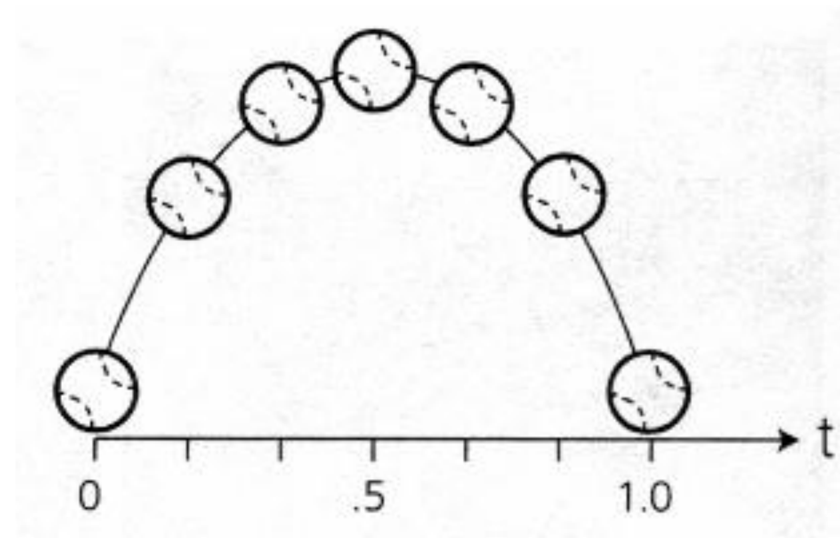
Animation, Motion Capture, Keyframing

source: http://scaq.blogspot.com/2006_11_01_archive.html

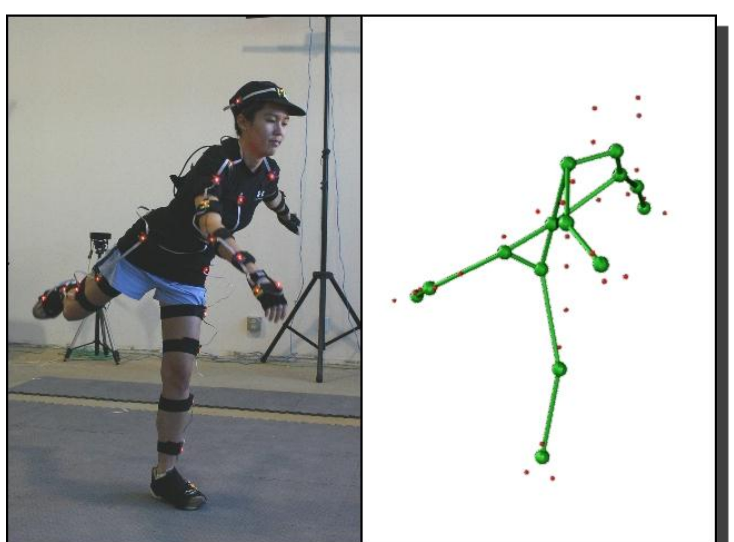
Overview

Animation Intro

Cell Animation



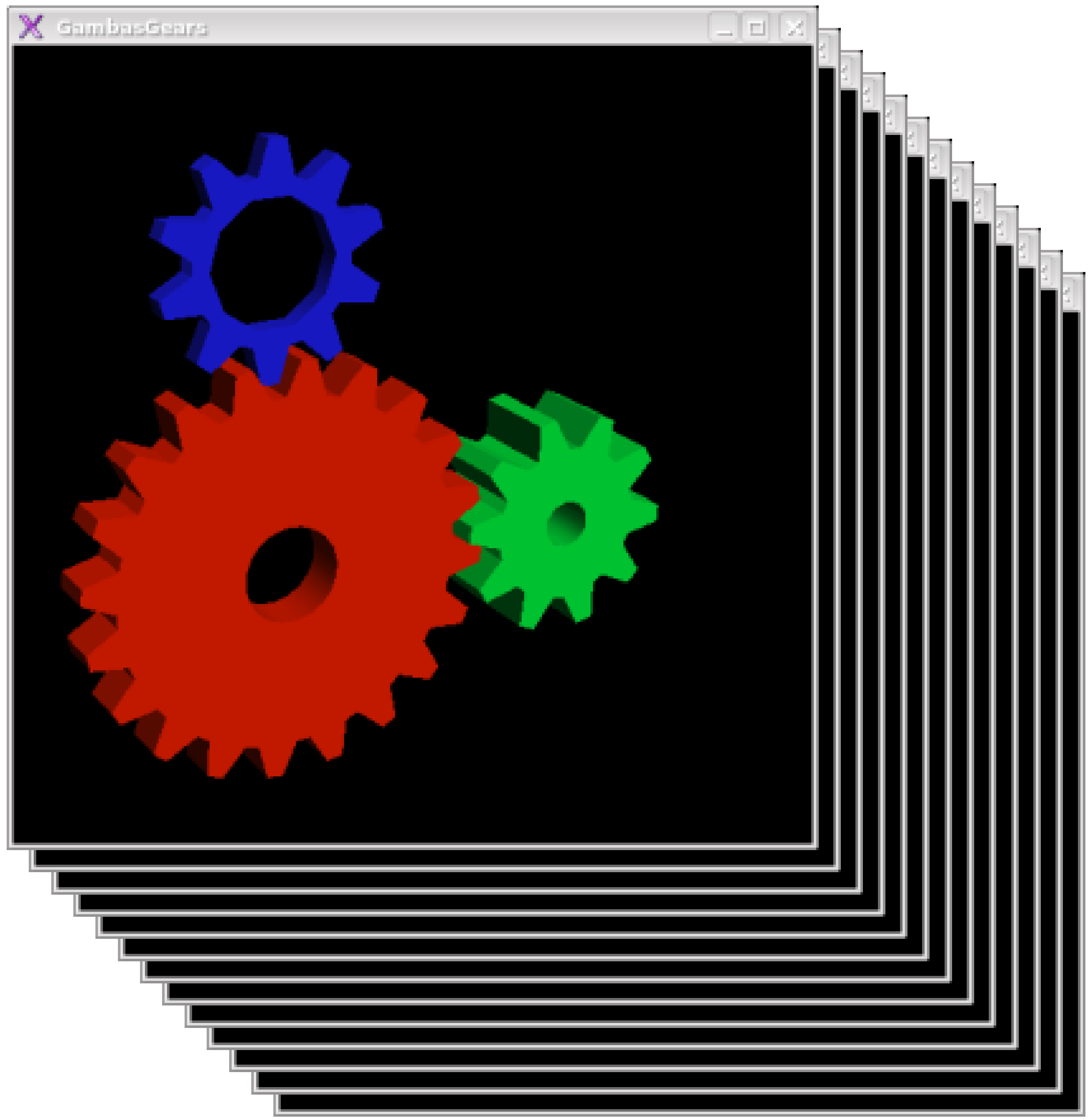
Keyframing



Data-driven Animation

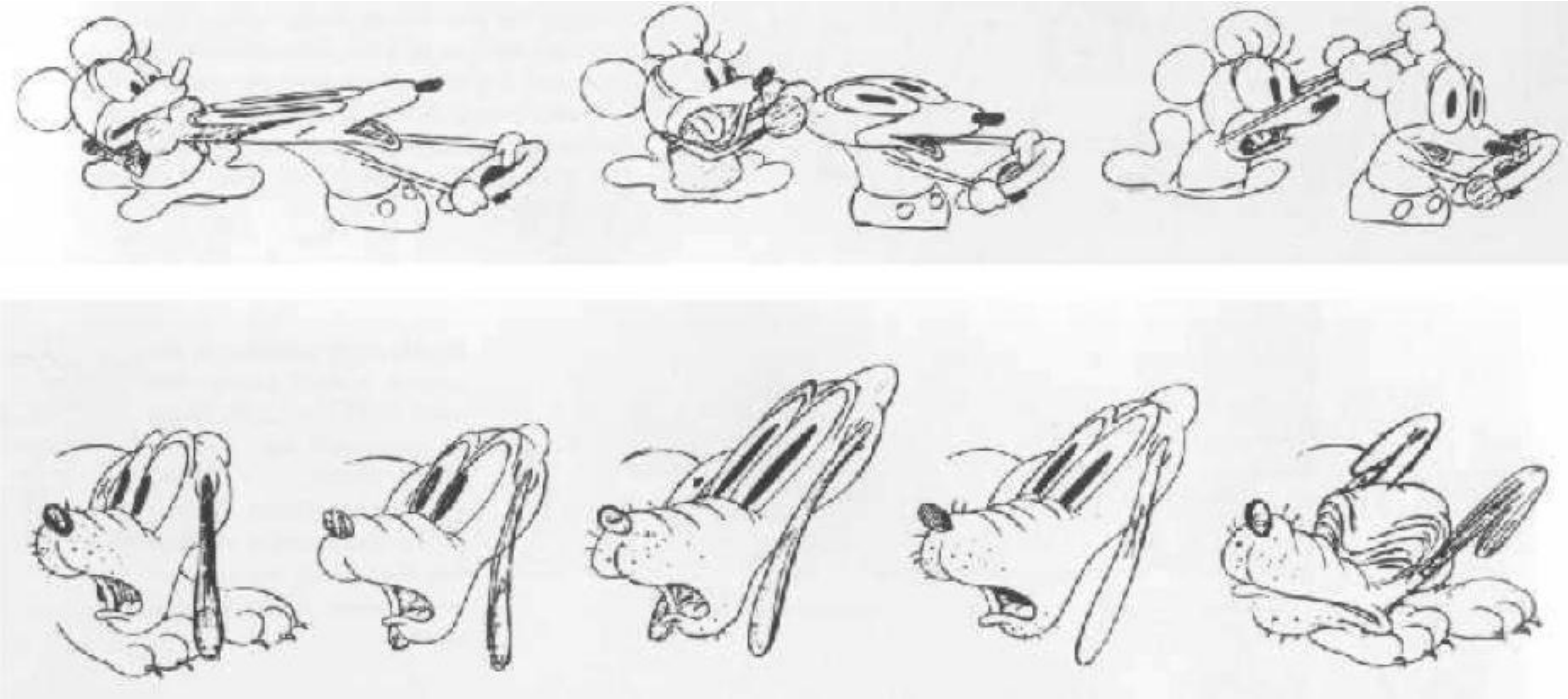
Physical Simulation

What is Animation?



Animation = Graphics × Time

Cell Animation



Keyframing

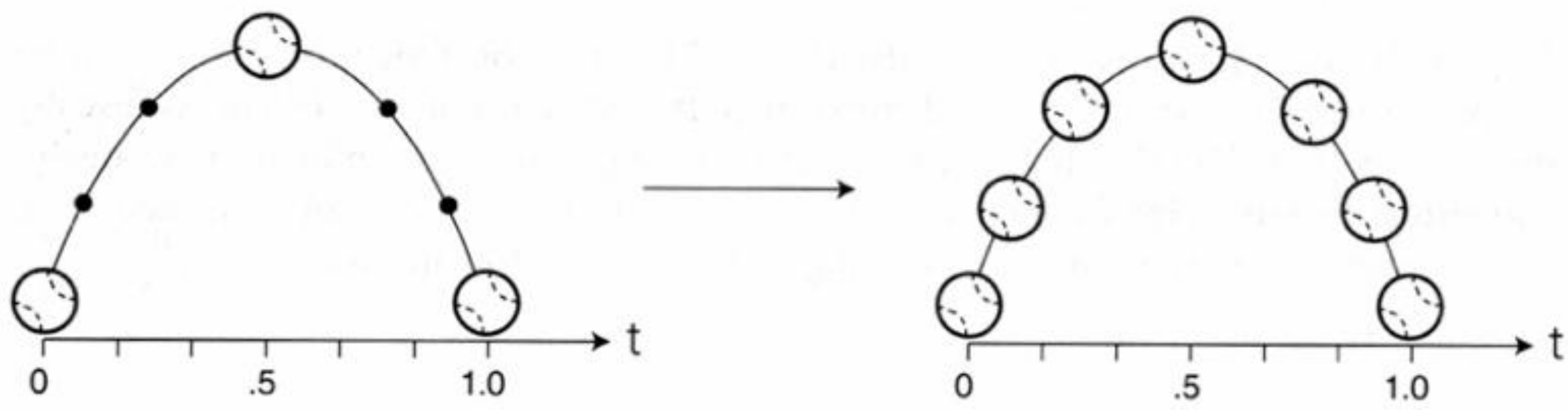
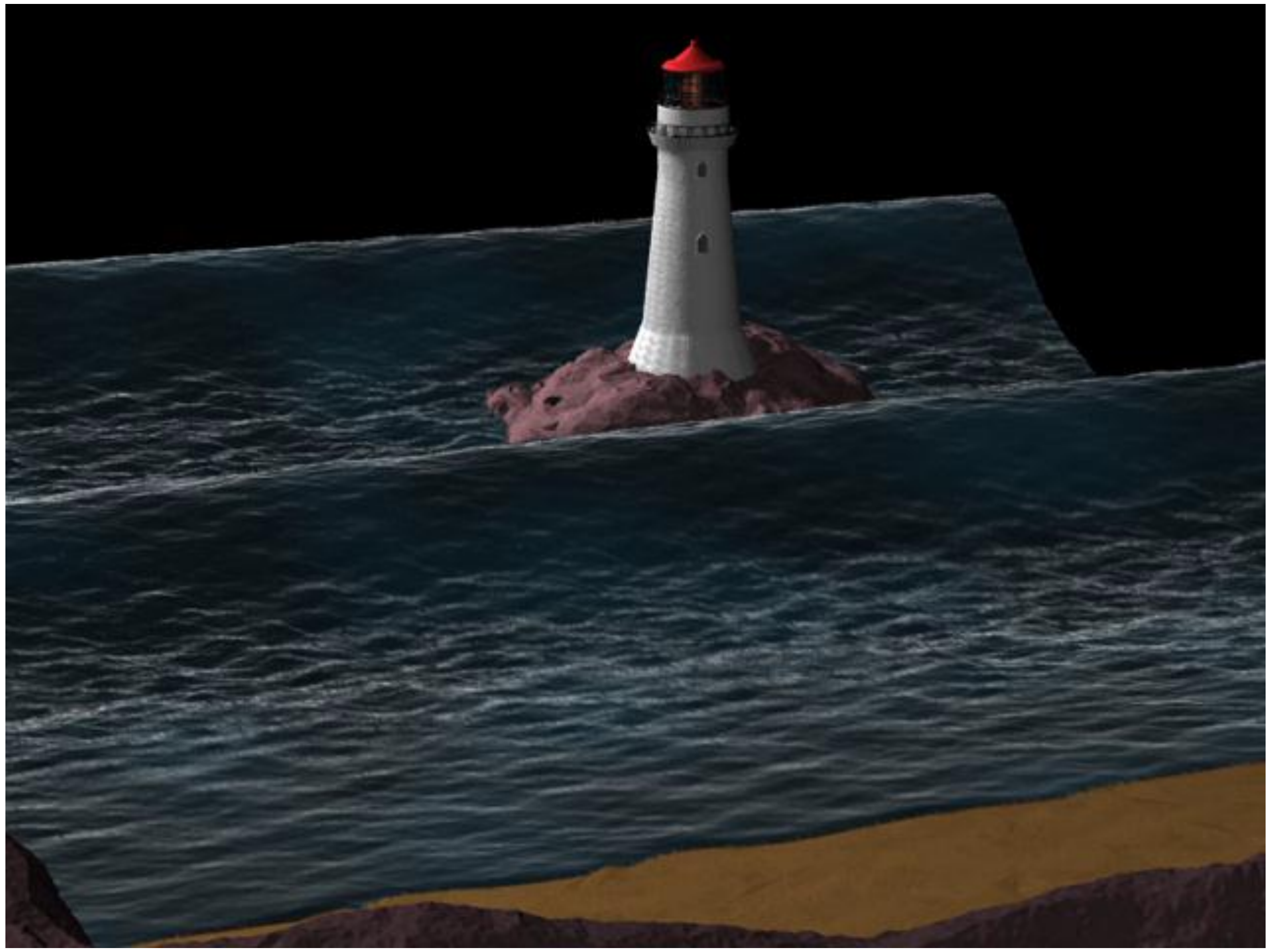


