Animations

Hakan Bilen
University of Edinburgh

Computer Graphics
Fall 2017

Some slides are courtesy of Steve Marschner and Kavita Bala

Animation

Artistic process

- What are animators trying to do?
  - What tools do they need?
- Basic principles are universal across media
  - 2D hand-drawn animation
  - 2D computer animation
  - 3D computer animation
- The 12 principles of animation laid out by Frank Thomas and Ollie Johnston in The Illusion of Life (1981)

https://www.youtube.com/watch?v=uDqjIdI4bF4

The 12 principles

1. Squash & Stretch
2. Anticipation
3. Staging
4. Straight ahead vs Pose-to-Pose
5. Follow through
6. Slow-in and slow-out
7. Arcs
8. Secondary action
9. Timing
10. Exaggeration
11. Solid drawing
12. Appeal

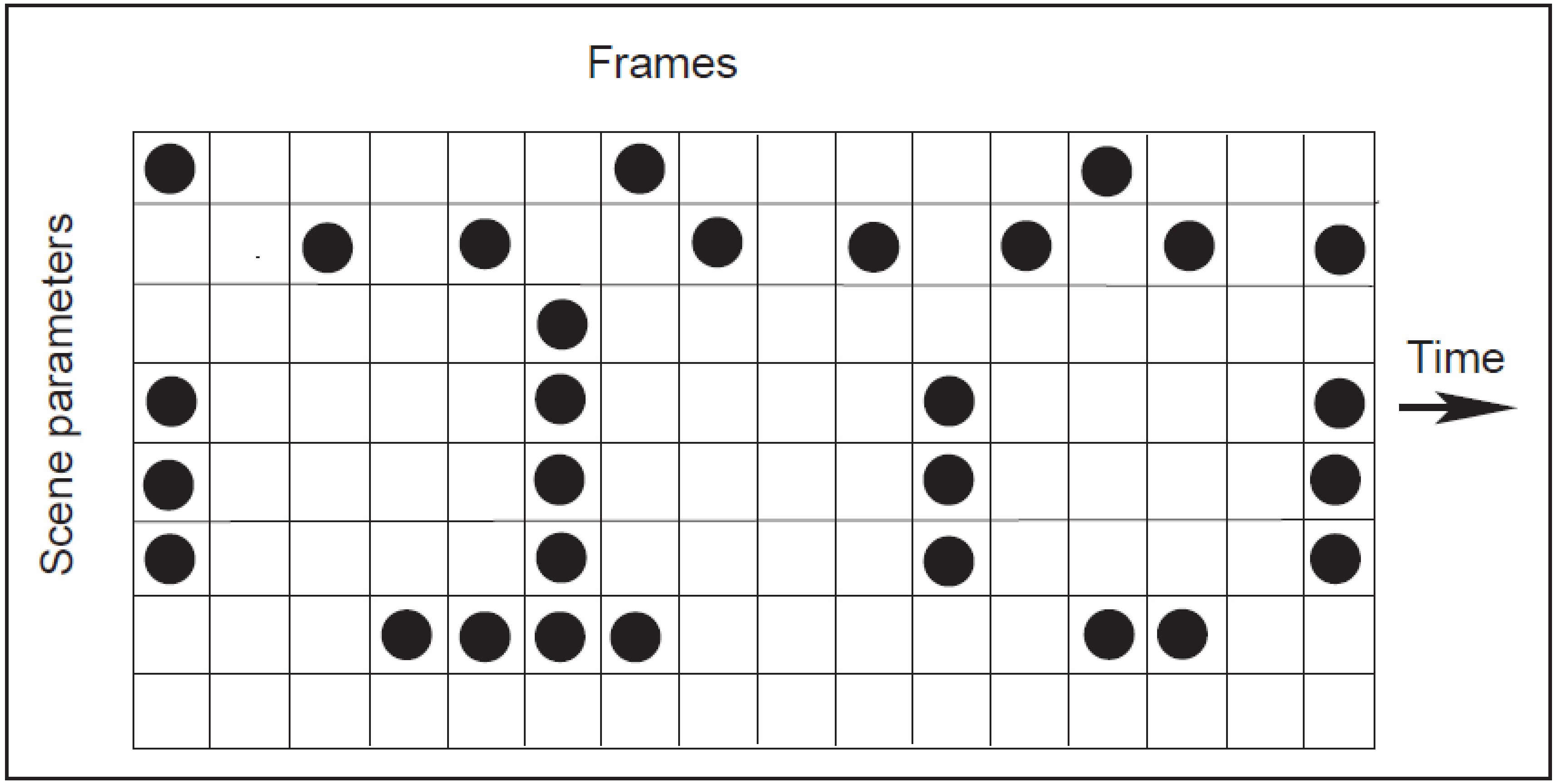
What is animation?

- Modeling = specifying shape
  - using all the tools we've seen: hierarchies, meshes, curved surfaces…
- Animation = specifying shape as a function of time
  - just modeling done once per frame?
  - yes, but need smooth, concerted movement
- "Straight ahead" is drawing frames in order
  - hard to get a character to land at a particular pose/time
- Keyframes
  - draw important poses and interpolate in-betweens
  - Key ideas
    - create high-level controls for adjusting geometry
    - interpolate these controls

Keyframe animation

Computer animation

- A 3D scene is animated by a set of parameters
  - Object and part locations, camera position, light source intensity
- Key frames to key values (interpolation)
  - https://www.youtube.com/watch?v=ZmNmQ3izNnI



Problems with interpolation

- Splines don't always output the right thing
- Problems
  - 3D rotations
    - Euler angles don't always interpolate in a natural way
  - Invalid configurations
    - Go through walls, anatomically impossible poses
- Solutions
  - More keyframes
  - Quaternions for rotation
  - Incorporate kinematics and constraints

