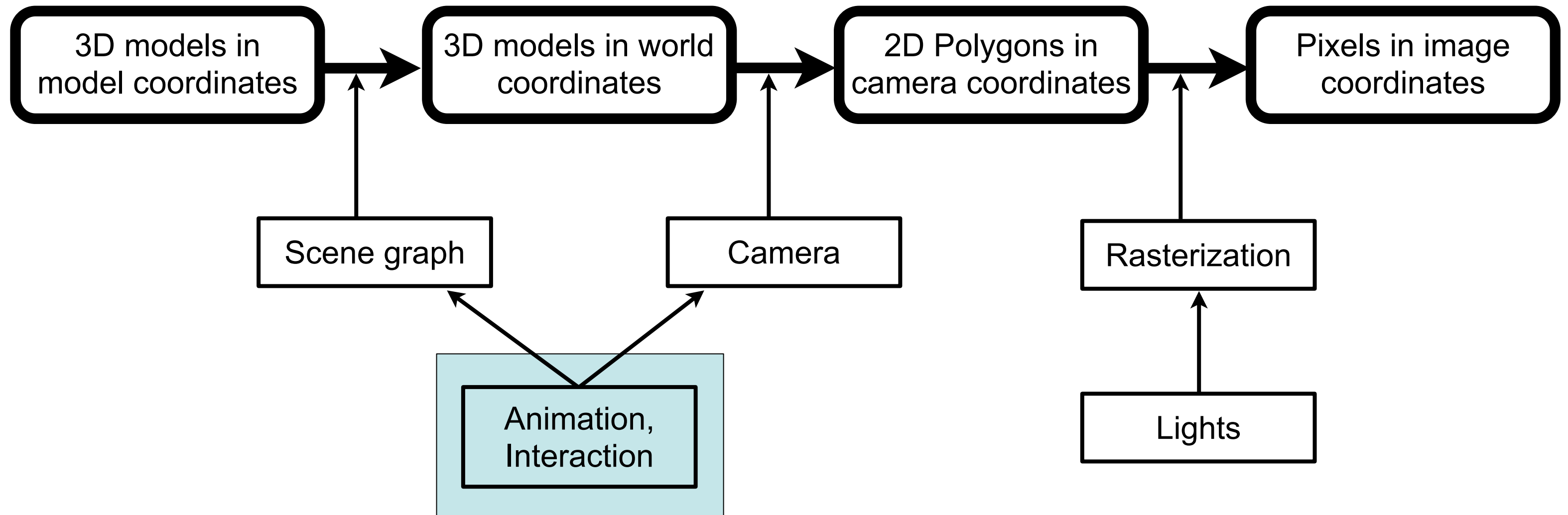


Chapter 9 - Animation

- Animation before the time of 3DCG
- Animation techniques
 - keyframing
 - bone animation & motion capture
 - simulation
- Animation principles

The 3D rendering pipeline (our version for this class)



Chapter 9 - Animation

- Animation before the time of 3DCG
- Animation techniques
 - keyframing
 - bone animation & motion capture
 - simulation
- Animation principles

Animation == bring to life

- Generally any kind of **moving** graphics
 - flipbooks
 - cartoon films
 - computer animation
- Sequence of single images
 - Movie: 24, TV: 30, Comp.: up to >100/sec.
- Impression of movement >6 fps (???)
- 3D animation most often at video frame rates



http://disney-clipart.com/aristocats/Disney_Aristocats_Kittens.php

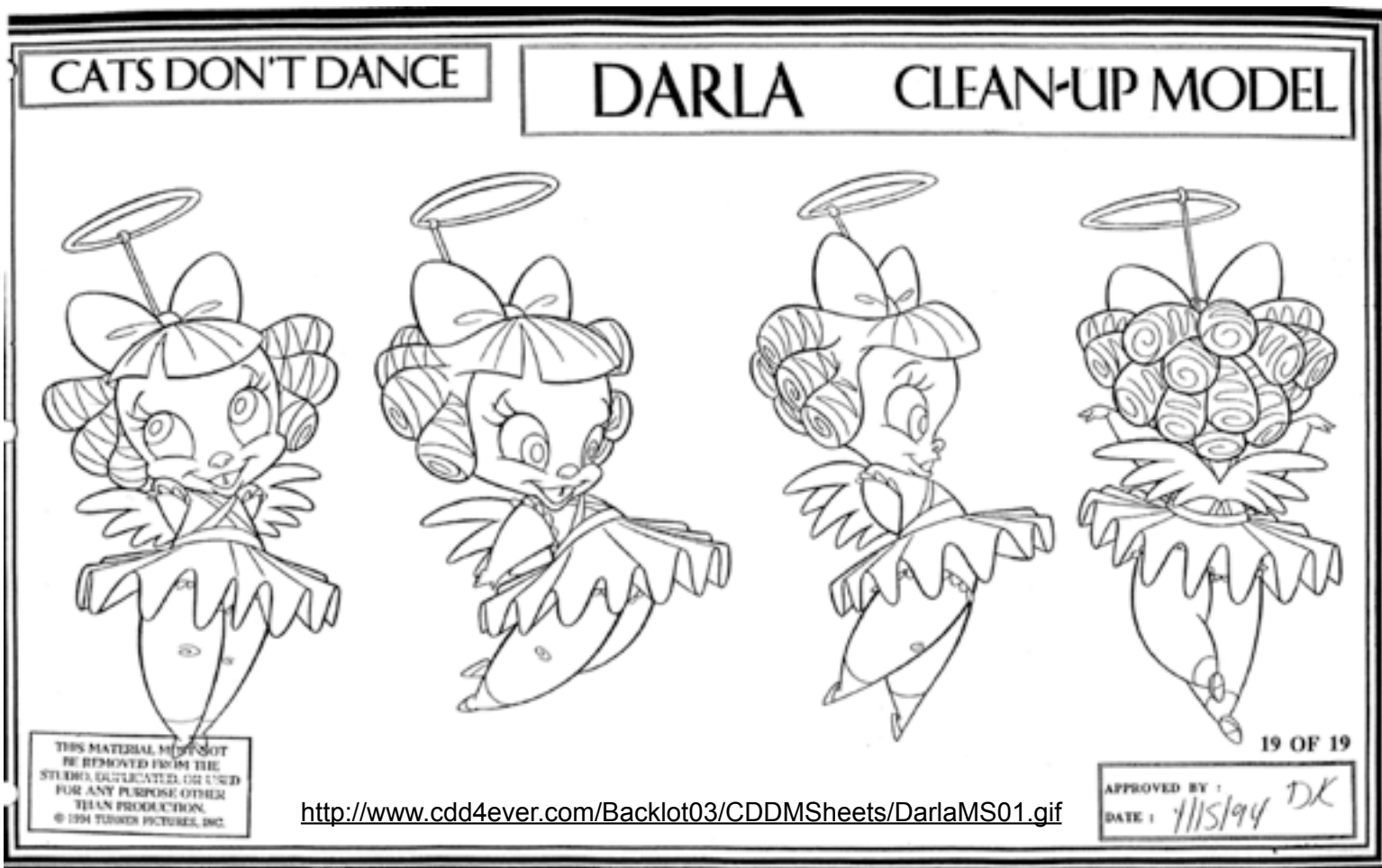


http://germanblogs.de/pub/germanblogs/digitalife/daumenkino_0.jpg

Creating a Classic Cartoon Animation

- Idea > treatment > story board, sound
- Draw keyframes (expensive)
 - important or tricky phases of motion
- Interpolate between keyframes (cheap)
 - easy and straightforward phases
- Color and film the single frames

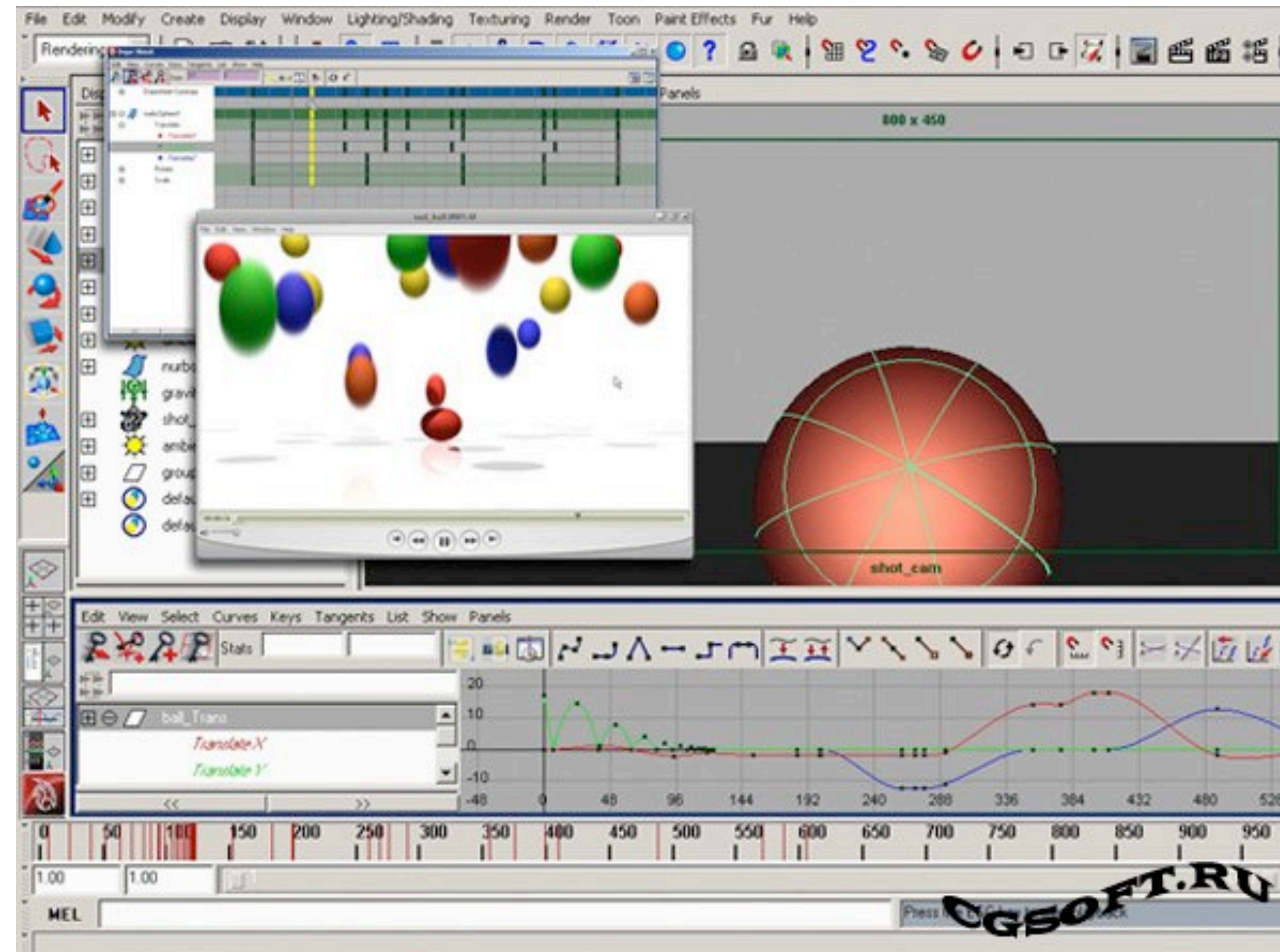
http://webshiva.com/Spring_2005_History_Animation/lectures/images/us_ns_2.jpg



Creating 3D Computer Animation

- Idea > treatment > story board
- Describe keyframes explicitly
 - complete description of the 3D world state
- Interpolate between keyframes
 - calculate state of the world for each frame
- Render and display/store single frames

