich, John F. Hughes, “Spatial Keyframing for Performance-driven Animation,” SCA 2005



- Associate a key pose with a 3D position
- Interpolate in pose space
- Video

Motion Capture

- Live action recording
  - track motion of reference points
  - convert to joint angles to drive an articulated 3D model
  - drive a deformable surface



Xsens, inertia sensors

Motion Capture in Films

I, Robot

Avatar by Weta Digital

Facial Motion Capture: FACET by Weta Digital

- Facial Mocap in King Kong
- Dawn of The Planet of The Apes（猩球崛起）
- War for The Planet of The Apes
  - SIGGRAPH 2017 talk (14:21)
- Academy® Scientific and Technical Award – Technical Achievement, 2017

Motion Capture in Games

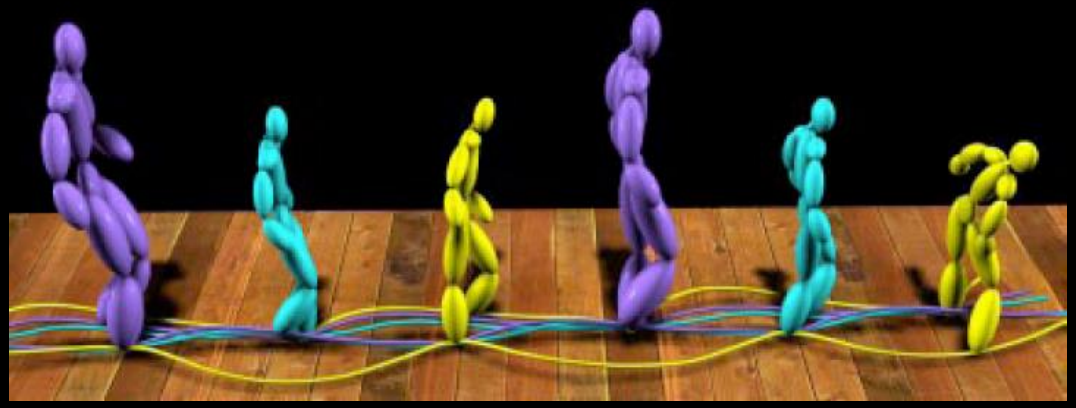
- NBA2K24

Quantic Dream—*Beyond Two Souls* (2013)

VIDEOGAMER.com

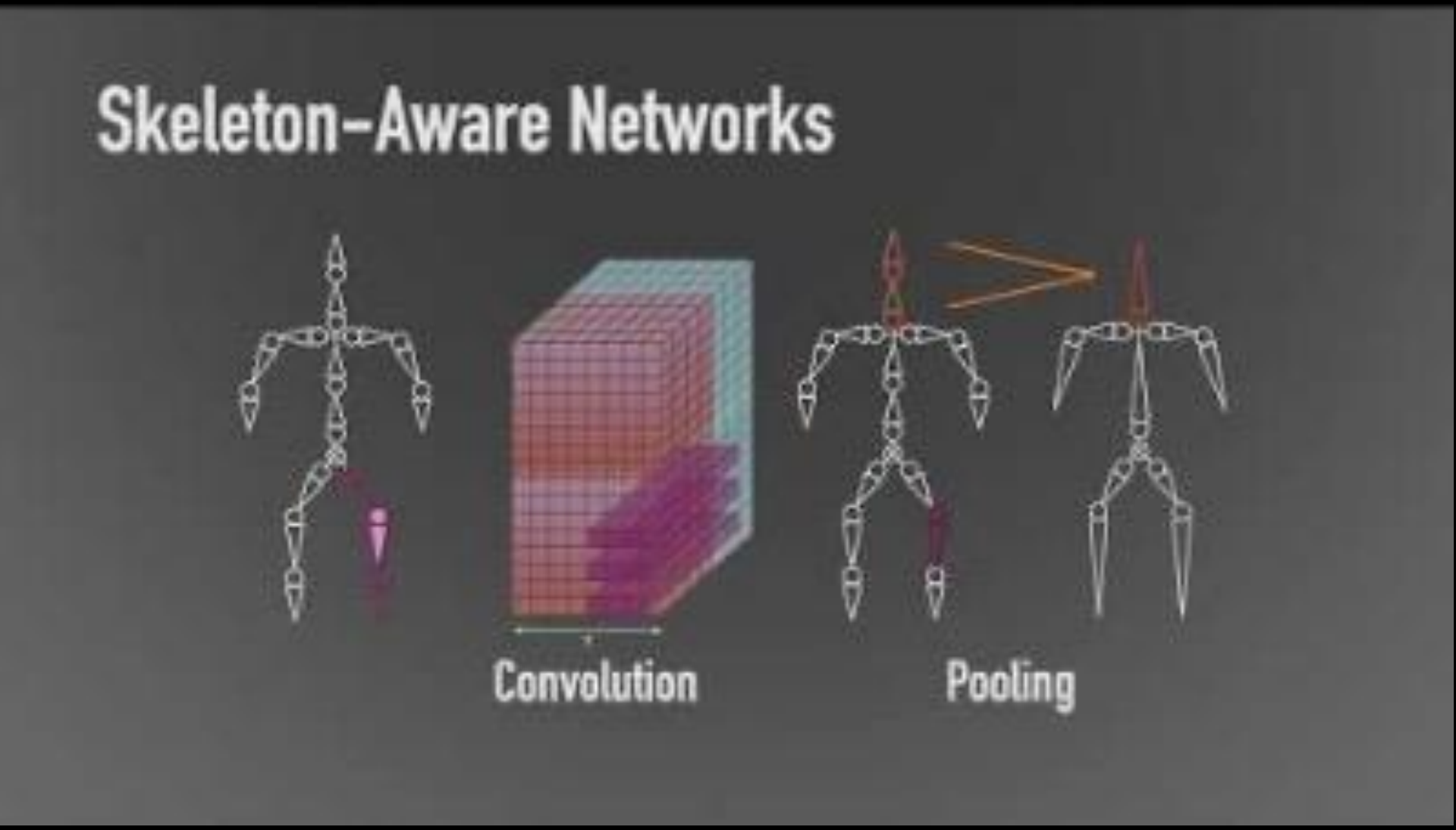
Motion Editing

- Get a specific motion
  - from capture, keyframes
  - specific character, action, style
- Want something else while preserving original
  - which part to preserve is case dependent
  - cannot characterize/distinguish motions well enough