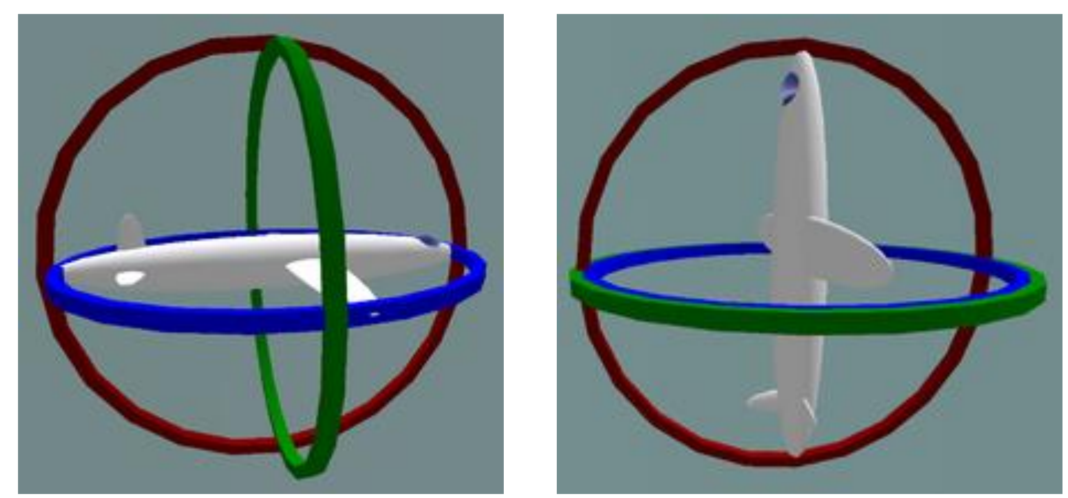
Gimbal lock

$$\begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

start

end

Occurs if during rotation one of the three rotation axes is by accident aligned with another



Quaternions

Given an unit length vector

$\vec{u} = (u_x, u_y, u_z)$ and angle θ

Quaternion can be written as

- $q = e^{\frac{\theta}{2}(u_x i + u_y j + u_z k)}$

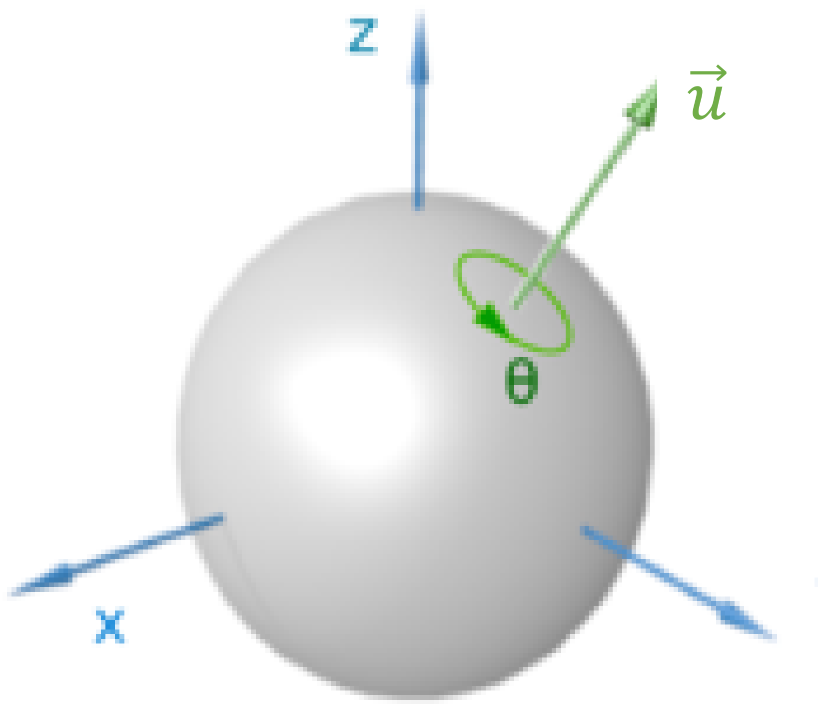
  $= \cos\frac{\theta}{2} + (u_x i + u_y j + u_z k)\sin\frac{\theta}{2}$

  $= [s\ ;\ \vec{v}]$

Sum up and scale

- $q_1 + q_2 = [s_1 + s_2; \vec{v}_1 + \vec{v}_2]$
- $\alpha q = [\alpha s\ ; \alpha\vec{v}]$

Spherical linear interpolation (slerp)

