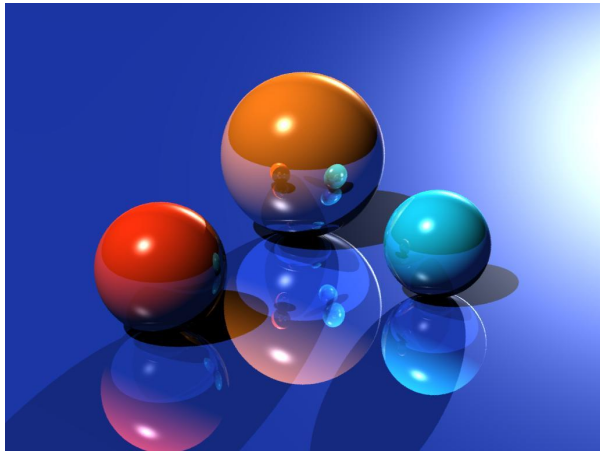
http://1.bp.blogspot.com/-DGdxCThSs20/TpMownEbDeI/AAAAAAAAAN8/04yjwR1WDsc/s1600/luxo.jpg

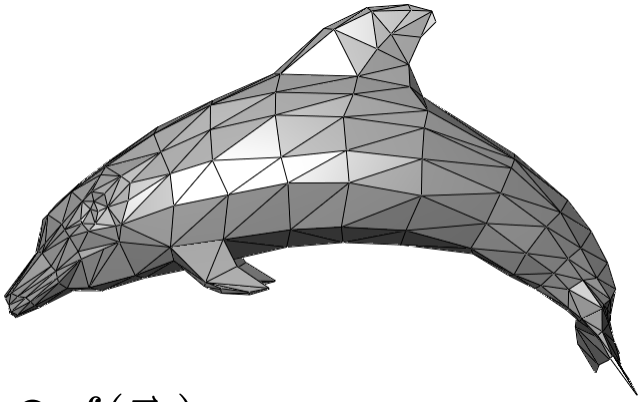
Animation Techniques

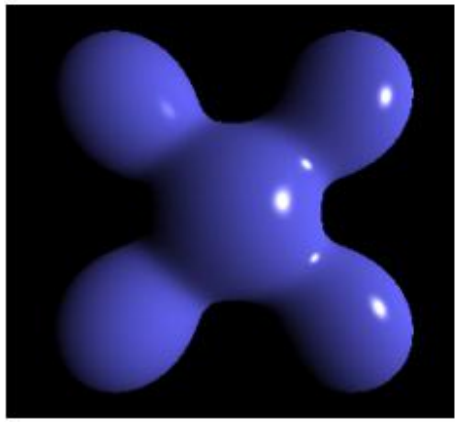
CS 148, Summer 2012
Introduction to Computer Graphics and Imaging

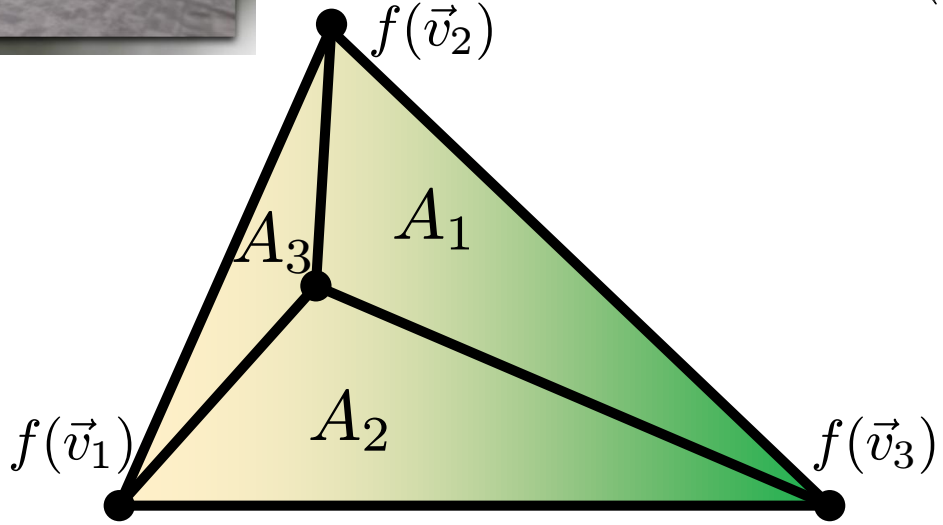
Justin Solomon

CS 148 So Far



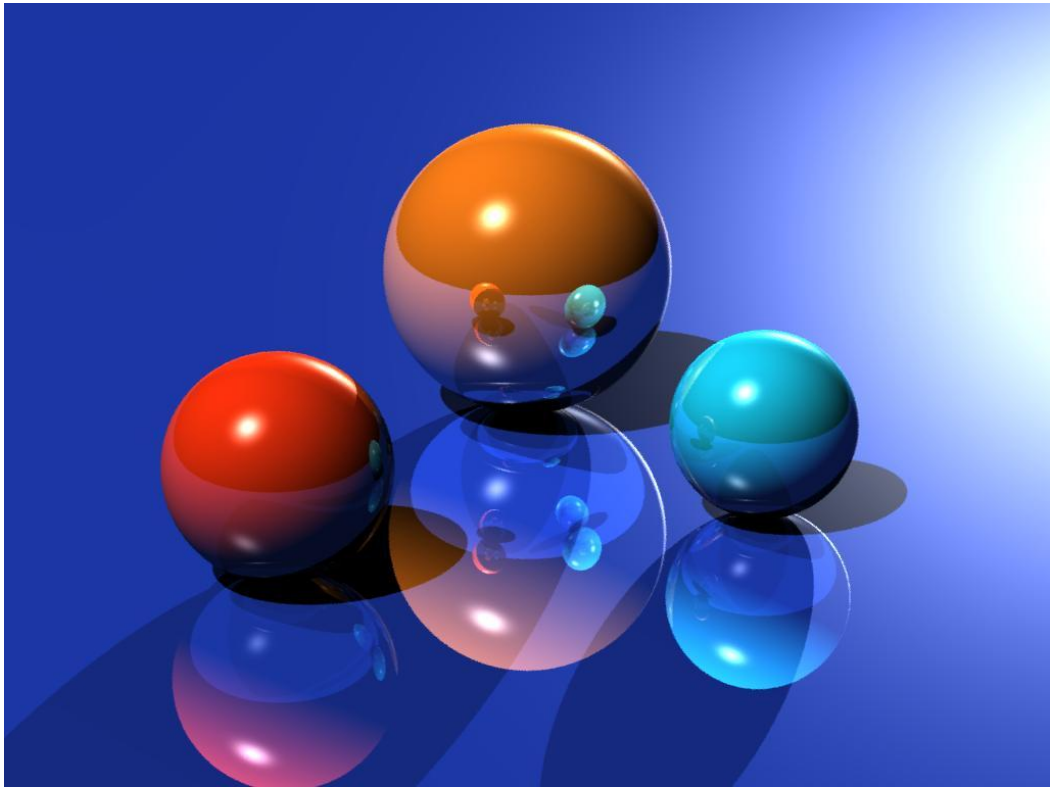


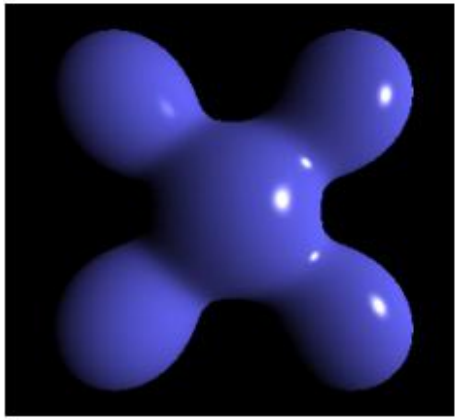




Mostly still frames

New Dimension: Time





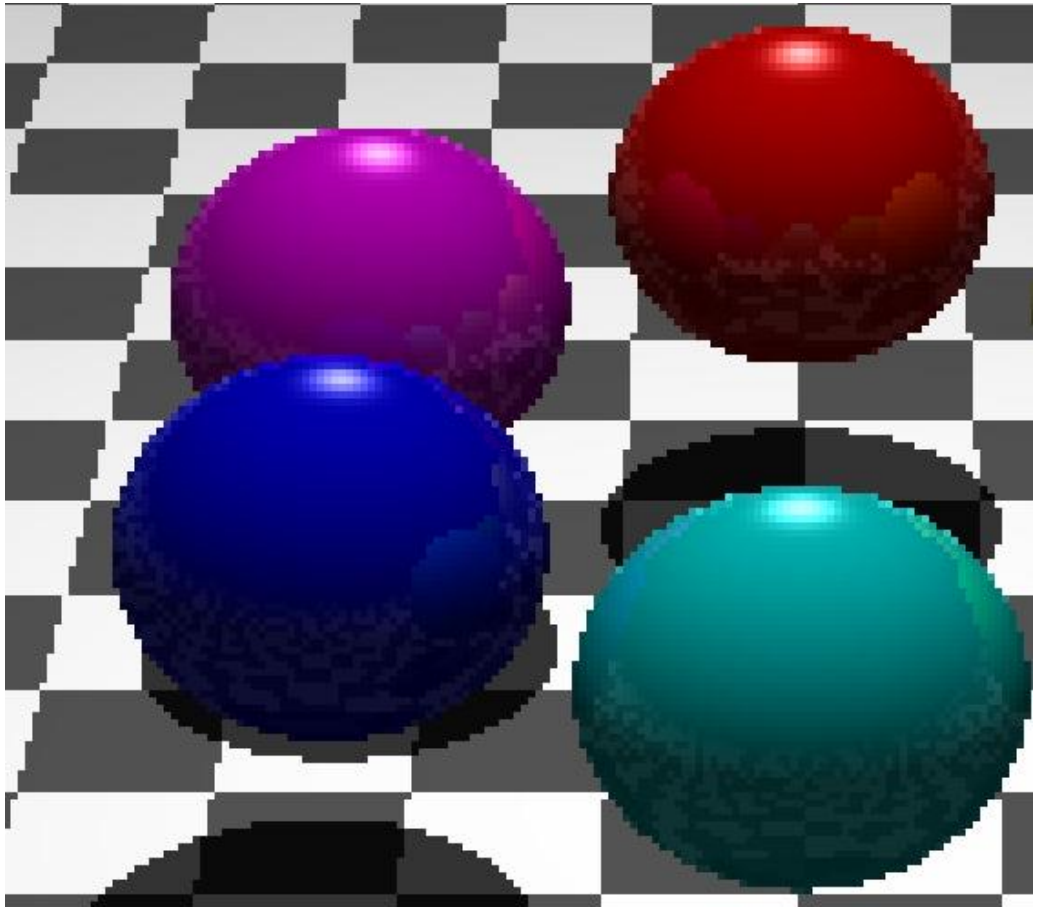
Most things stay the same

New Dimension: Time

http://images.amazon.com/images/G/01/dvd/aplus/transformers/transformers8-hi.jpg

Some things get easier

New Dimension: Time



Many things get harder

Properties of Traditional Animation

- **Squash and stretch**
  Distortion to convey flexibility
- **Timing**
  Speed conveys mass and personality
- **Anticipation**
  Prepare audience for action
- **Follow-through and overlap**
  Continuity with next action

Lasseter 1987, via http://run.usc.edu/cs480-s11/lec19-animation/19-animation-6up.pdf

Properties of Traditional Animation

- **Slow in and out**

  Transition speed conveys subtleties

- **Arcs**

  Motion is usually curved

- **Exaggeration**

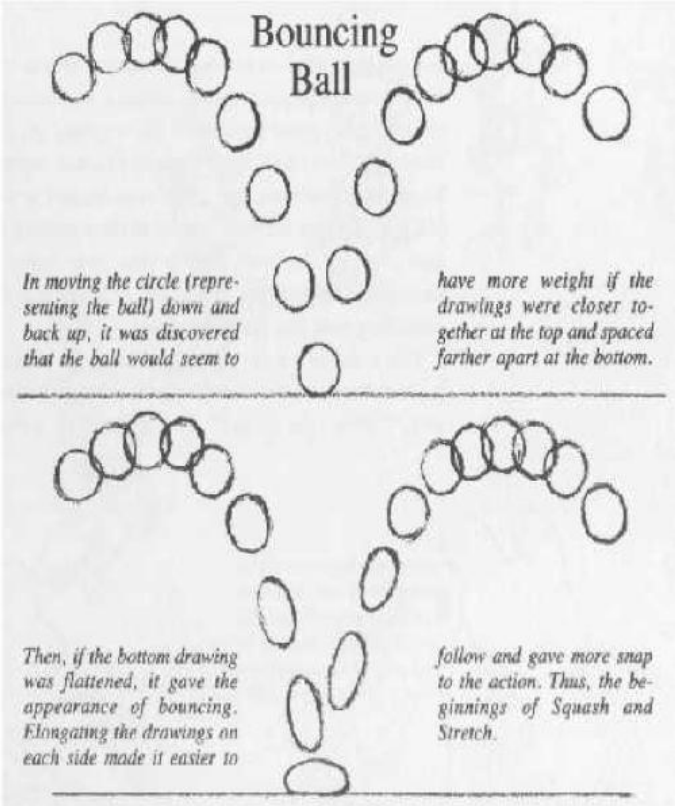
  Emphasize emotional content

- **Secondary action**

  Occurs as a consequence

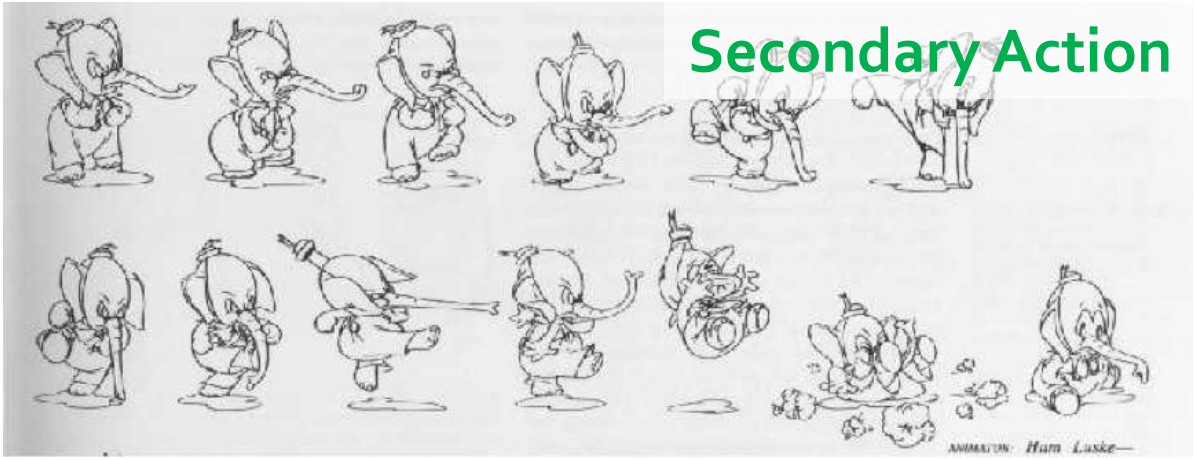
Lasseter 1987, via http://run.usc.edu/cs480-s11/lec19-animation/19-animation-6up.pdf

Properties of Traditional Animation



Squash/Stretch

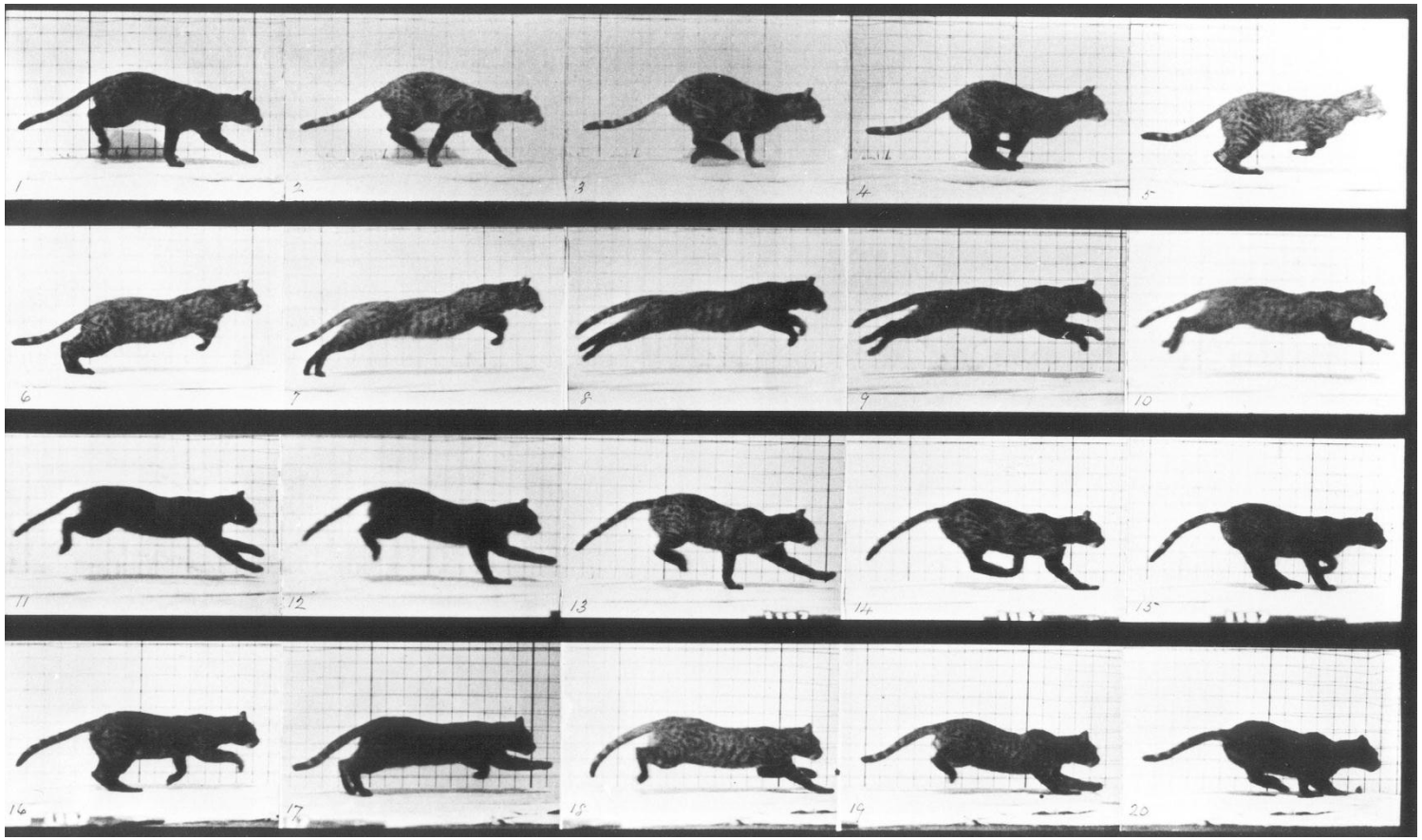
Anticipation



Secondary Action

http://run.usc.edu/cs480-s11/lec19-animation/19-animation-6up.pdf

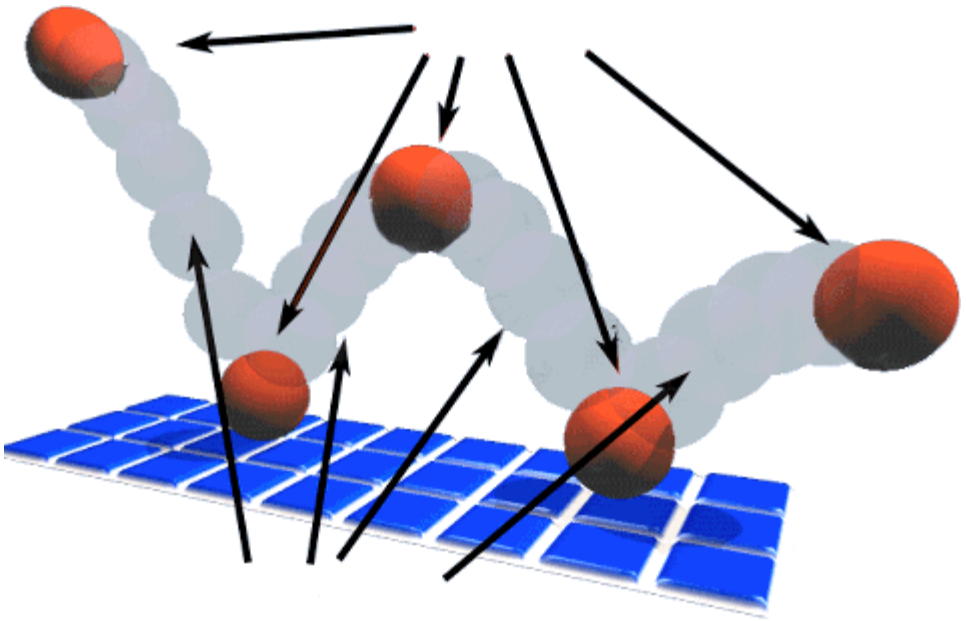
Specifying Animation



http://sphmajor.files.wordpress.com/2012/05/leaping_cat_by_animation_stock.jpg

Specifying every frame is hard

Keyframes



Automatically fill in motion between these points in time.

http://graphics.stanford.edu/courses/cs148-10-summer/docs/10_anim_interact.pdf

Specify significant poses

Neglected Issue

http://www.youtube.com/watch?v=47d_genmk6A

Global keyframes make unnatural motion

Not a New Idea

http://www.superrune.com/technical/tutorial_breakdown.php

Tweening: Not a fun job!