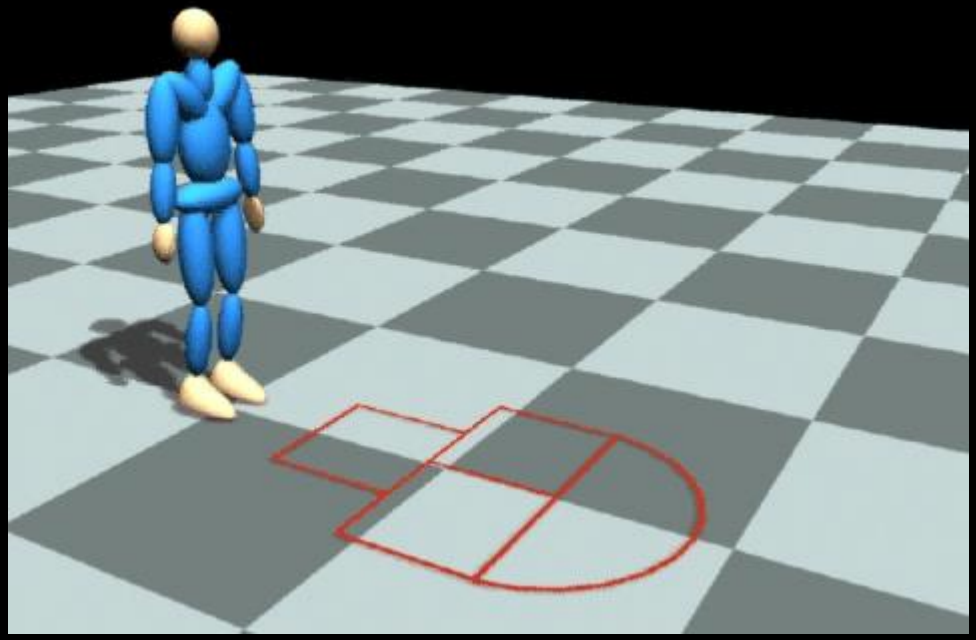
Motion Retargeting Video

Skeleton-Aware Networks for Deep Motion Retargeting



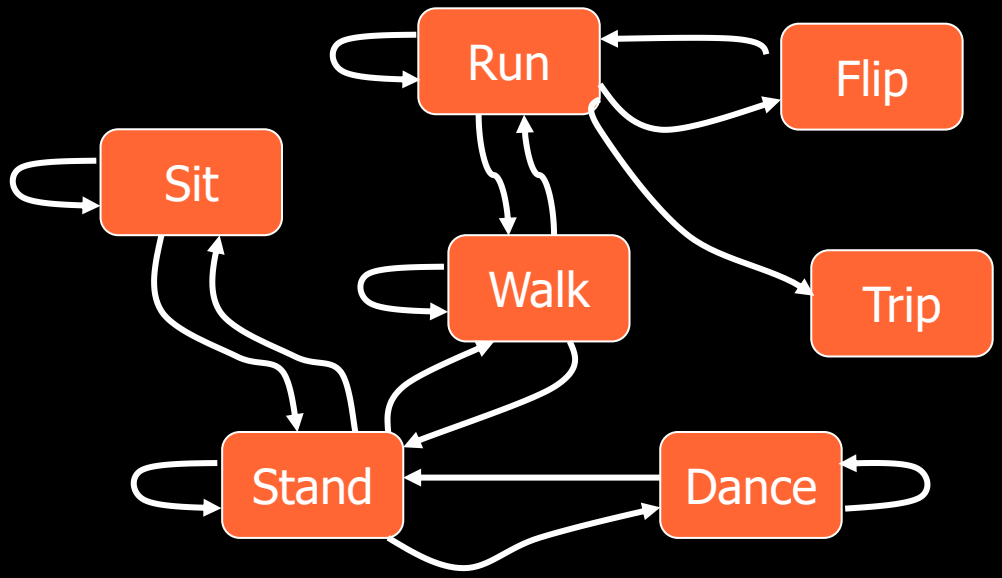
Optimization-based Motion Synthesis

- Video



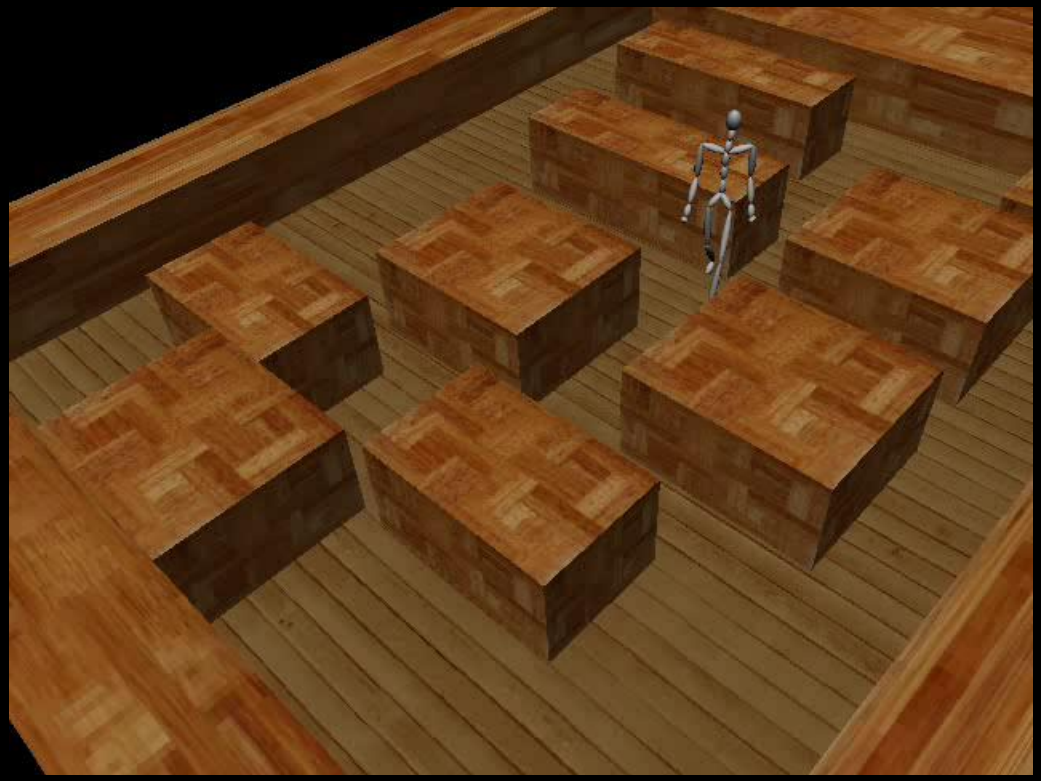
Motion Synthesis Using Motion Graph

- Build motion graph that connects multiple short motion clips
- Synthesizing motion by traversing the graph