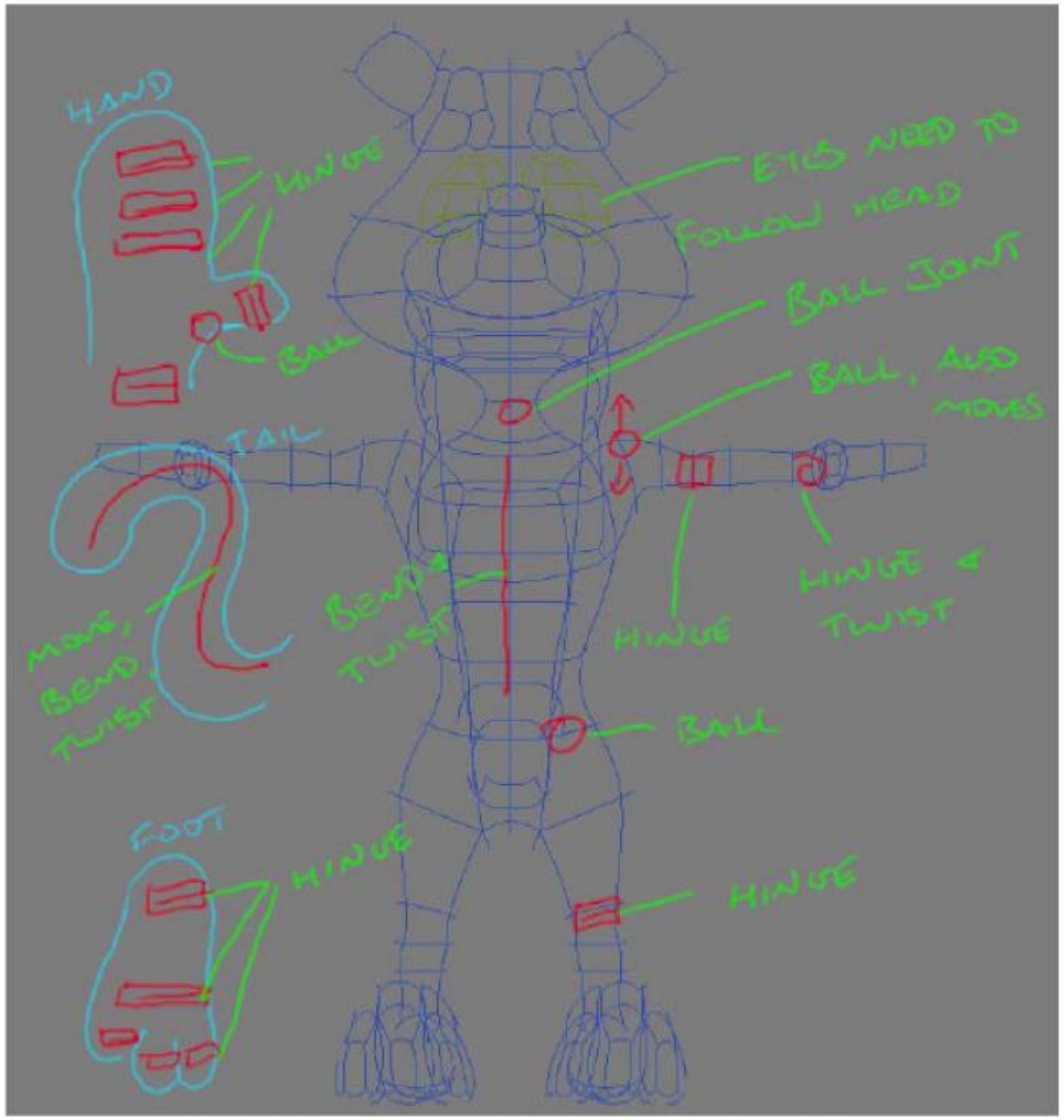


en.wikipedia.org

Controlling geometry

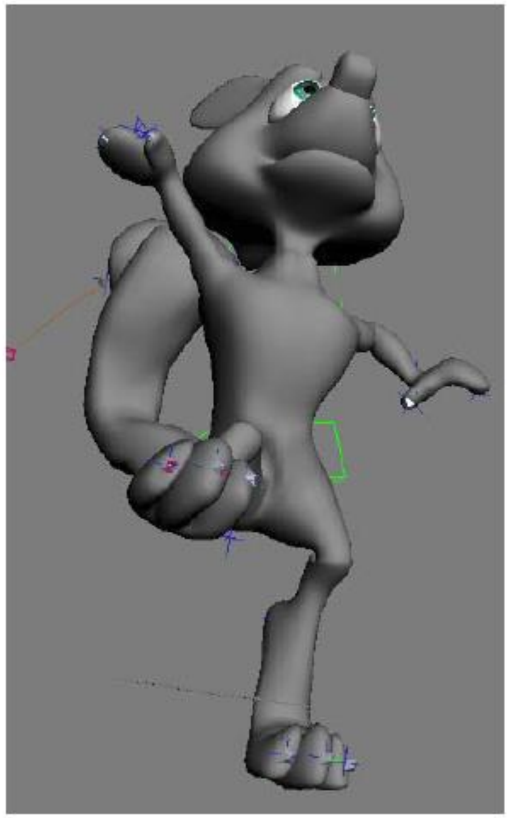
- Parameterize the motion by using smaller set of meaningful degrees of freedom (DOFs)

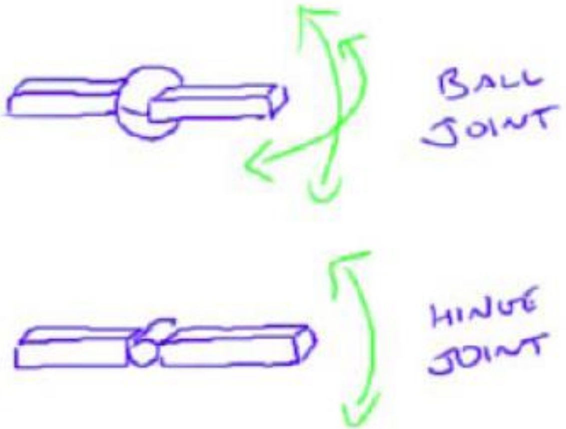
Character with DOFs



[Greenberg/Pellacini | CIS 565]