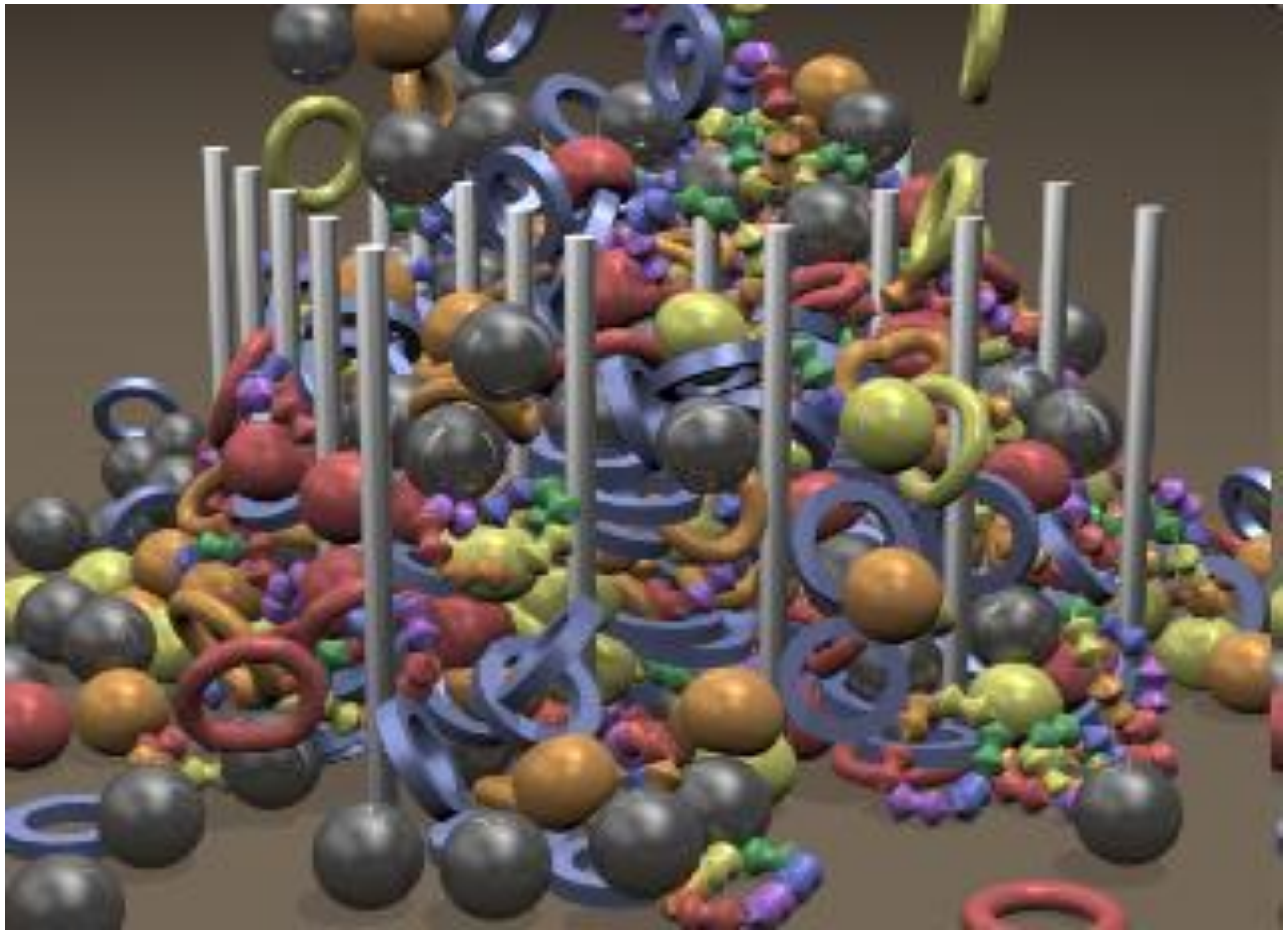
Figure 10.9 **Inbetweening with nonlinear interpolation.** Nonlinear interpolation can create equally spaced inbetween frames along curved paths. The ball still moves at a constant speed. (Note that the three keyframes used here and in Fig. 10.10 are the same as in Fig. 10.4.)

Data-driven Animation

http://graphics.cs.cmu.edu/

Physics-based Animation

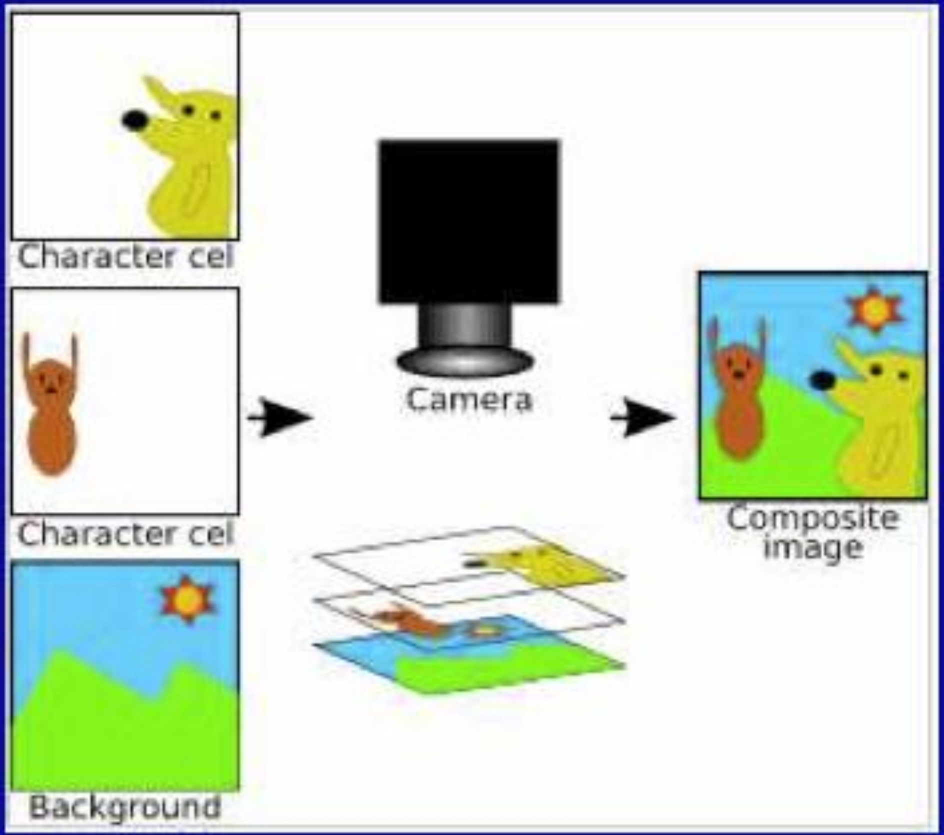




http://physbam.stanford.edu/~fedkiw/

Traditional Cel Animation

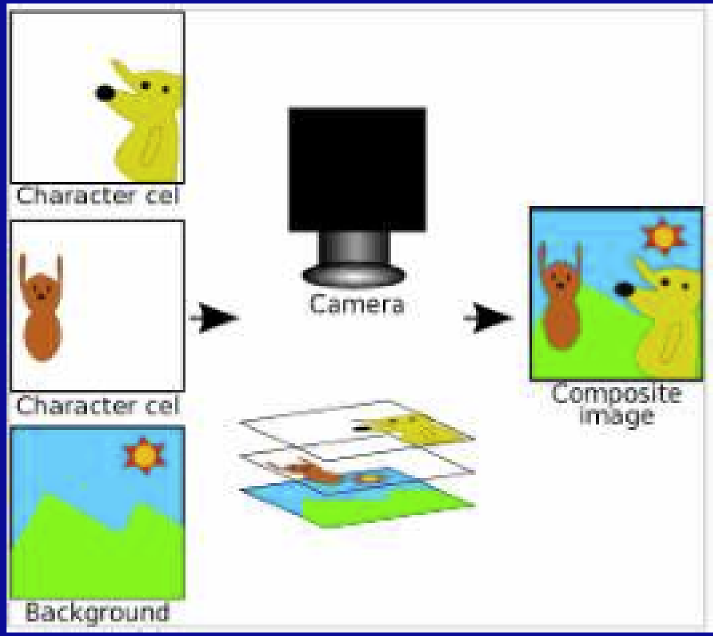
- Each frame is drawn by hand



- Film runs at 24 frames per second (fps)
  - That's 1440 pictures to draw per minute
- Artistic issues:
  - Artistic vision has to be converted into a sequence of still frames
  - Not enough to get the stills right--must look right at full speed
    - » Hard to "see" the motion given the stills
    - » Hard to "see" the motion at the wrong frame rate

Traditional Animation: The Process

- Key Frames
  - Draw a few important frames in pencil
    - » beginning of jump, end of jump and a frame in the air
- Inbetweens
  - Draw the rest of the frames
- Painting
  - Redraw onto clear sheet of plastic called a *cel*, color them in



- Use one layer for background, one for object
  - Draw each separately
  - Stack them together on a copy stand
  - Transfer onto film by taking a photograph of the stack

- Can have multiple animators working simultaneously on different layers, avoid re-drawing and flickering

Principles of Traditional Animation
[Lasseter, SIGGRAPH 1987]

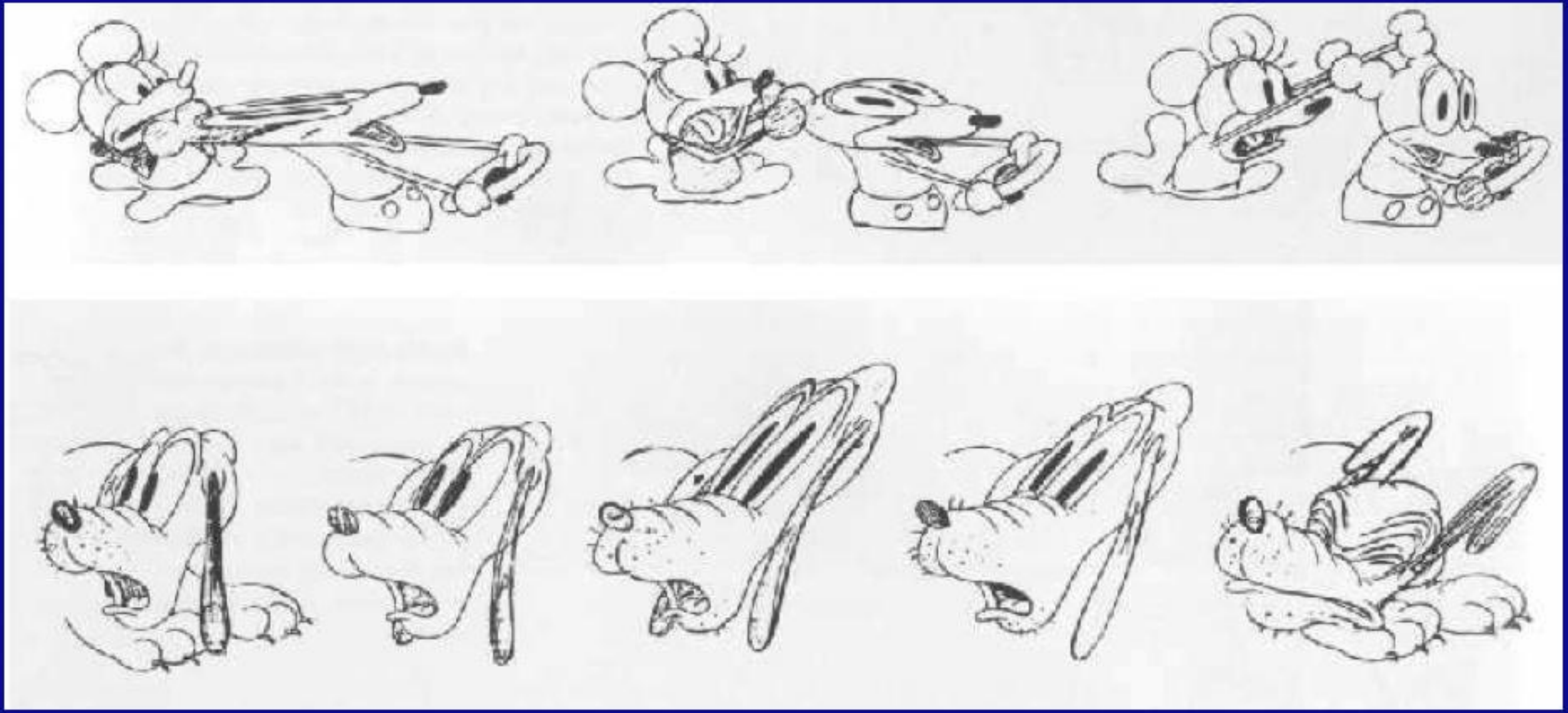
- Stylistic conventions followed by Disney's animators and others