Motion Graph Example

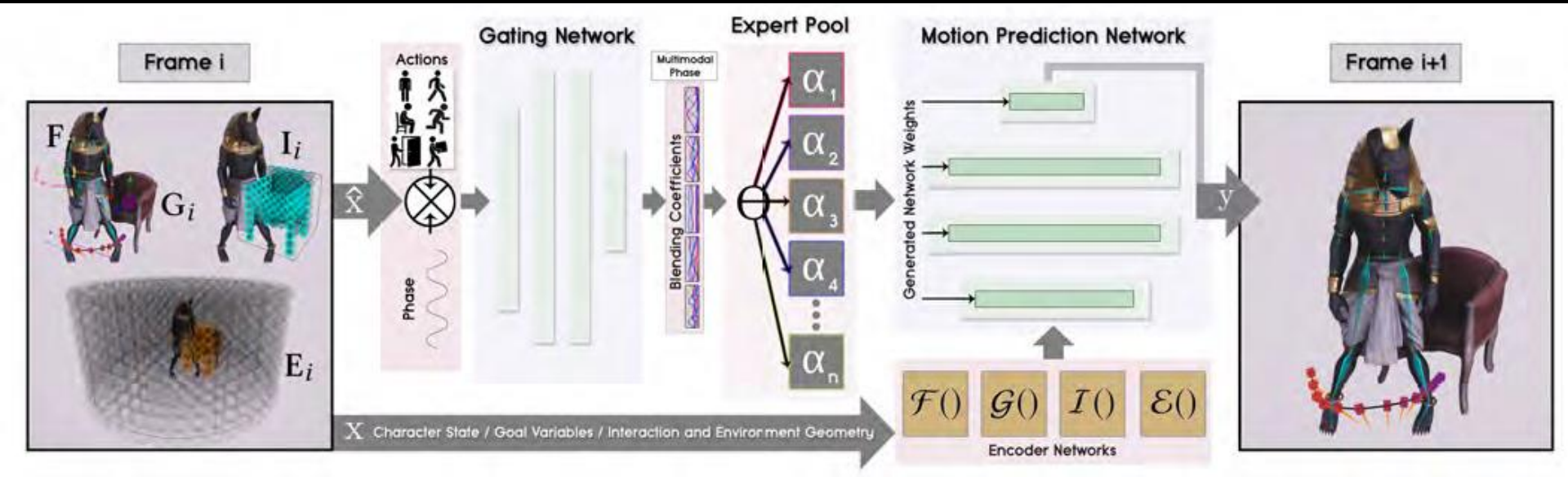
- video



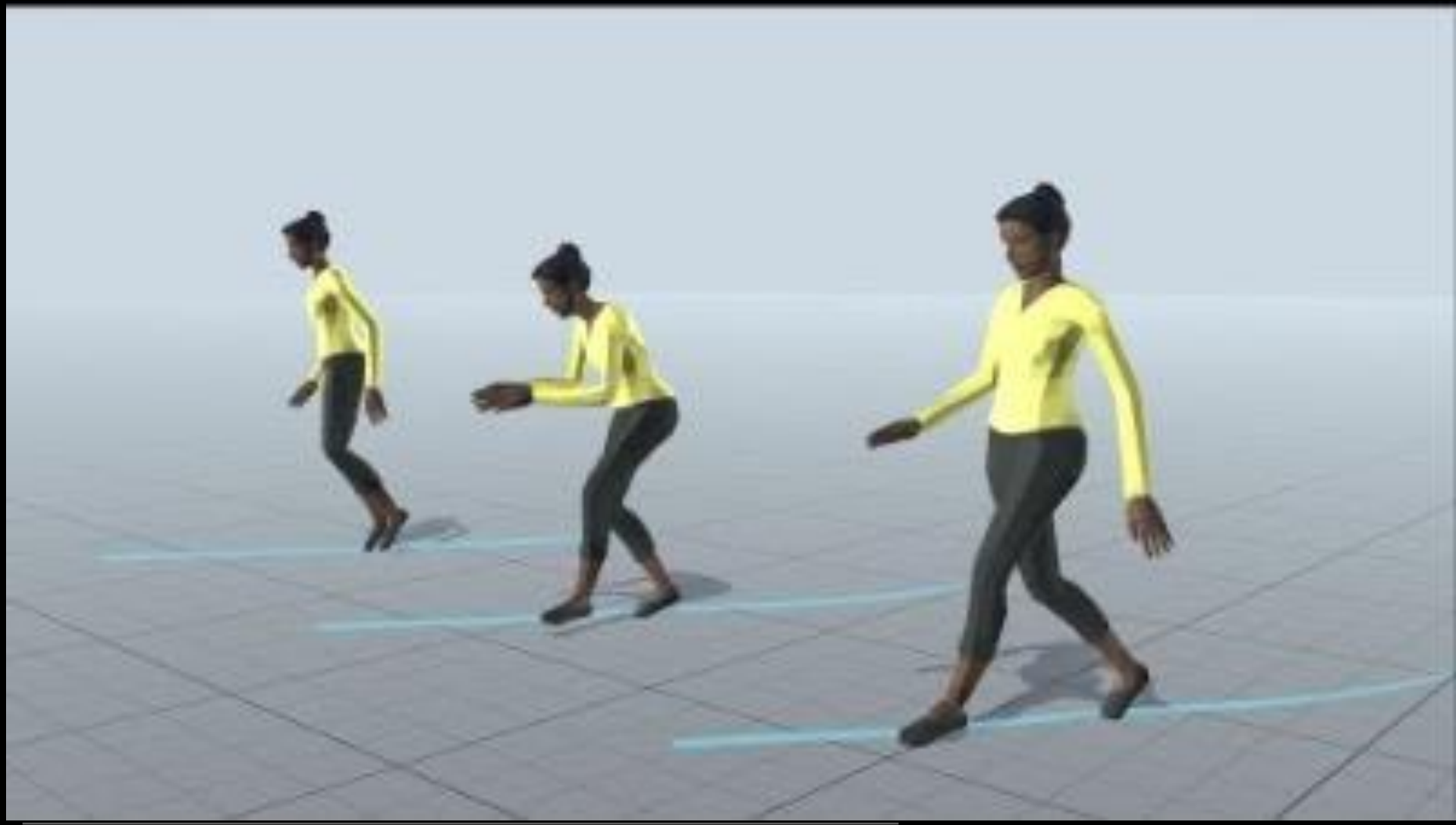
Interactive Avatar Control
Lee, Chai, Reitsma, Hodgins, Pollard, SIGGRAPH'02

Deep Learning for Motion Control and Synthesis

- "Neural State Machine for Character-Scene Interactions," SIGGRAPH Asia 2019
- https://youtu.be/7c6oQP1u2eQ



MoGlow: Probabilistic and controllable Motion Synthesis, SIGGRAPH Asia 2020



Dynamics and Simulation

Dynamics and Simulation

- Generate motion based on physical laws (e.g., Newton's laws, Fluid dynamics)
- Simulated physical phenomena
  - gravity
  - momentum
  - collision
  - friction
  - fluid flow (liquid, gas, turbulence)
  - flexibility, elasticity, fracture

Dynamics – Particle Systems

Particle Systems [Reeves83]