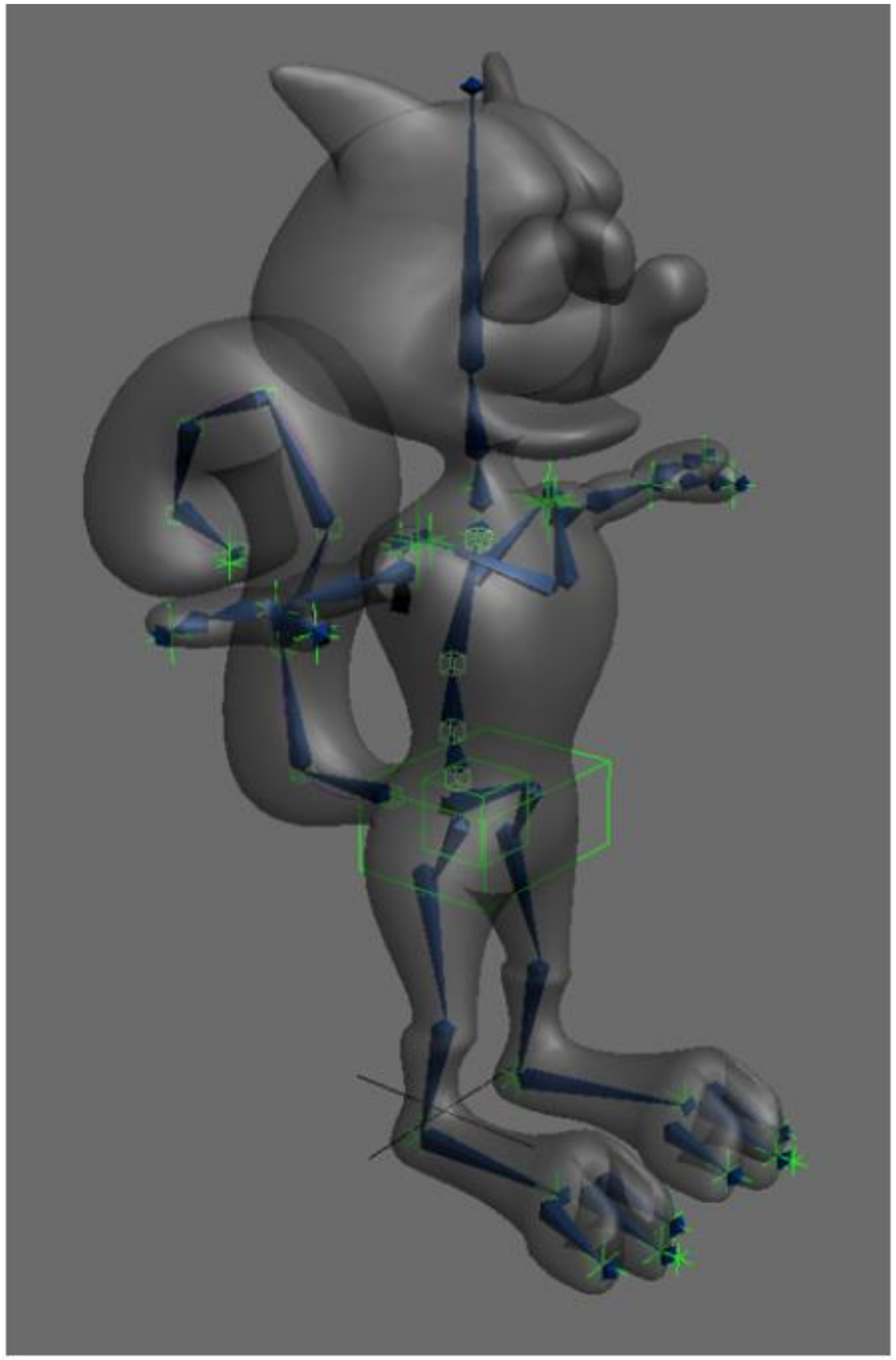
A visual description of the possible movements for the squirrel





Rigged character

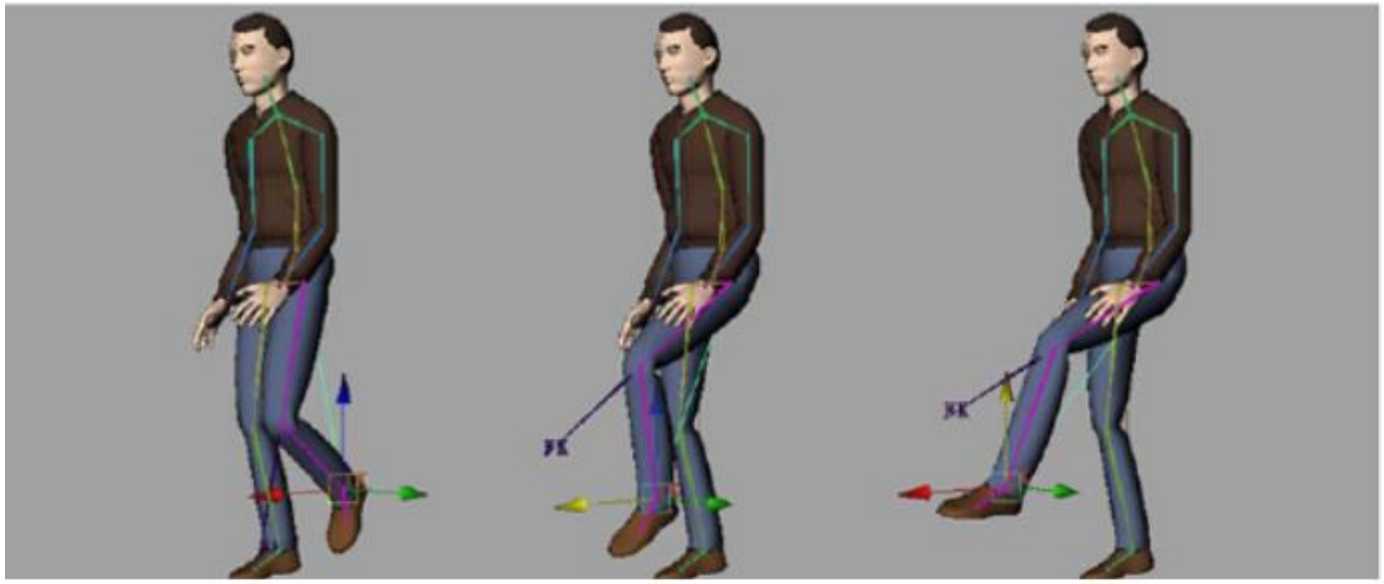
- A digital skeleton
- Made up of joints and bones
- The controls are useful, intuitive DOFs for an animator to use