CAPS, Late 1980s

Digital ink and paint system.

Rescuers Down Under, 1990

http://img2-3.timeinc.net/ew/i/2011/10/06/Rescuers-Down-Under_610.jpg

Computer-Aided Production System

CAPS, Late 1980s

http://www.youtube.com/watch?v=ckE5U9FsgsE

Computer-Aided Production System

Software for Keyframed Animation

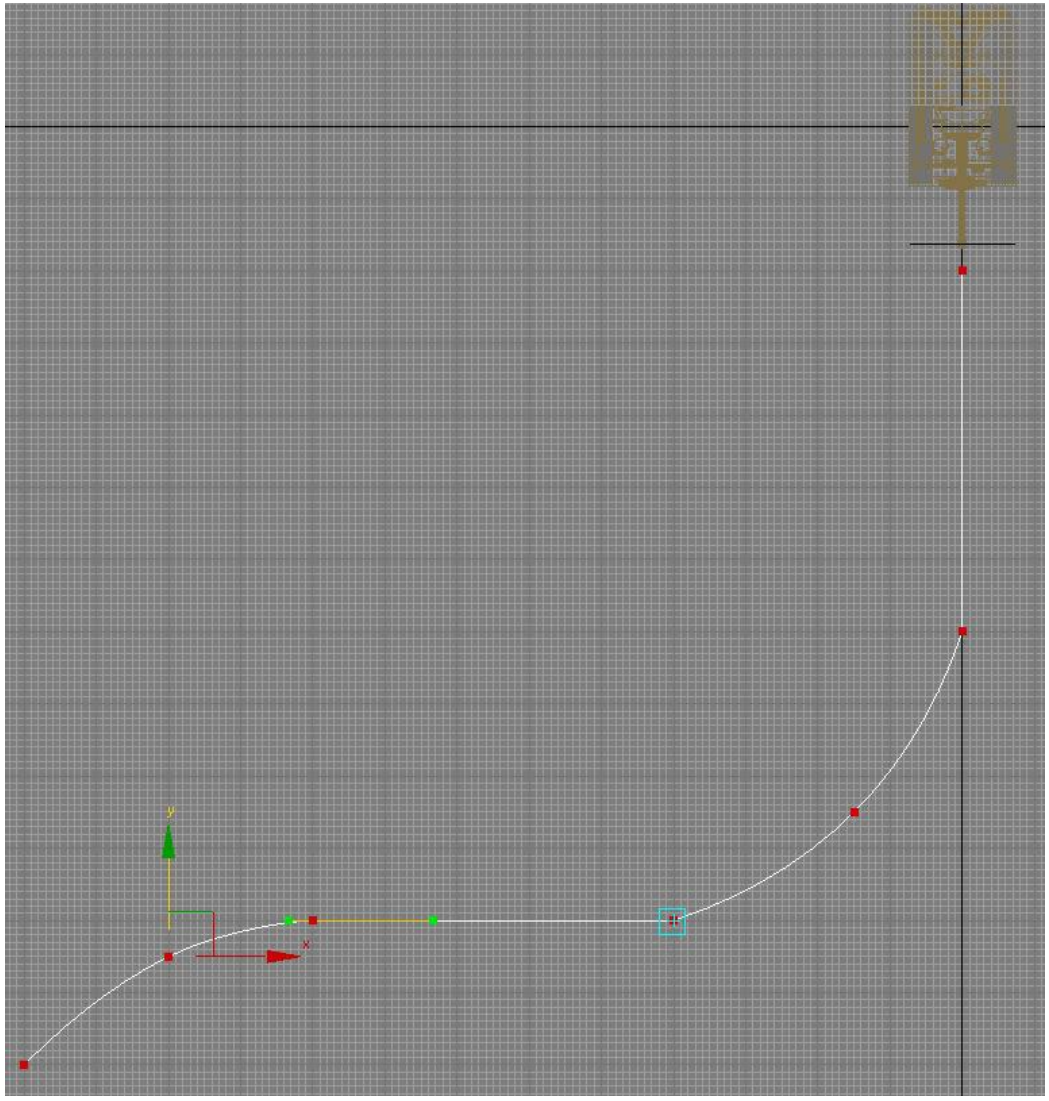
Artist specifies keyframes, computer does tweening.

Software for Keyframed Animation

Artist specifies keyframes,
computer does ~~tweening~~.

interpolation

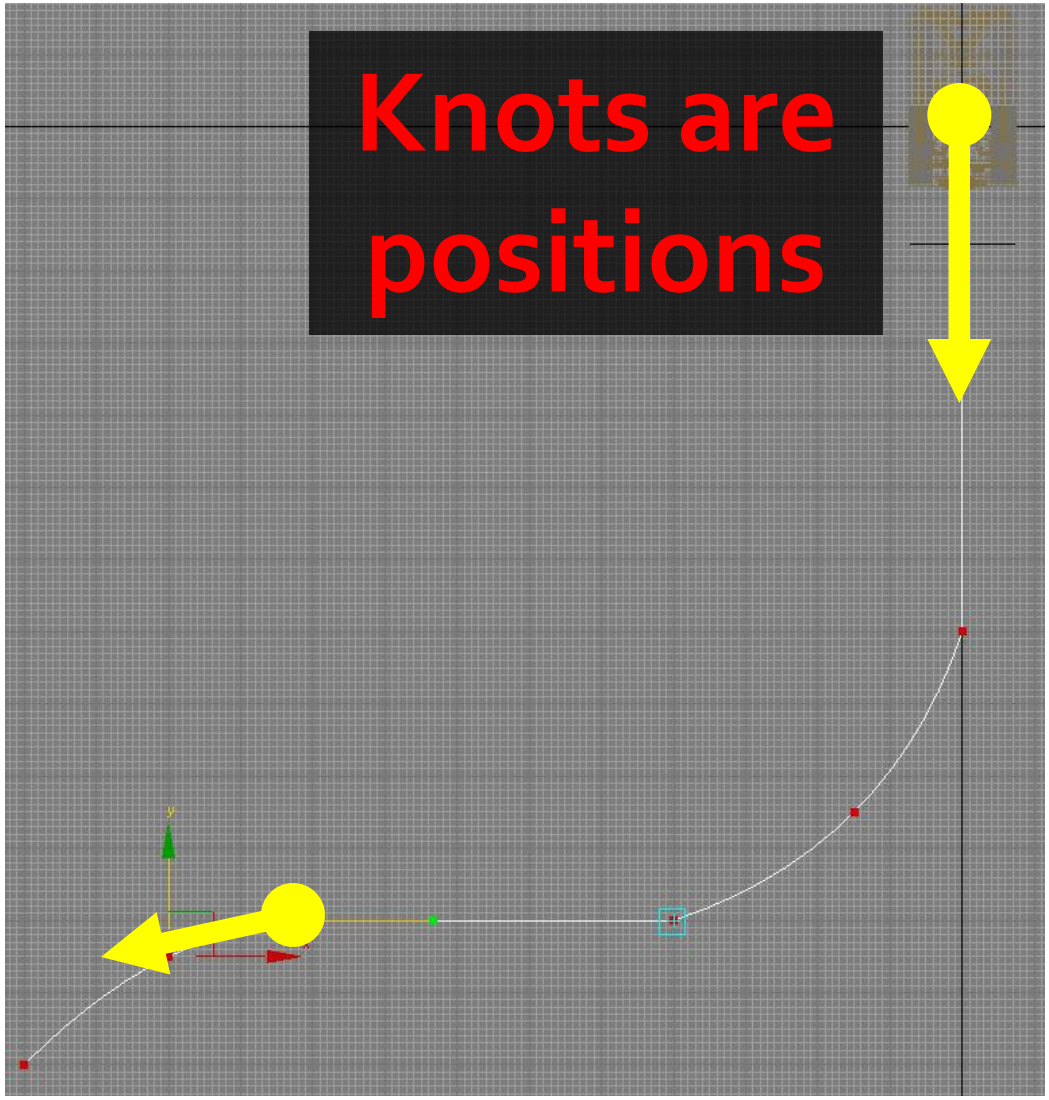
Animation Splines



Curves specify **paths** that objects take over time.

http://media.photobucket.com/image/recent/tango_s/tank_animation_spline.jpg

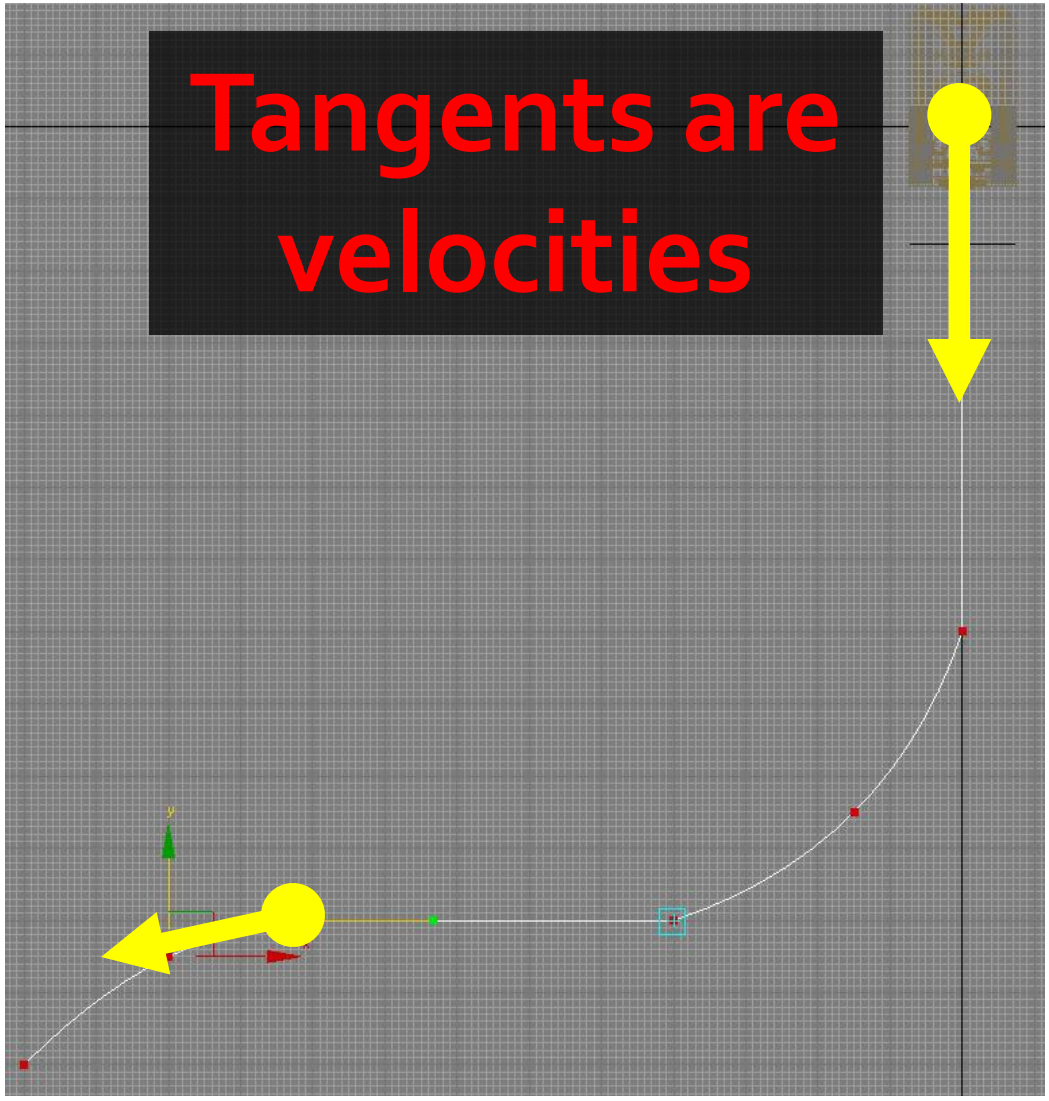
Animation Splines



Curves specify **paths** that objects take over time.

http://media.photobucket.com/image/recent/tango_s/tank_animation_spline.jpg

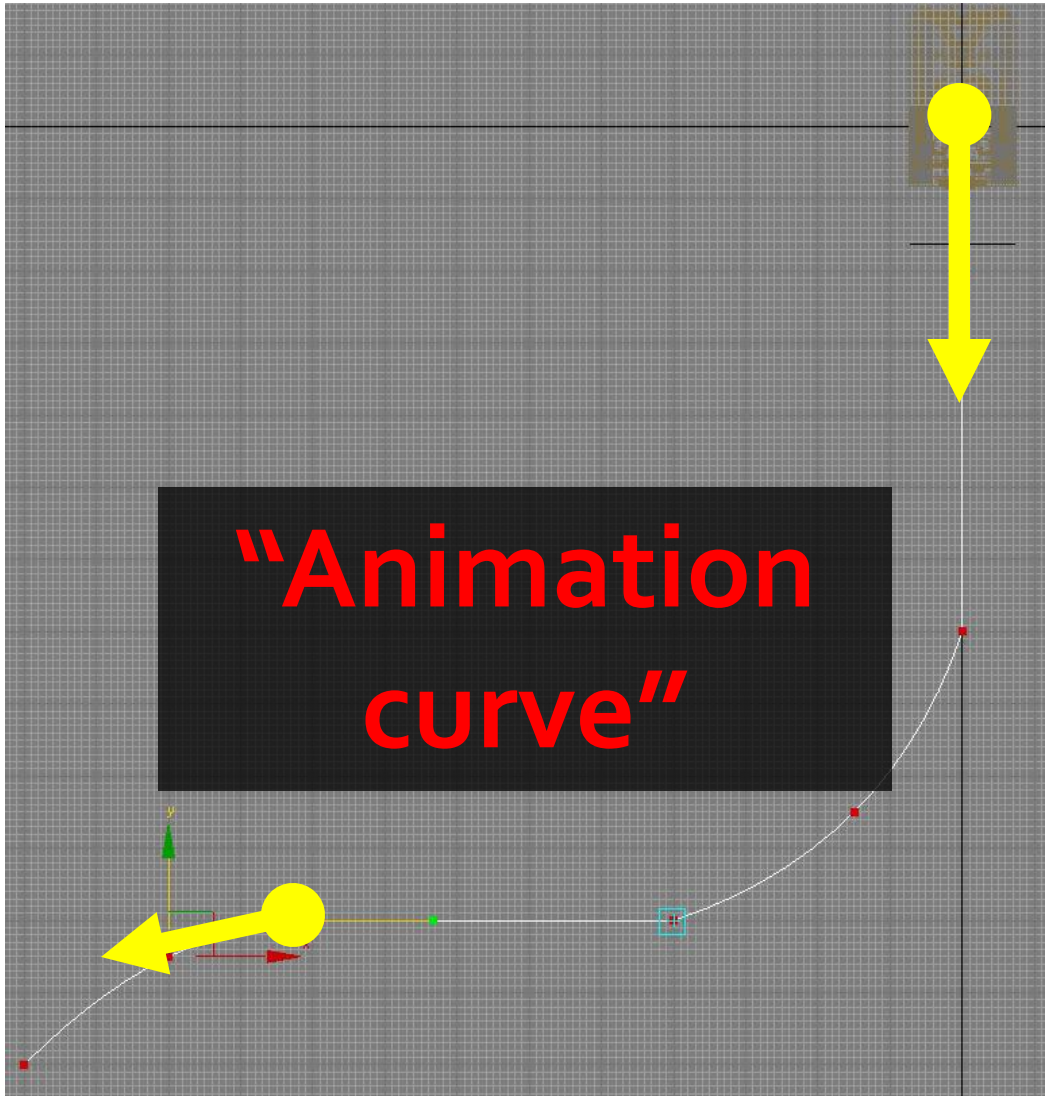
Animation Splines



Curves specify **paths** that objects take over time.

http://media.photobucket.com/image/recent/tango_s/tank_animation_spline.jpg

Animation Splines



Curves specify **paths** that objects take over time.