<http://me-cheza.blogspot.com/2009/10/gnomonology-intro-to-keyframe-animation.html>



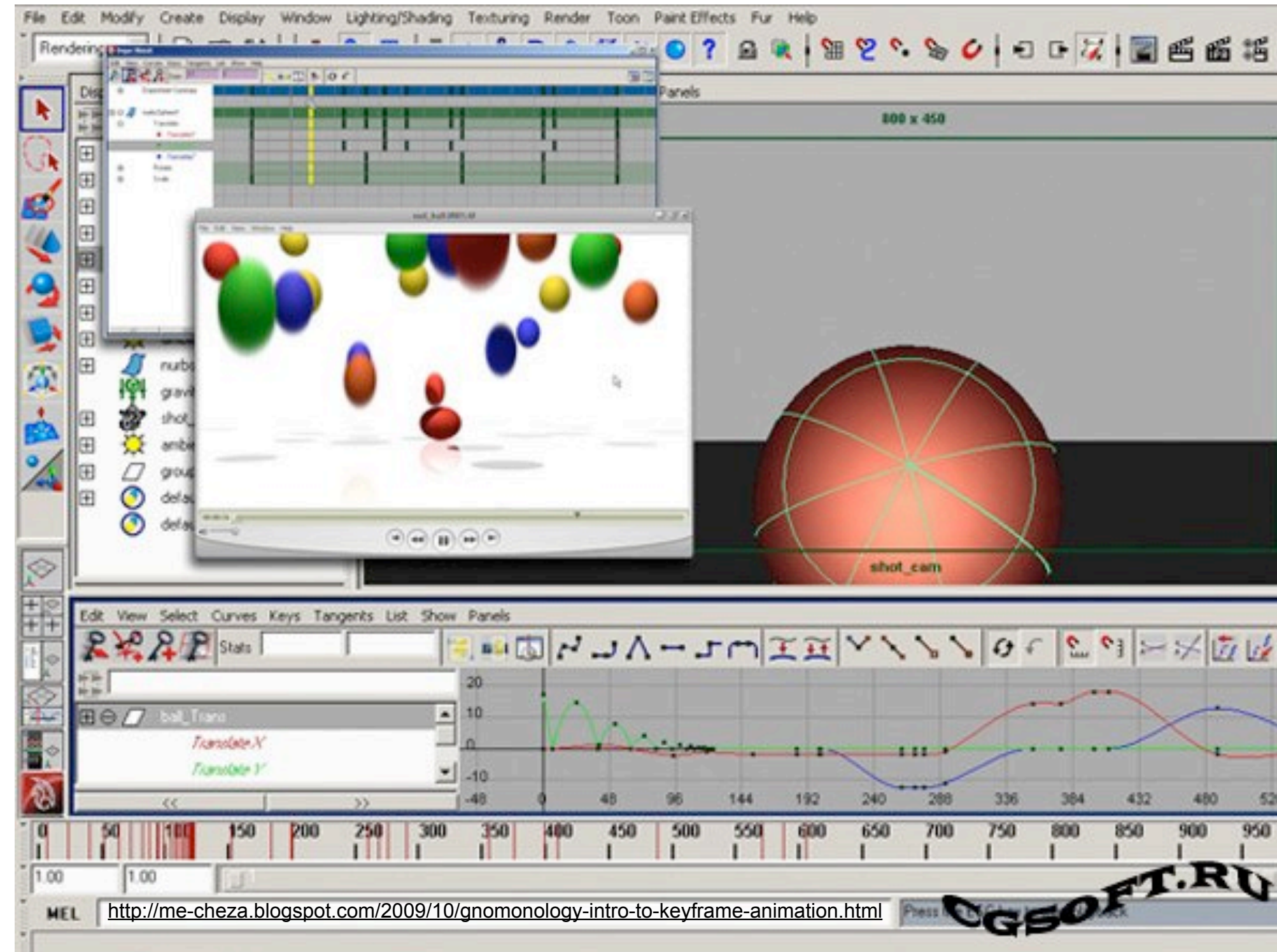
Maya

Chapter 9 - Animation

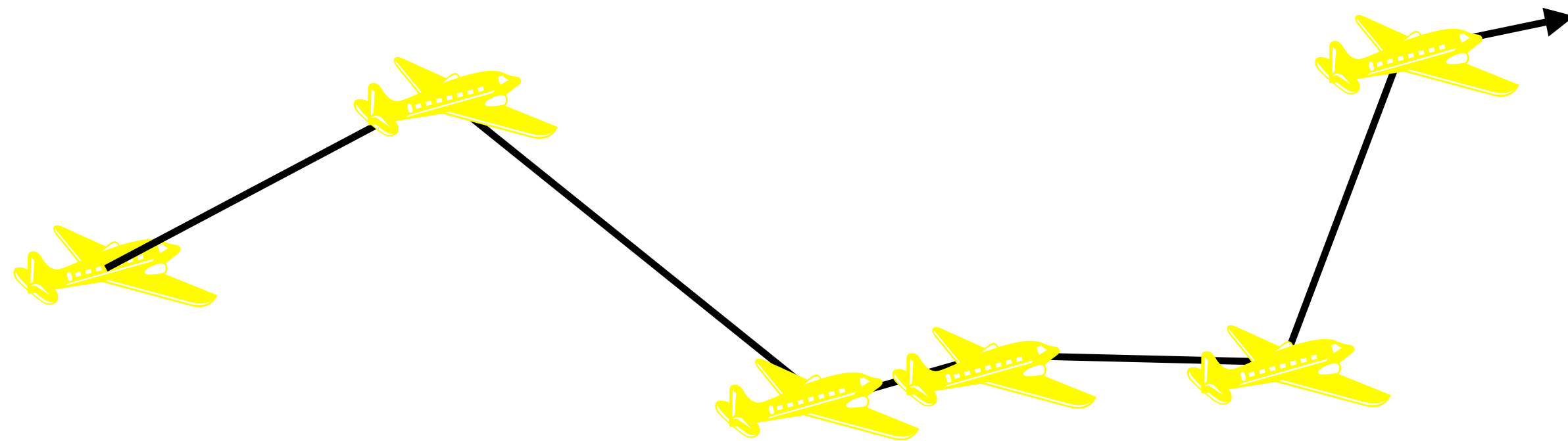
- Animation before the time of 3DCG
- Animation techniques
 - keyframing
 - bone animation & motion capture
 - simulation
- Animation principles

Keyframing

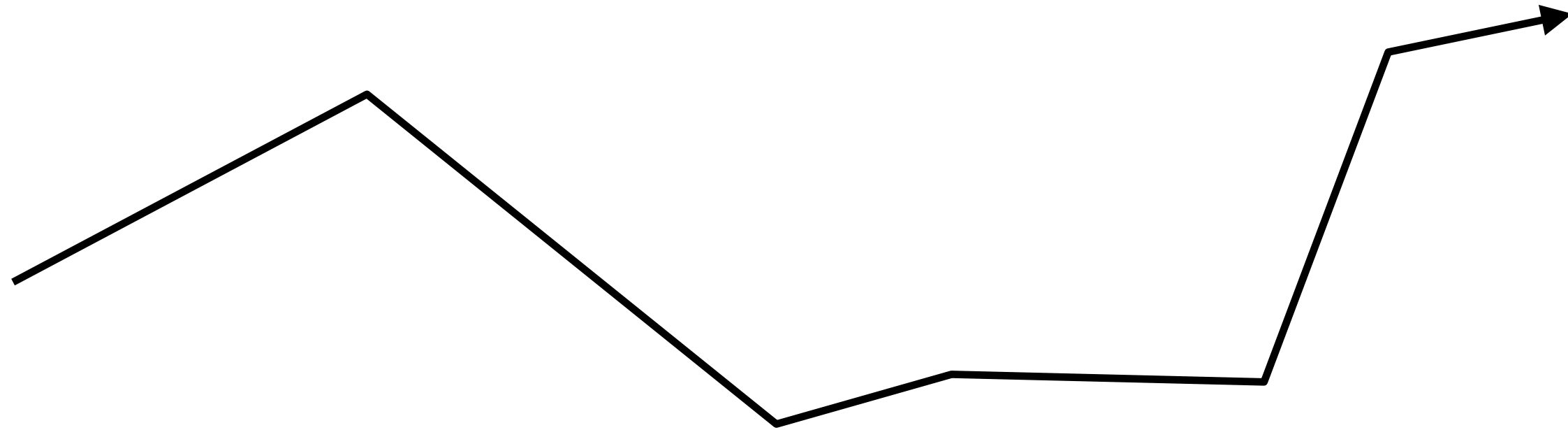
- Define certain parameters of the scene for certain frames
 - not all in every keyframe
 - also known from other authoring systems (e.g. Flash, MS Expression Blend)
 - also applied in purely textual programming and scripting languages (e.g. XAML, JavaFX)



Keyframing the Position

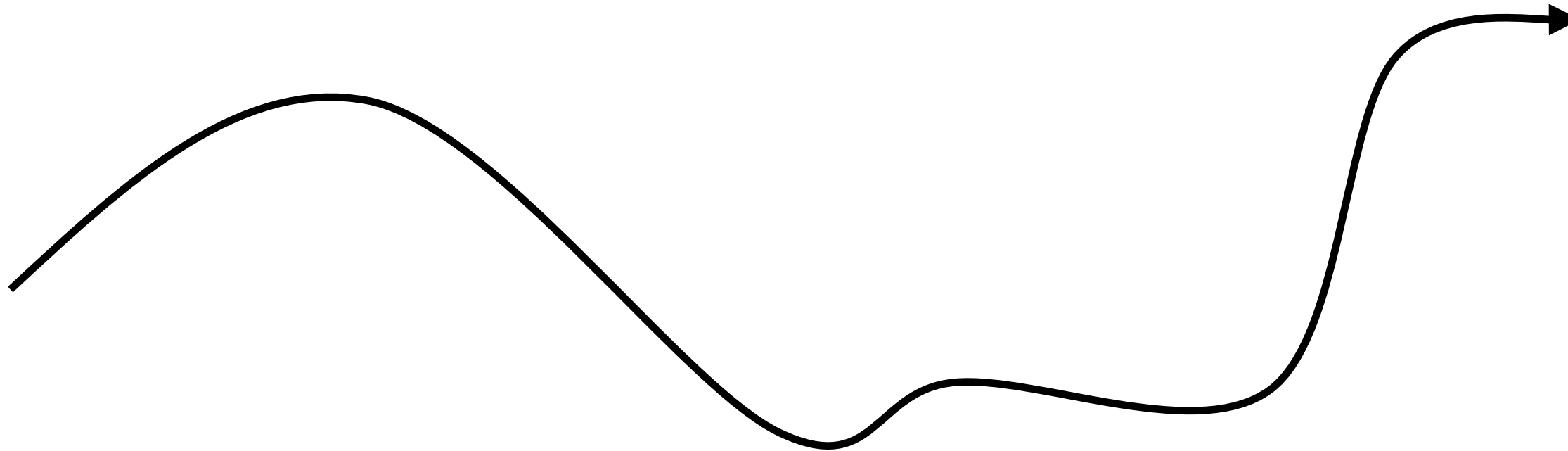


Linear Interpolation



$$x = x_0 + \frac{t - t_0}{t_1 - t_0} (x_1 - x_0), y = y_0 + \frac{t - t_0}{t_1 - t_0} (y_1 - y_0)$$