https://www.youtube.com/watch?v=cGvalWG8HBU

Articulated figures

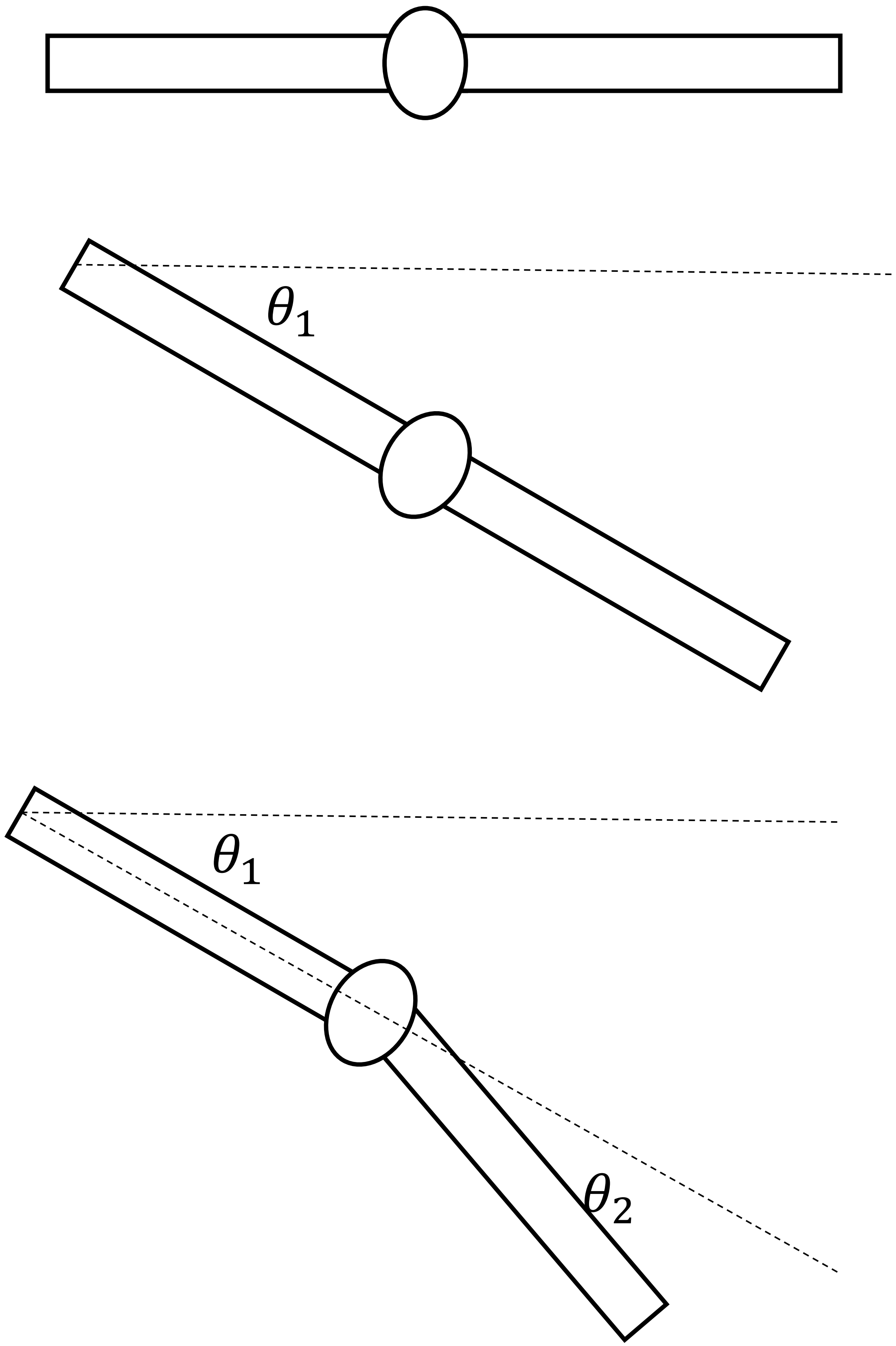
Forward Kinematics

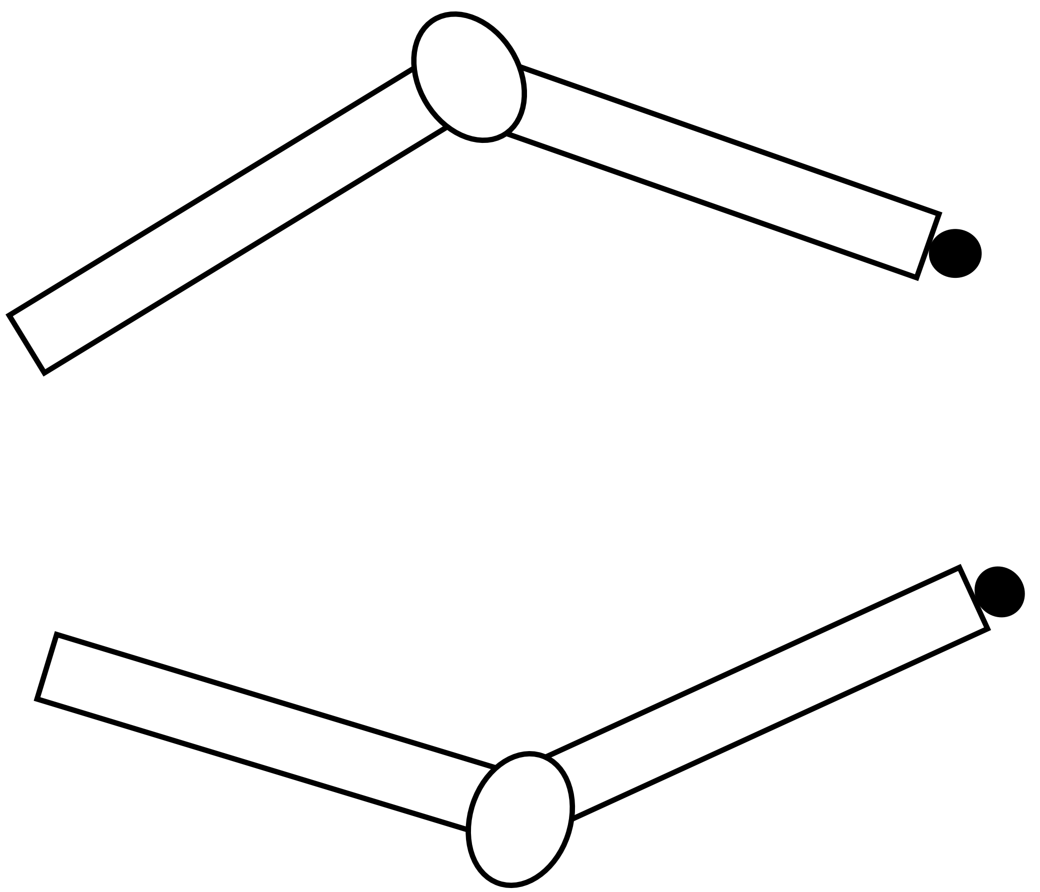


Inverse Kinematics

Forward and inverse kinematics

Constraints





Inverse kinematics

- Multiple solutions possible
- Consider constraints (bending knee in one direction)

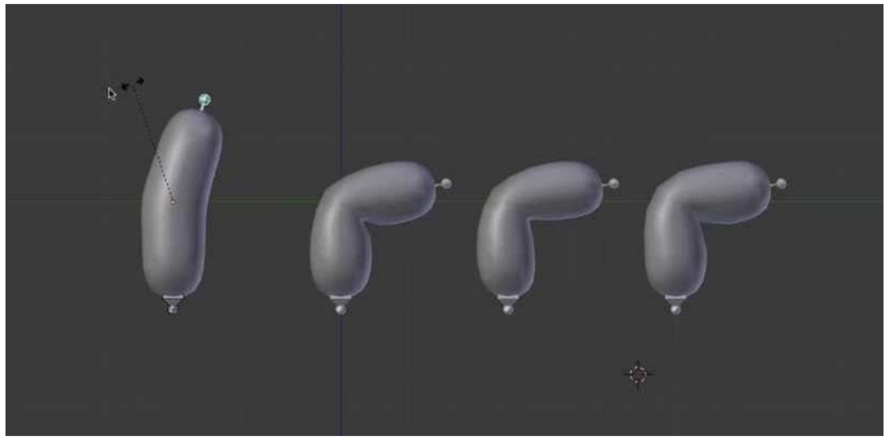
Surface deformation