- From experience built up over many years
  - Squash and stretch -- use distortions to convey flexibility
  - Timing -- speed conveys mass, personality
  - Anticipation -- prepare the audience for an action
  - Followthrough and overlapping action -- continuity with next action
  - Slow in and out -- speed of transitions conveys subtleties
  - Arcs -- motion is usually curved
  - Exaggeration -- emphasize emotional content
  - Secondary Action -- motion occurring as a consequence
  - Appeal -- audience must enjoy watching it

http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/prin_trad_anim.htm

Squash and Stretch

Use distortions to convey flexibility

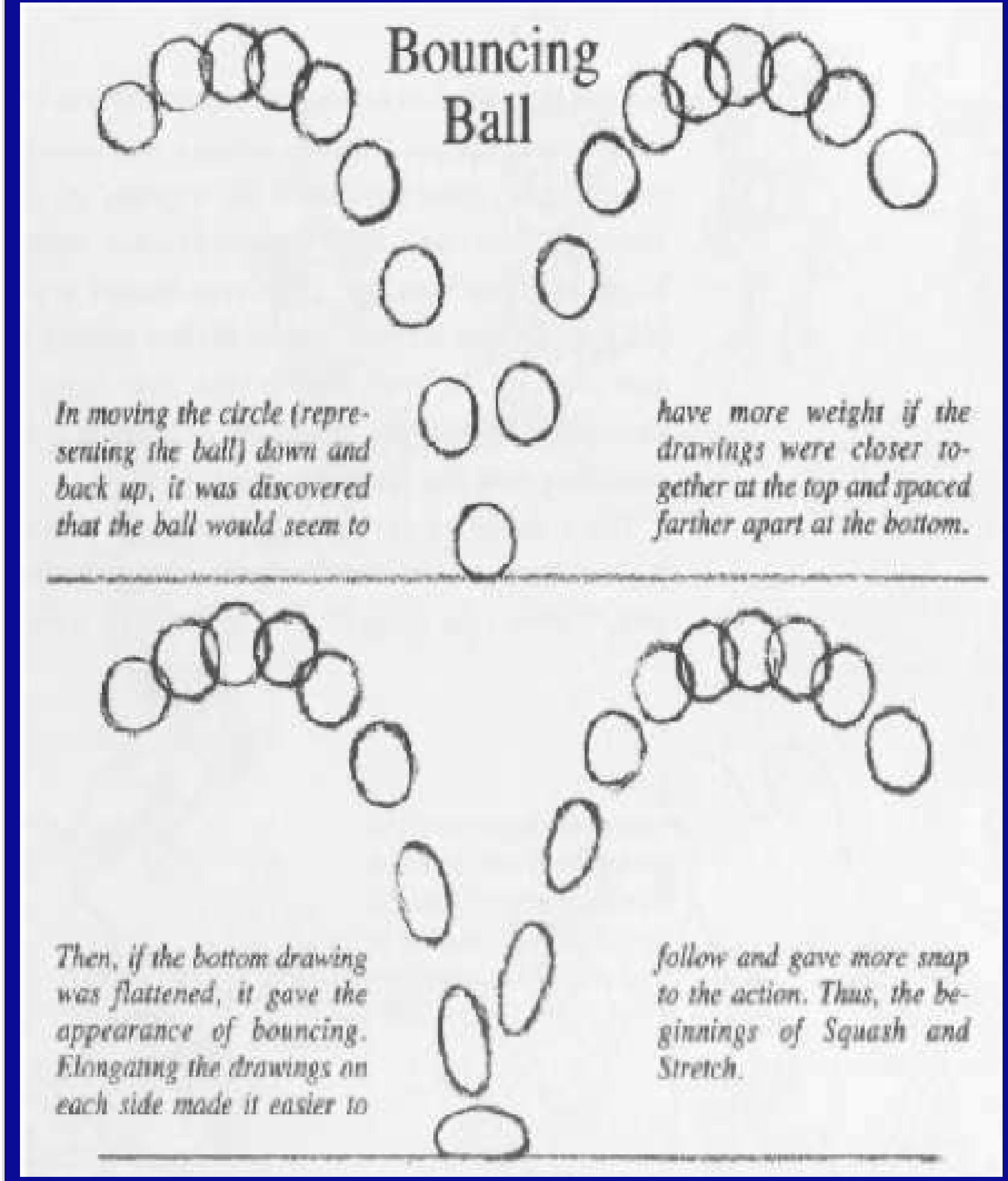


Principles of Traditional Animation

The famous half-filled flour sack, guide to maintaining volume in any animatable shape, and proof that attitudes can be achieved with the simplest of shapes.

Squash and Stretch

Use distortions to convey flexibility



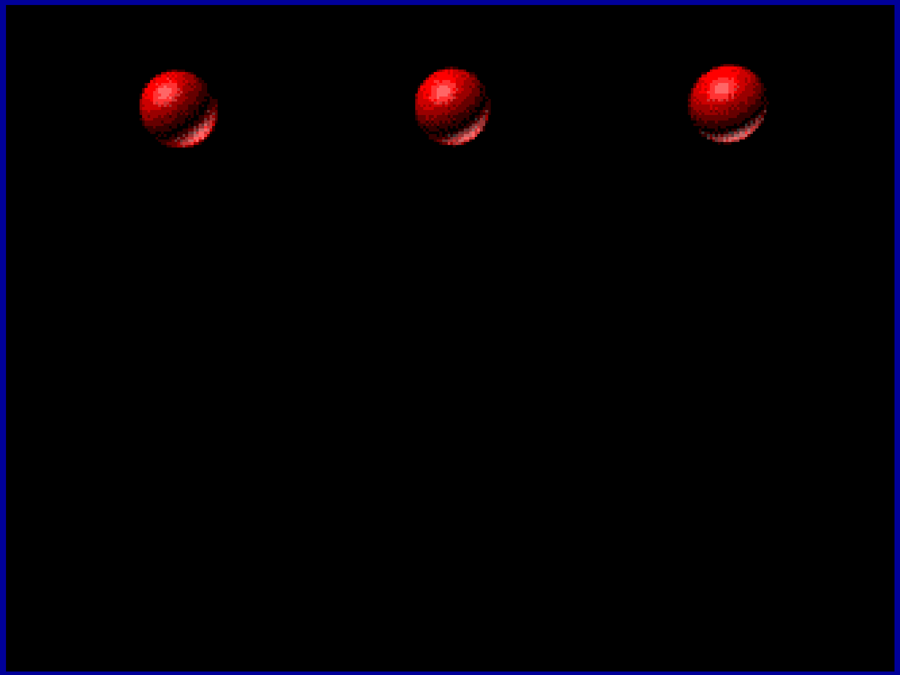
Defines the rigidity of the material

Gives the sense that the object is made out of a soft, pliable material.

Elongating the drawings before and after the bounce increases the sense of speed, makes it easier to follow and gives more snap to the action.

Slow in and out

Speed of transitions conveys subtleties



http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/bouncing_ball_example_of_slow_in_out.htm

The ball on the left moves at a constant speed with no squash/stretch.
The ball in the center does slow in and out with a squash/stretch.
The ball on the right moves at a constant speed with squash/stretch.

Timing & Motion

Speed conveys mass, personality

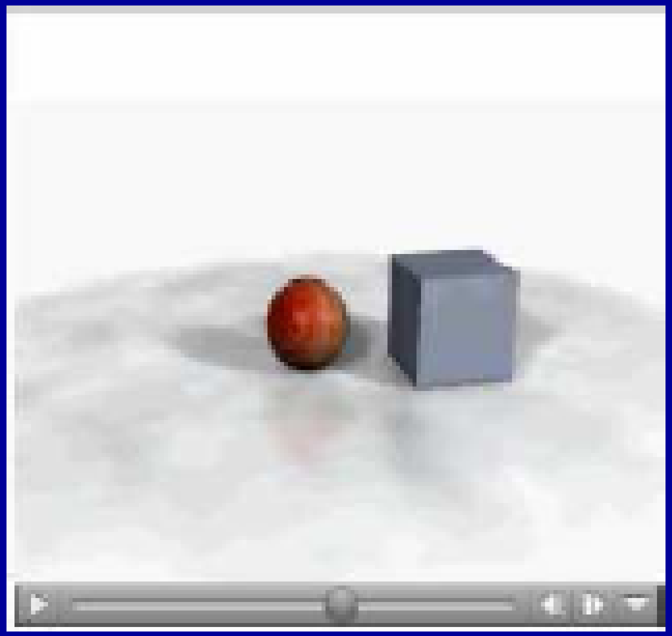
A heavier object takes a greater force and a longer time to accelerate and decelerate

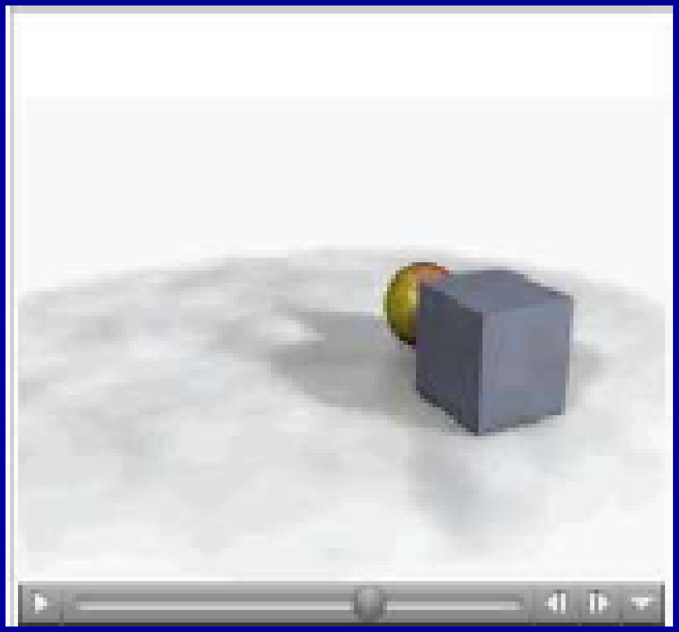
A larger object moves more slowly than a smaller object and has greater inertia

Motion also can give the illusion of weight

For example, consider a ball hitting a box

http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/timing.htm





Timing & Motion

Timing can also indicate an emotional state

Consider a scenario with a head looking first over the right shoulder and then over the left shoulder

No in-betweens - the character has been hit by a strong force and its head almost snappedd off
One in-betweens - the character has been hit by something substantial, .e.g., frying pan
Two in-betweens - the character has a nervous twitch
Three in-betweens - the character is dodging a flying object
Four in-betweens - the character is giving a crisp order
Six in-betweens - the character sees something inviting
Nine in-betweens - the character is thinking about something
Ten in-betweens - the character is stretching a sore muscle

Anticipation

Prepare the audience for an action

Don't surprise the audience
Direct their attention to what's important

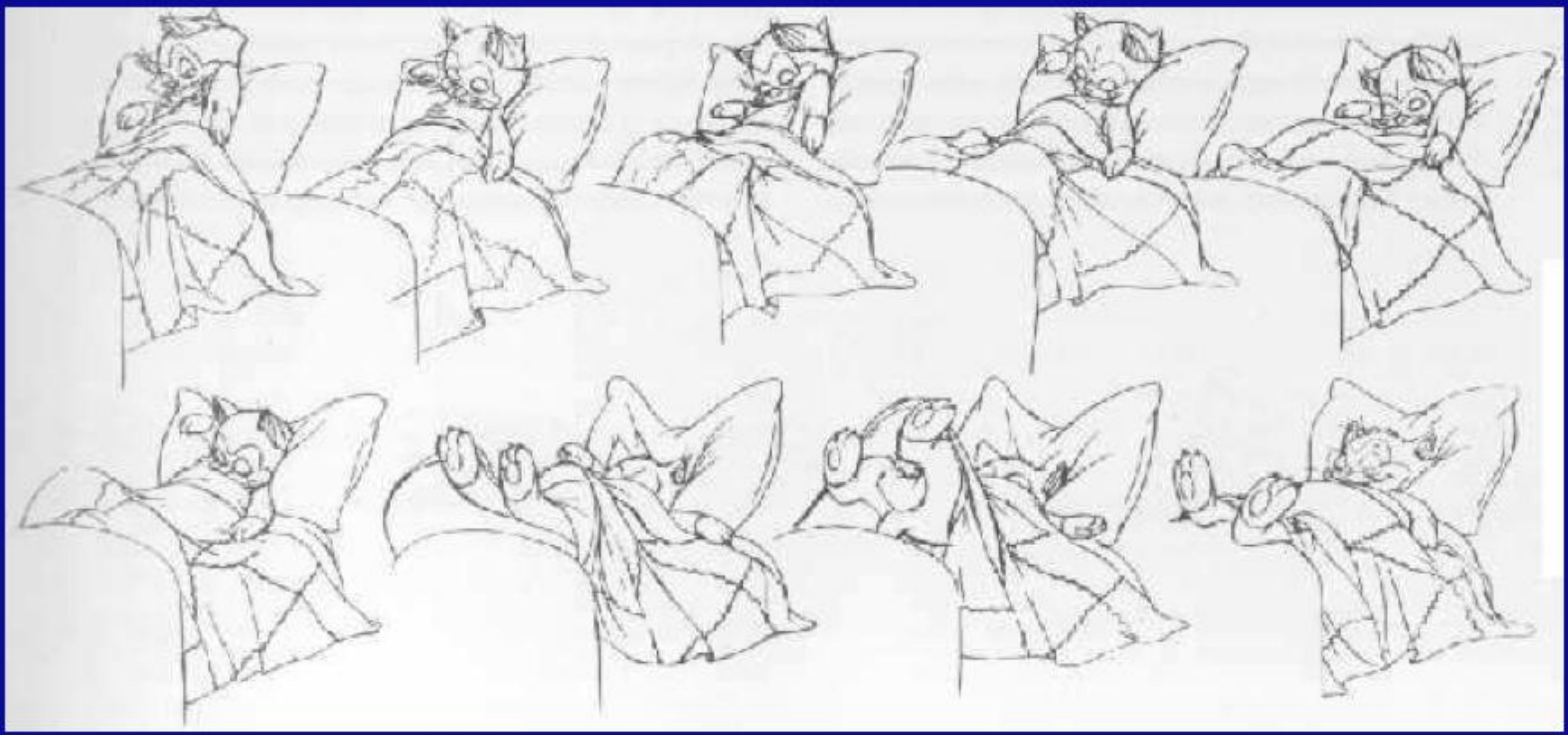
Follow Through and Overlapping Action

The termination of an action and establishing its relationship to the next action

Audience likes to see resolution of action
Discontinuities are unsettling

Secondary Action

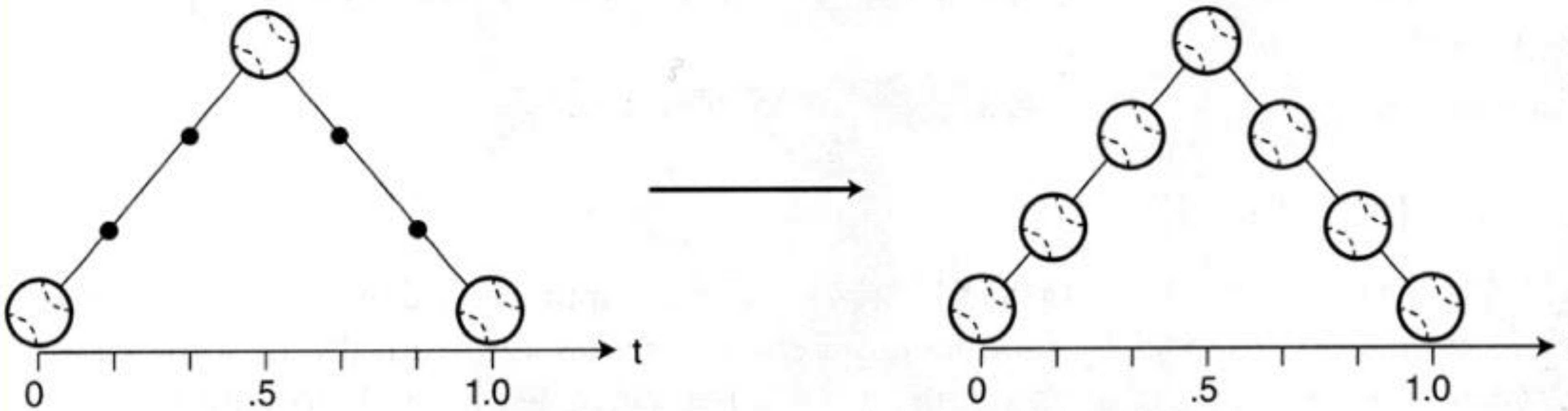
Motion occurring as a consequence



Example

Keyframing Basics

Figure 10.5 **Inbetweening with linear interpolation.** Linear interpolation creates inbetween frames at equal intervals along straight lines. The ball moves at a constant speed. Ticks indicate the locations of inbetween frames at regular time intervals (determined by the number of frames per second chosen by the user).