http://media.photobucket.com/image/recent/tango_s/tank_animation_spline.jpg

Framework for Animation Curves

- **Tension**

  Sharpness near keyframes

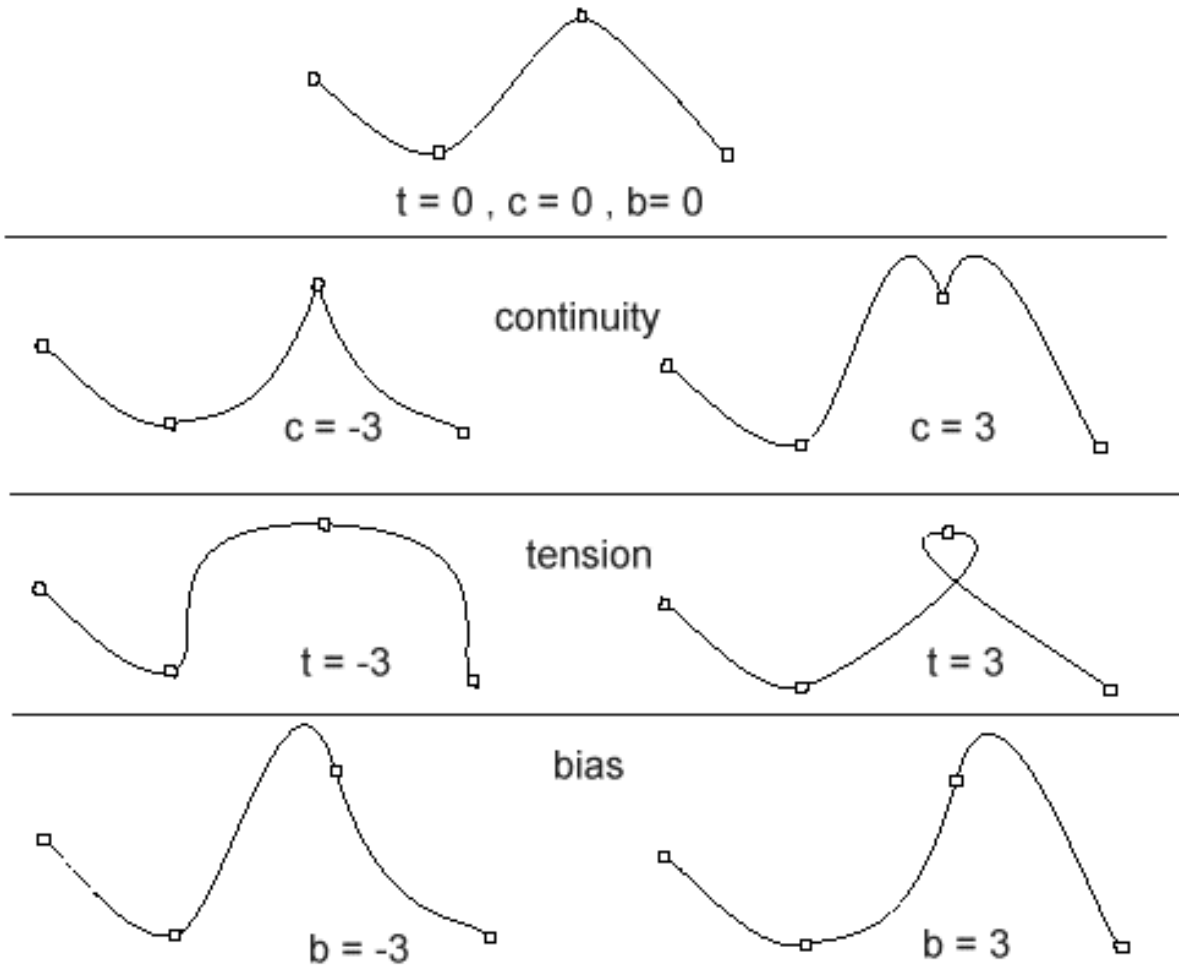
- **Continuity**

  Different in/out tangents

- **Bias**

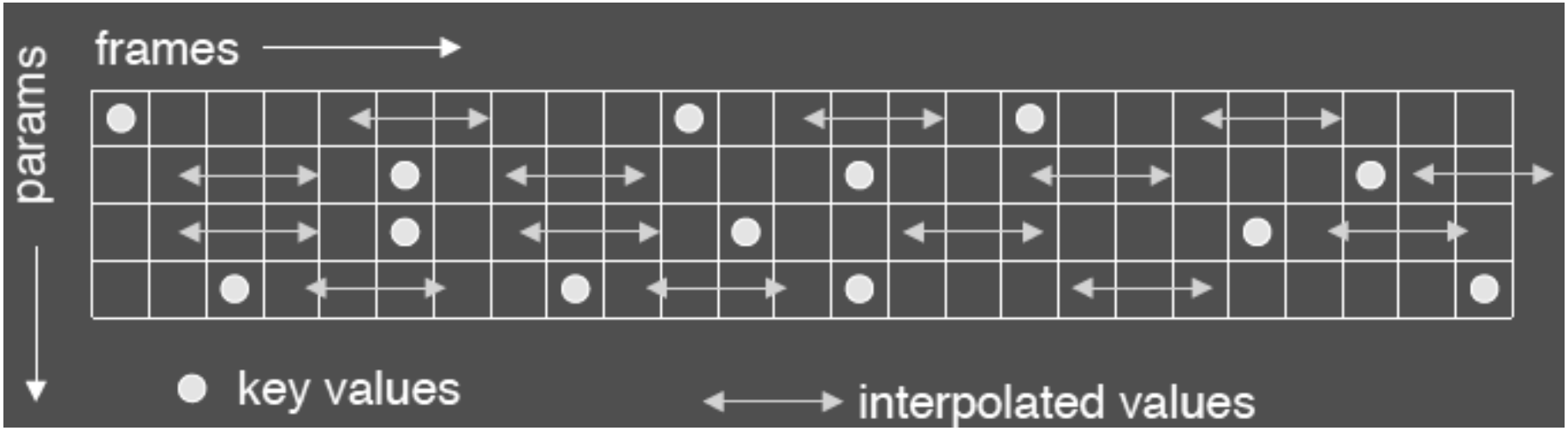
  Overshoot or undershoot

Framework for Animation Curves



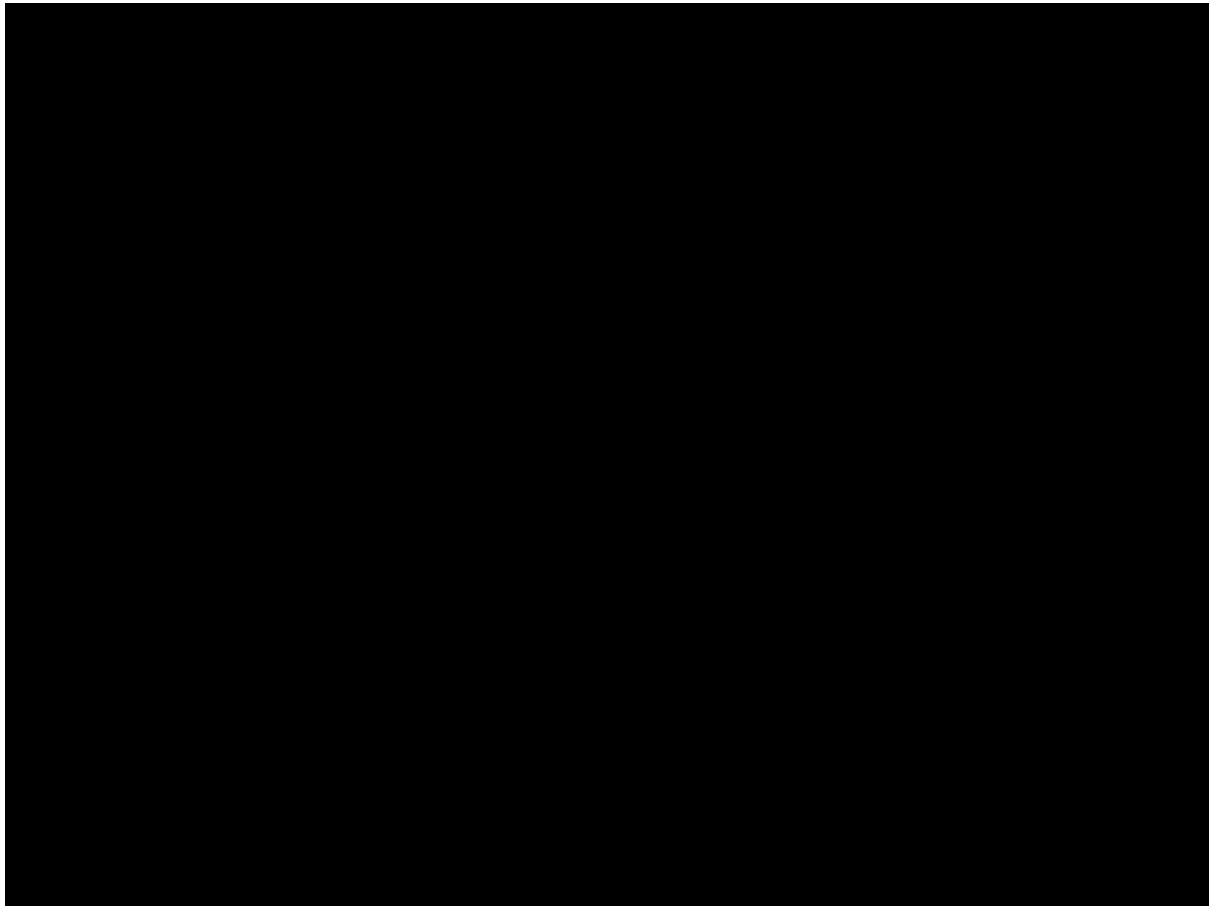
http://www.virtools.co.kr/dc/onlineref/Virtools/images/curvepointtcb.gif

Overlap



http://run.usc.edu/cs480-s11/lec19-animation/19-animation-6up.pdf

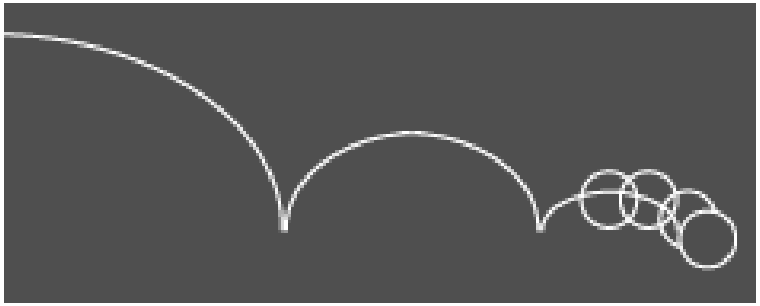
What Happens Without Overlap



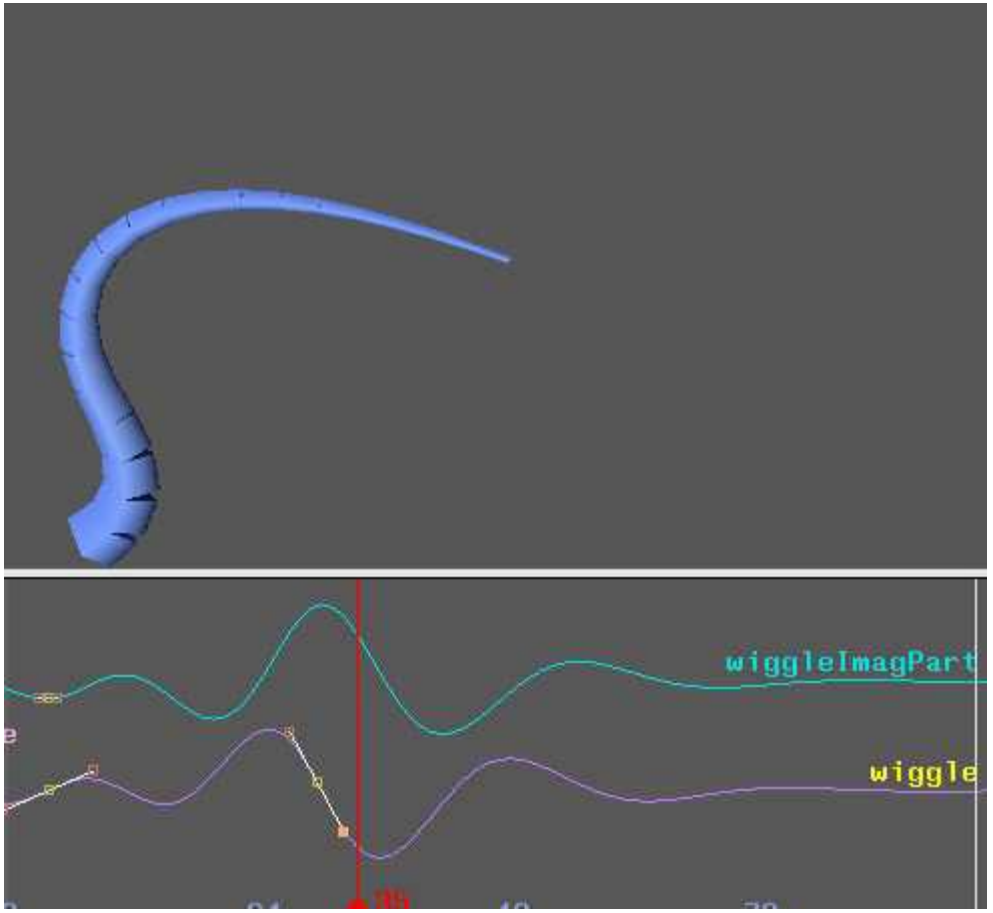
http://youtu.be/EZawqQVgkOA?t=245

Jerky motion!

Specialized Curves for Animation



C^1 discontinuities

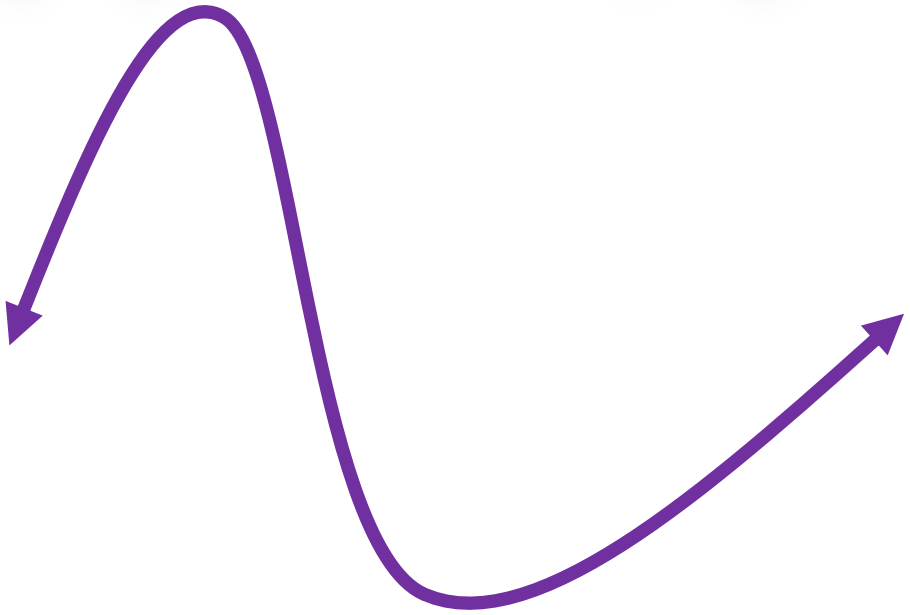


"Wiggly Splines"

Kass and Anderson, SIGGRAPH 2008

Parameterization

$$\gamma(t) \mapsto \gamma(2t)$$



Same shape, different velocities

Arc Length Parameterization

$$s(t) = \int_0^t \|\gamma'(\tilde{t})\| \, d\tilde{t}$$

Arc length

$$\gamma(t(s))$$

Arc length parameterization

Arc Length Parameterization

$$s(t) = \int_0^t \|\gamma'(\tilde{t})\| \, d\tilde{t}$$

$$\frac{d}{ds}\gamma(t(s)) = \frac{\gamma'}{ds/dt} = \frac{\gamma'}{\|\gamma'\|}$$

Unit speed!

Potential Framework

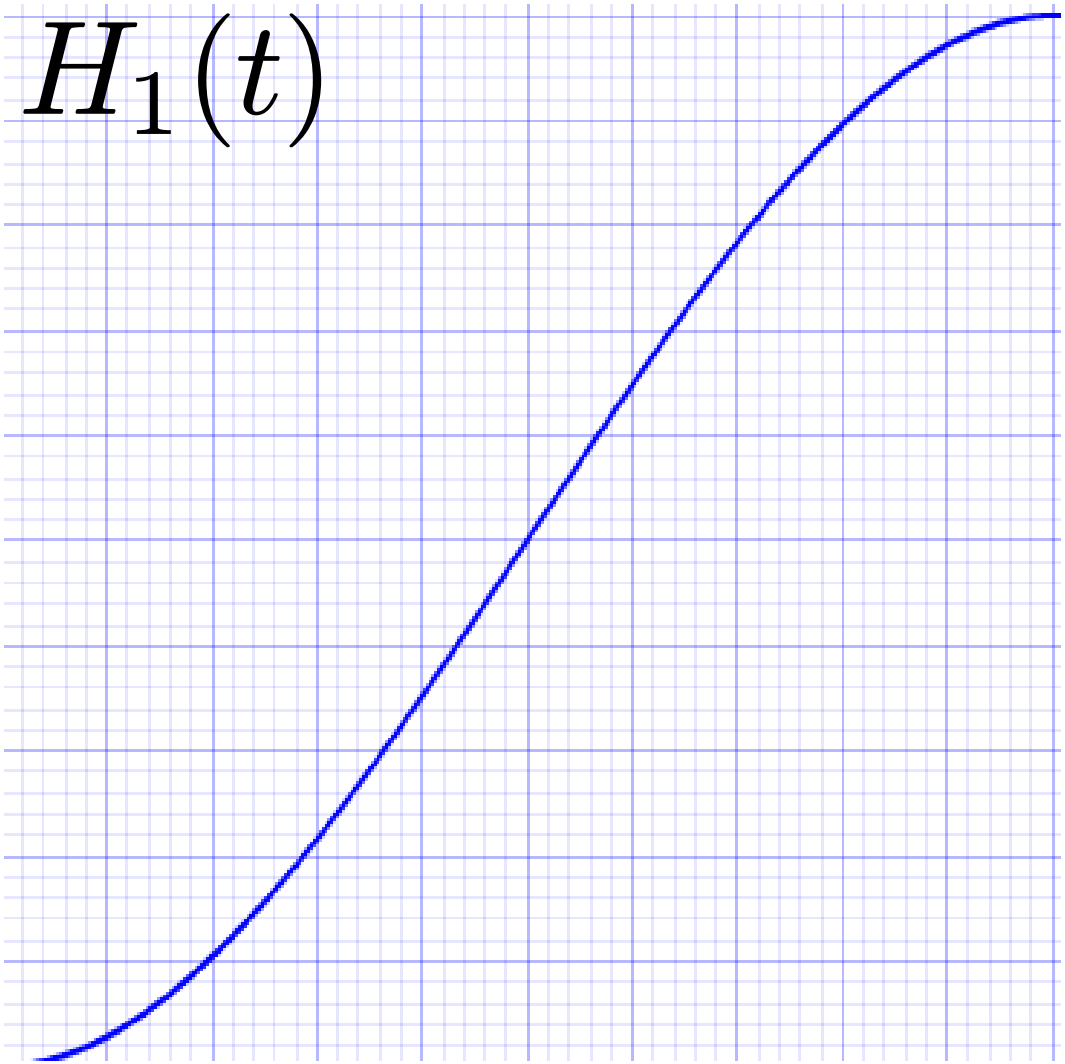
- Use splines to determine shape

$$\gamma(t)$$

- Use different splines to determine deviation from arc length parameterization a

$$\gamma(t(s(a)))$$

Recall: "Ease" Function



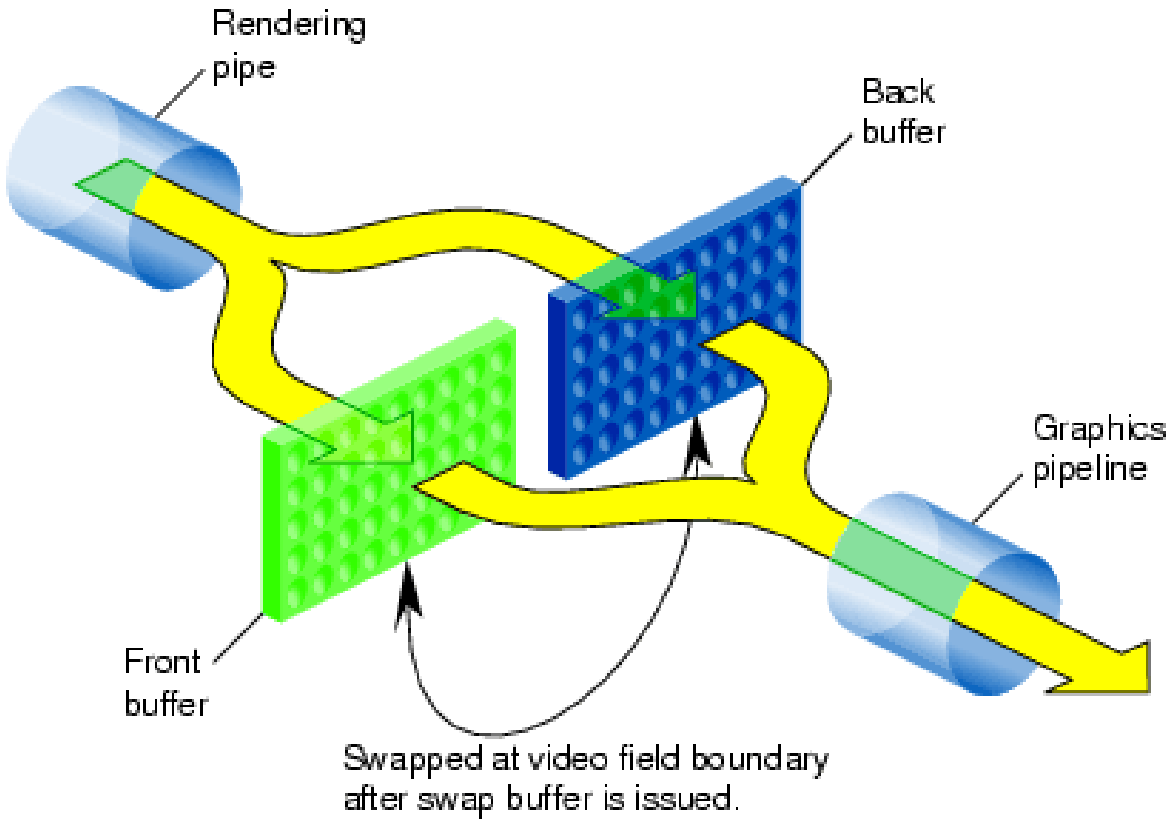
Ends slow

Starts slow

Consideration for Interactivity

If you draw directly to video buffer, the user will see the drawing happen!