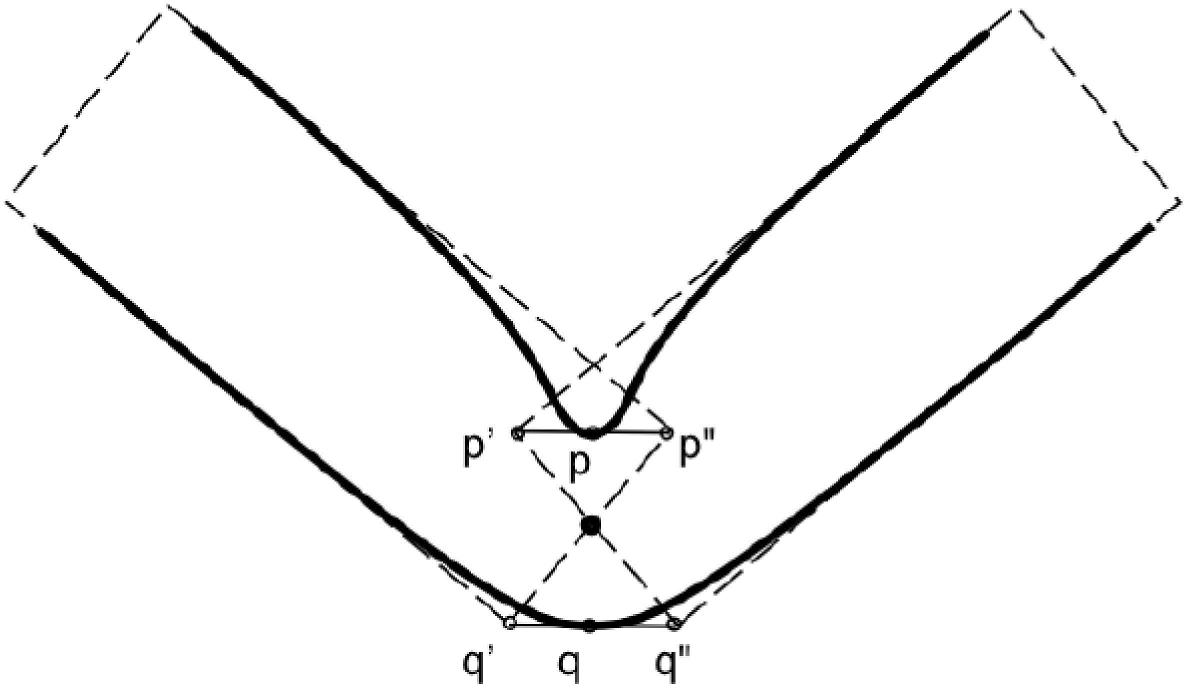
Mesh skinning

A simple way to deform a surface to follow a skeleton

- Surface has control points $\boldsymbol{p_i}$ (triangle vertices, spline control pts)
- Each bone has a transformation matrix $\boldsymbol{M_j}$ (rigid motion)
- Every point-bone pair has weight $\boldsymbol{w_{ij}}$
  - Only non-zero for nearby bones
  - Weights are input by the user