Keyframing Basics

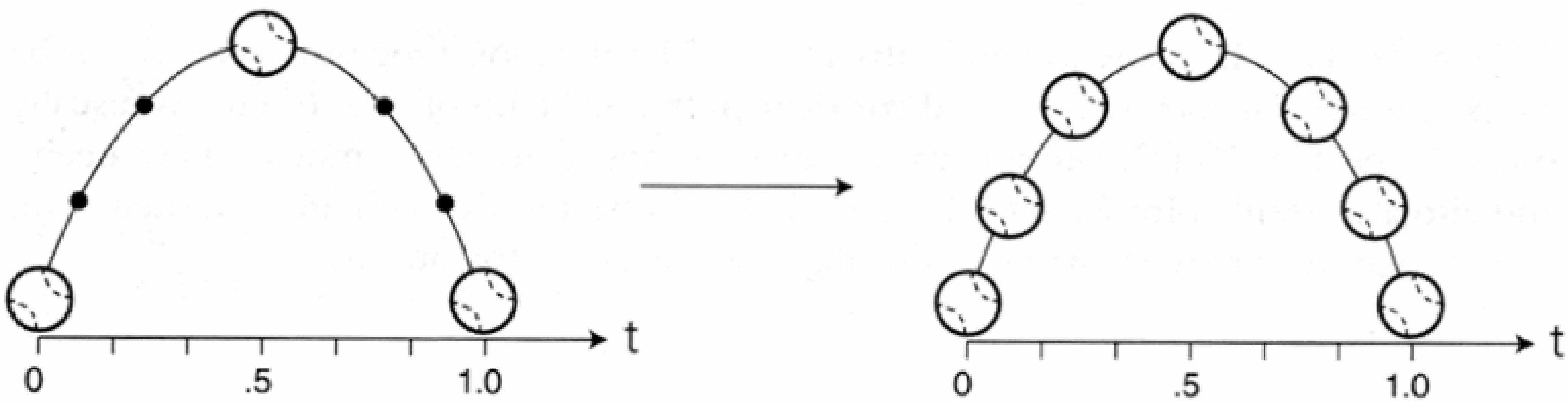


Figure 10.9 **Inbetweening with nonlinear interpolation.** Nonlinear interpolation can create equally spaced inbetween frames along curved paths. The ball still moves at a constant speed. (Note that the three keyframes used here and in Fig. 10.10 are the same as in Fig. 10.4.)

Keyframing Basics

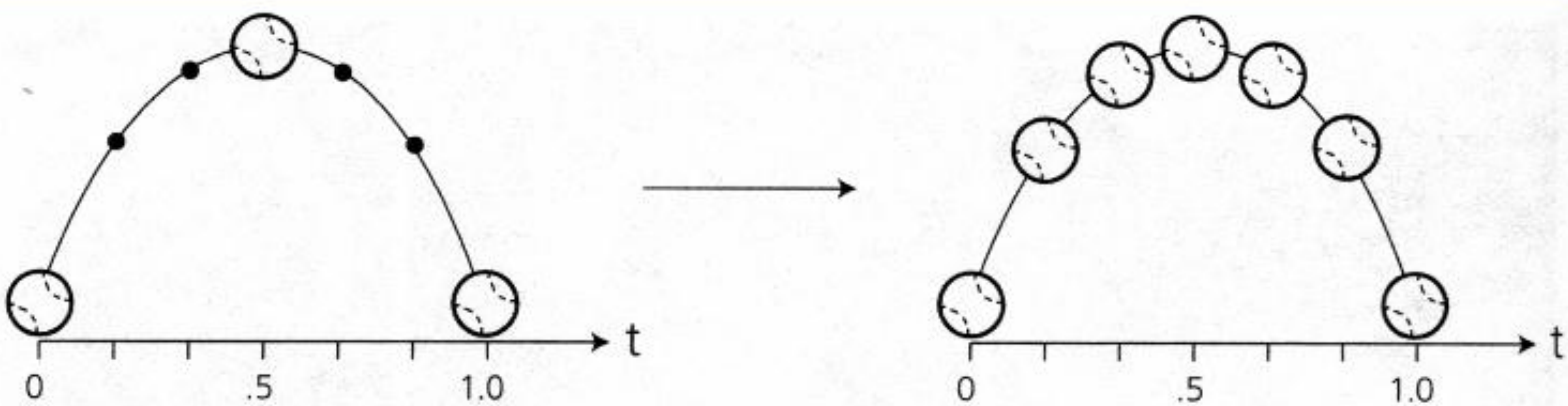
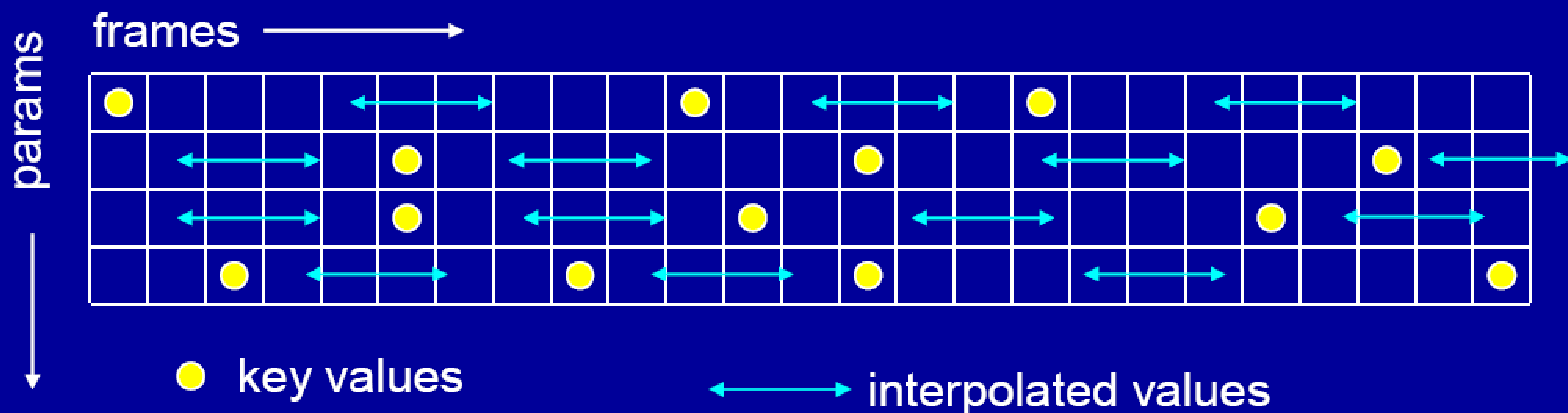


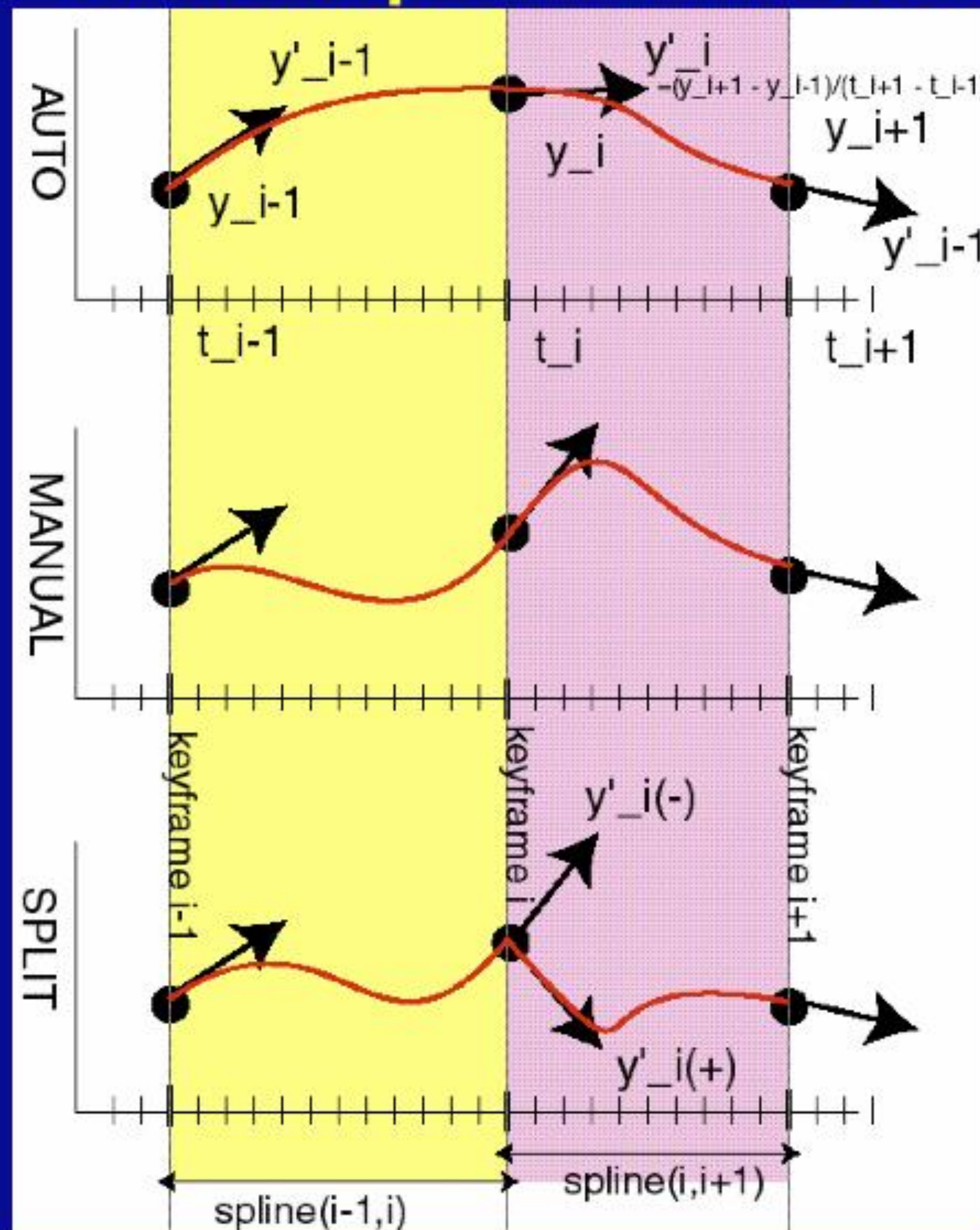
Figure 10.10 Inbetweening with nonlinear interpolation and easing. The ball changes speed as it approaches and leaves keyframes, so the dots indicating calculations made at equal time intervals are no longer equidistant along the path.

Keyframing Basics

- For each variable, specify its value at the "important" frames. Not all variables need agree about which frames are important.
- Hence, *key values* rather than key frames
- Create path for each parameter by interpolating key values



How Do You Interpolate Between Keys?