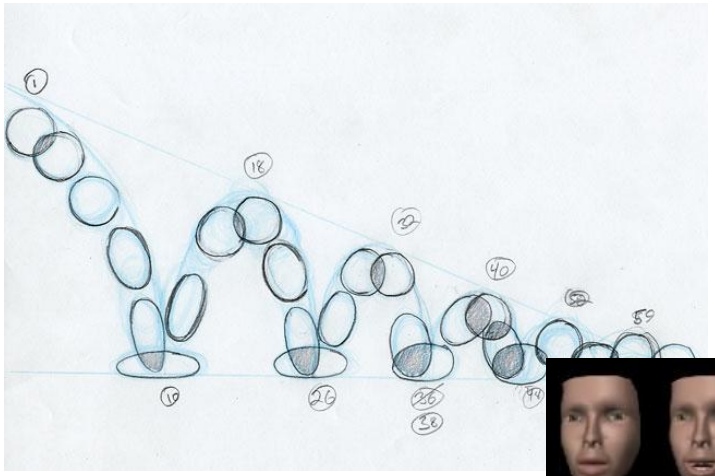
Double Buffering

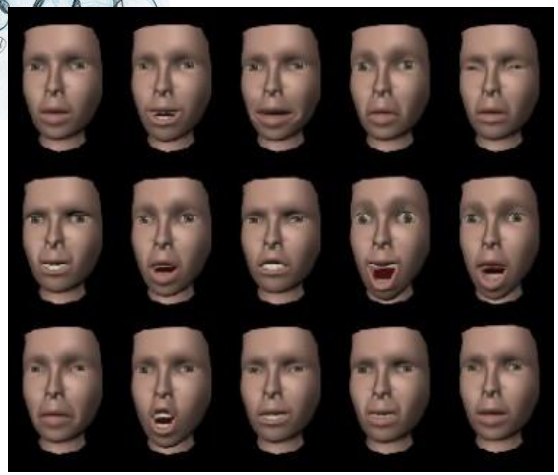


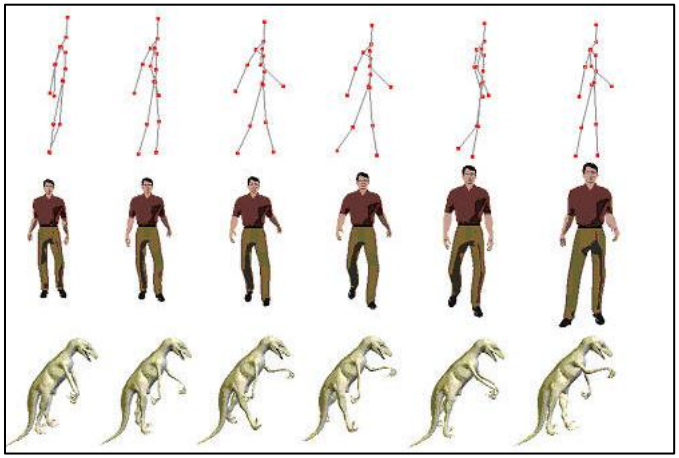
http://techpubs.sgi.com/library/dynaweb_docs/linux/SGI_Developer/books/Perf_GetStarted/sgi_html/figures/double.buffering.gif

Draw on one buffer, display on the other

Representing Motion







http://3.bp.blogspot.com/-gIg9r_-WBK8/T5pCekgleUI/AAAAAAAAAHc/05Is6dG_6F4/s1600/ball_bounce_sketch2.jpg
http://www.blendernation.com/wp-content/uploads/2007/09/blendermodo.png
http://ncca.bournemouth.ac.uk/gallery/files/innovations/2004/Gonzalez_Lisa_101/images/medium/thumbnail.jpg
http://web.cecs.pdx.edu/~fliu/project/vbha/Video%20based%20animation.jpg

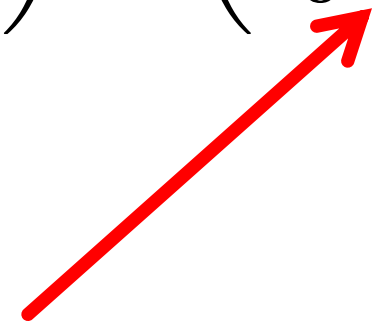
Choose structure for desired motion

Representing Rigid Motion

$$\frac{1}{2}\begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} + \frac{1}{2}\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix} = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$$

90° CW

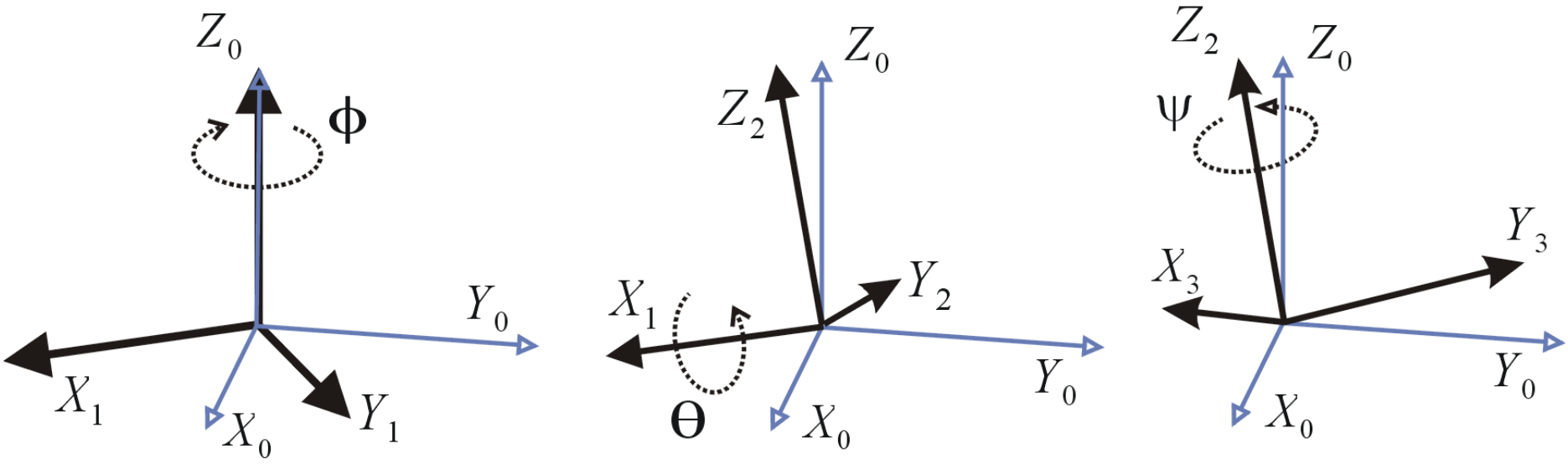
90° CCW



Not a rotation matrix!

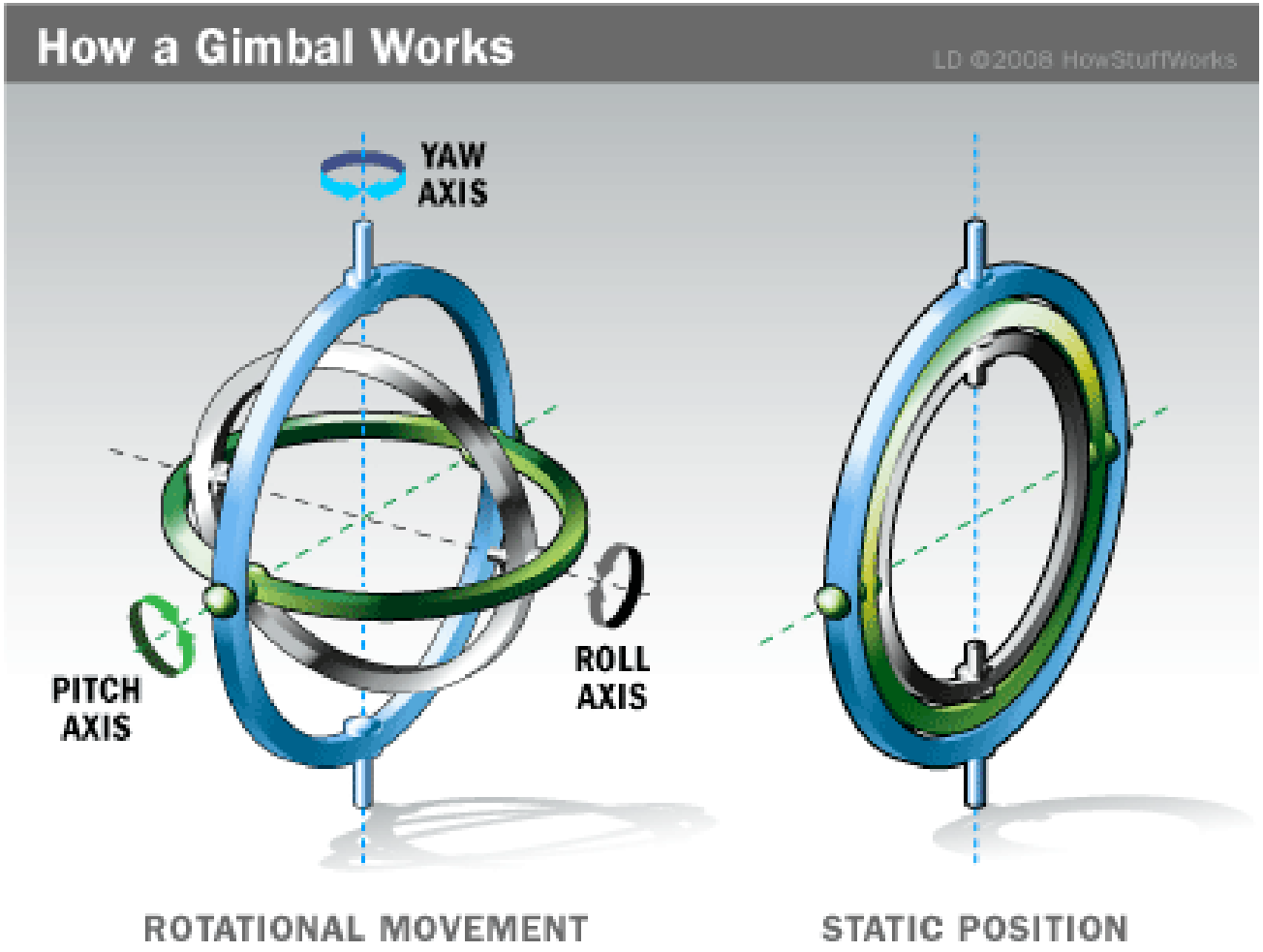
Not easy!

Euler Angles



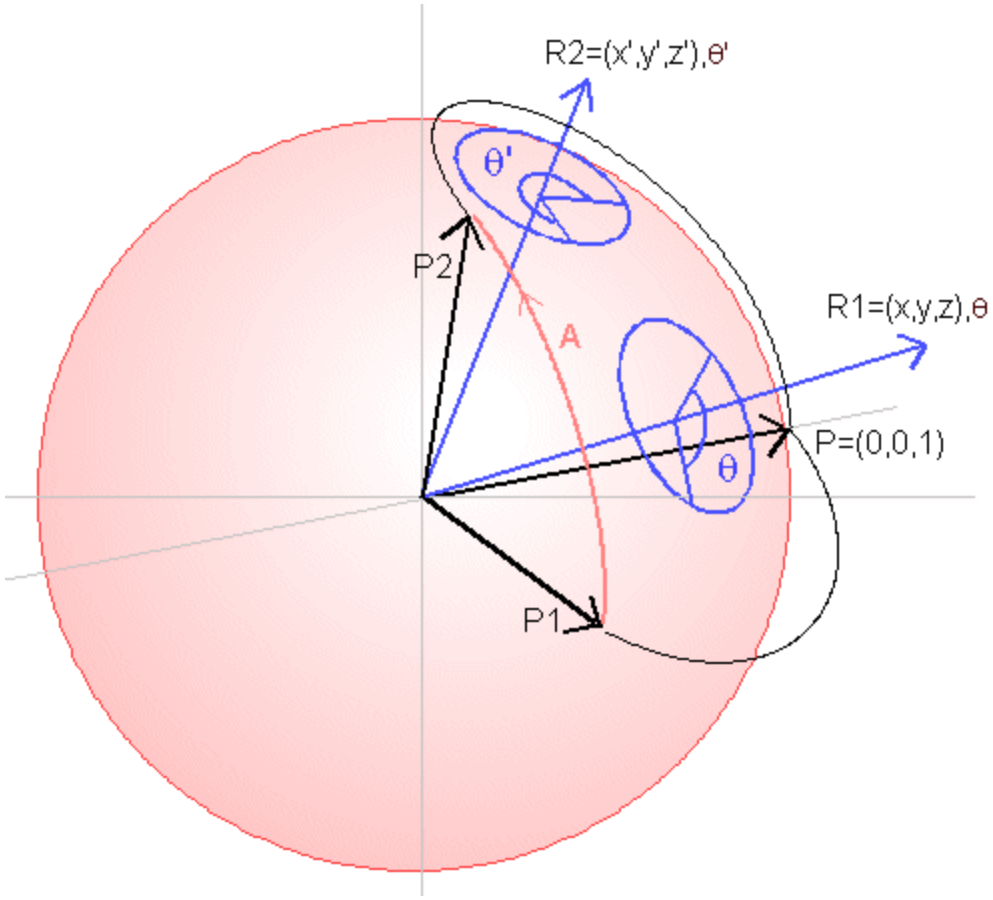
http://upload.wikimedia.org/wikipedia/commons/7/73/EulerG.png