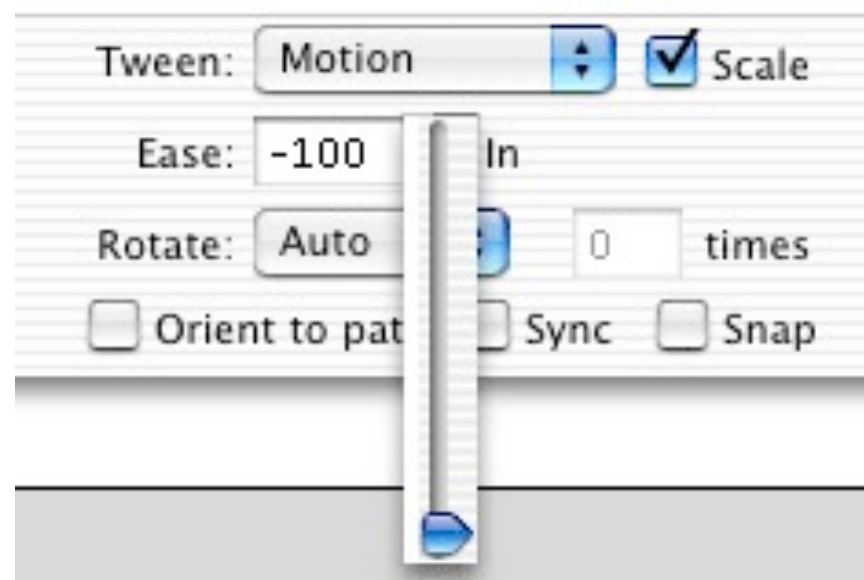
Spline Interpolation (Non-Linearity in Space/Value)



- still only define key frames as control points of the spline
- interpolate in a smooth curve
- risk of overshooting when controlling the splines

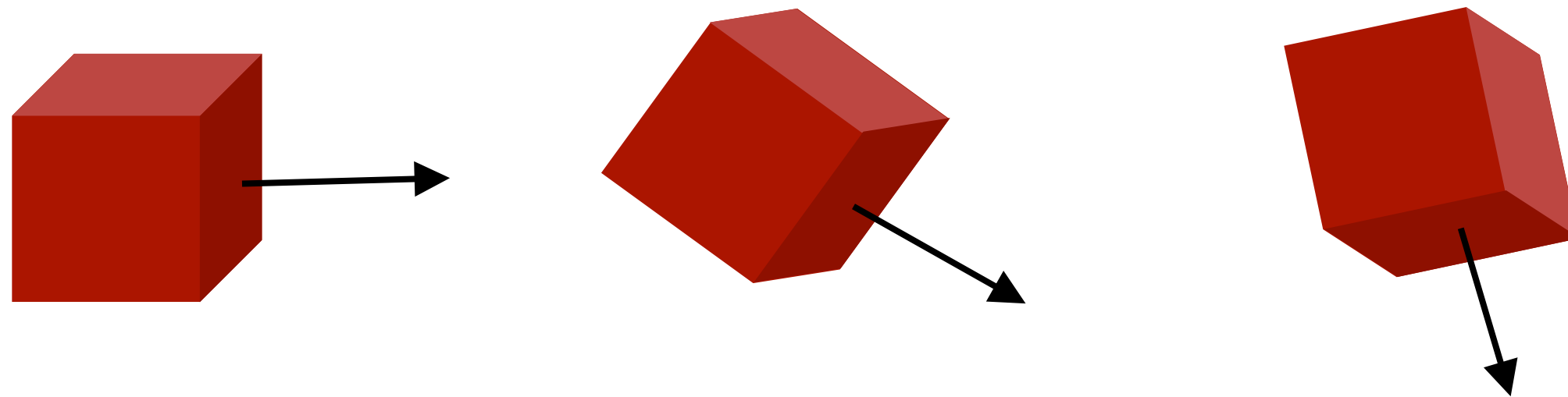
Non-Linearity in Time

- In reality, physics does not allow properties of objects to change in an instant
 - Example: Object taking up speed
- “Ease in” and “ease out”
 - Starting and ending phase of movement
 - Smooth transition
 - Example: Speed changes from zero to given velocity
- Other non-linear behavior over time:
 - E.g. constant acceleration greater than 0 (or varying acceleration)



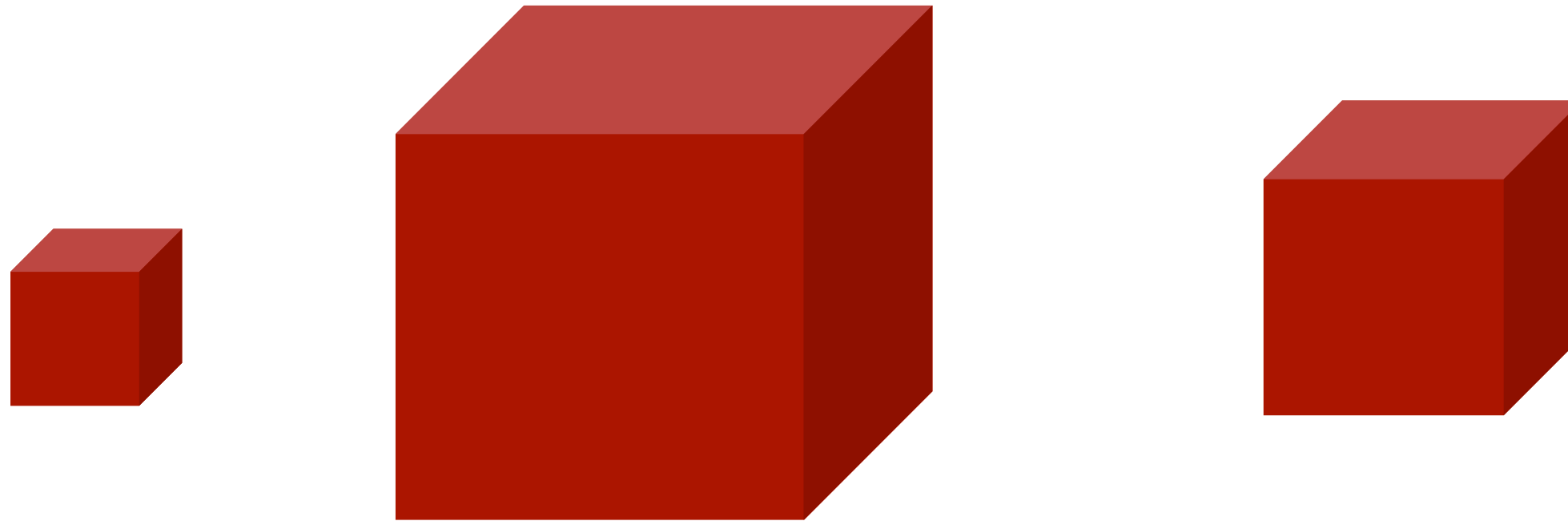
Ease in parameter
in Flash motion tweens

Keyframing the Orientation

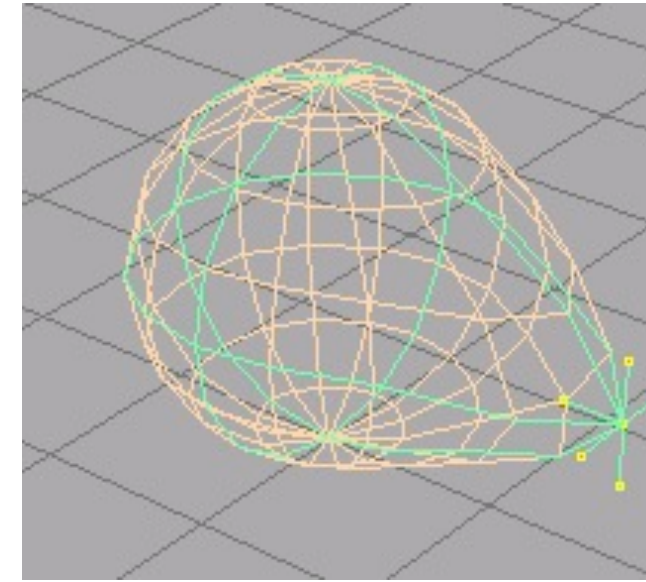
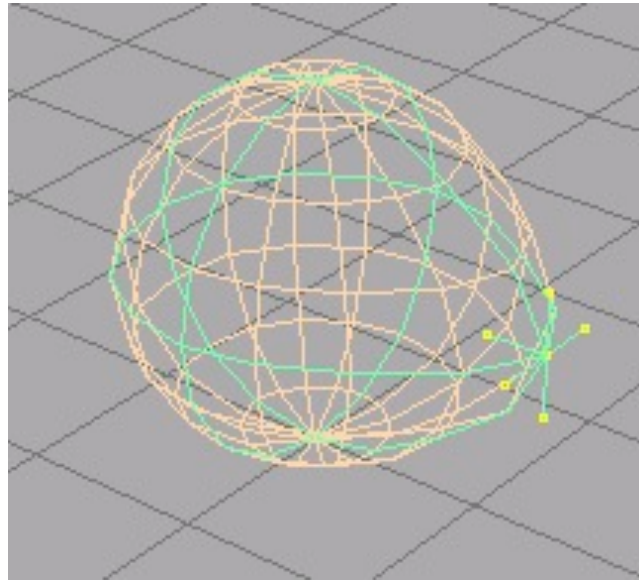
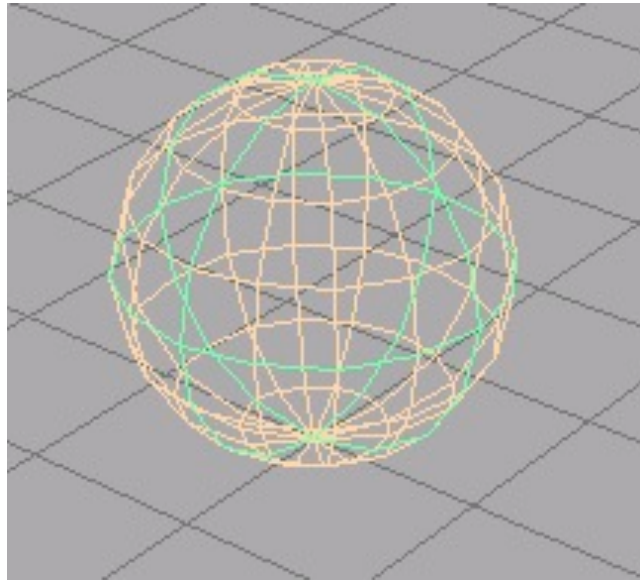


- Choose rotation axis
- interpolate angle about this axis
- or: shortest path on the unit sphere