- $\boldsymbol{p_i' = \sum_j w_{ij} M_j p_i}$



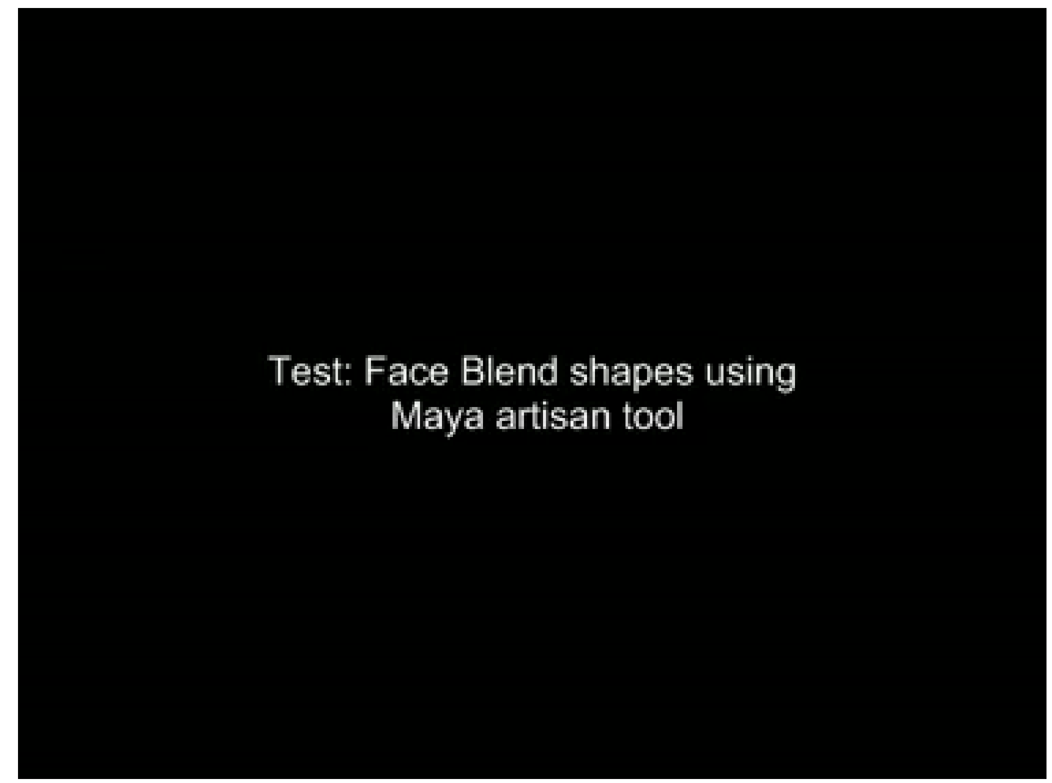


[Lewis et al. SIGGRAPH 2000]

Blend shapes

- Another very simple surface control scheme
- Based on interpolating among several key poses

jake-hempson.com



http://videos.weebly.com/uploads/5/1/7/7/5177454/testblends_506.mp4

Motion capture

Movies

A method for creating complex motion quickly: measure it from the real world

[*The Two Towers* | New Line Productions]

Motion capture

Games

Motion capture

Magnetic MoCap

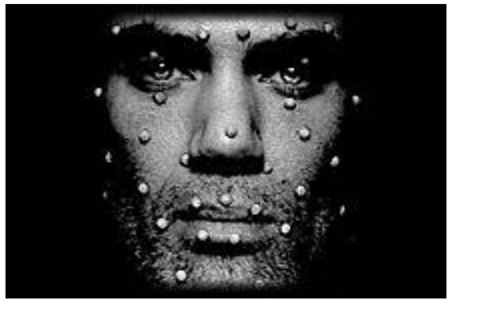
- Tethered, distortions from nearby metal, 60Hz