Gimbal Lock



http://static.ddmcdn.com/gif/gimbal-2.gif

SLERP

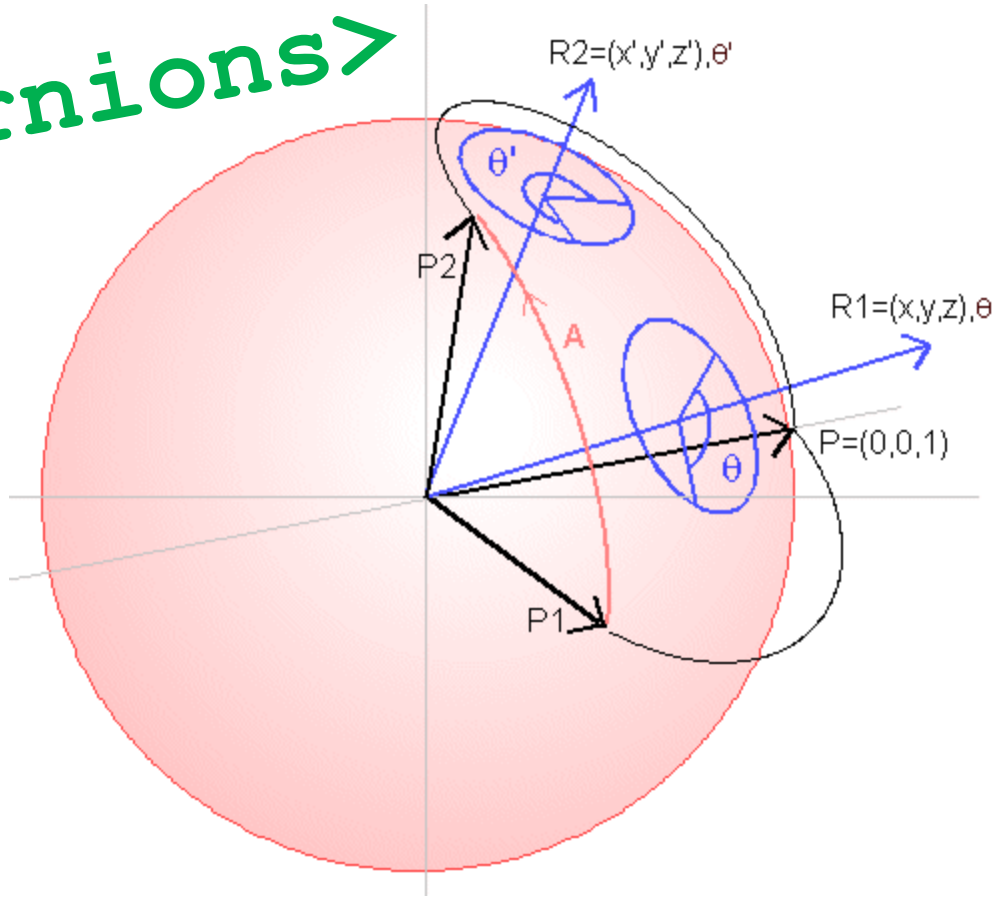


http://www.fastgraph.com/slerp1.gif

Spherical Linear Interpolation

SLERP

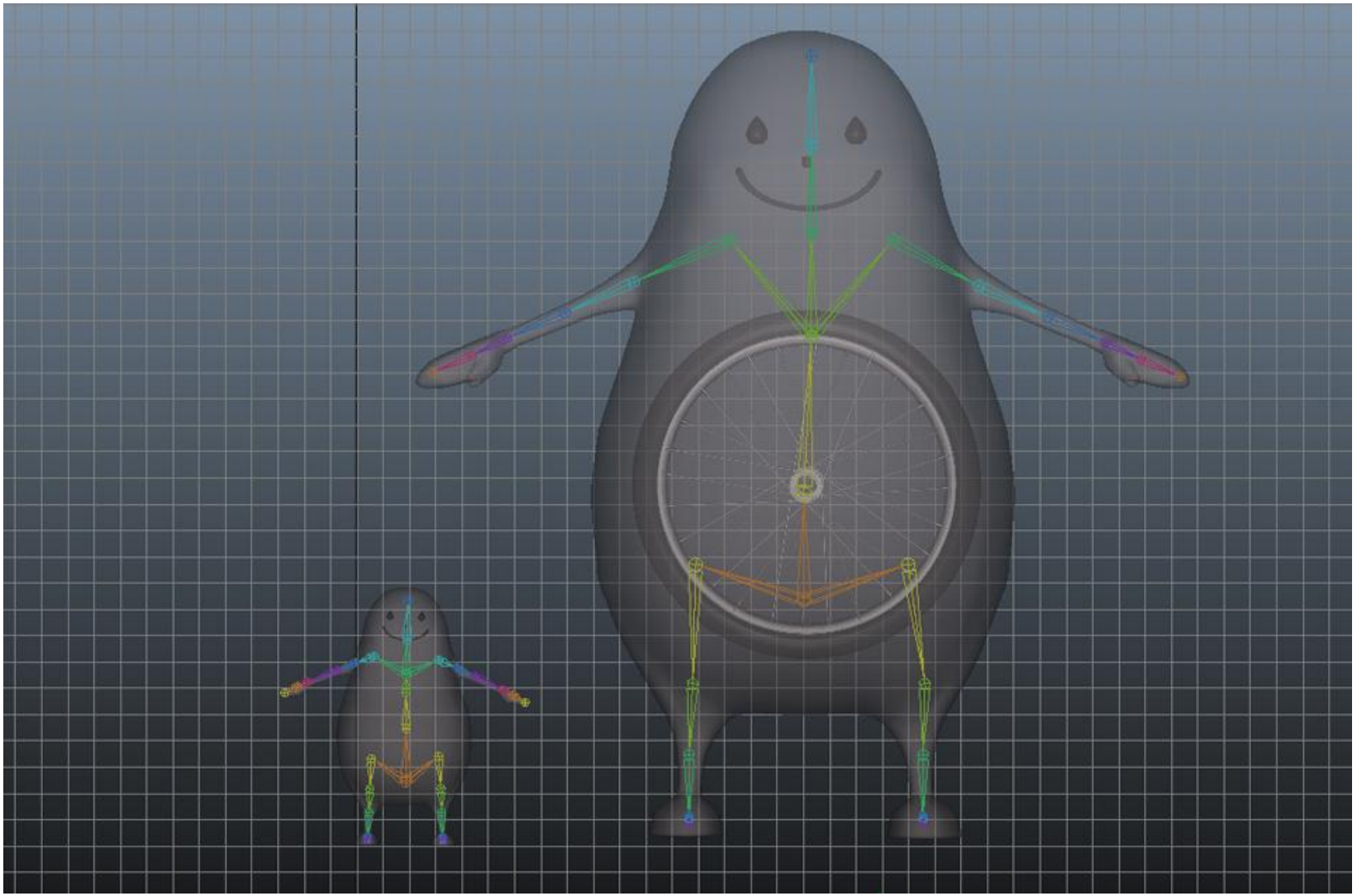
<quaternions>



http://www.fastgraph.com/slerp1.gif

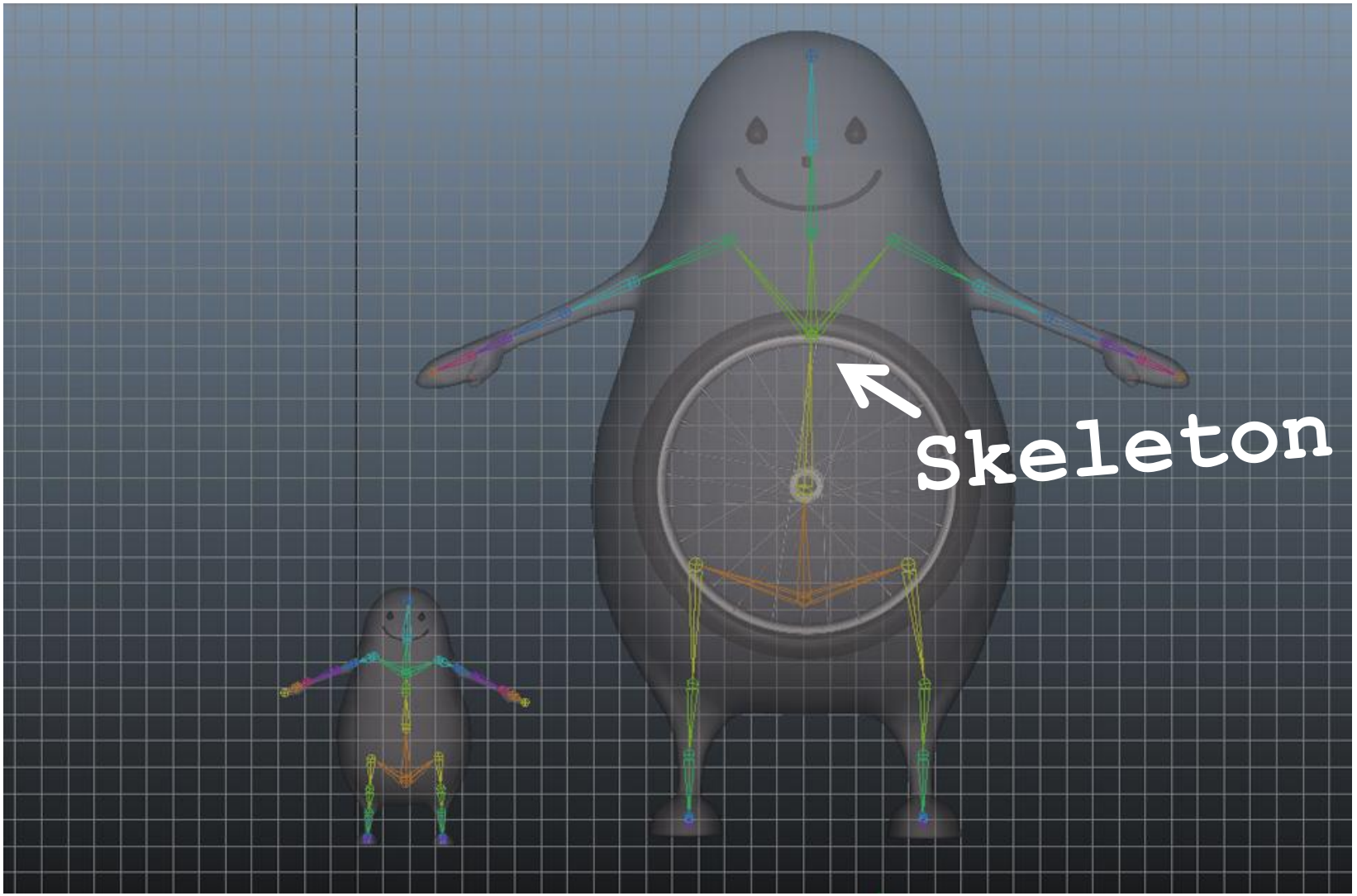
Spherical Linear Interpolation

Character Animation



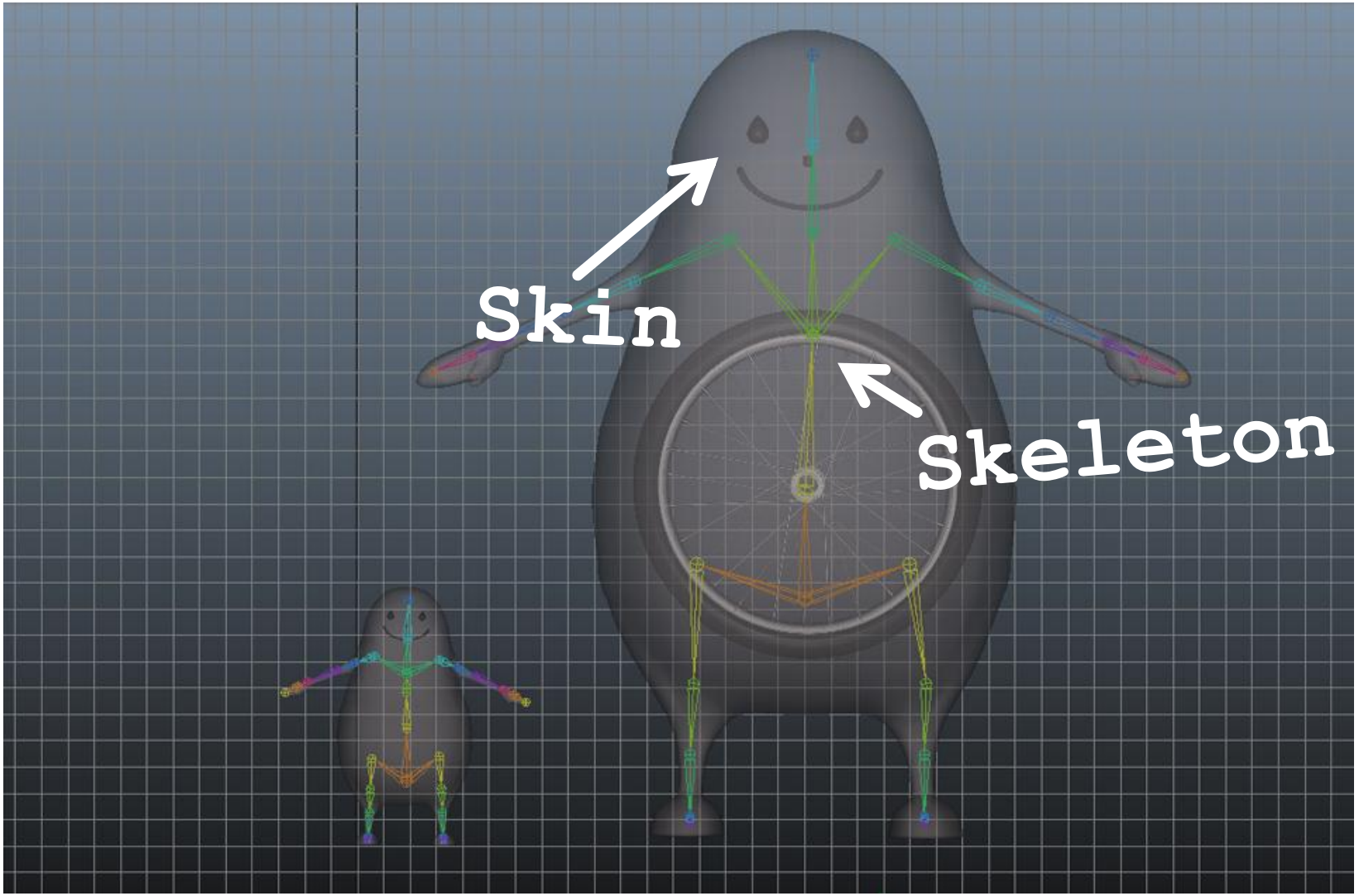
http://foldthebike.files.wordpress.com/2011/05/skeleton.jpg

Character Animation



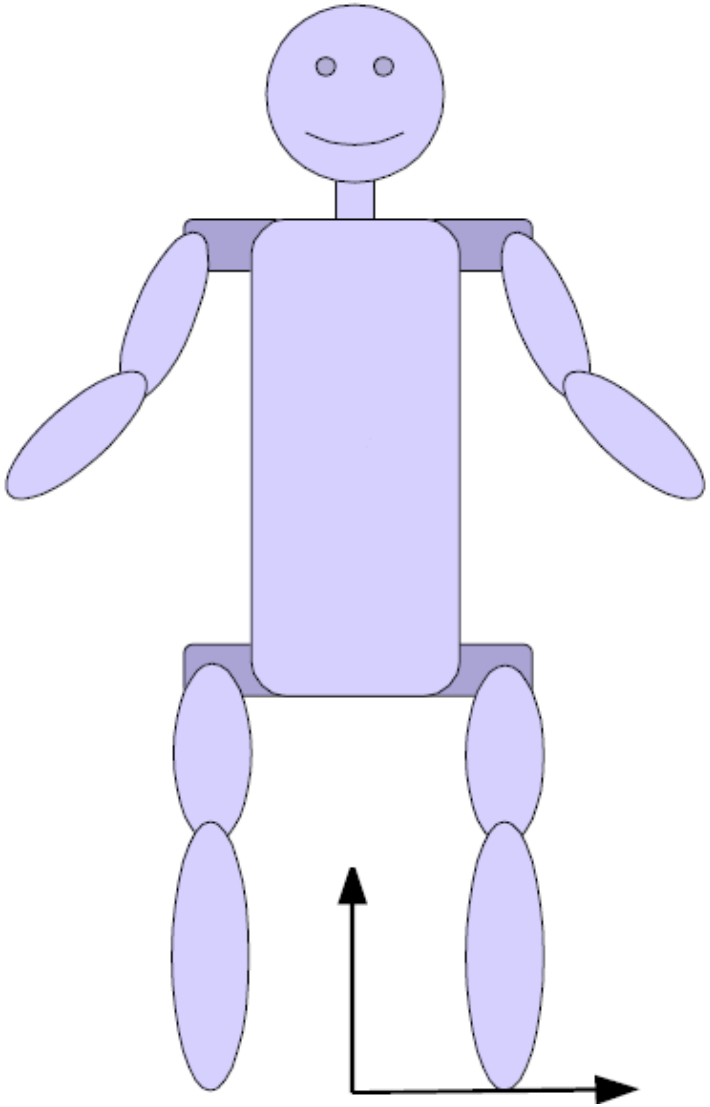
http://foldthebike.files.wordpress.com/2011/05/skeleton.jpg

Character Animation



http://foldthebike.files.wordpress.com/2011/05/skeleton.jpg

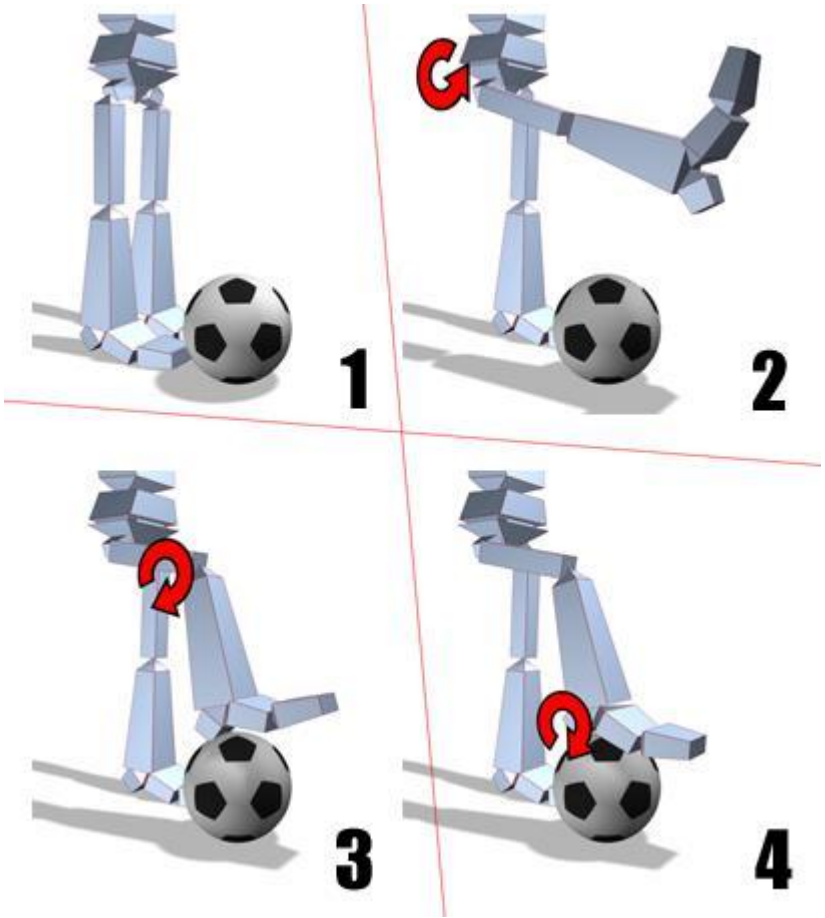
Recall: Hierarchical Modeling



```
Body
  Torso
    Head
    Shoulder          Hips
      LeftArm           LeftLeg
        UpperArm          UpperLeg
        LowerArm          LowerLeg
        Hand              Foot
      RightArm          RightLeg
        UpperArm          UpperLeg
        LowerArm          LowerLeg
        Hand              Foot
```

http://graphics.stanford.edu/courses/cs148-10-summer/docs/07_rendering2.pdf

Manipulating the Skeleton

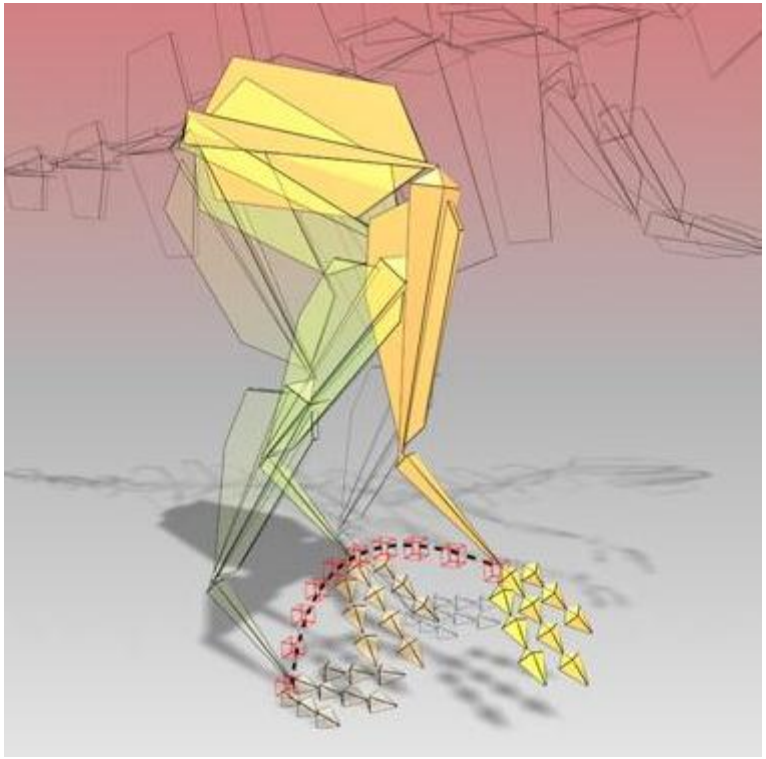


http://www.kxcad.net/autodesk/3ds_max/autodesk_3ds_max_9_reference/graphics/il_hier_fk_manipulation_max-2.jpg

Manipulate degrees of freedom directly, construct geometry hierarchically.

Forward kinematics (FK)

Manipulating the Skeleton

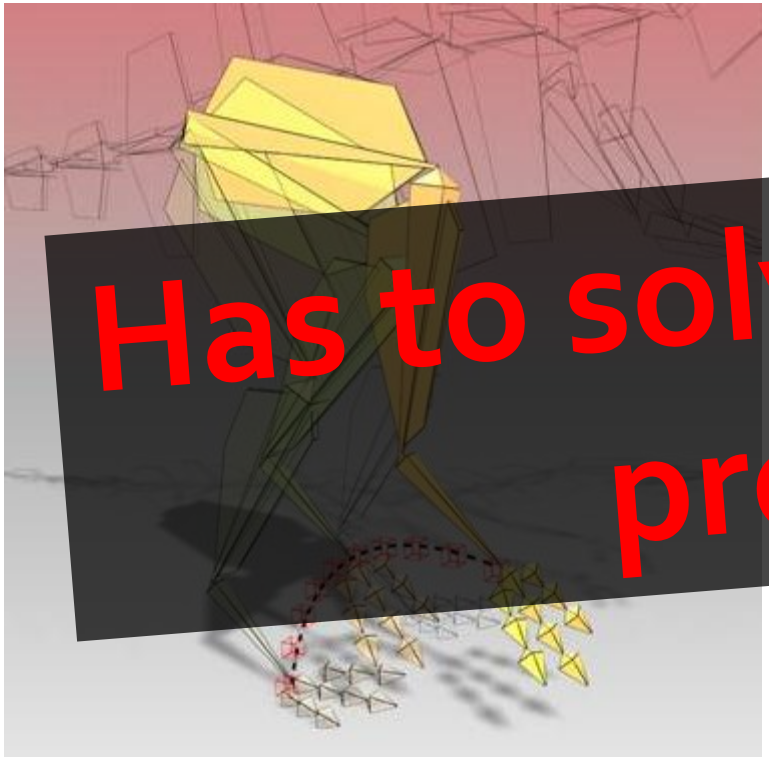


Determine change in parameters from position of end effector.

http://www.kxcad.net/autodesk/3ds_max/autodesk_3ds_max_9_reference/inverse_kinematics_ik.html

Inverse kinematics (IK)

Manipulating the Skeleton



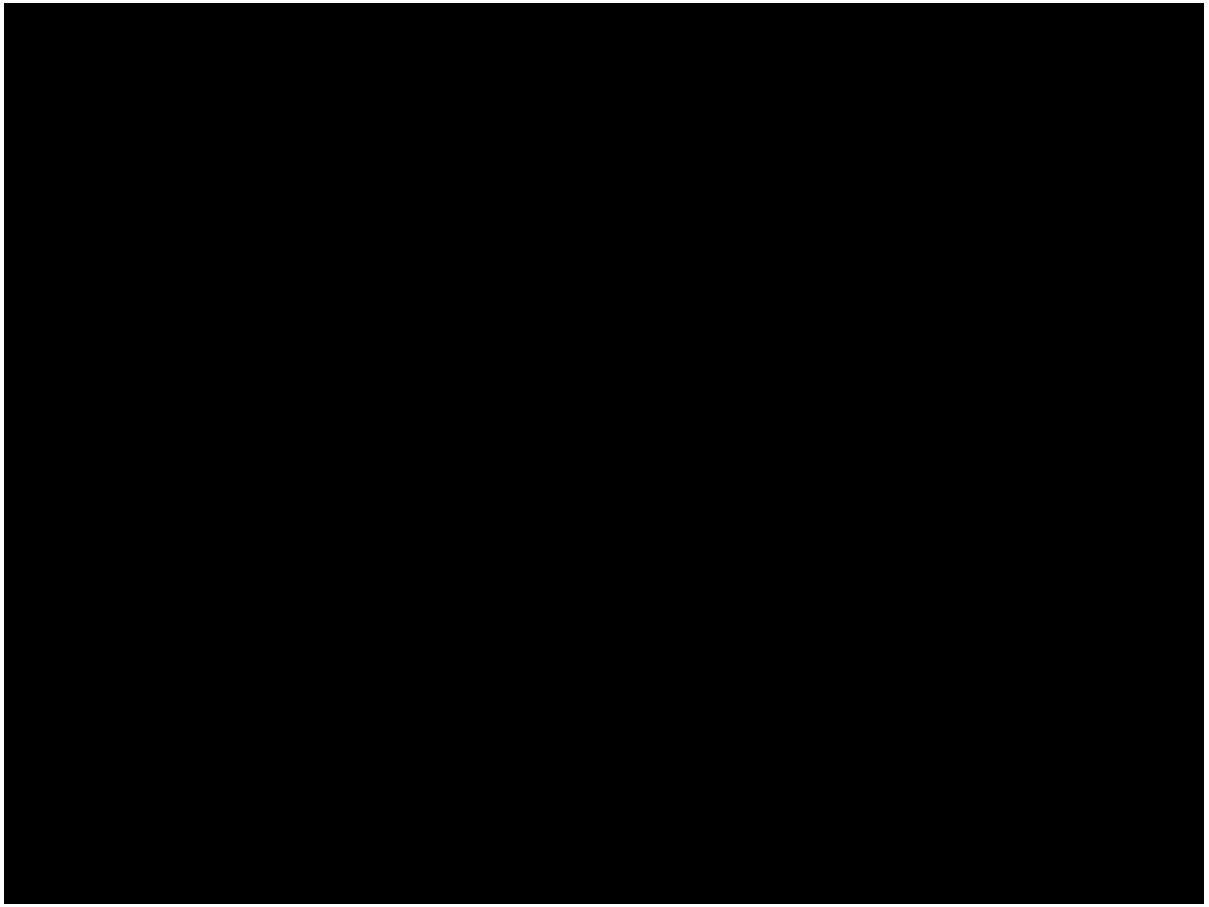
Has to solve a nonlinear problem!