Keyframing the Size

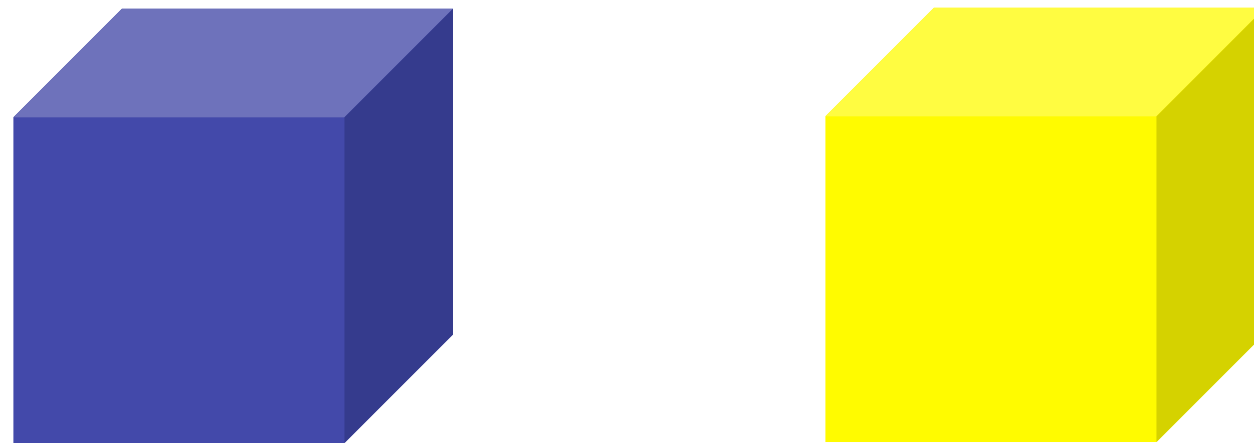


Keyframing Mesh Deformation

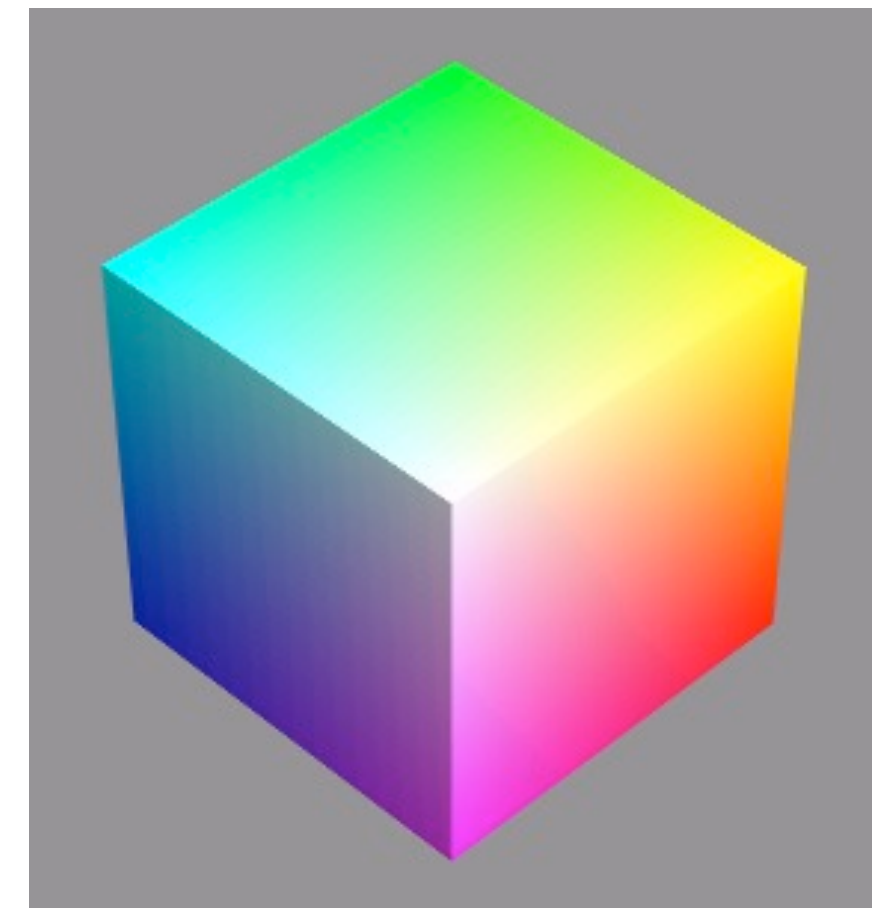


- Grab a control point
- Keyframe its position
- Deform the polygon mesh accordingly

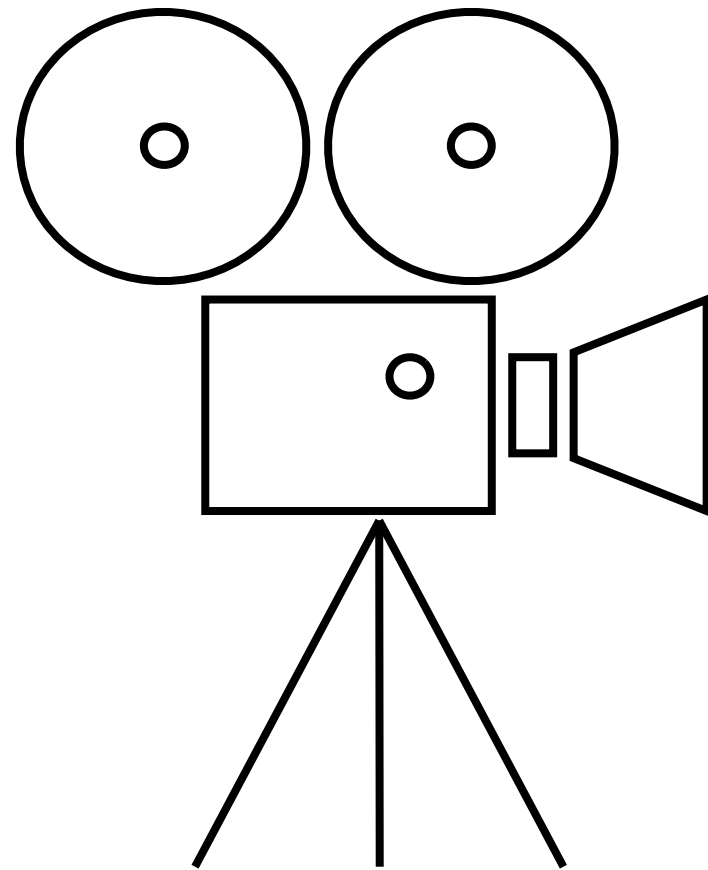
Keyframing the Color



- Can be done in RGB or HSV color space
- what's between yellow and blue then??
- RGB: _____ HSV: _____



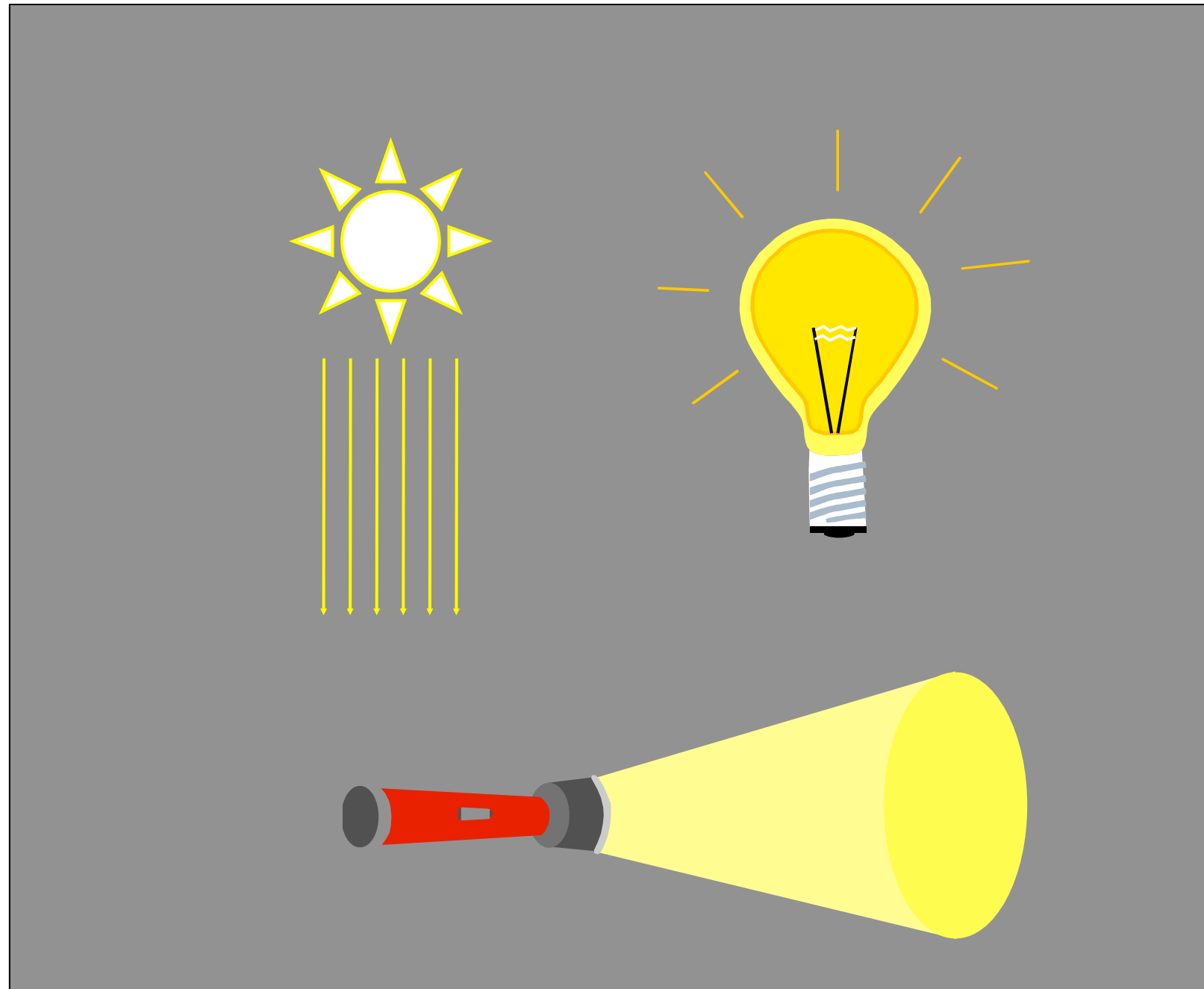
Keyframing the Virtual Camera



- Position
- Orientation

- Field of view
- Depth of field

Keyframing the Light Setup



- directional light
 - positional light
 - ambient light
 - spotlight
 - area light
-
- position
 - direction
 - beam angle