Represent “fuzzy” objects (such as fire, smoke) as a collection of particles

Particles contain local state

- Position
- Velocity
- Age
- Lifespan
- Rendering properties

Dynamics – Simulated Flames

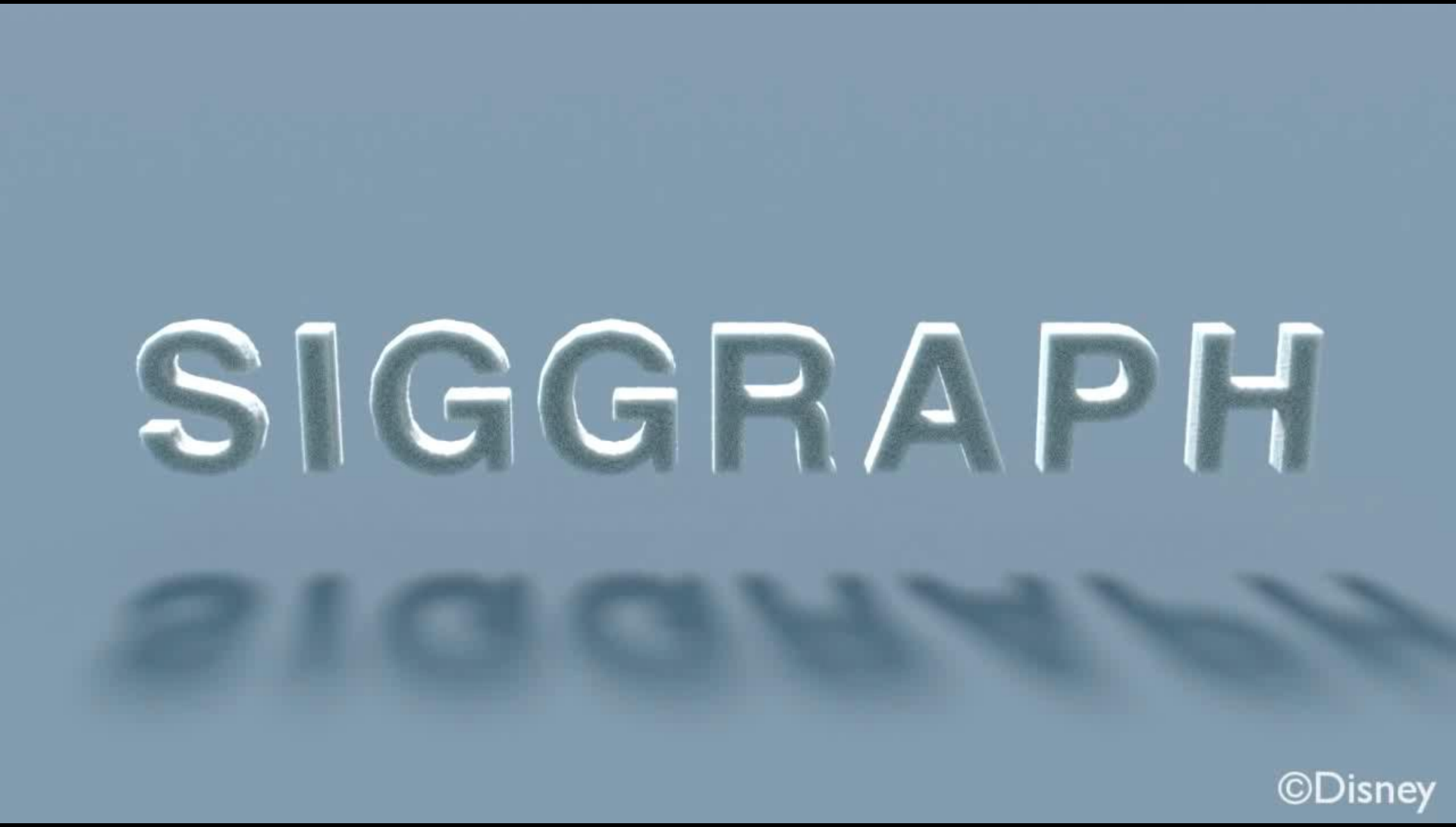
Duc Quang Nguyen, Ronald Fedkiw and Henrik Wann Jensen, SIGGRAPH 2002