Problems with Interpolation

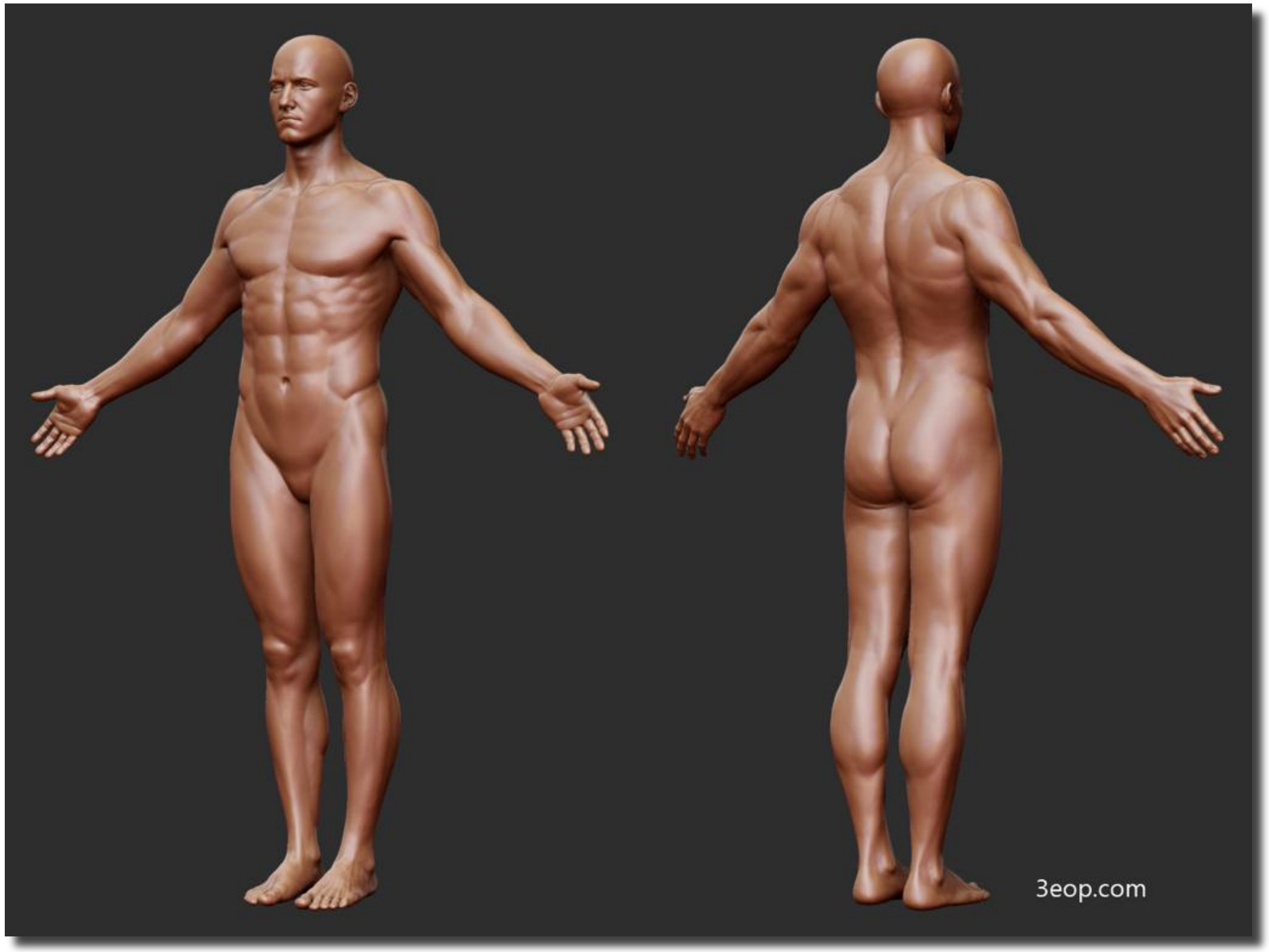
- Splines don't always do the right thing
- Classic problems
  - –Important constraints may break between keyframes
    - » feet sink through the floor
    - » hands pass through walls
  - –3D rotations
    - » Euler angles don't always interpolate in a natural way
- Classic solutions:
  - –More keyframes!
  - –Quaternions help fix rotation problems

Keyframing: Issues

- What should the key values be?
- When should the key values occur?
- How can the key values be specified?
- How are the key values interpolated?
- What kinds of BAD THINGS can occur from interpolation?
  - Invalid configurations (pass through objects)
  - Unnatural motions (painful twists/bends)
  - Jerky motion

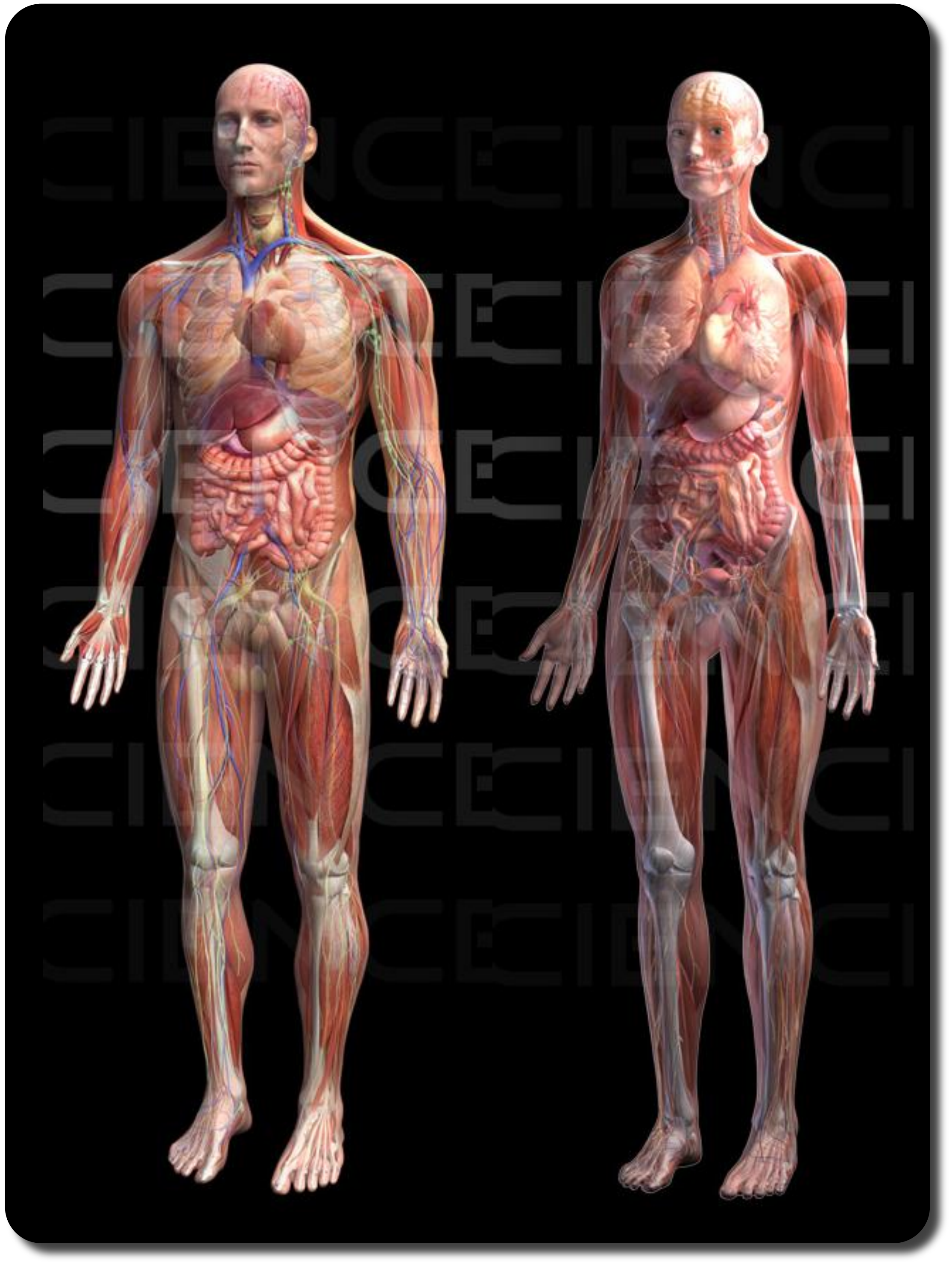
Data-Driven Animation

- Capturing the data or effect we want to animate.
- The classic example is humans.



source: http://www.3eop.com/data/3d/images/08_05_26_anatomy_study_male.jpg

Body Representation

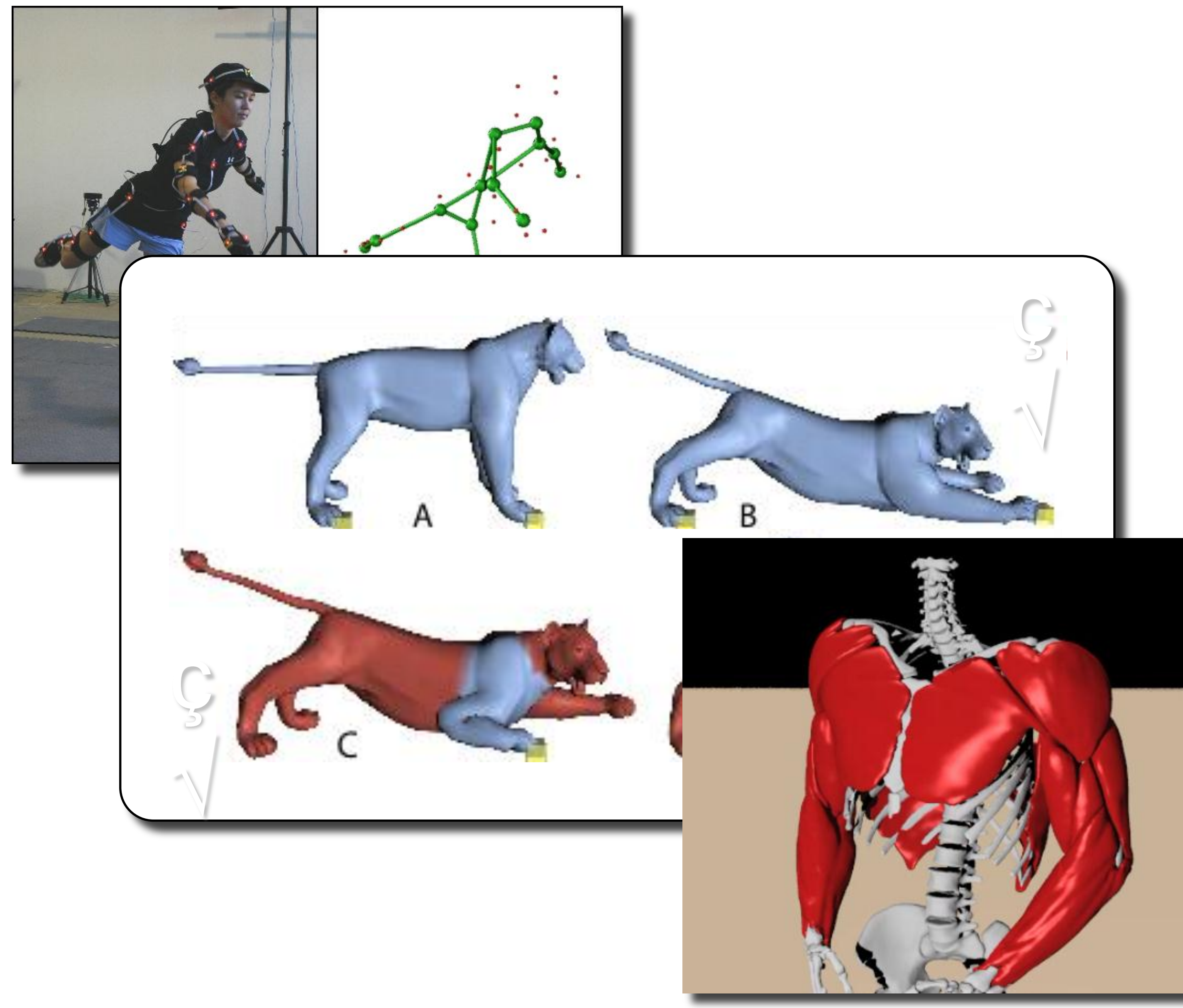


How to represent a human body on a computer?

source: http://www.3eop.com/data/3d/images/08_05_26_anatomy_study_male.jpg

Body Representation

- Kinematic Skeleton
- Anatomical
- Pure Mesh
- What are the advantages and disadvantages?



Motion Capture

- Animation
- Interactive characters
- Robot control

Motion Capture

Record movements of actors

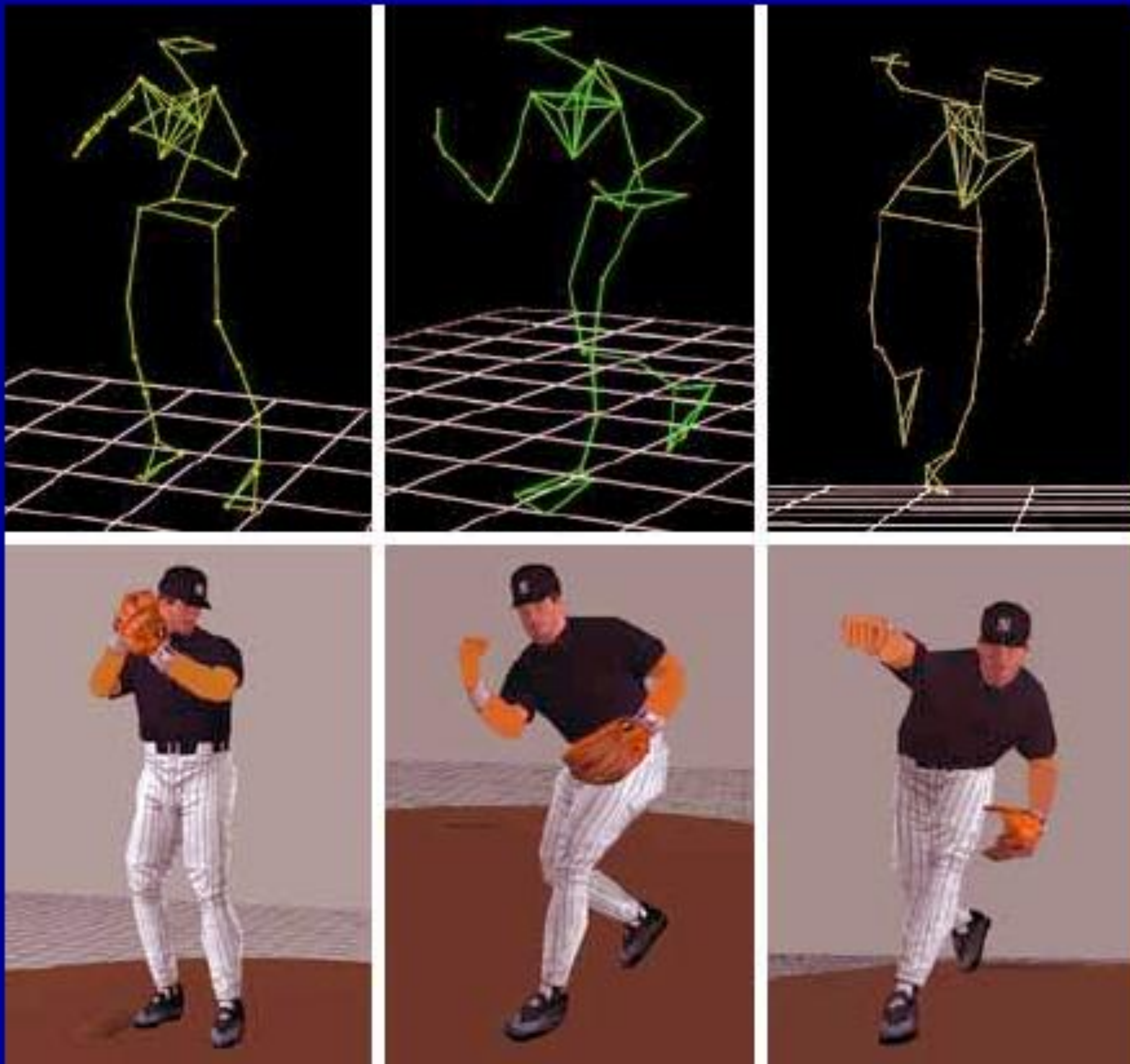
- Motion capture lab at CMU (1^{ST} Floor of Wean):
  - Vicon M camera system, 12 cameras
  - 9mm markers