Other Things to Keyframe

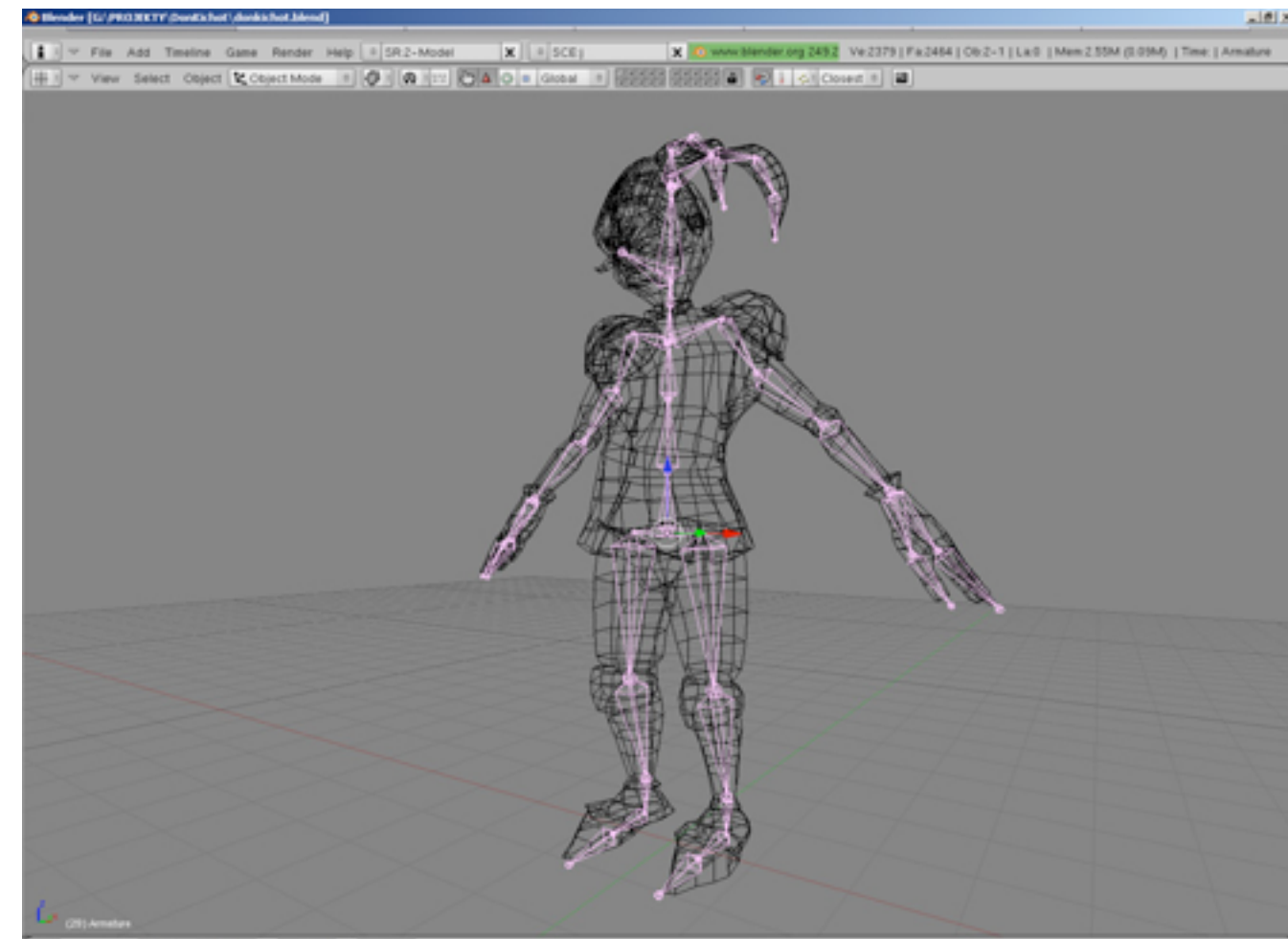
- levels of detail
- visibility
- transparency, shininess
- texture / bump maps
- shading parameters
- rendering method

Chapter 9 - Animation

- Animation before the time of 3DCG
- Animation techniques
 - keyframing
 - bone animation & motion capture
 - simulation
- Animation principles

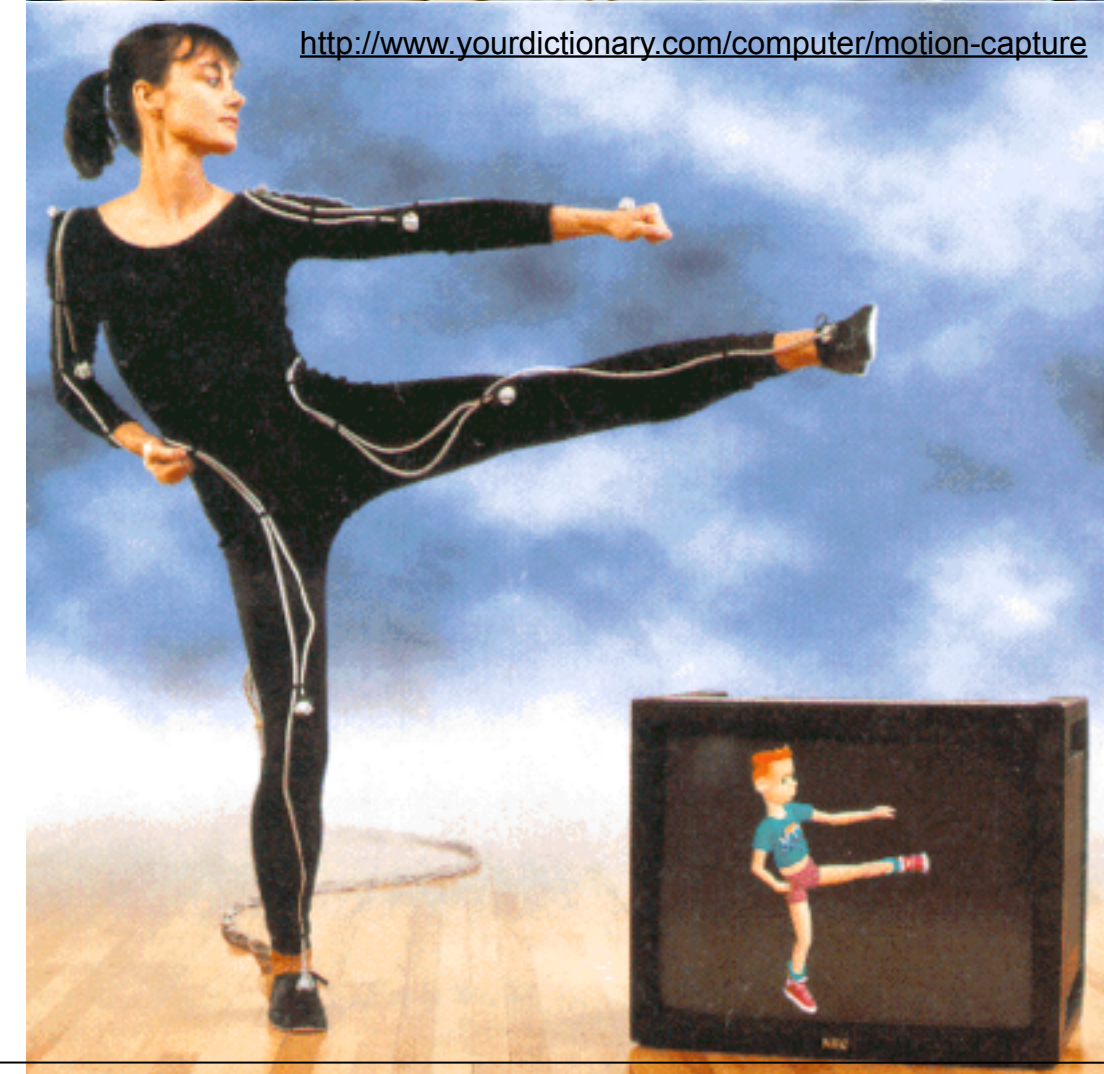
Bone animation

- Also: skeletal animation
- Define a skeleton for a polygon mesh
 - topology/structure of the model
- Move only the bones of this skeleton
 - by keyframing joint angles
 - by motion capture data
 - by inverse kinematics
- Polygon mesh follows and deforms
 - connection between bone and mesh is not rigid
 - mesh stays closed and smooth



Motion Capture

- Tracking position and/or orientation of
 - limbs of an actor
 - feature points of a face
 - optical markers on a suit
- Define a relation between tracked feature points and 3D scene points
- Move the mesh exactly along the tracked data
- Still gives the most realistic results



Real-Time Rendering and Motion Capturing

- “Avatar” (2009, James Cameron)
 - Large motion-capture stage
 - “full performance capture”
 - Skull caps for actors with facial expression capture cameras
- “Virtual Camera” Augmented Reality technology
 - Shows virtual counterparts of actors in real-time
- Huge amount of data assets
- Rendering machine:
4,000 servers
with 35,000 processors

<http://www.junauza.com/2010/01/technology-behind-avatar-movie.html>



Making of Avatar (Cut)

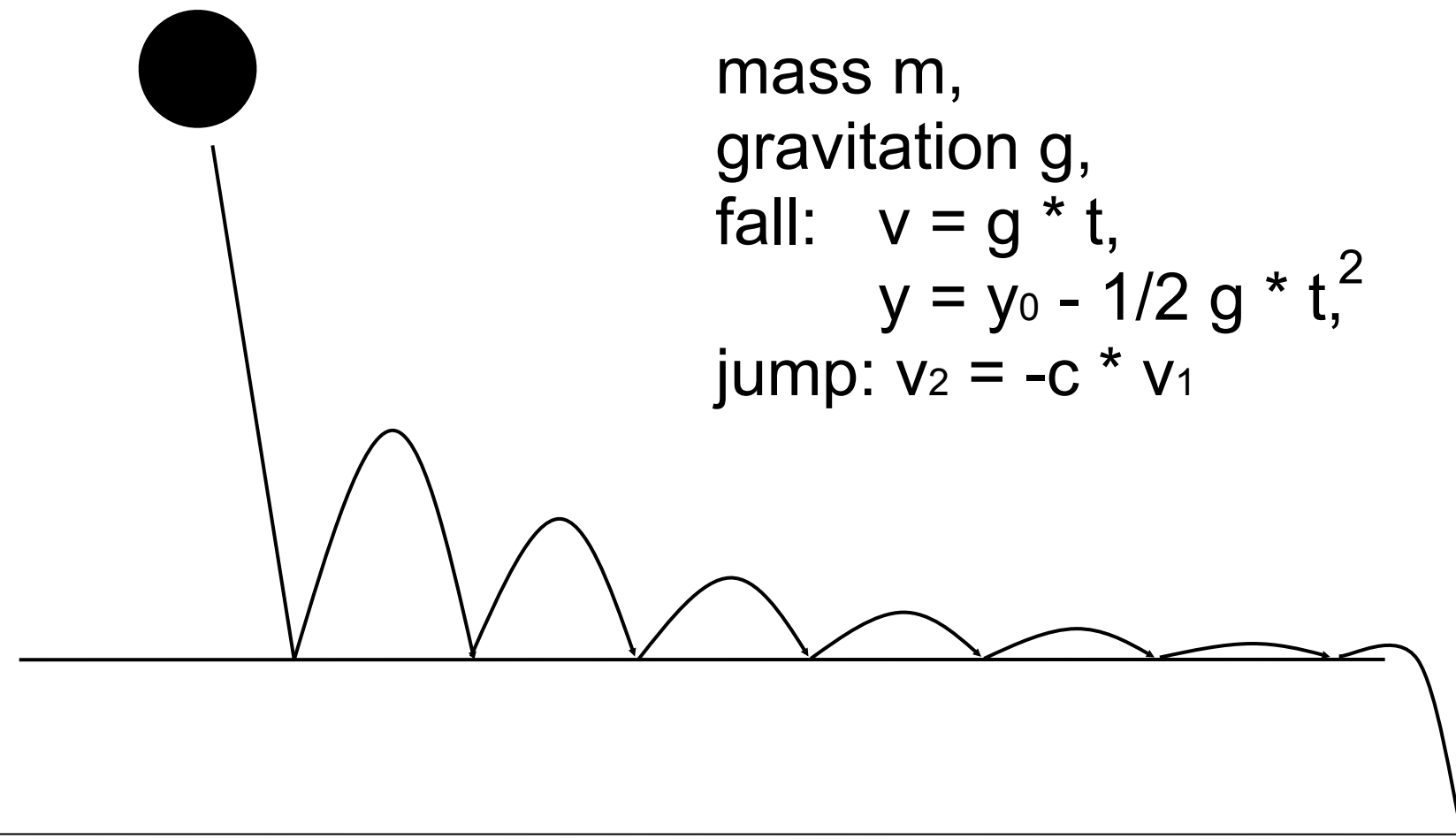


Chapter 9 - Animation

- Animation before the time of 3DCG
- Animation techniques
 - keyframing
 - bone animation & motion capture
 - simulation
- Animation principles

Physics simulation

- Physics engine is often an integral part of 3D games
 - calculations can be done efficiently on GPUs, for example
 - can handle large numbers of objects
- Not all aspects of physics need to be simulated
- Two examples
 - Inverse kinematics
 - Particle systems