Mechanical MoCap

- Direct measures of joint angles, restrict motion

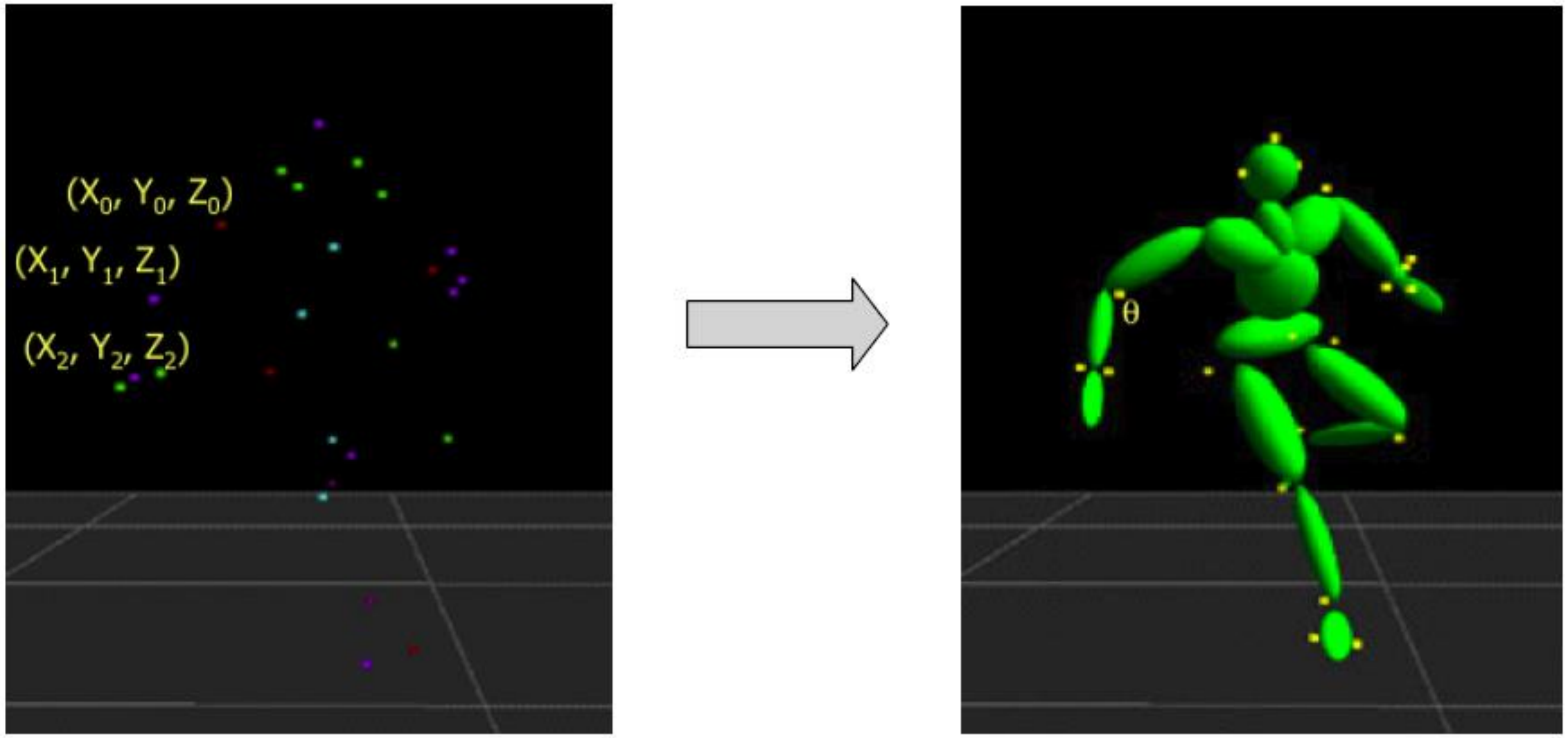
Optical markers

- Passive markers, observed by cameras, 8 or more cameras, occlusions are problematic



Motion capture

Data processing

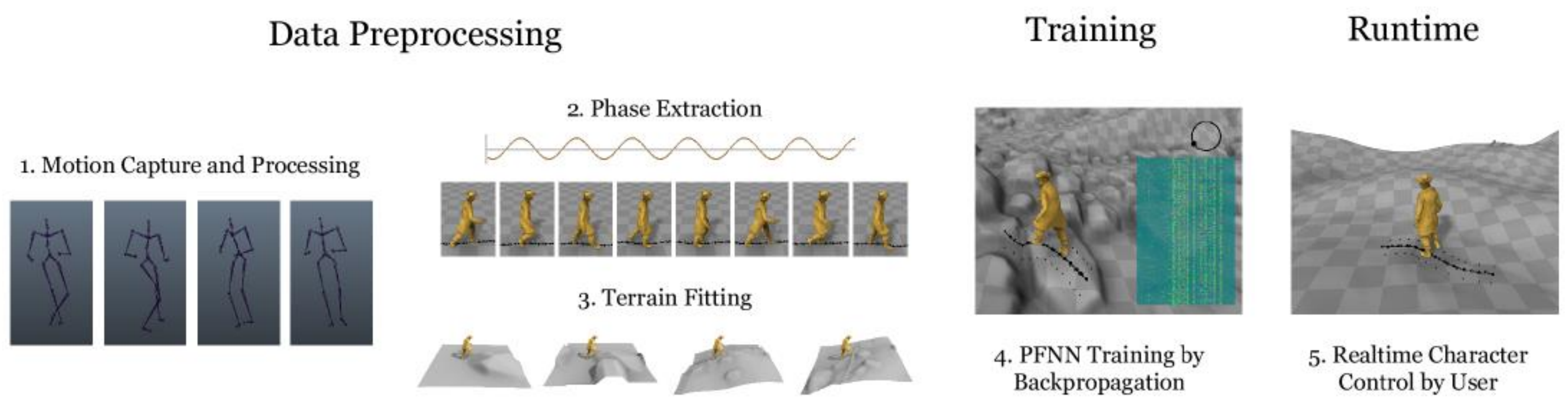


- Which marker is which?
  - Start with a known pose and track
- Calibration: match skeleton, find offsets to markers
  - A nonlinear optimization
- Computing joint angles: explain data using skeleton DOFs
  - Inverse kinematics

Example

Phase-Functioned Neural Networks for Character Control

https://www.youtube.com/watch?v=Ul0Gilv5wvY&t=208s



Summary

- The 12 principles
- Keyframing
  - Gimbal lock
  - Quaternions
- Controlling geometry
  - Character rigging
  - Forward / inverse kinematics
  - (Deformations) Mesh skinning
  - Blending
- Motion capture
- Other techniques:
  - physics-based animation
  - procedural techniques

HAL 9000 Animations

https://www.youtube.com/watch?v=HurJ3b7n_8w

Reading

B1: Chapter 16