Determine changes in parameters from position of end effector.

http://www.kxcad.net/autodesk/3ds_max/autodesk_3ds_max_9_reference/inverse_kinematics_ik.html

Inverse kinematics (IK)

Manipulating the Skeleton



http://www.youtube.com/watch?v=W3NYVXJBc54&feature=related

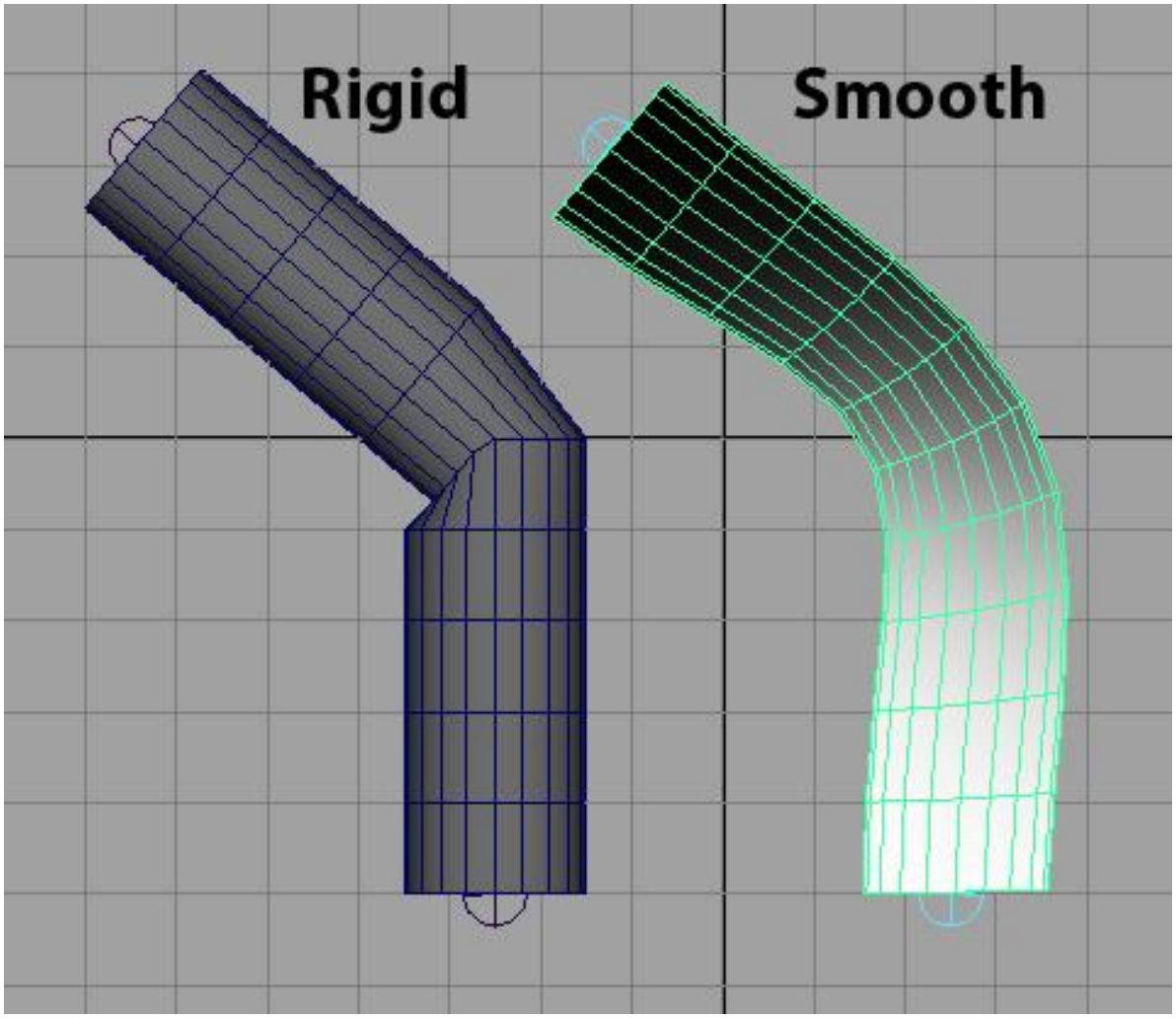
Inverse kinematics (IK)

Manipulating the Skeleton

http://www.youtube.com/watch?v=_QZN2ICovOo

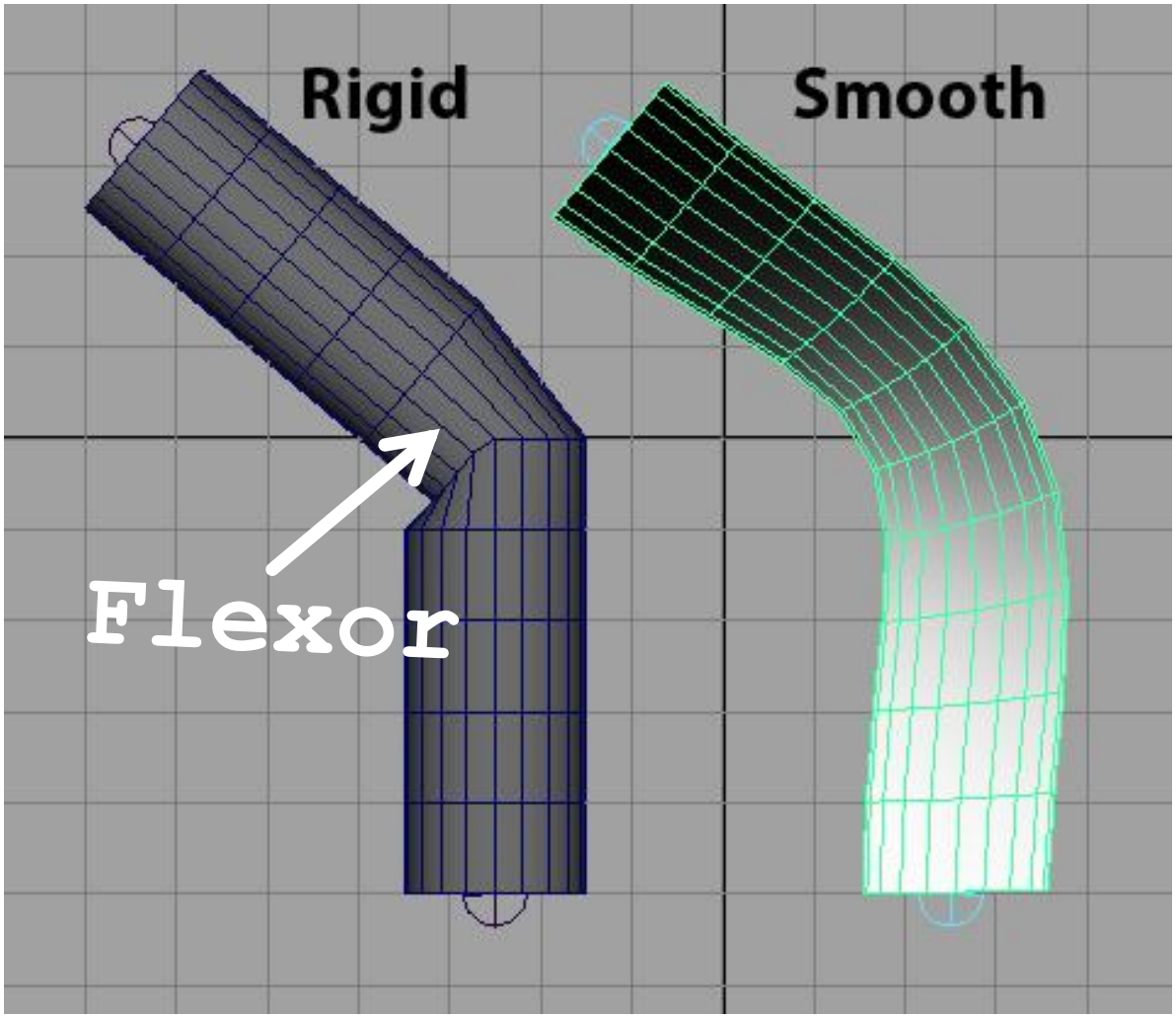
Motion capture

Skinning



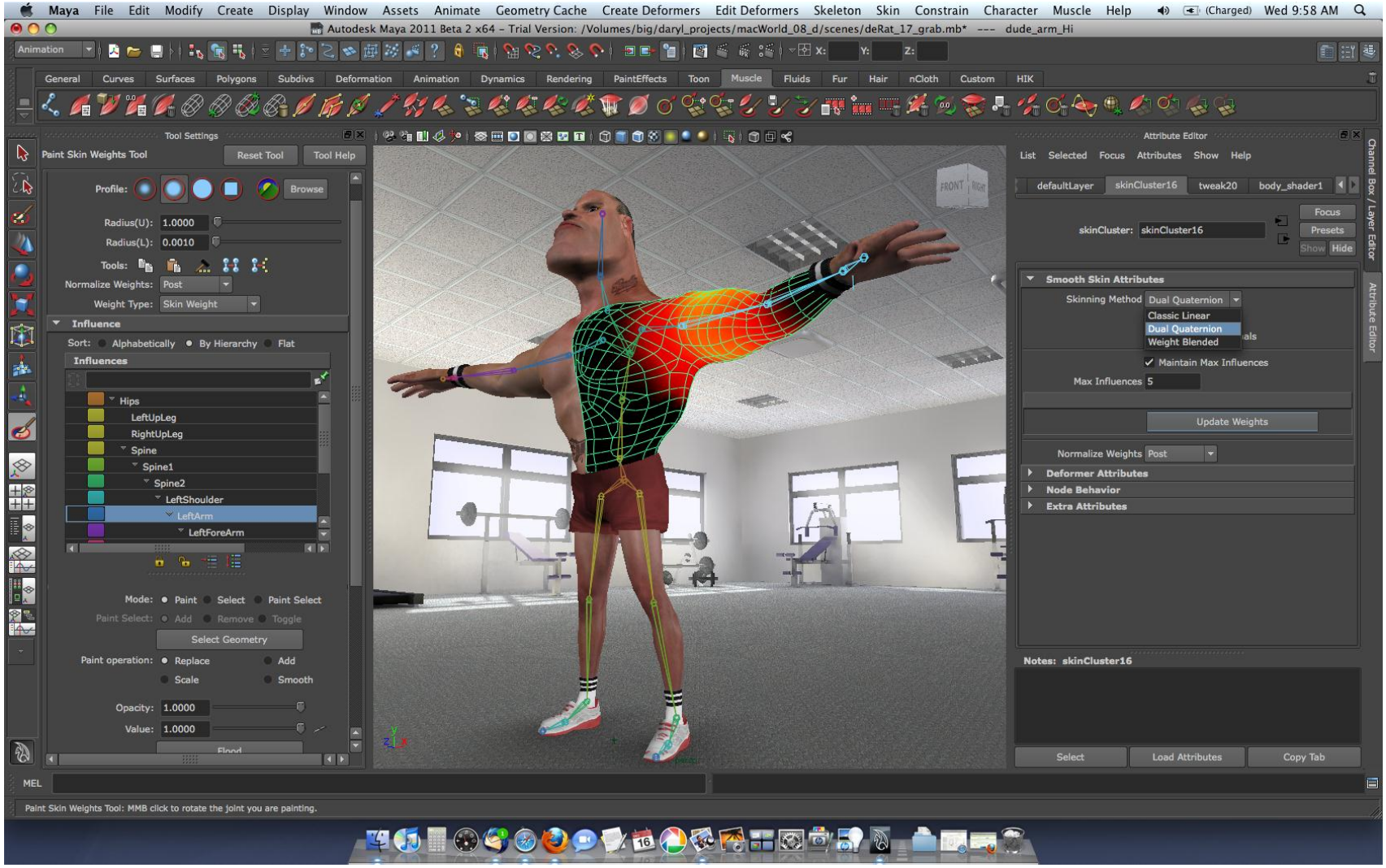
http://terencejacobson.com/Lesson6Pics/pico1.jpg

Skinning



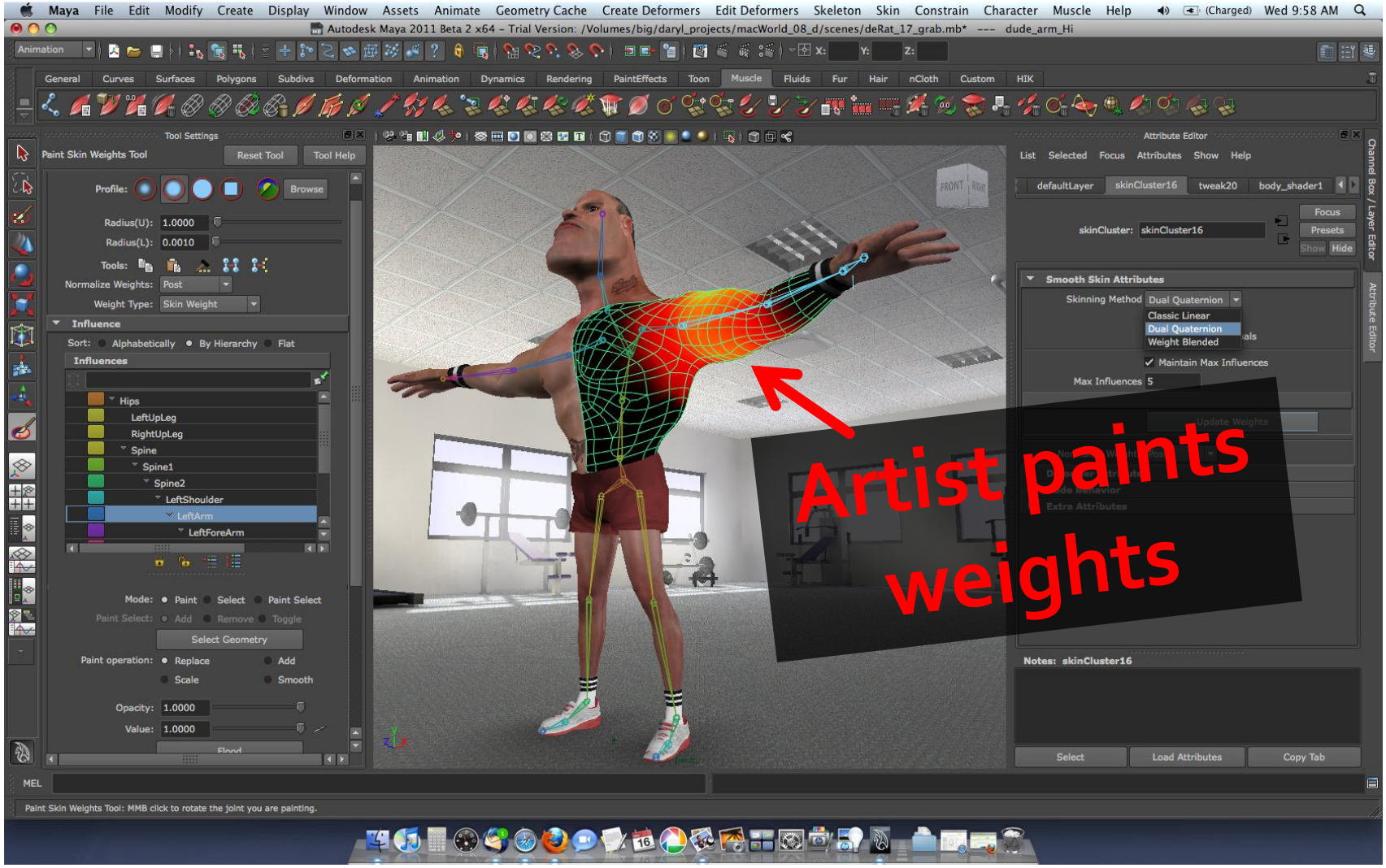
http://terencejacobson.com/Lesson6Pics/pico1.jpg

Smooth Skinning in Maya



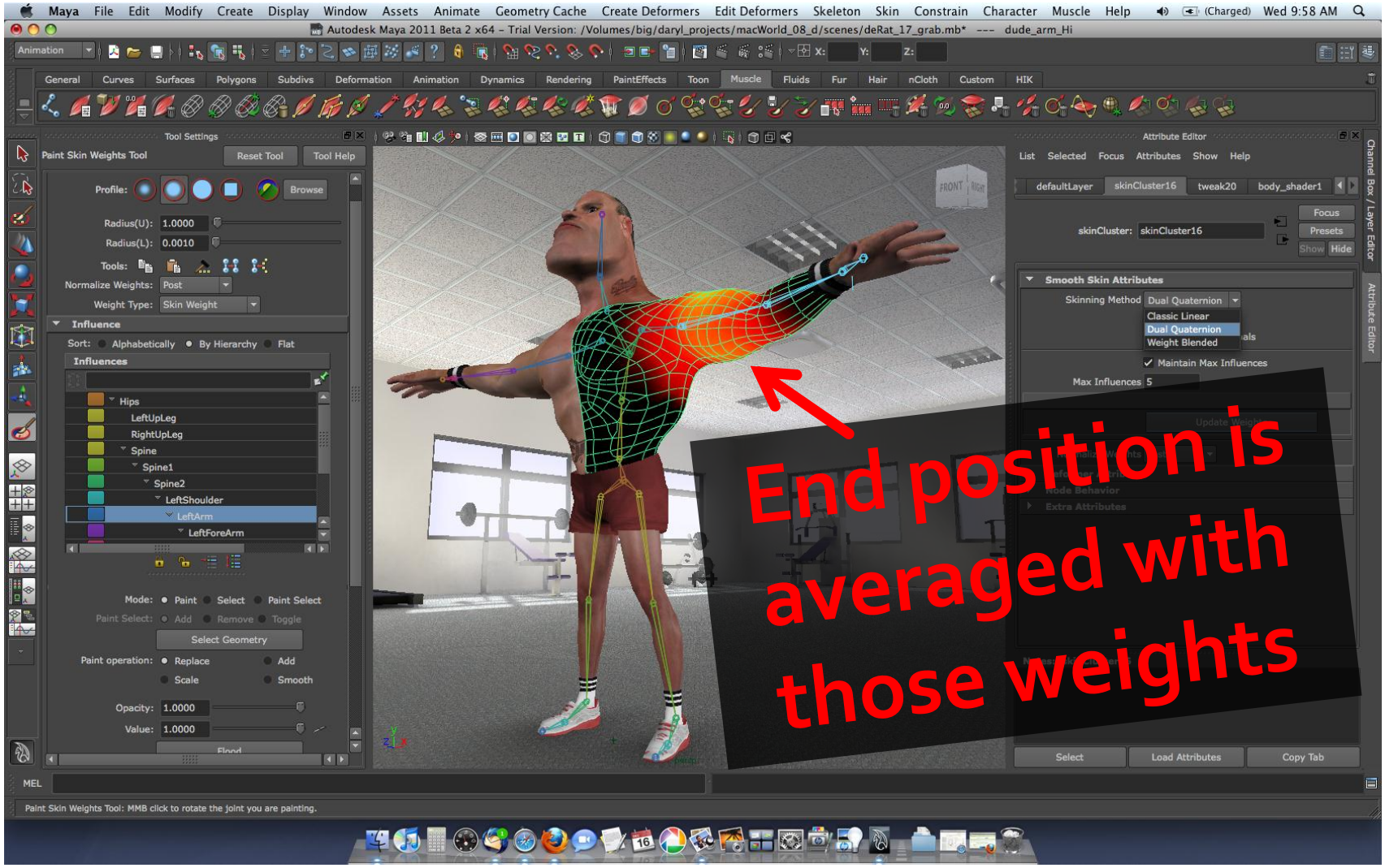
http://www.creativeplanetnetwork.com/the_wire/wp-content/uploads/2010/03/maya2011_osx_accelerated_skinning_workflow.png

Smooth Skinning in Maya



http://www.creativeplanetnetwork.com/the_wire/wp-content/uploads/2010/03/maya2011_osx_accelerated_skinning_workflow.png

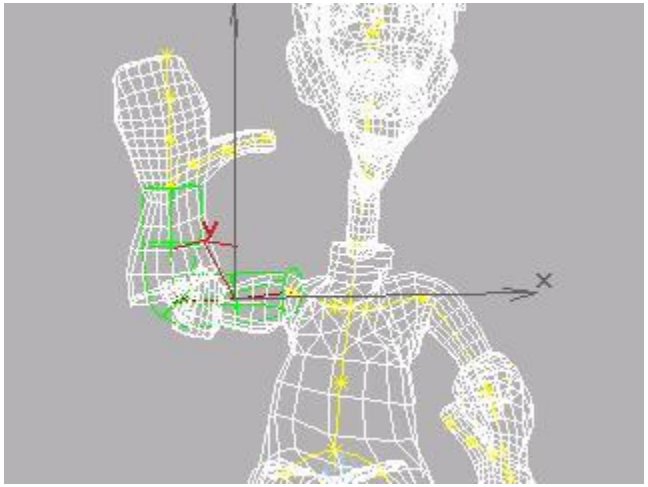
Smooth Skinning in Maya



http://www.creativeplanetnetwork.com/the_wire/wp-content/uploads/2010/03/maya2011_osx_accelerated_skinning_workflow.png

Rigging [rig-ing]:
Preparing a static 3D mesh for animation.