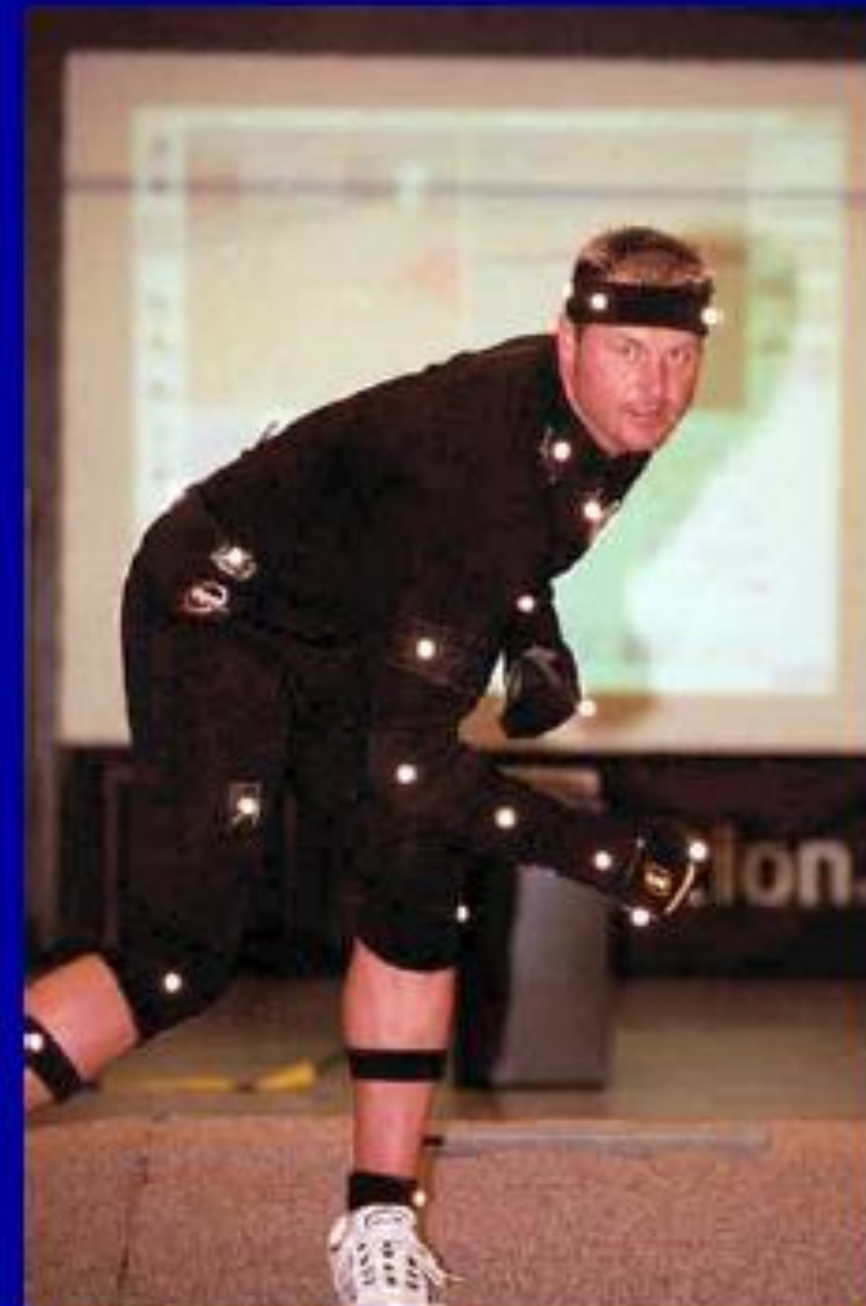
Motion Capture

Motion capture

- track motion of reference points
  - » body or face
  - » magnetic
  - » optical
  - » exoskeletons
- convert to joint angles (not so straightforward)
- use these angles to drive an articulated 3-D model
- modify the motion for the situation
- give the user control

Motion Capture



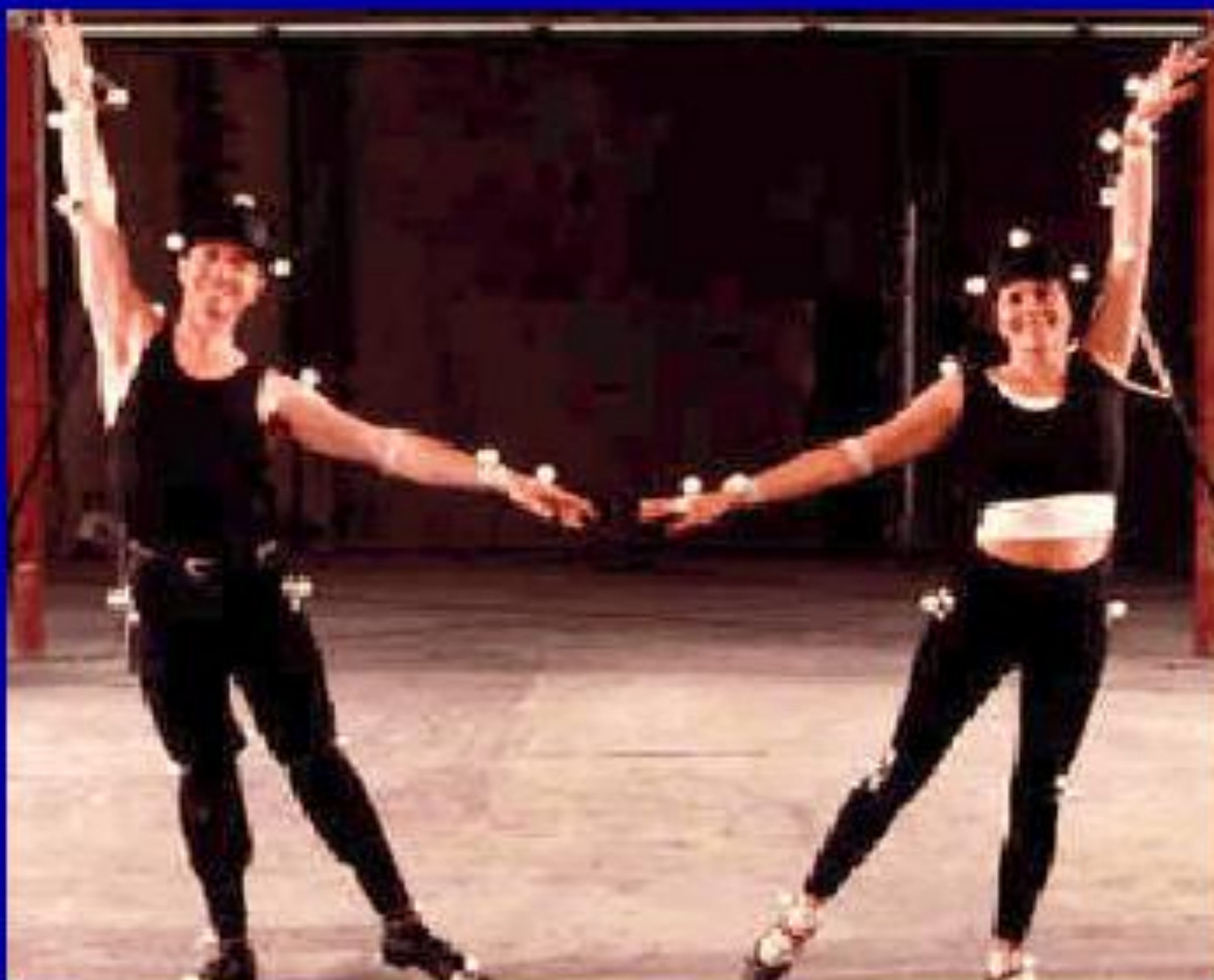


http://popularmechanics.com/technology/computers/2001/11/motion_sickness/index3.phtml

Technologies: Optical Passive

Vicon, Motion Analysis

Position of markers only

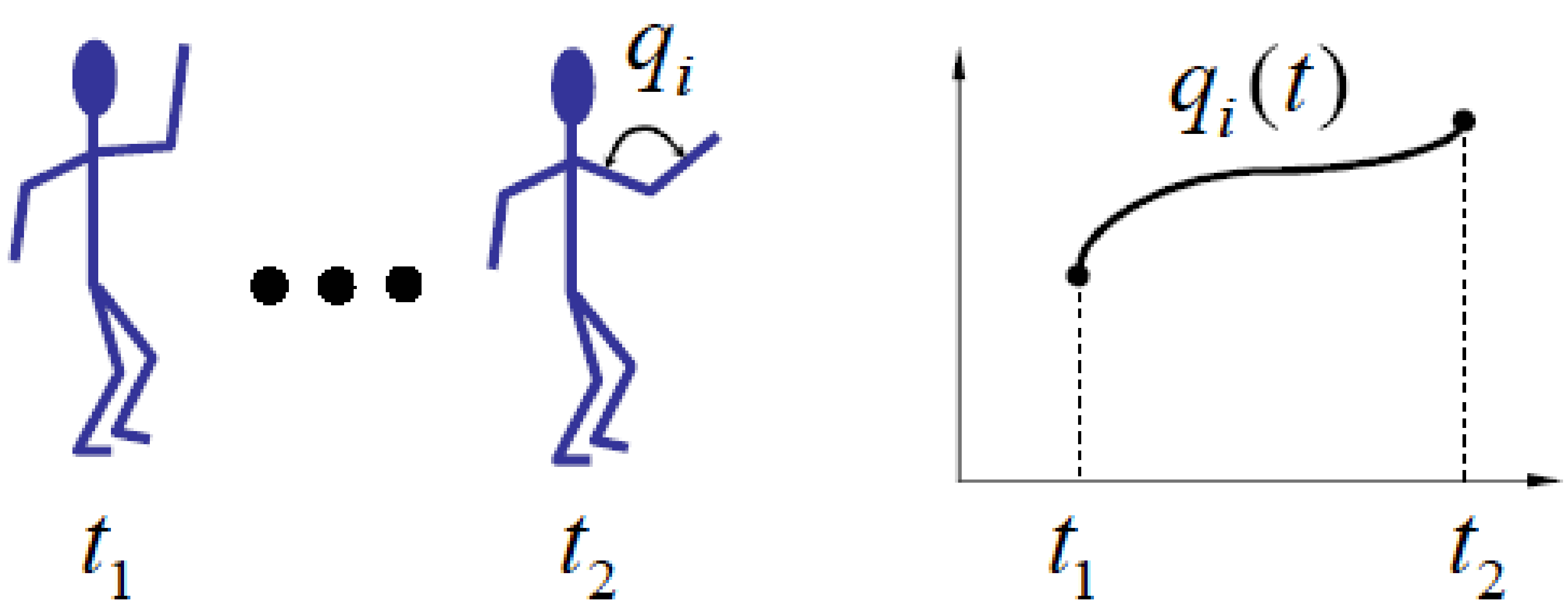


Articulated Models

Articulated models:

- rigid parts
- connected by joints

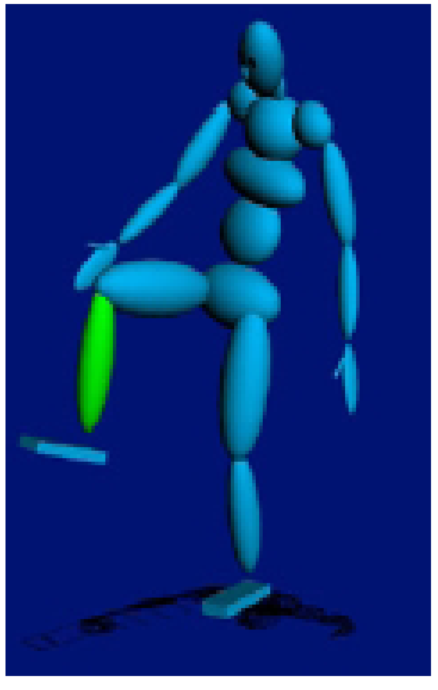
They can be animated by specifying the joint angles (or other display parameters) as functions of time.



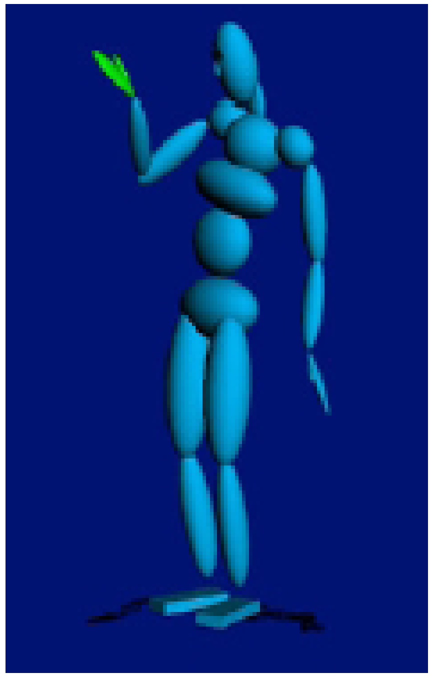
Forward Kinematics

Describes the positions of the body parts as a function of the joint angles.