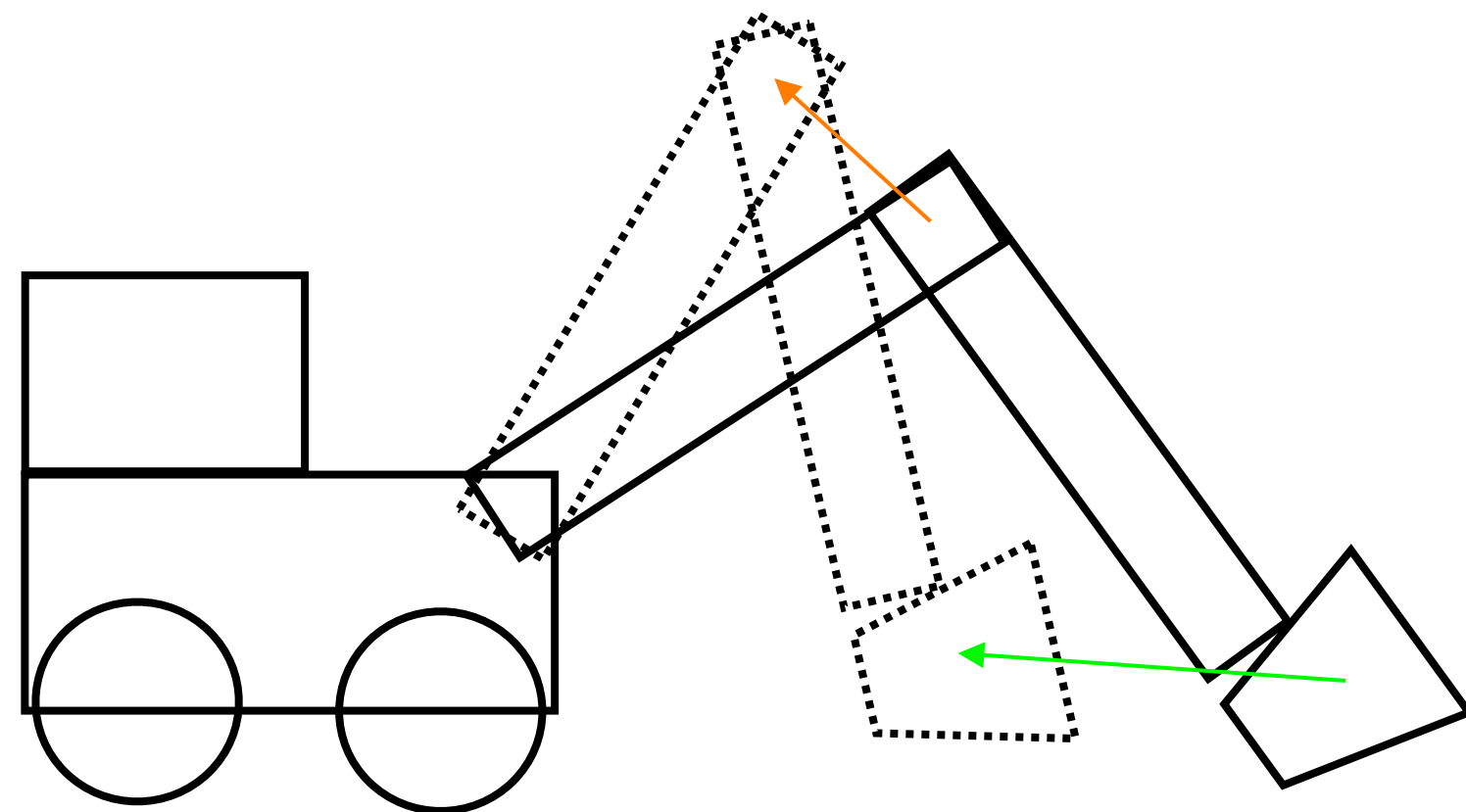


mass m ,
gravitation g ,
fall: $v = g * t$,
 $y = y_0 - 1/2 g * t^2$,
jump: $v_2 = -c * v_1$

Inverse Kinematics

- Kinematics describes, how an object moves
- *Forward* kinematics: how does the object move, given the joint angles
- *Inverse* kinematics: what are the joint angles, given the object motion

- Mainly a way to save work in keyframing



Particle Systems

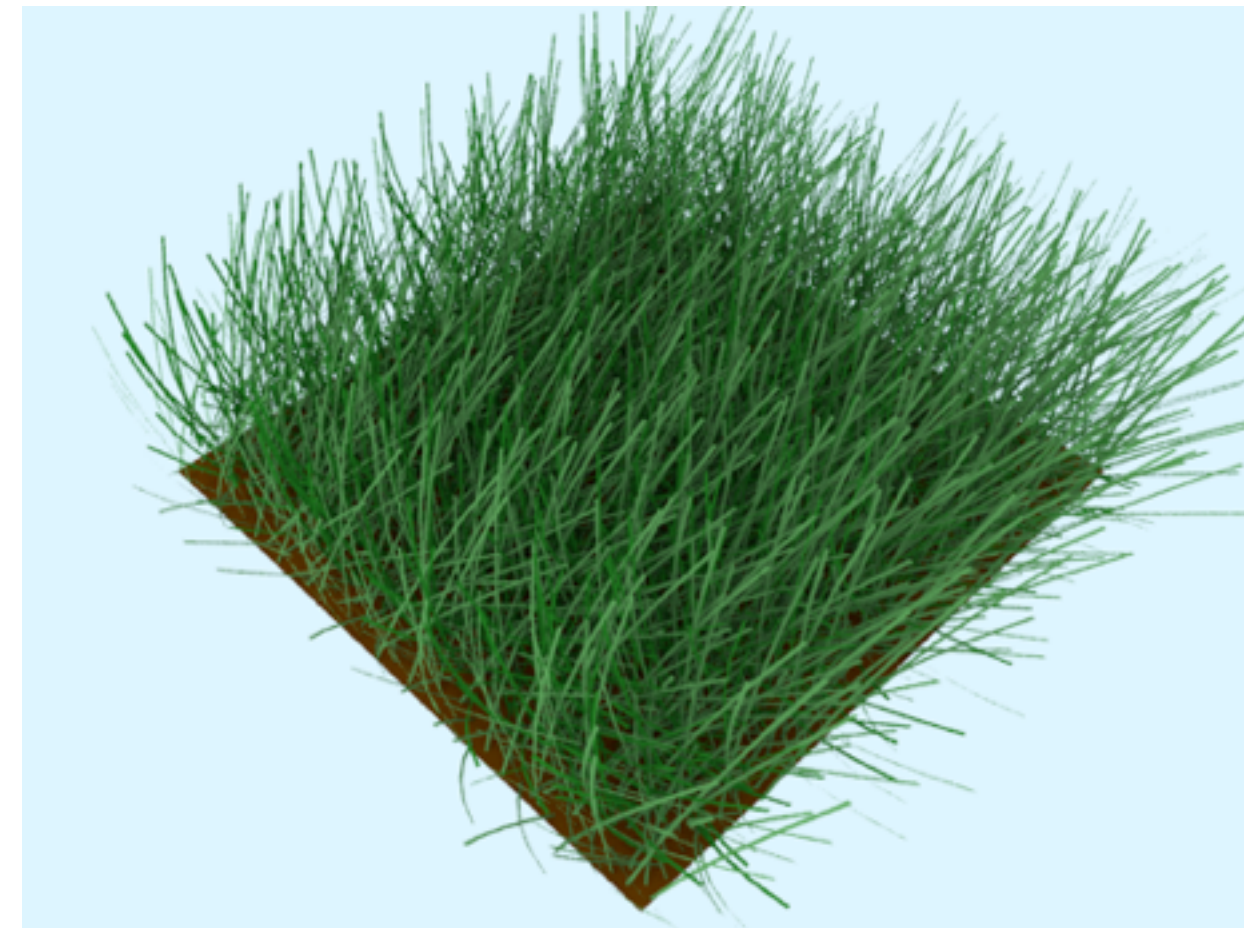
- Used for various phenomena
 - dust, explosions
 - fire
 - grass, hair, fur
- Generates a large number of objects
- Moves them with simple physics
- Handle collisions etc..

- No detailed influence on single objects
- Parameters of creation and motion can be controlled



http://www.cg-tutorials.com/oneadmin/_files/linkdir/1685_Create_fire_effects_with_particle_system.jpg

<http://www.blender3darchitect.com/wp-content/uploads/2009/07/blender-3d-yafaray-realistic-grass.png>



AI Example: Flocks, Herds, Schools

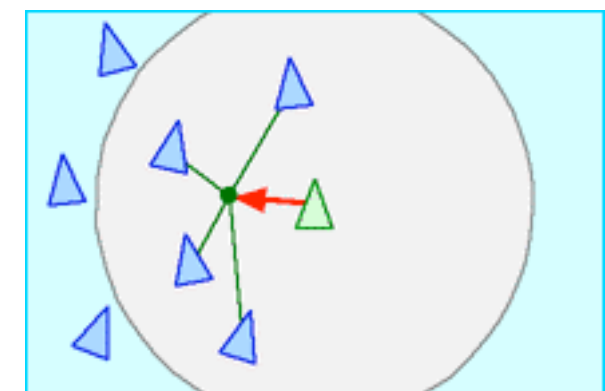
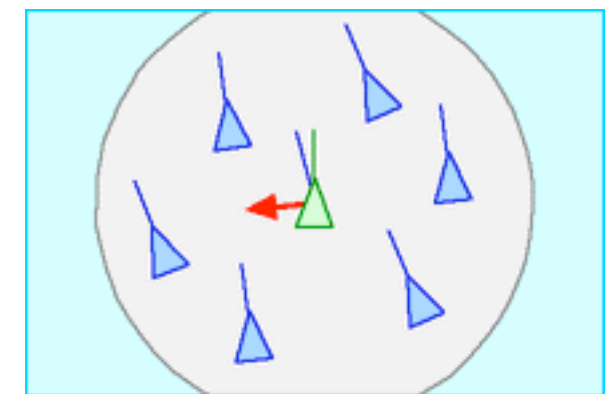
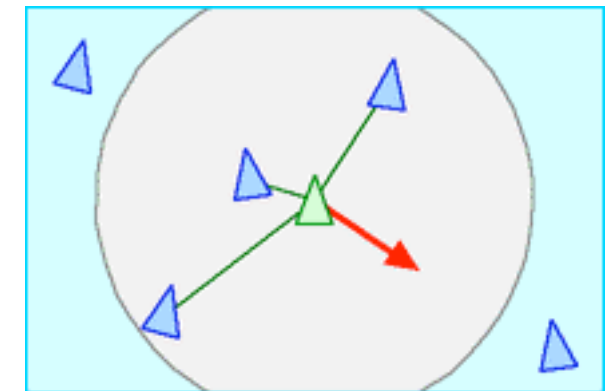
- A classic example of a simulation of a natural phenomenon (1987)
- <http://www.red3d.com/cwr/boids/>
- [Reynolds, C. W. (1987) Flocks, Herds, and Schools: A Distributed Behavioral Model, in Computer Graphics, 21(4) (SIGGRAPH '87 Conference Proceedings) pages 25-34.]