Realflow:
Commercial fluid simulation software

Simulated Snow in Animation

Simulated Snow in Animation

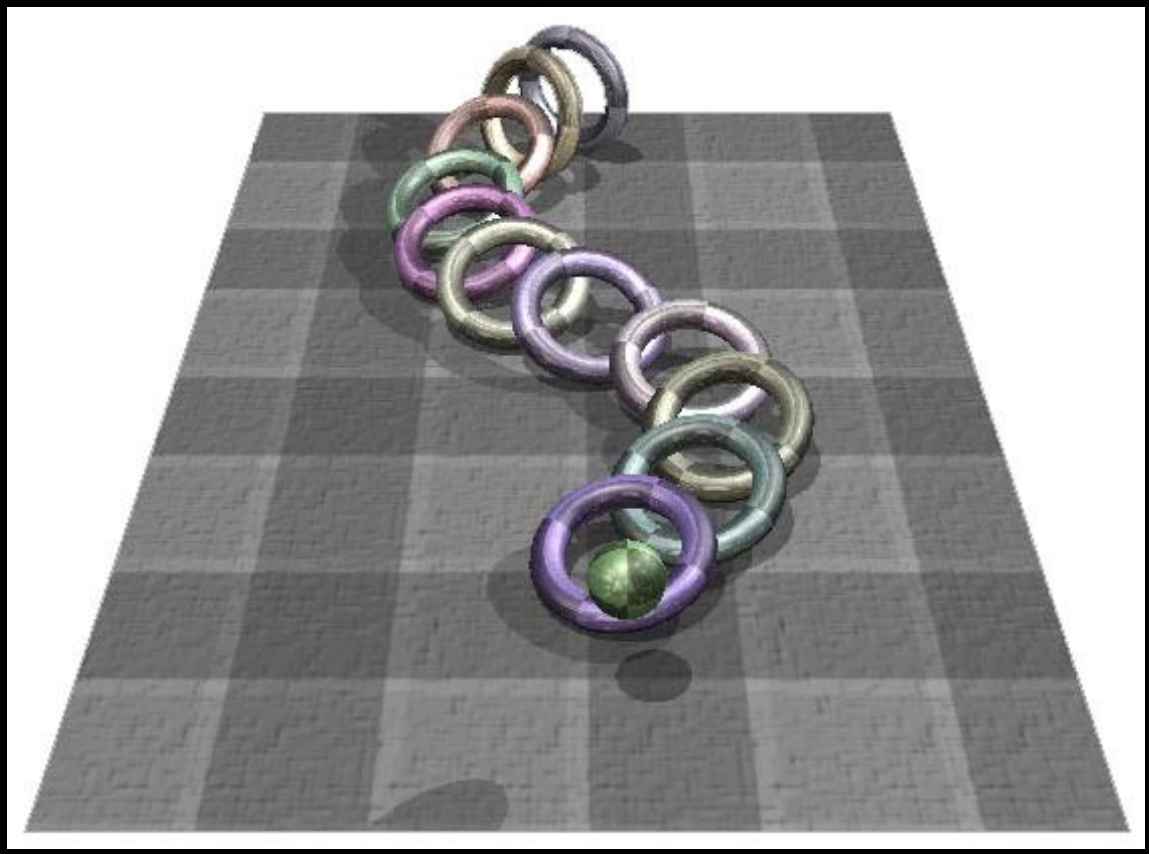
trailer



Dynamics – Rigid Bodies

Rigid Bodies

- Integration
- Collisions
- Constraints



Dynamics – Deformable Objects

Deformable Objects

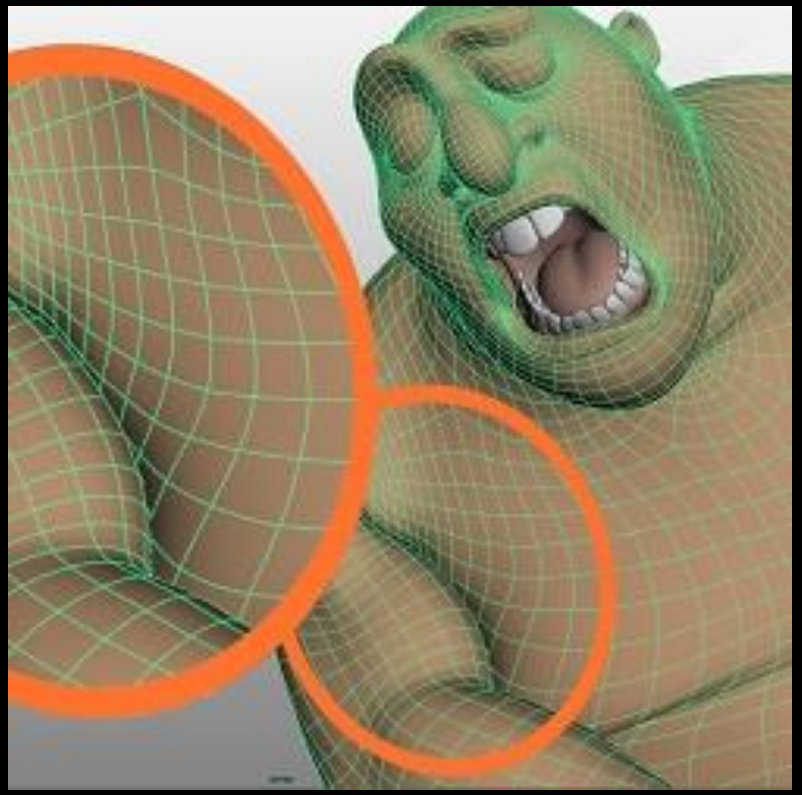
- FFD
- Elastics
- Finite Elements

Doug James & Dinesh Pai, SIGGRAPH 2002

Dynamics – Deformable Objects

Skinning

- Skeleton-driven deformation



McAdams, SIGGRAPH 2011

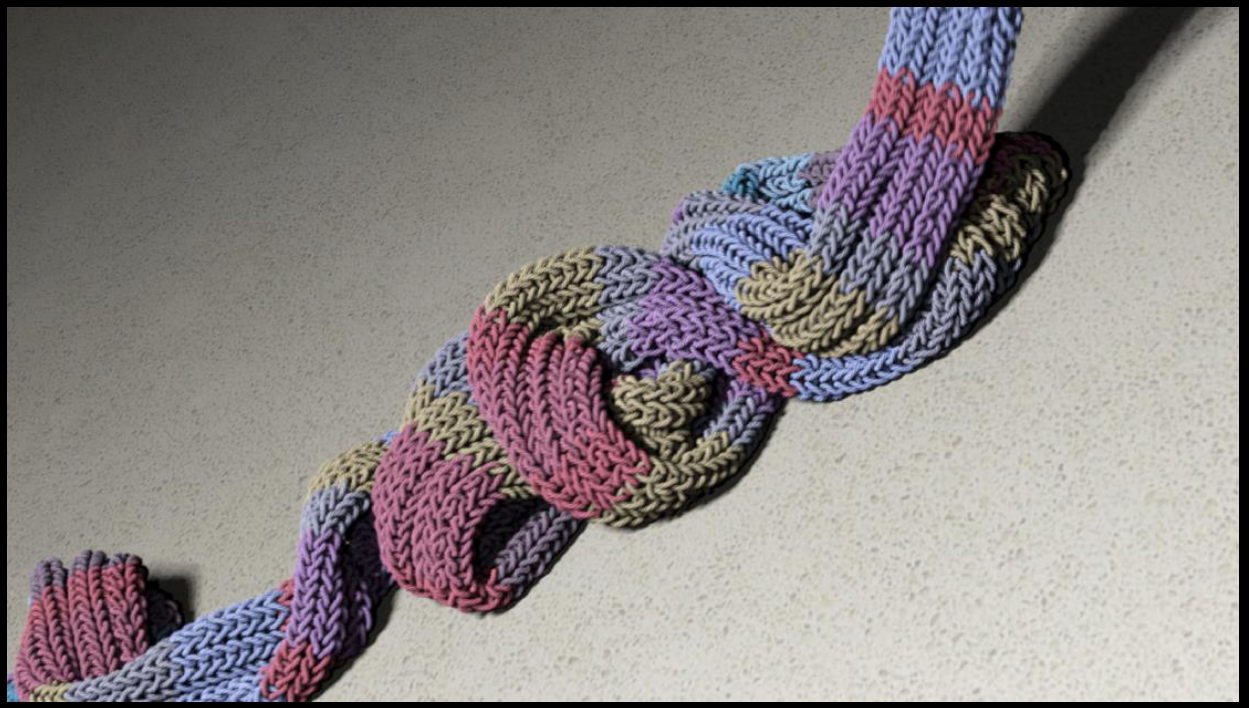
Thin Skin Elastodynamics

- Duo Li, Shinjiro Sueda, Debanga R. Neog, Dinesh K. Pai