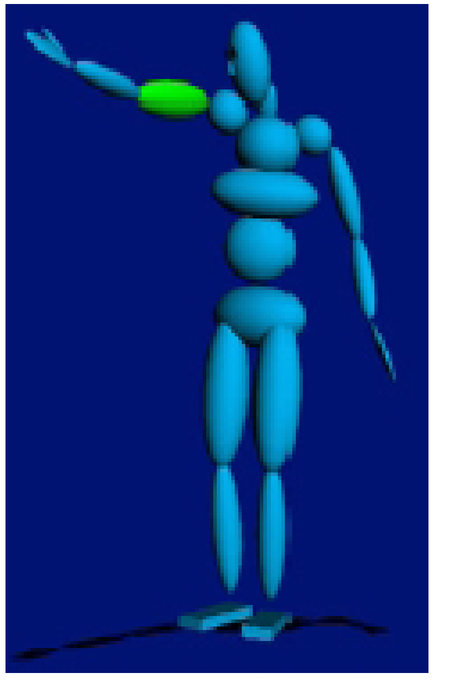
1 DOF: knee



2 DOF: wrist

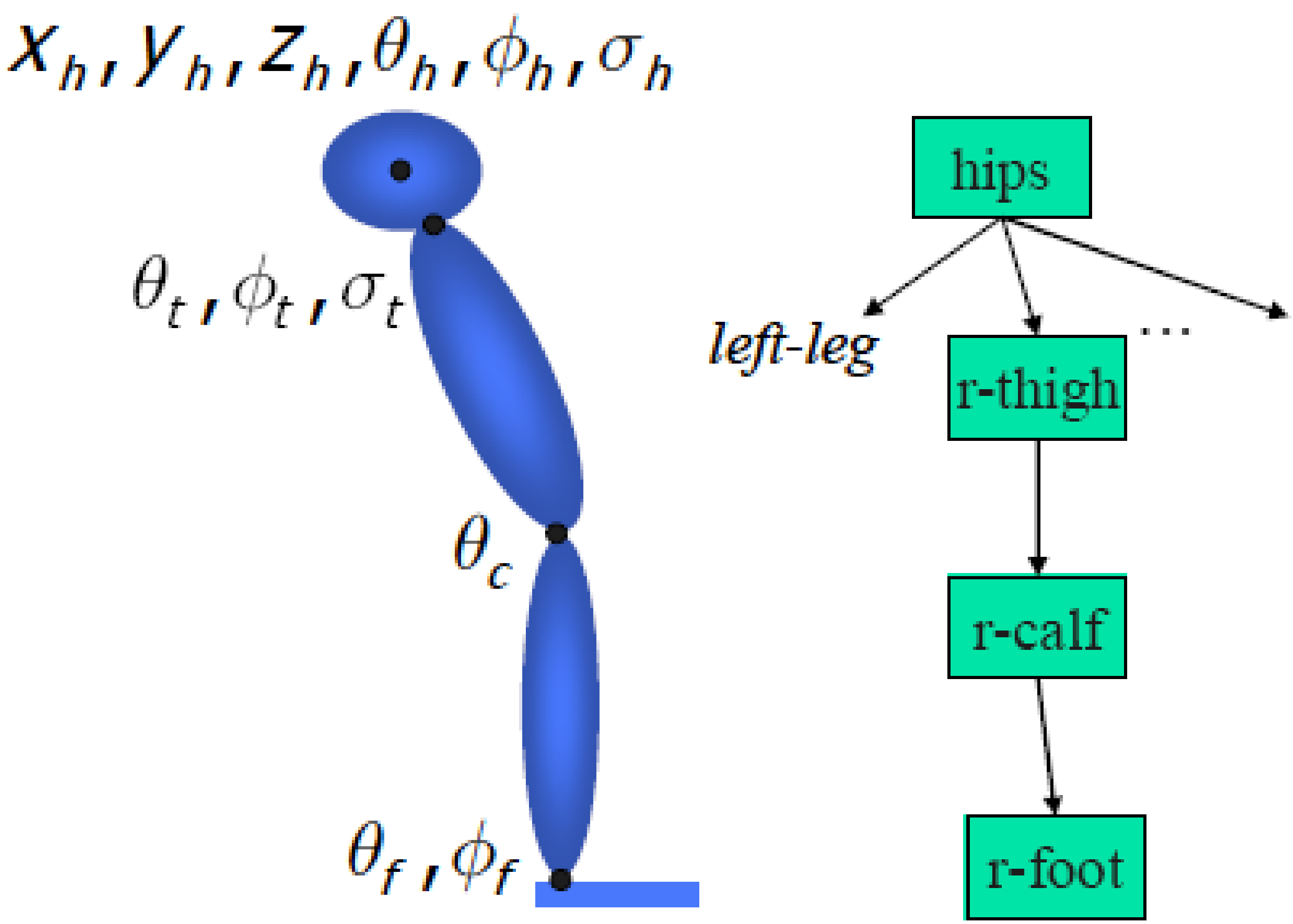


3 DOF: arm

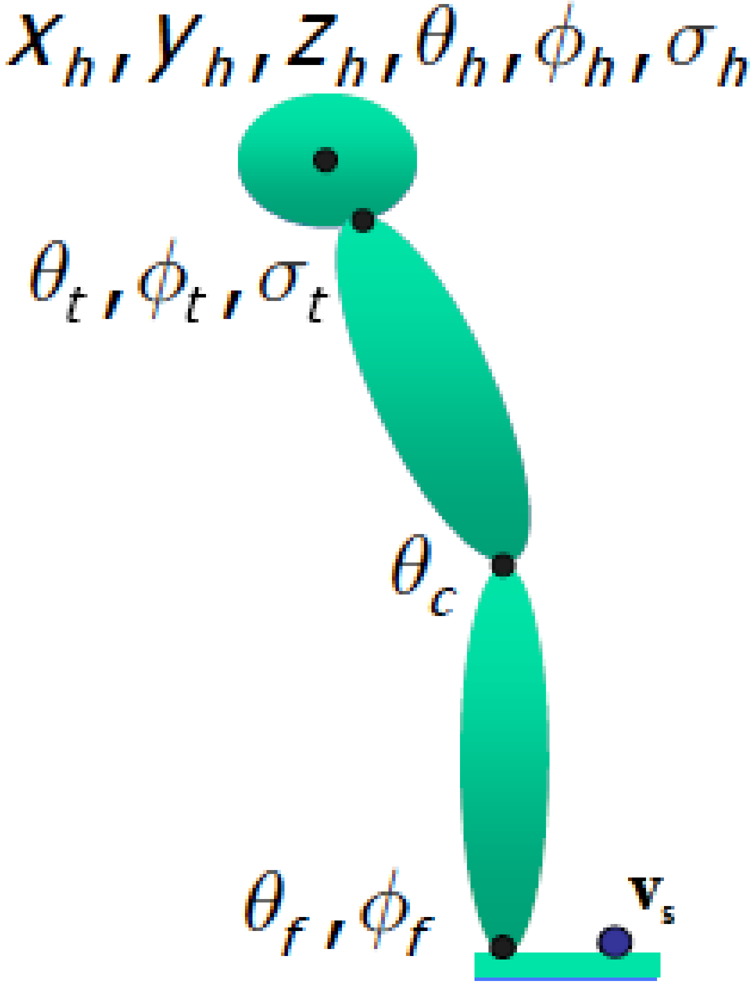


Skeleton Hierarchy

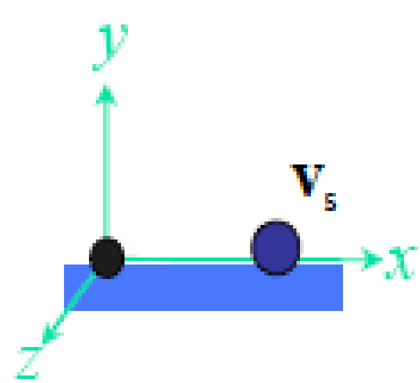
Each bone transformation described relative to the parent in the hierarchy:



Forward Kinematics



Transformation matrix for a sensor/effecter $\mathbf{v}_s$ is a matrix composition of all joint transformation between the sensor/effecter and the root of the hierarchy.



$$\mathbf{v}_w = \mathbf{T}(x_h, y_h, z_h)\mathbf{R}(\theta_h, \phi_h, \sigma_h)\ \mathbf{TR}(\theta_t, \phi_t, \sigma_t)\ \mathbf{TR}(\theta_c)\ \mathbf{TR}(\theta_f, \phi_f)\ \mathbf{v}_s$$

$$v_w = \mathbf{S}\left(\underbrace{x_h, y_h, z_h, \theta_h, \phi_h, \sigma_h, \theta_t, \phi_t, \sigma_t, \theta_c, \theta_f, \phi_f}_{\mathbf{p}}\right) v_s = \mathbf{S}(\mathbf{p})\, v_s$$

Inverse Kinematics

Forward Kinematics

- Given the skeleton parameters (position of the root and the joint angles) ***p*** and the position of the sensor/effecter in local coordinates v_s, what is the position of the sensor in the world coordinates v_w.
- Not too hard, we can solve it by evaluating $\mathbf{S}(\mathbf{p})v_s$

Inverse Kinematics

- Given the the position of the sensor/effecter in local coordinates v_s and the position of the sensor in the world coordinates v_w, what are the skeleton parameters ***p***.
- Much harder requires solving the inverse of

the non-linear function $\mathbf{S}(\mathbf{p})$

- We can solve it by root-finding $\mathbf{p}$? such that $\mathbf{S}(\mathbf{p})v_s - \mathrm{v_w} = 0$
- We can solve it by optimization $\underset{\mathbf{p}}{\text{minimize}} \ \left(\mathbf{S}(\mathbf{p})v_s - \mathrm{v_w}\right)^2$

Kinematics vs. Dynamics

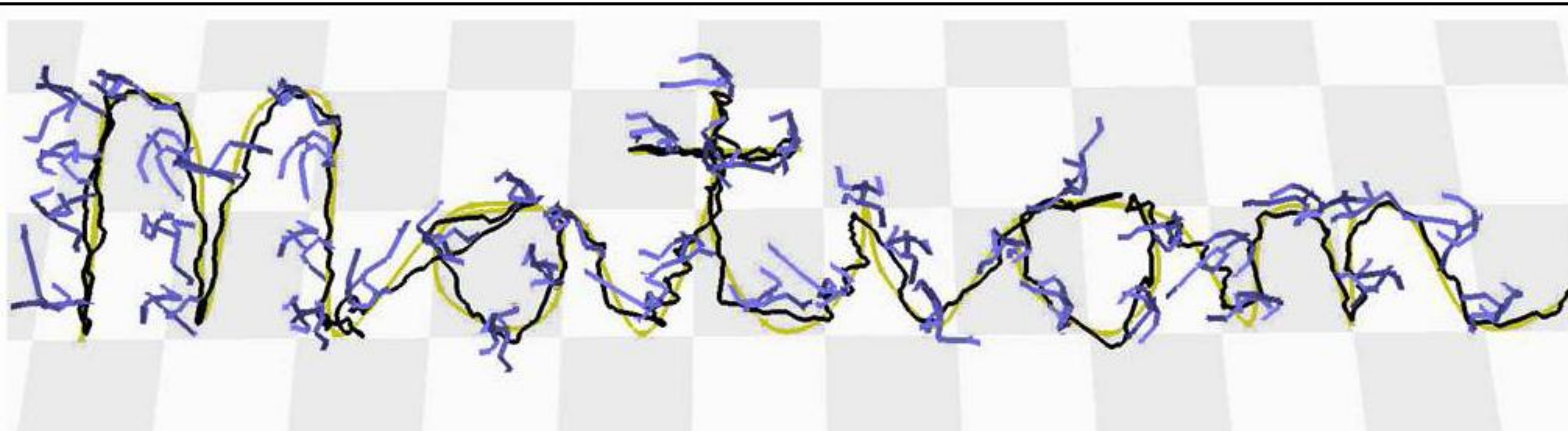
Kinematics

Describes the positions of the body parts as a function of the joint angles.

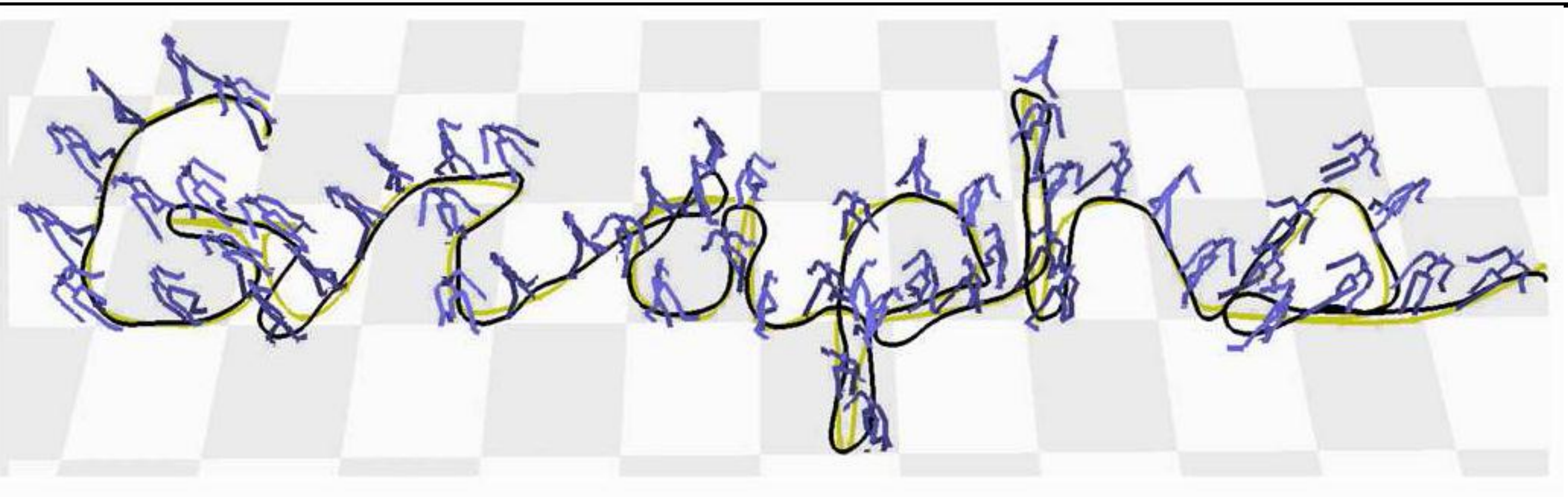
Dynamics

Describes the positions of the body parts as a function of the applied forces.