- Each bird/fish has 3 simple control principles

- Separation: steer to avoid crowding local flockmates

- Alignment: steer towards the average heading of local flockmates

- Cohesion: steer to move toward the average position of local flockmates



Stanley & Stella in Breaking the Ice (1987)



Chapter 9 - Animation

- Animation before the time of 3DCG
- Animation techniques
 - keyframing
 - bone animation & motion capture
 - simulation
- Animation principles

Animation Principles

- Known by cell animators for a long time
- Will make your animations look appealing
- Often have to do with exaggeration
 - support our perception of a character/motion



- Examples here from tutorials at
 - <http://www.comet-cartoons.com/toons/3ddocs/charanim/>
 - http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/prin_trad_anim.htm
 - http://billysalisbury.com/tutorials_principles.htm

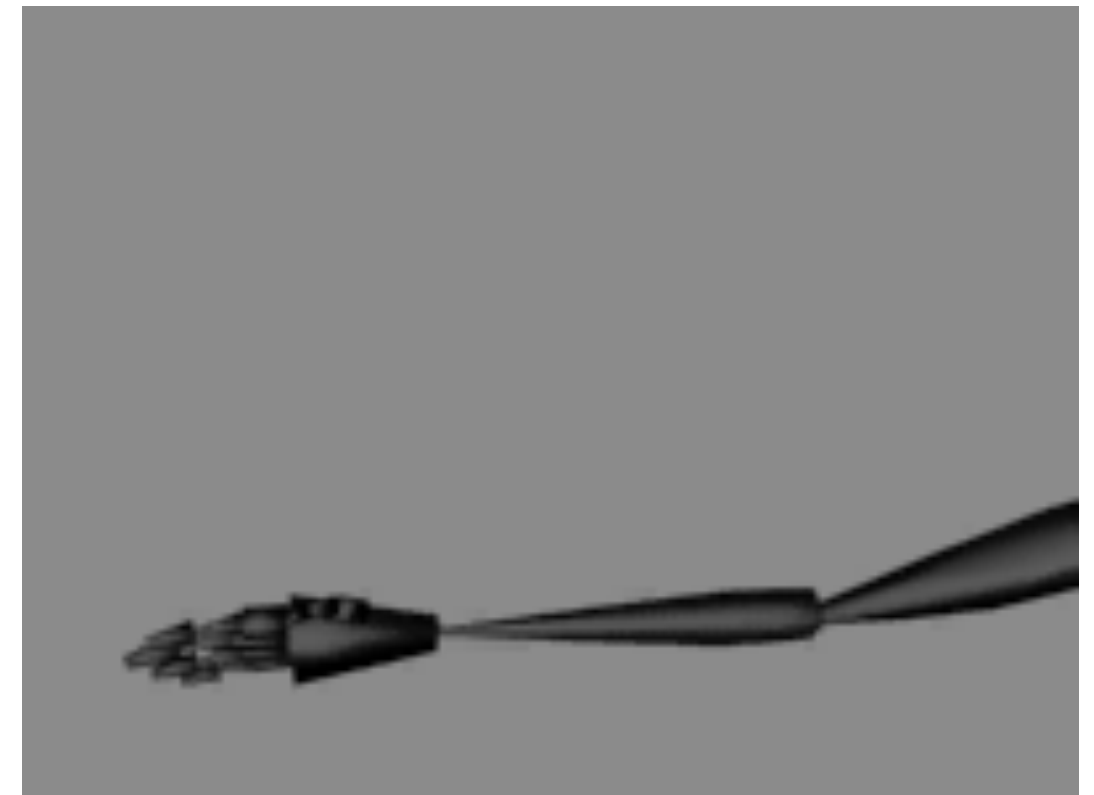
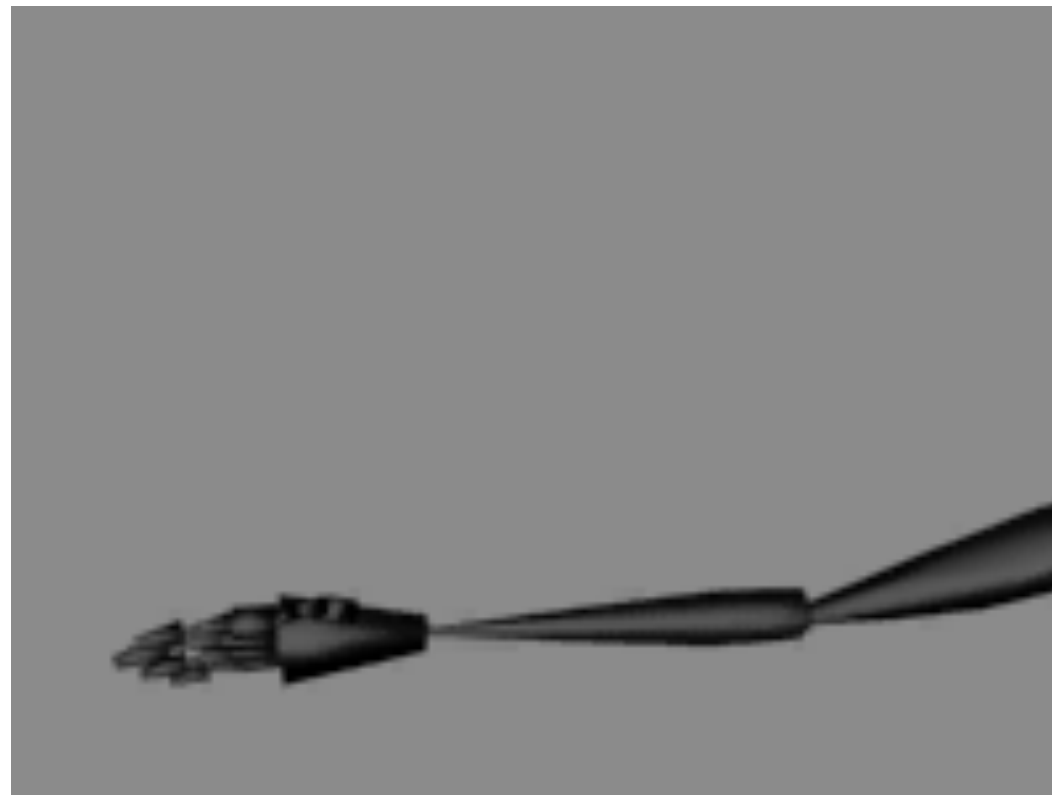
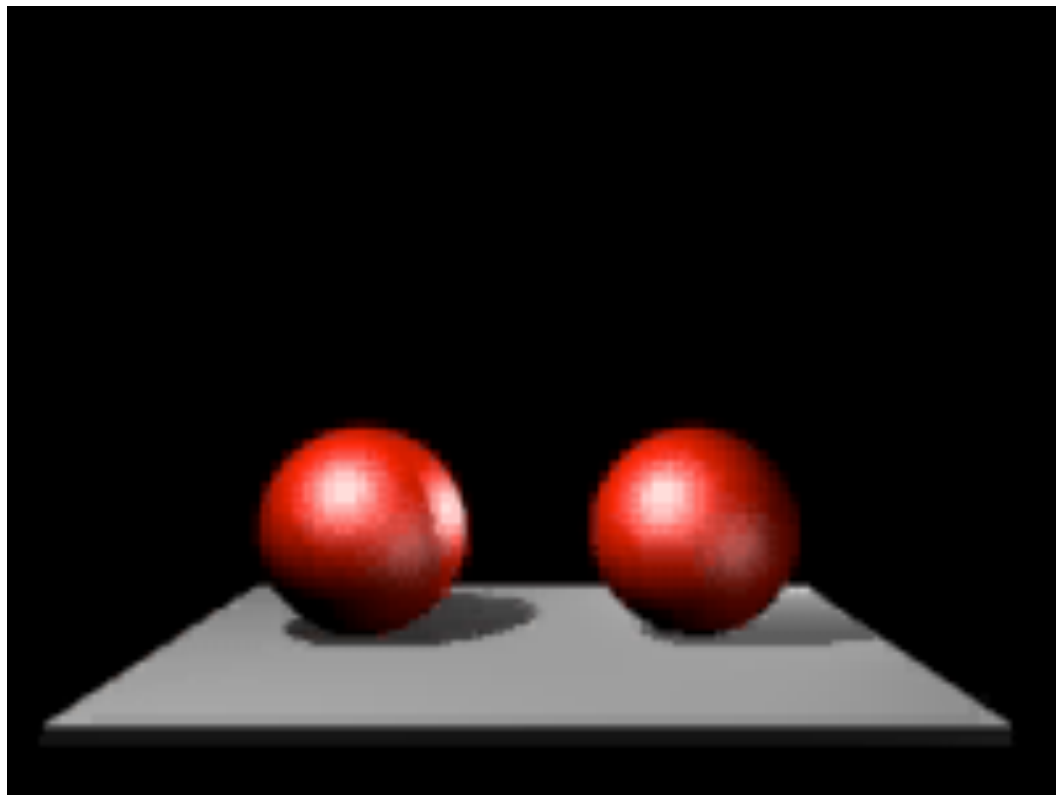
Timing

- The exact same motion can express entirely different things at different speeds
- Generally: slow timing conveys calm, fast timing conveys hectic
- "The difference between the right timing and the almost right timing, is the difference between lightning and a lightning bug."



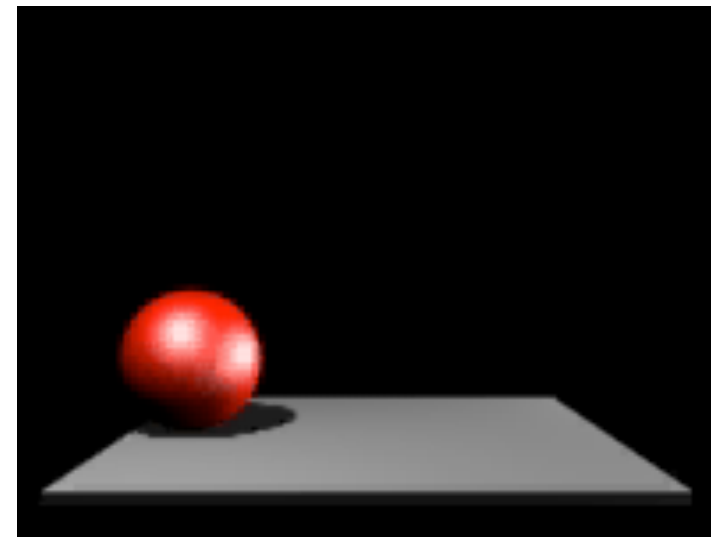
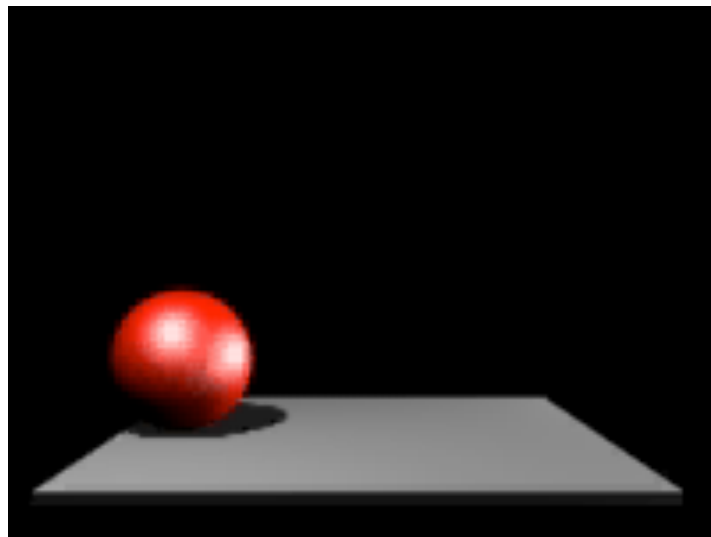
Ease In and Out (or Slow In and Out)

- All motions in nature start slowly and accelerate
- Due to physics (inertia of mass)
- Heavy objects generally accelerate slower
- Light objects accelerate faster
- Can be combined with object deformations