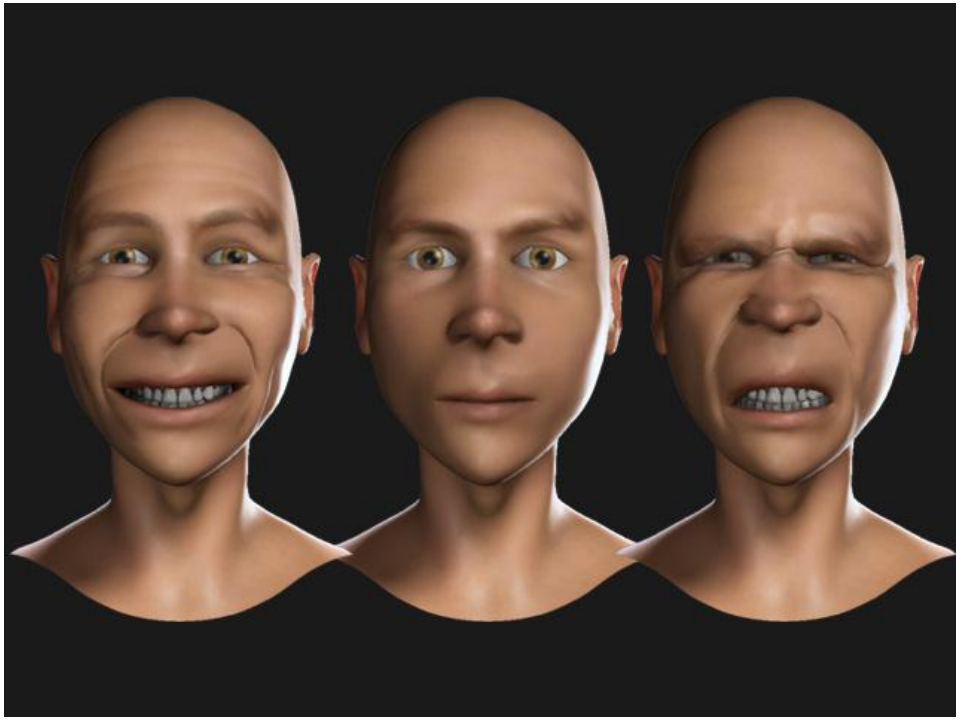
Advanced Rigging

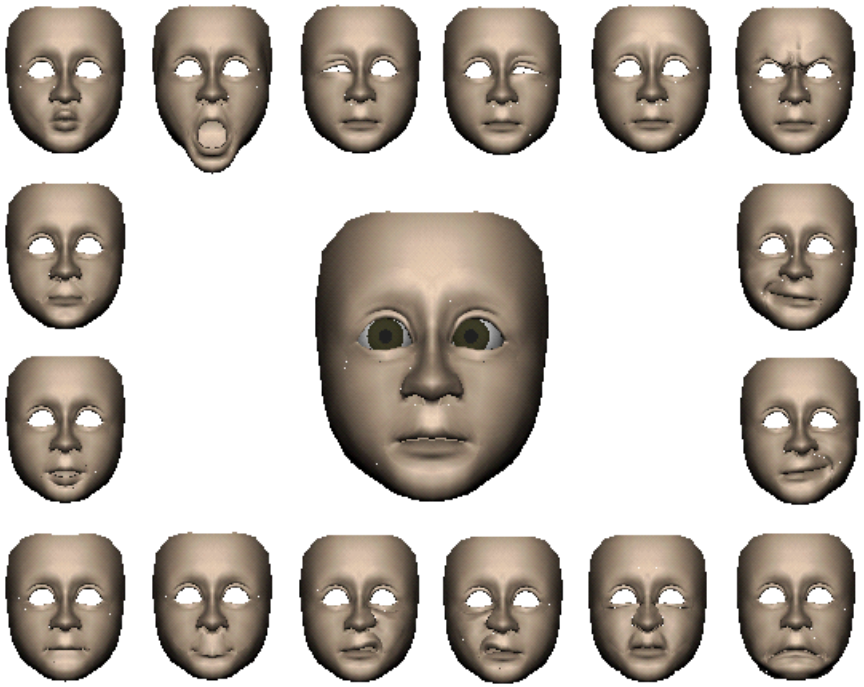


http://igl.ethz.ch/projects/skinning/context-aware-deformation/skinning-teaser.png
http://www.character-studio.net/jpg/bulge_01.jpg

Muscle bulge

Blendshape





http://www.chadvernon.com/blog/wp-content/uploads/2008/11/blendshapes001.jpg
http://download.autodesk.com/us/maya/2010help/images/MED/Stargate/English/Deform/bgirlblends.png

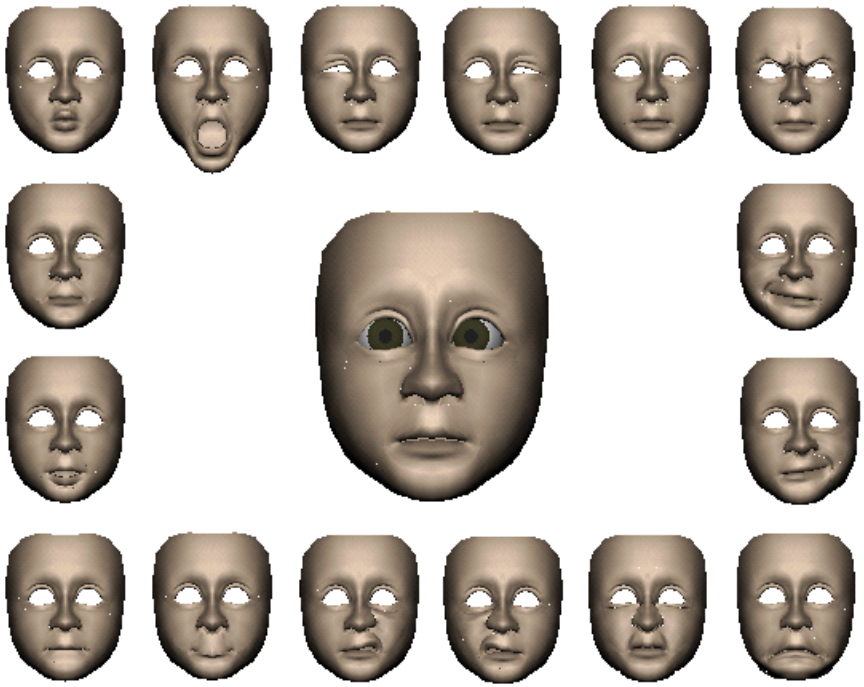
Linear shape model

Blendshape

$$\vec{b} = \text{base shape} \in \mathbb{R}^{3|V|}$$

$$\vec{v}_i = \text{displacement vector} \in \mathbb{R}^{3|V|}$$

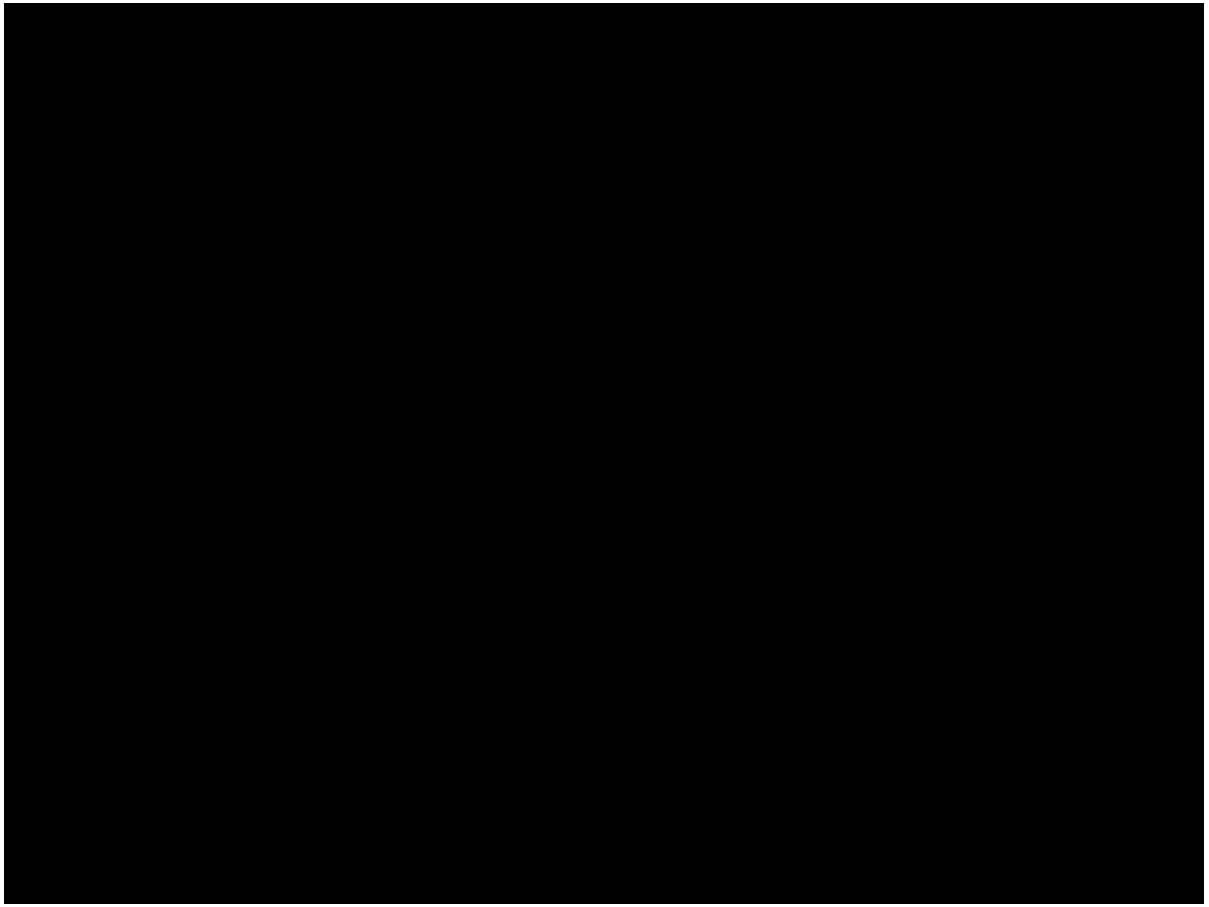
$$\vec{v} = \text{final shape} = \vec{b} + \sum_i a_i \vec{v}_i$$



http://download.autodesk.com/us/maya/2010help/images/MED/Stargate/English/Deform/bgirlblends.png

Linear shape model

Morphable Model



https://www.youtube.com/watch?v=nice6NYb_WA

Obtain blendshape from statistics

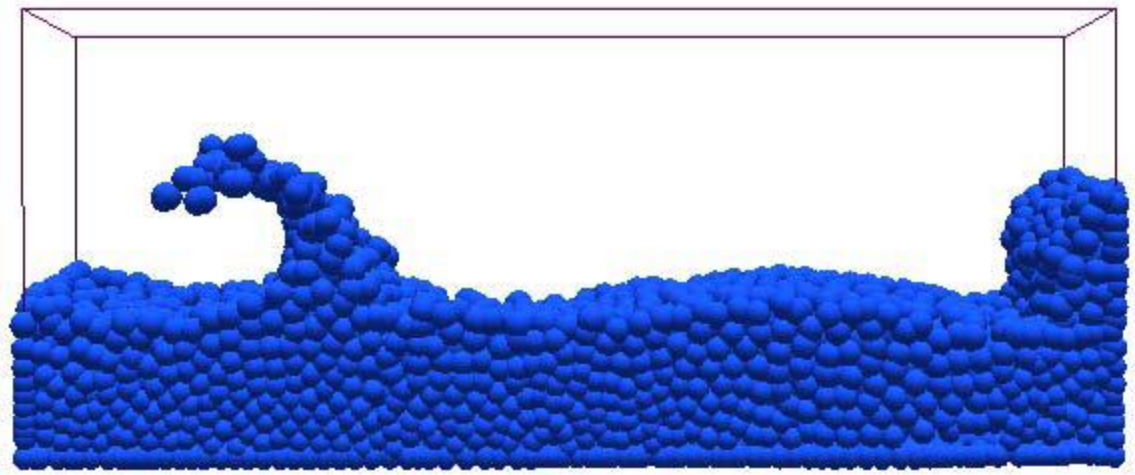
Physics-Based Animation

Must ensure stability and detect collisions with surfaces.

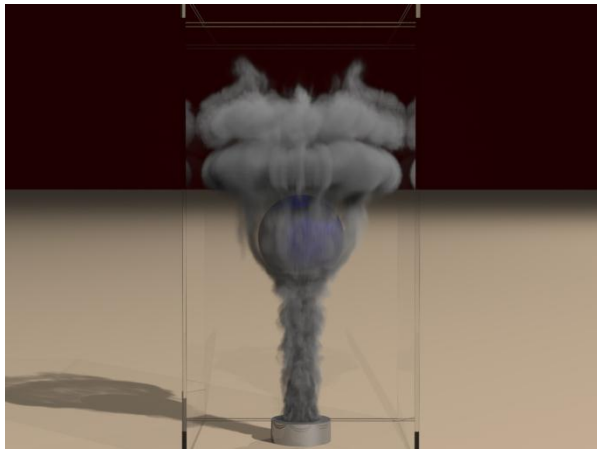
http://run.usc.edu/cs599-s10/cloth/baraff-witkin98.pdf
http://www.gris.uni-tuebingen.de/people/staff/spabst/

Cloth

Physics-Based Animation



Lagrangian



Eulerian

http://www.glowinggoo.com/sph/bin/sph_wave.png
http://physbam.stanford.edu/~mlentine/images/refinement.png

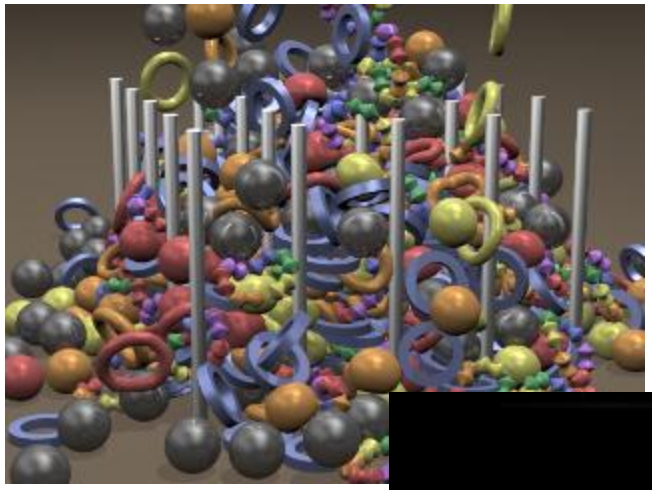
Fluids

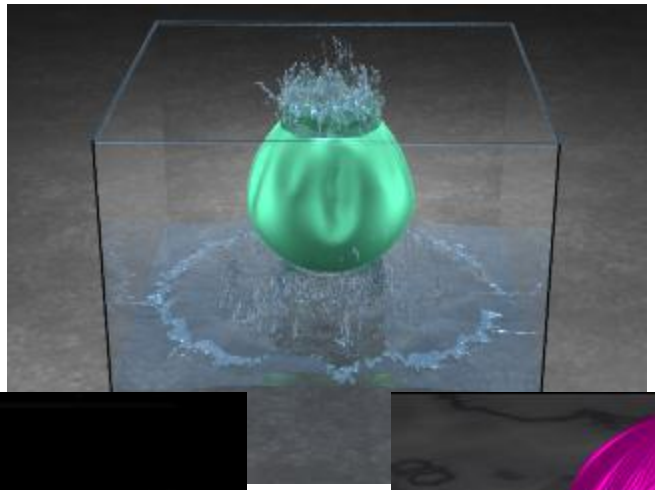
Physics-Based Animation

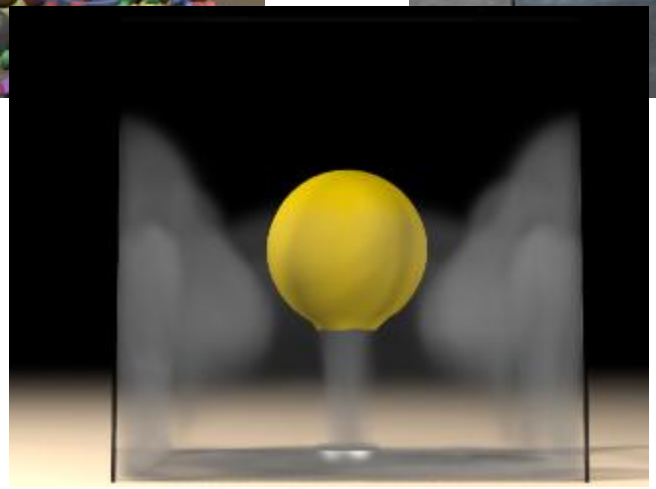
http://www.gris.uni-tuebingen.de/people/staff/spabst/images/goldenDragons_hr.jpg