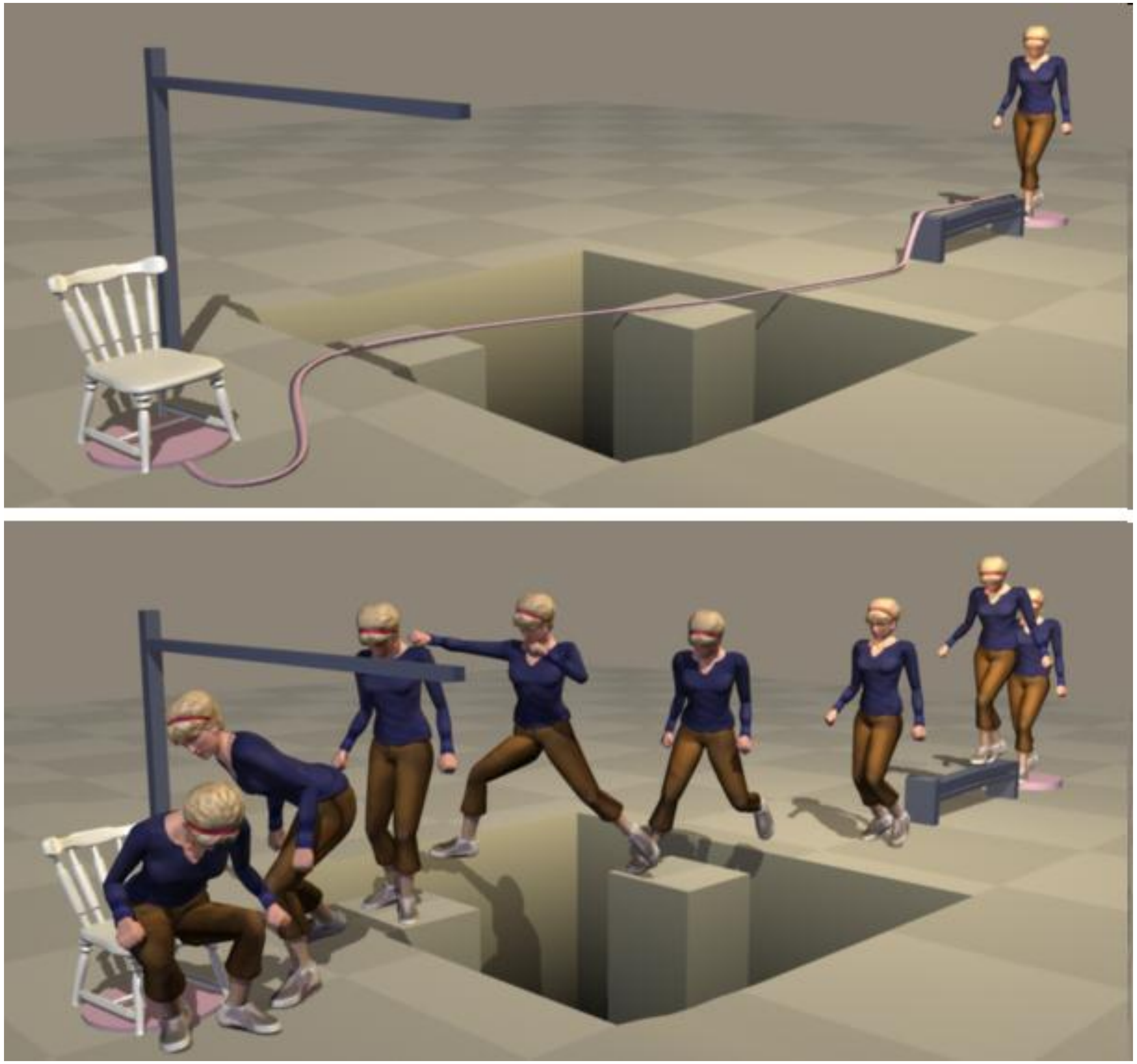
Motion Graphs



http://www.cs.wisc.edu/graphics



Interpolated Motion Graphs



http://graphics.cs.cmu.edu/

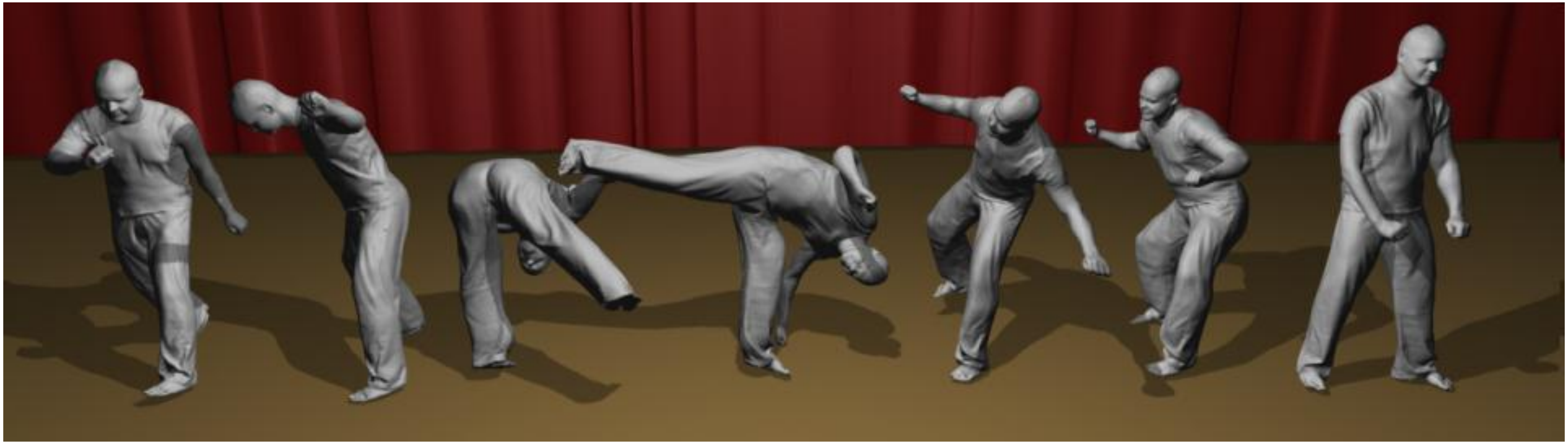
Hand Animation to 3D Animation

http://graphics.cs.cmu.edu/

Dense Body Capture

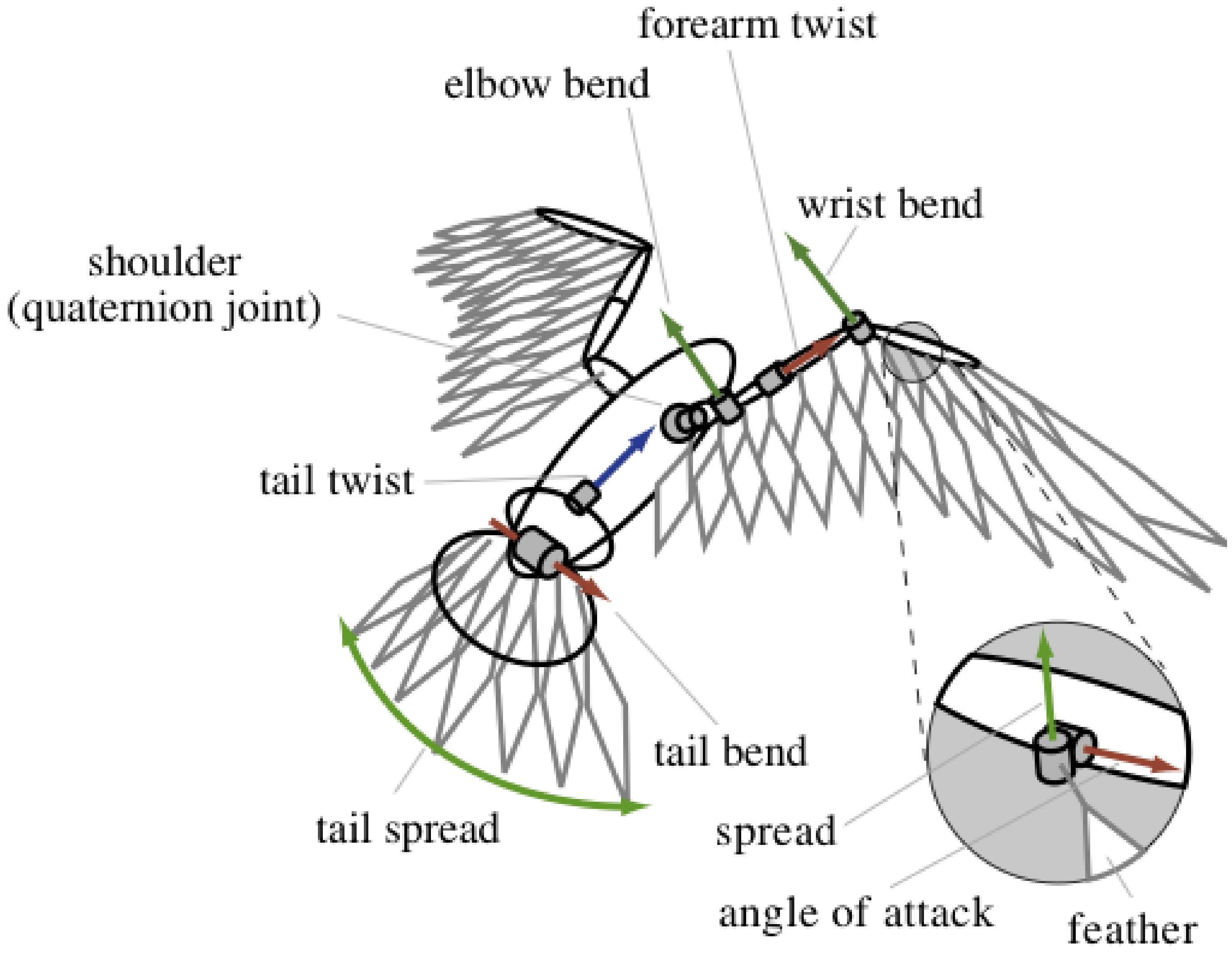
Laser Range Scanning

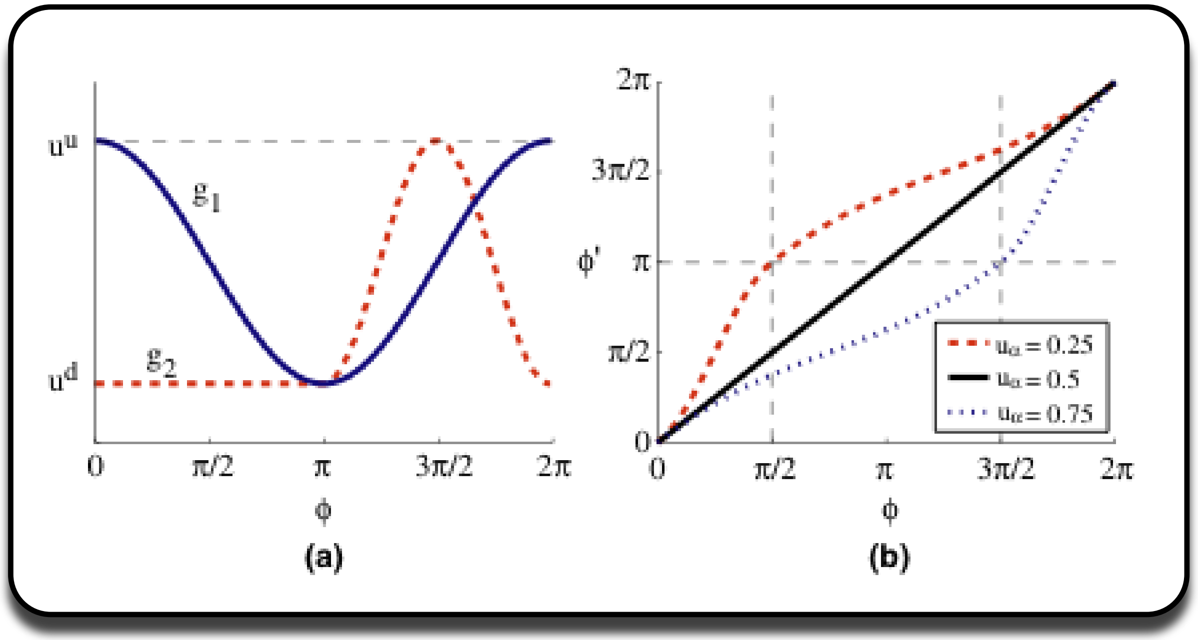
Performance Capture from Sparse Multi-view Video



de Aguiar et al

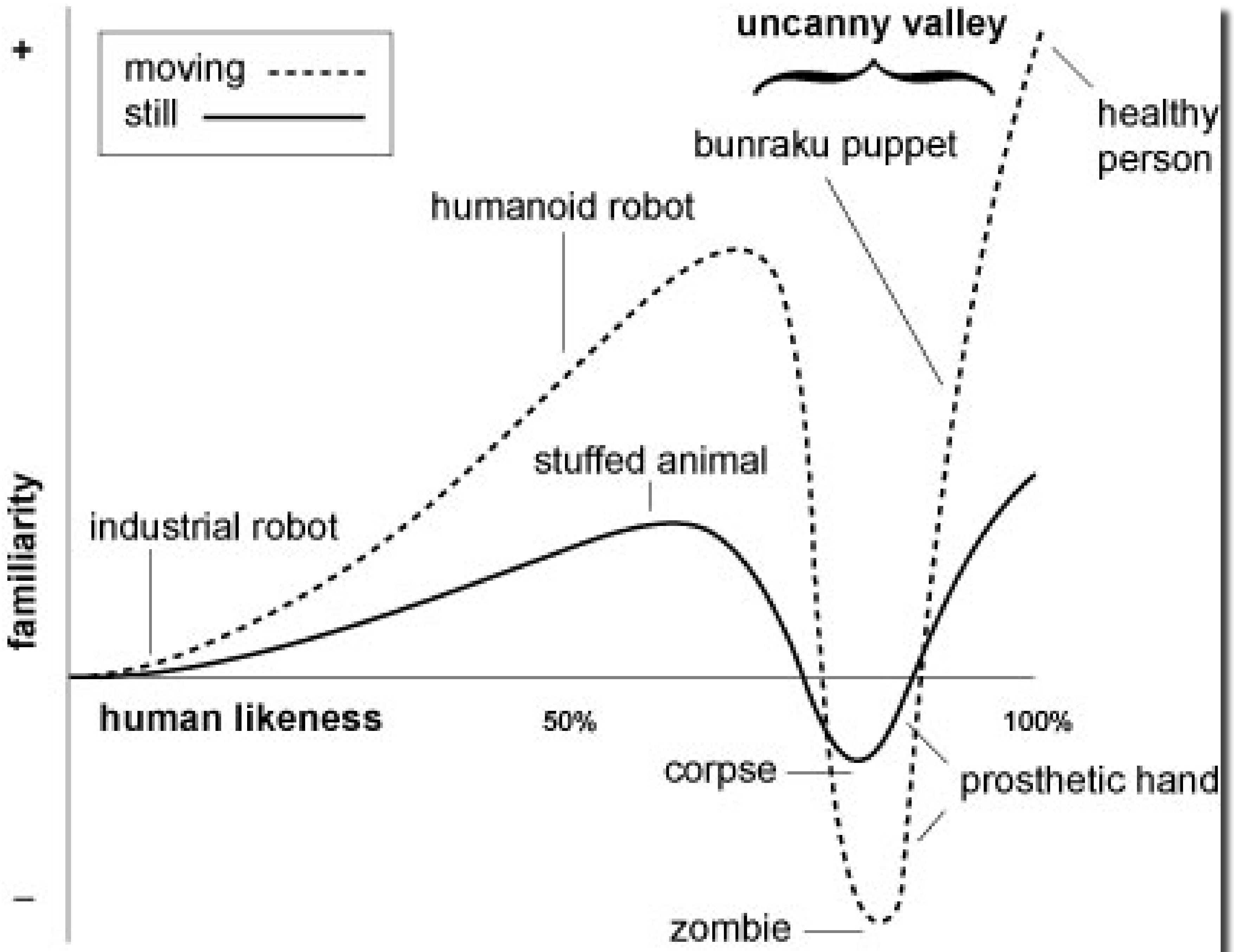
Bird Flight





source: Wu and Popović [2003]

Uncanny Valley



http://www.youtube.com/watch?v=9YaTUQaRCh4