- Siggraph 2013

Dynamics – Cloth

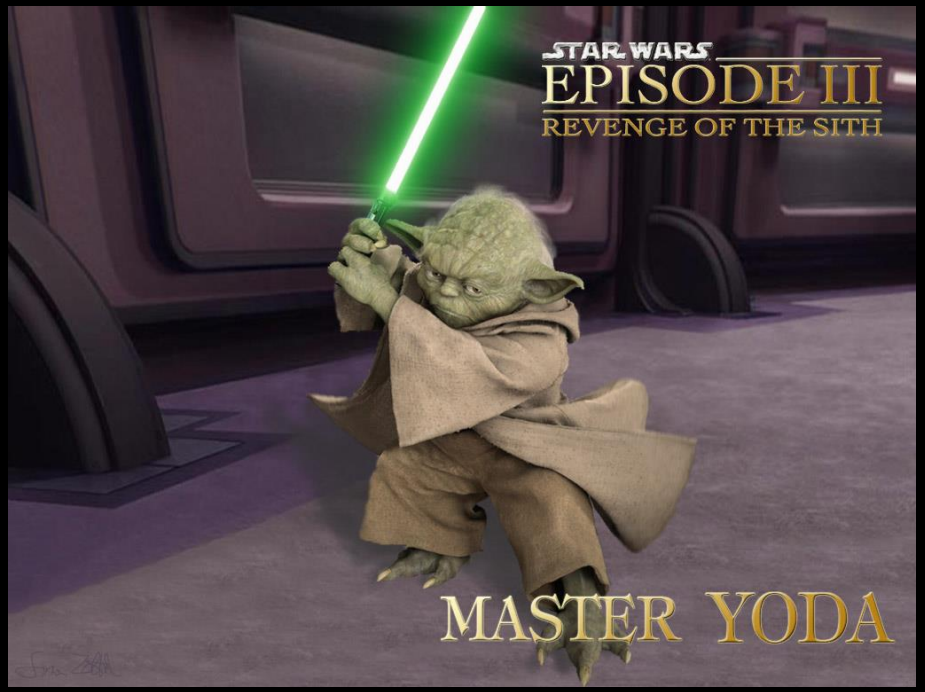
Cloth Simulation

- Stable Integration
- Material Properties

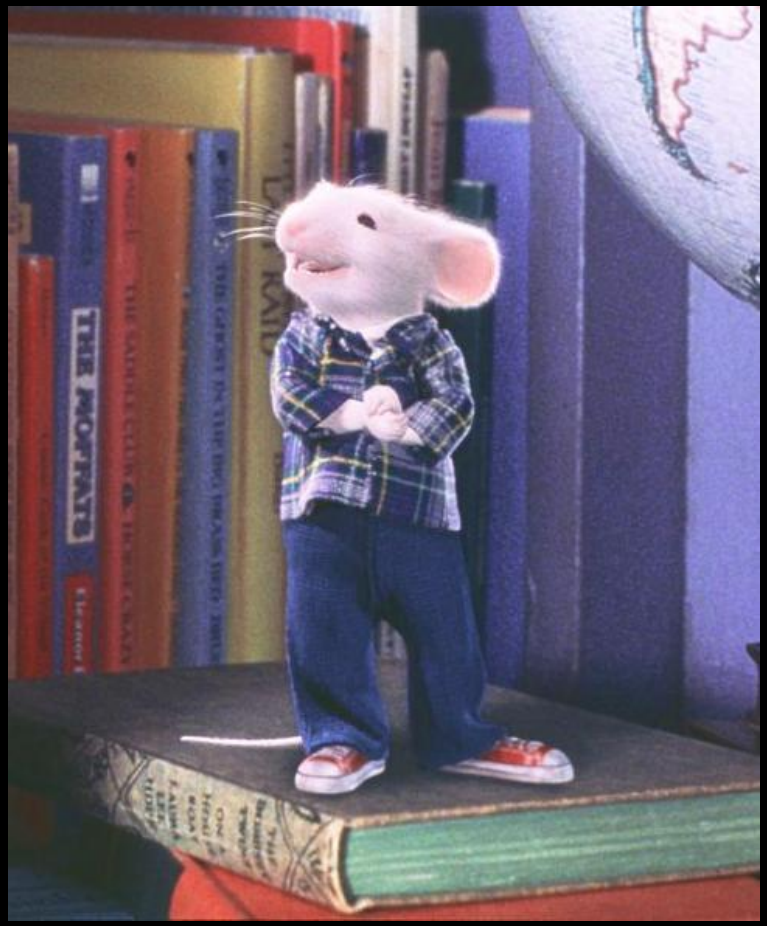


Kaldor, James, and Marschner, SIGGRAPH'08

Simulated Cloth in Films



Star Wars

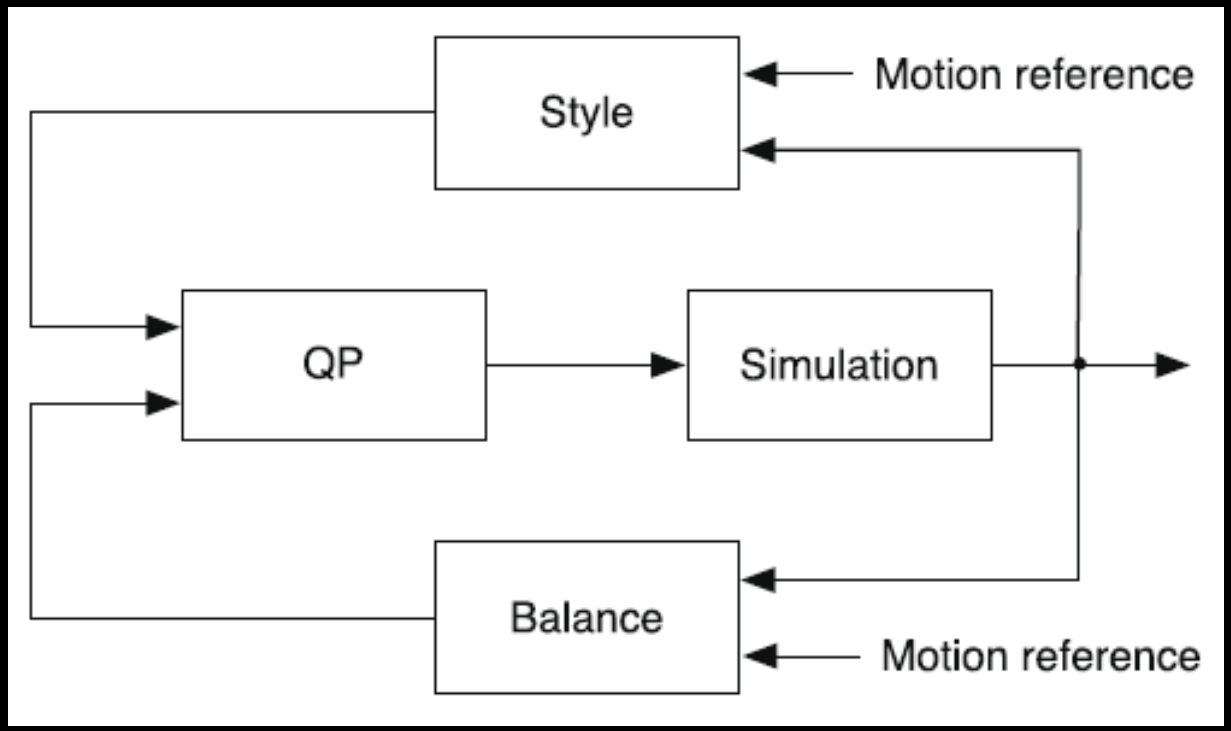


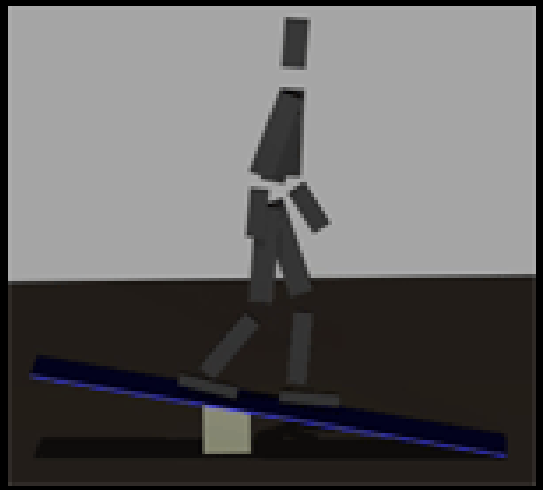
Stuart Little

Cloth Simulation in CoCo

https://youtu.be/U8U2xyyEhjs

Dynamics + Control





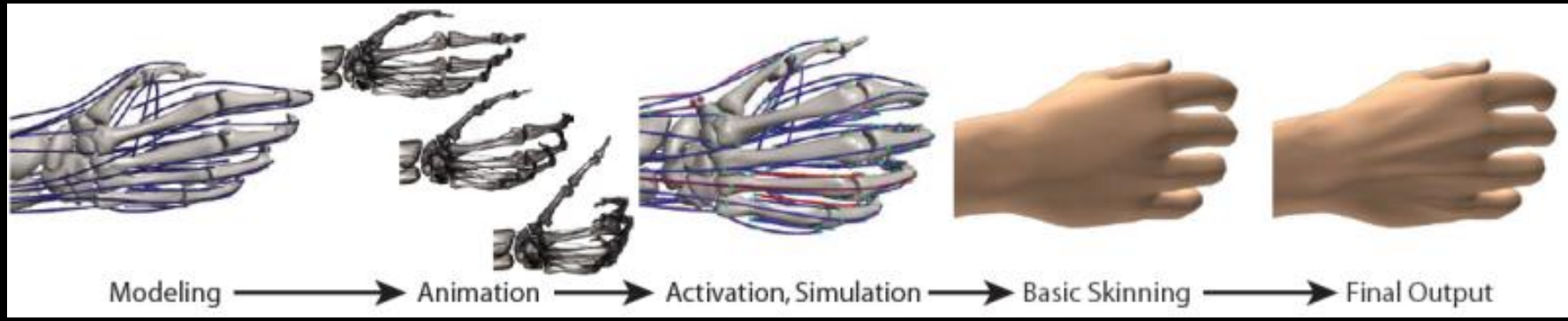
da Silva, Abe, and Popović, SIGGRAPH 2008

Adversarial Skill Embeddings, SIG 2022

Adversarial Imitation Learning & Unsupervised Reinforcement Learning

Musculotendon Simulation of Hand

- Dynamics simulation + control



Shinjiro Sueda et al., SIGGRAPH 2008

Movie (goto 1:15)

Side-by-Side Reality Check

We compare the simulated tendons of the thumb to several real thumb photographs

Behavioral Animation

- Animating by describing an actor's behavior
- An actor's behavior defines how the actor interacts with other actors and the environment

```
TRex()
if(player is close)
        eatPlayer()
else if(can see player)
        chasePlayer()
else
        wander()
```

PSCrowd Demo:
real-time crowd engine for PS3

- Real-time crowd behavior engine for PS3

Behavioral Animation (cont.)

- Useful for crowd animations

The Lion King, Stampede Scene (1994)

The Lion King, Stampede Scene (2019)

The Making of Lion King 2019

- https://www.youtube.com/watch?v=94e9Y45Elsw

Summary

- Keyframing: interpolating between keyframes
- Skeletal animation: human and animals
  - Kinematics: representing and posing a character
  - Motion capture
  - Motion editing
  - Motion synthesis
- Dynamics and simulation:
  - passive objects
  - active objects with force/torque control
- Behavior animation: group and crowd