Deformable solids

Physics-Based Animation



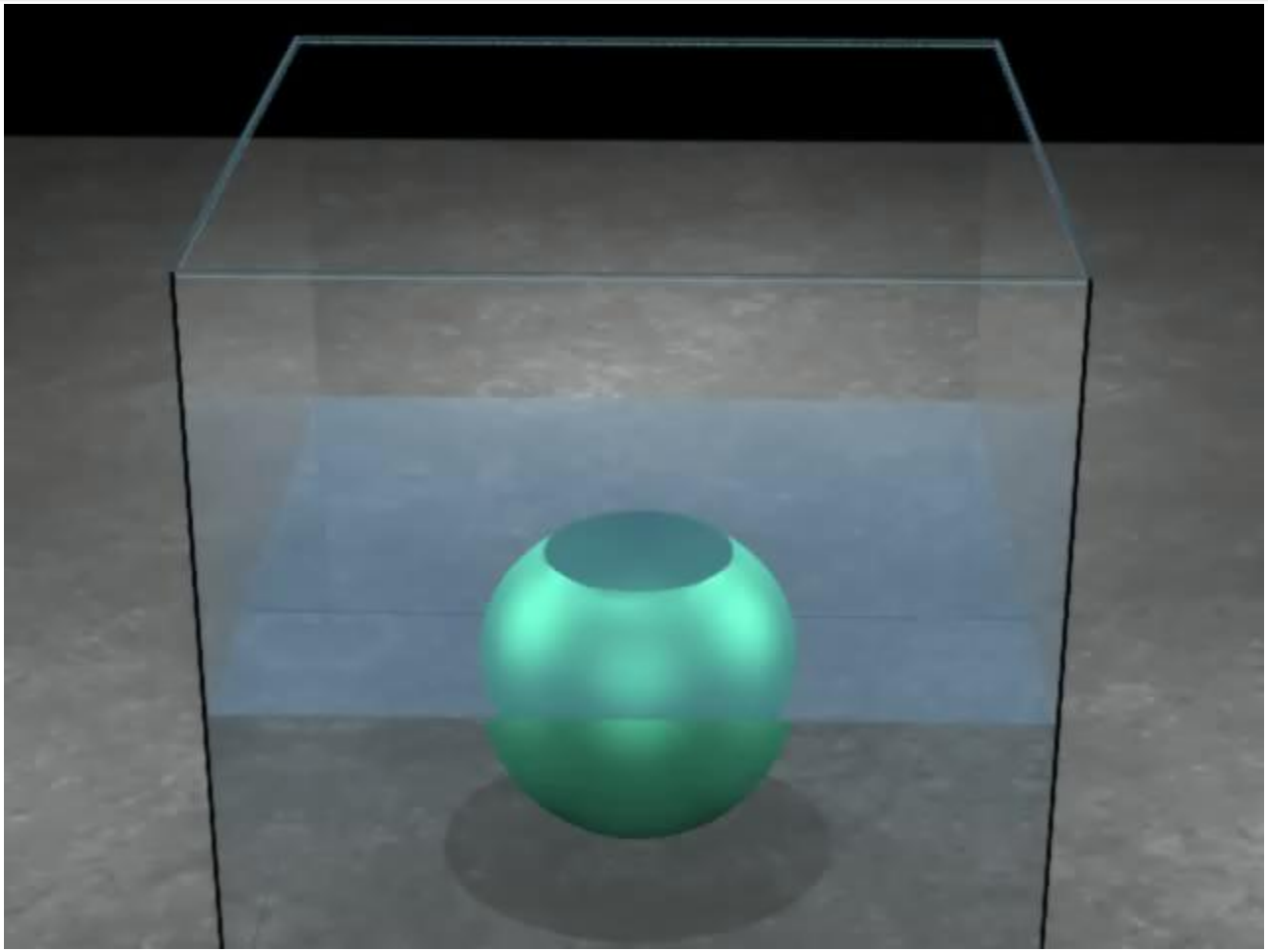




http://physbam.stanford.edu/~fedkiw/

Coupling, interfaces, and interactions

Physics-Based Animation



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

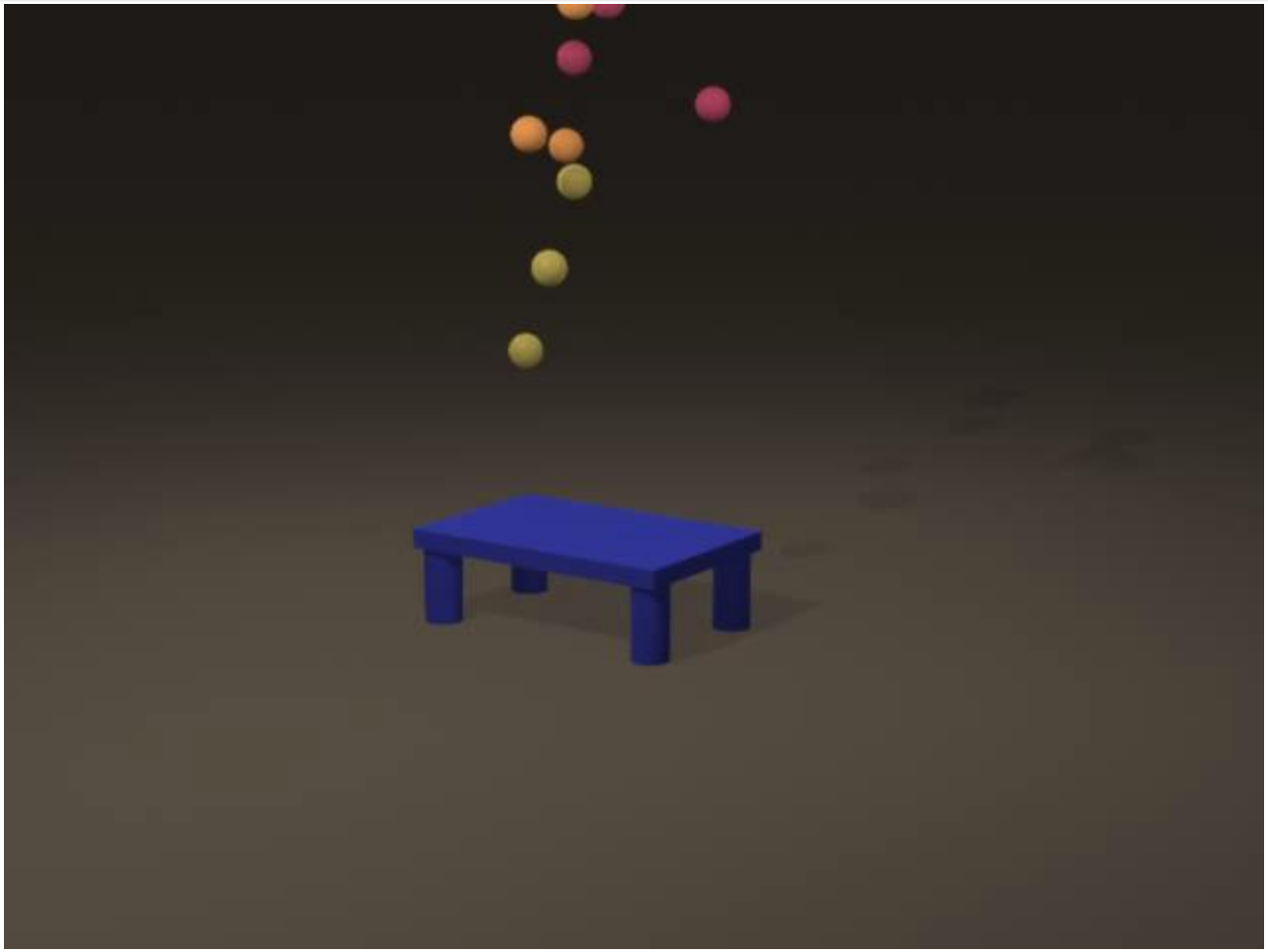
Two-way solid-fluid coupling

Physics-Based Animation

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

Detailed cloth simulation

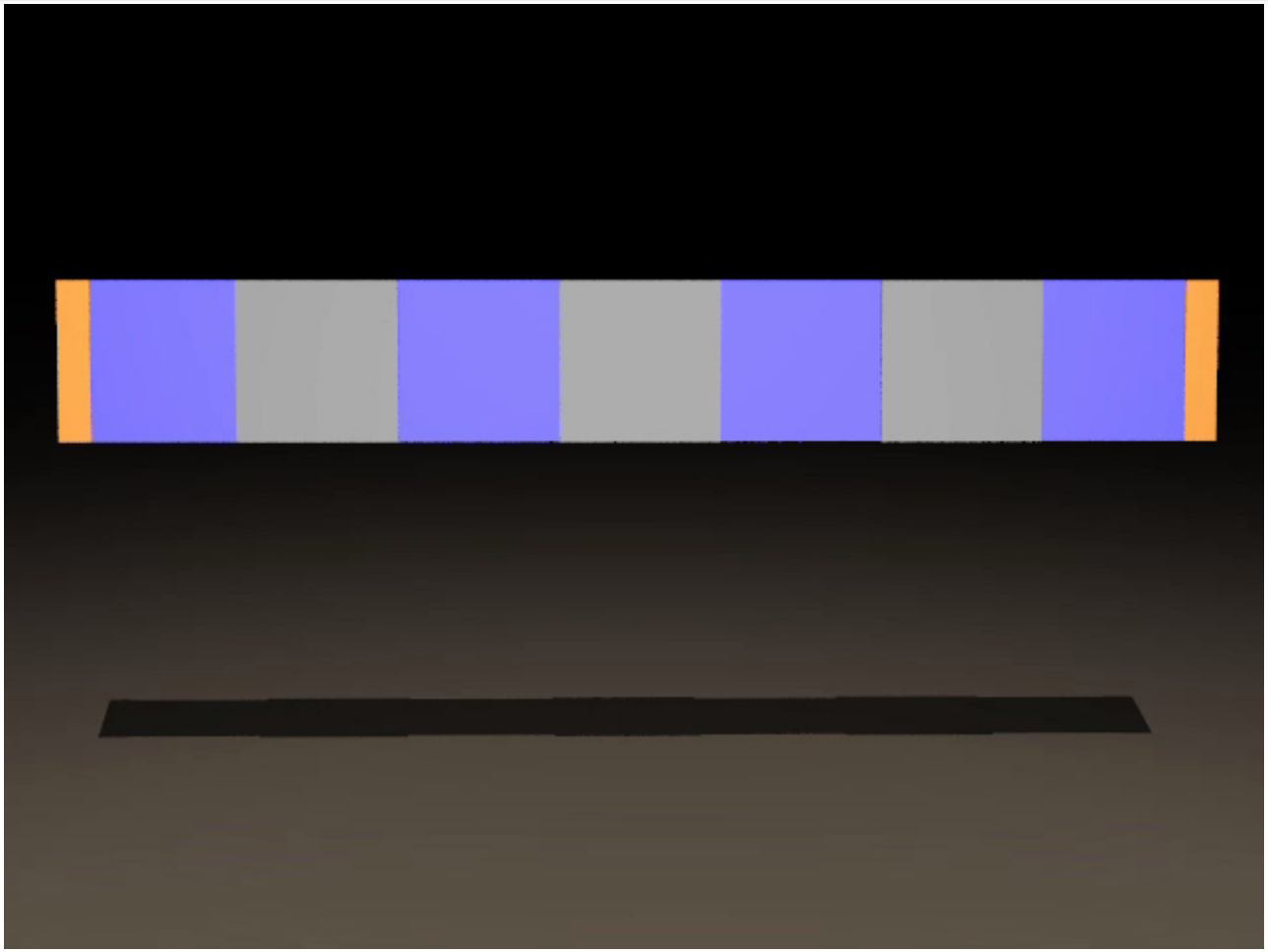
Physics-Based Animation



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

Fracture and rigid body

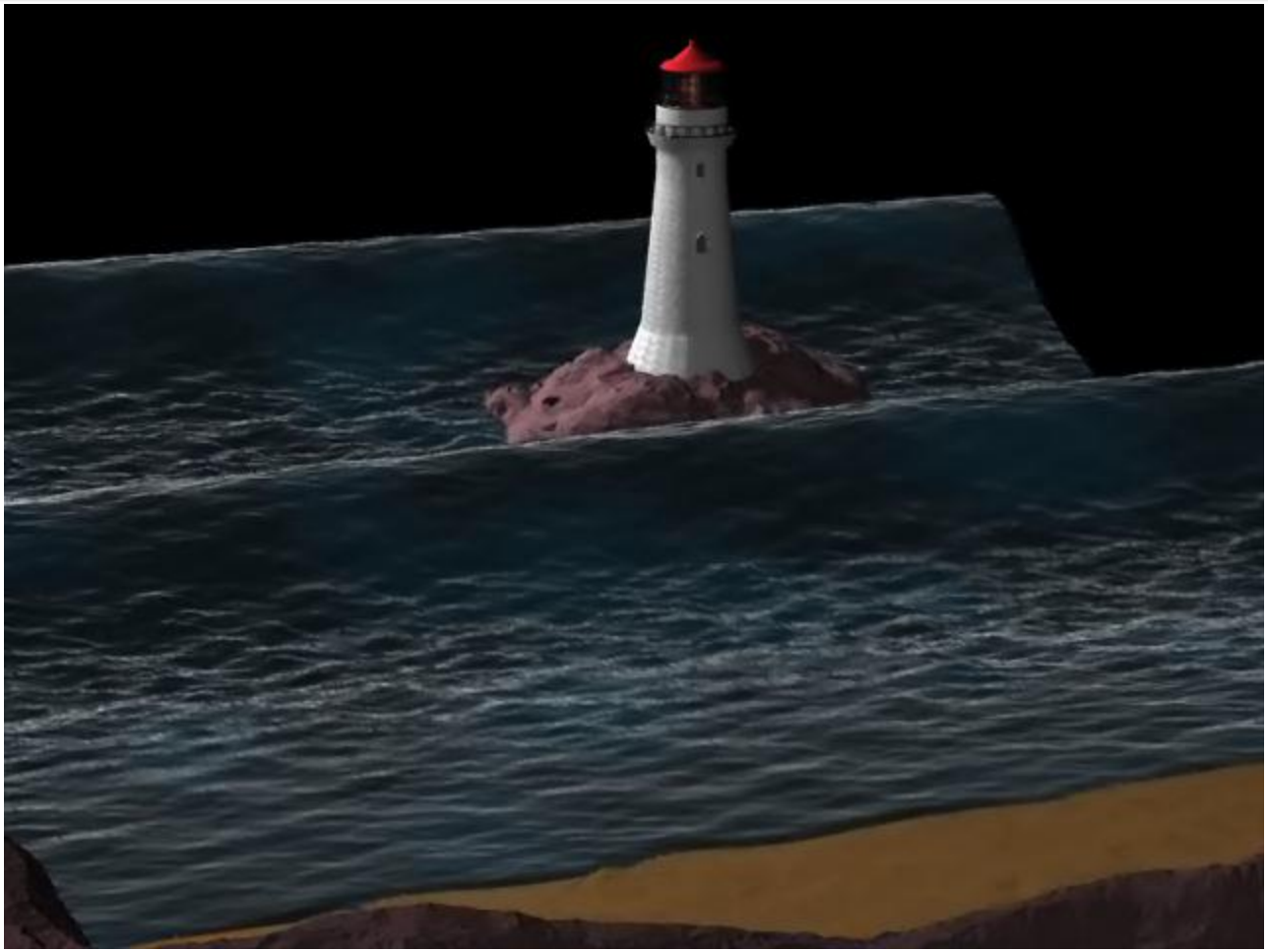
Physics-Based Animation



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

Deformable-rigid coupling

Physics-Based Animation



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

Coupled fluid simulation

Procedural Animation

https://www.youtube.com/watch?v=yzrl7pCAbcs

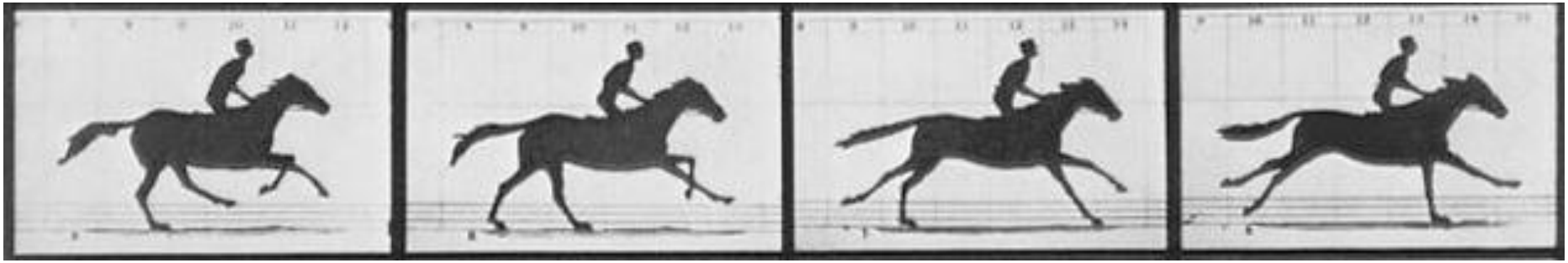
Simple rules to generate behavior

Recall: Motion Blur

http://www.matkovic.com/anto/3dl-test-balls-01.jpg

Randomly sample positions

Why Blur?

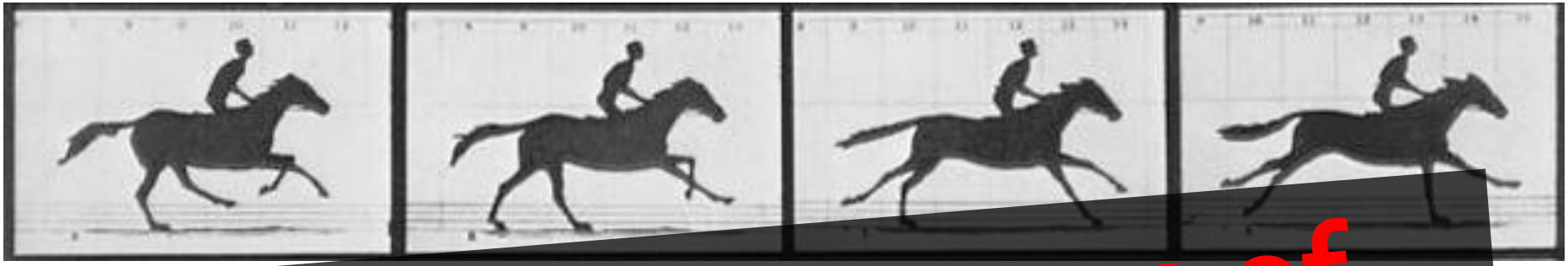


Frame represents an interval in time.

Frame should represent distribution of intensities and colors during this interval.

http://graphics.stanford.edu/courses/cs148-10-summer/docs/10_anim_interact.pdf

Why Blur?



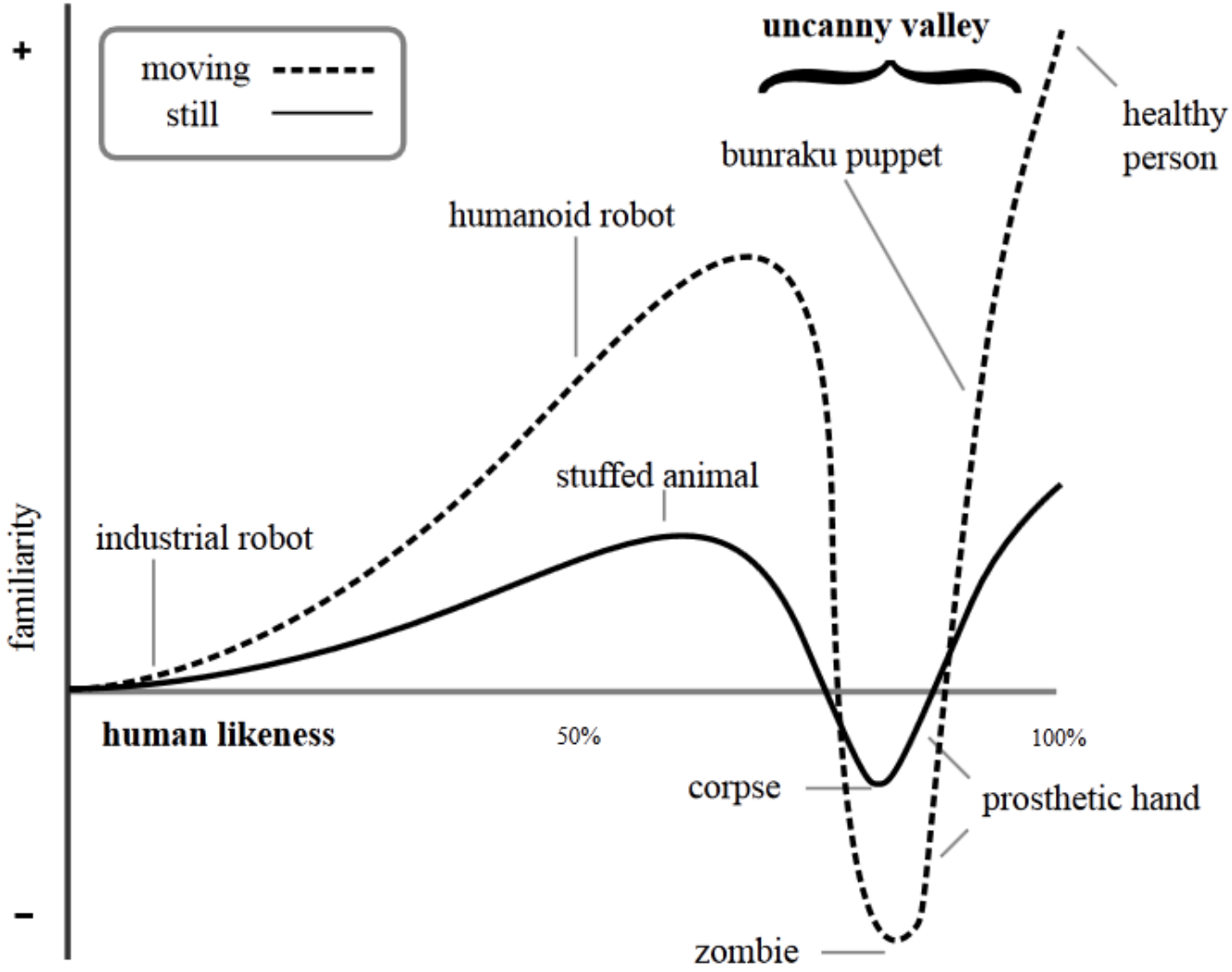
Another instance of aliasing

Frame represents an interval in time.

Frame should represent distribution of intensities and colors during this interval.

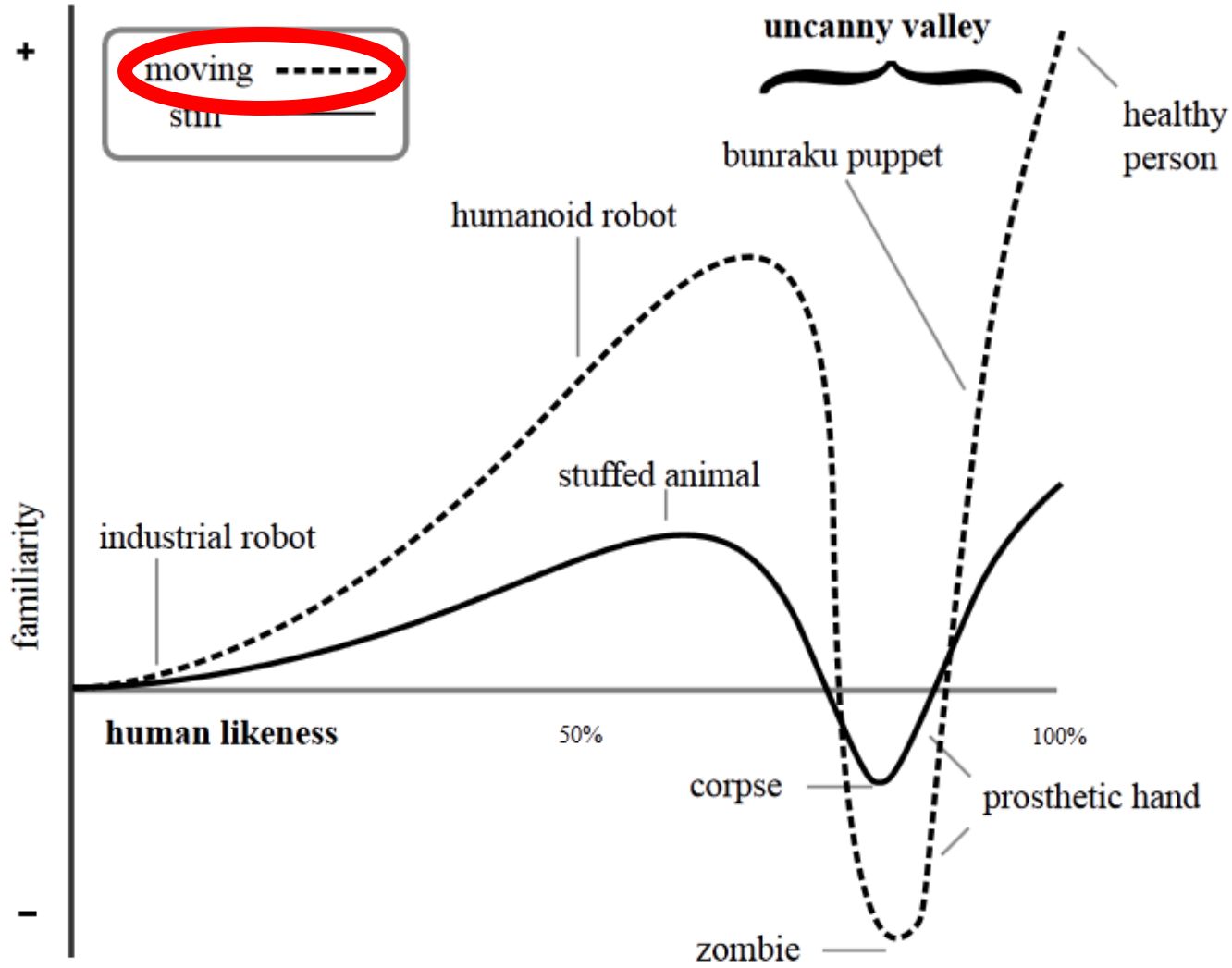
http://graphics.stanford.edu/courses/cs148-10-summer/docs/10_anim_interact.pdf

Recall: Uncanny Valley



http://en.wikipedia.org/wiki/File:Mori_Uncanny_Valley.svg

Recall: Uncanny Valley



http://en.wikipedia.org/wiki/File:Mori_Uncanny_Valley.svg

http://1.bp.blogspot.com/-DGdxCThSs20/TpMownEbDeI/AAAAAAAAAN8/04yjwR1WDsc/s1600/luxo.jpg

Animation Techniques

CS 148, Summer 2012
Introduction to Computer Graphics and Imaging

Justin Solomon