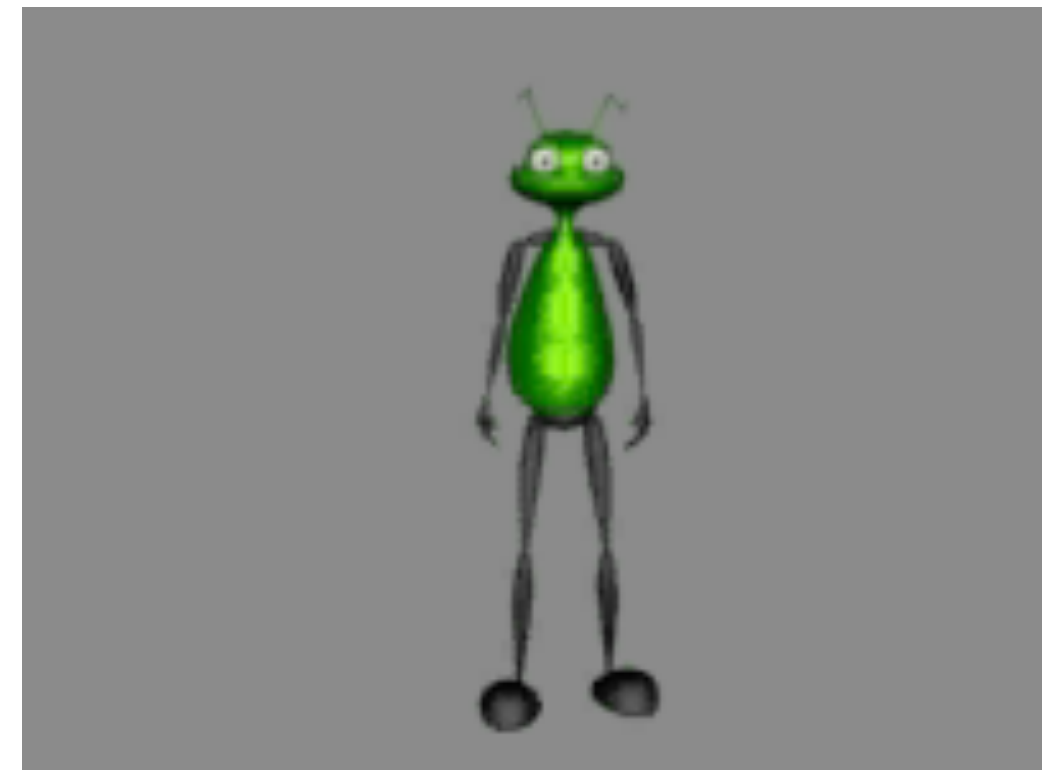
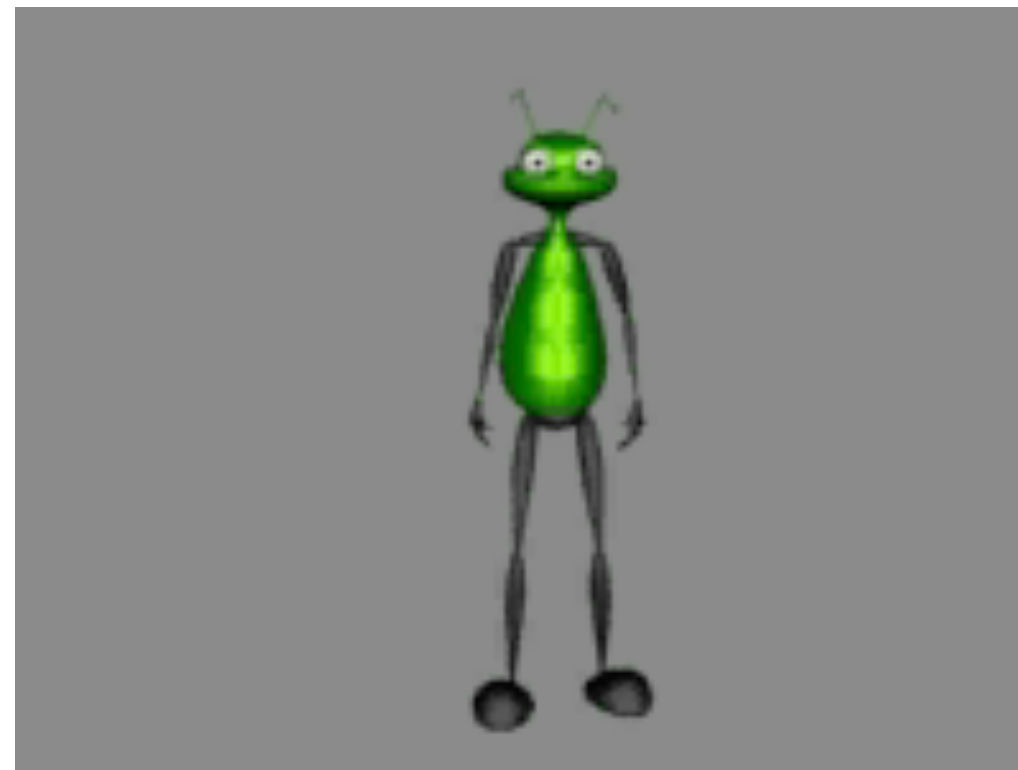
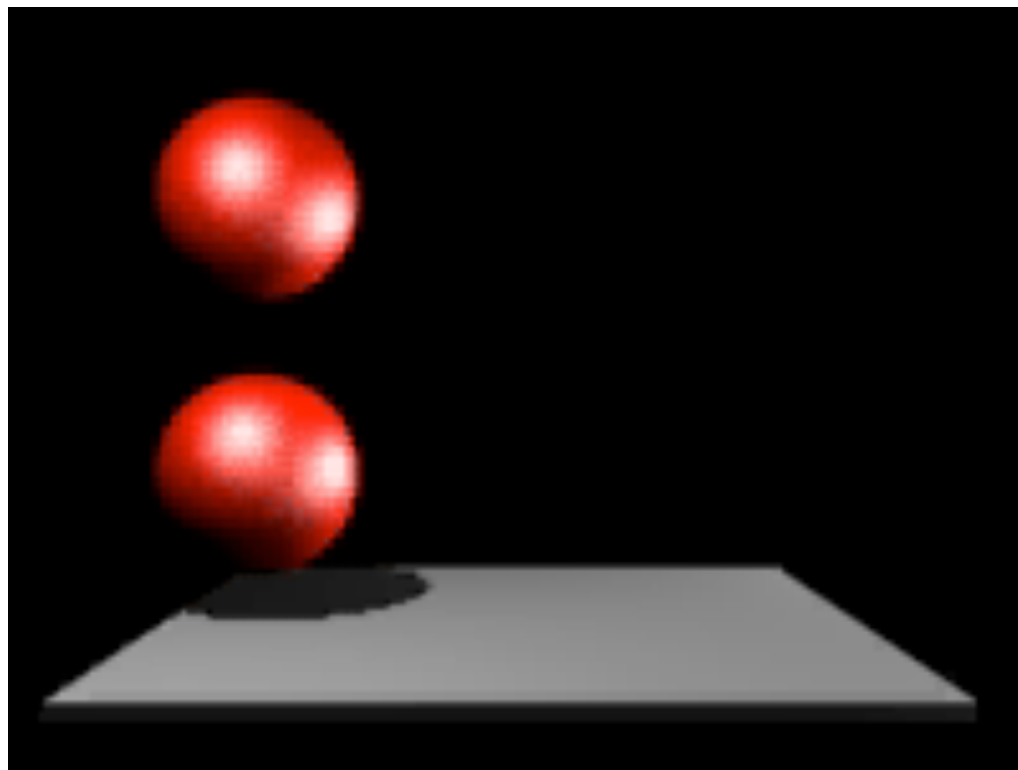
Arcs

- Many motions in nature happen in arcs.
- Linear motions only in machines
- Motion in arcs look more natural on characters



Anticipation

- Motions in nature never start abruptly.
- There is always a phase before the actual motion, when the character already knows he wants to move.
- Is used with much exaggeration in cartoons



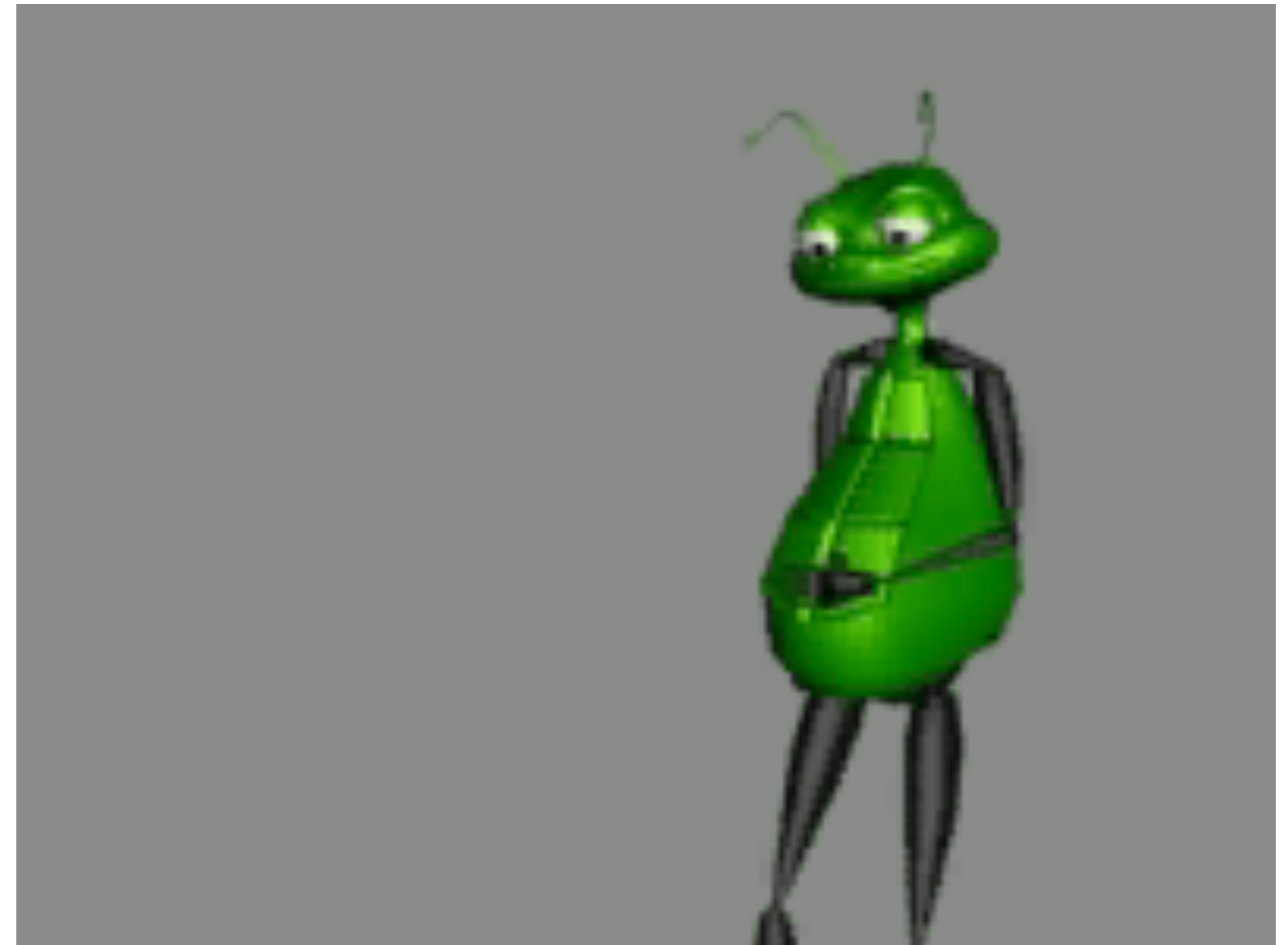
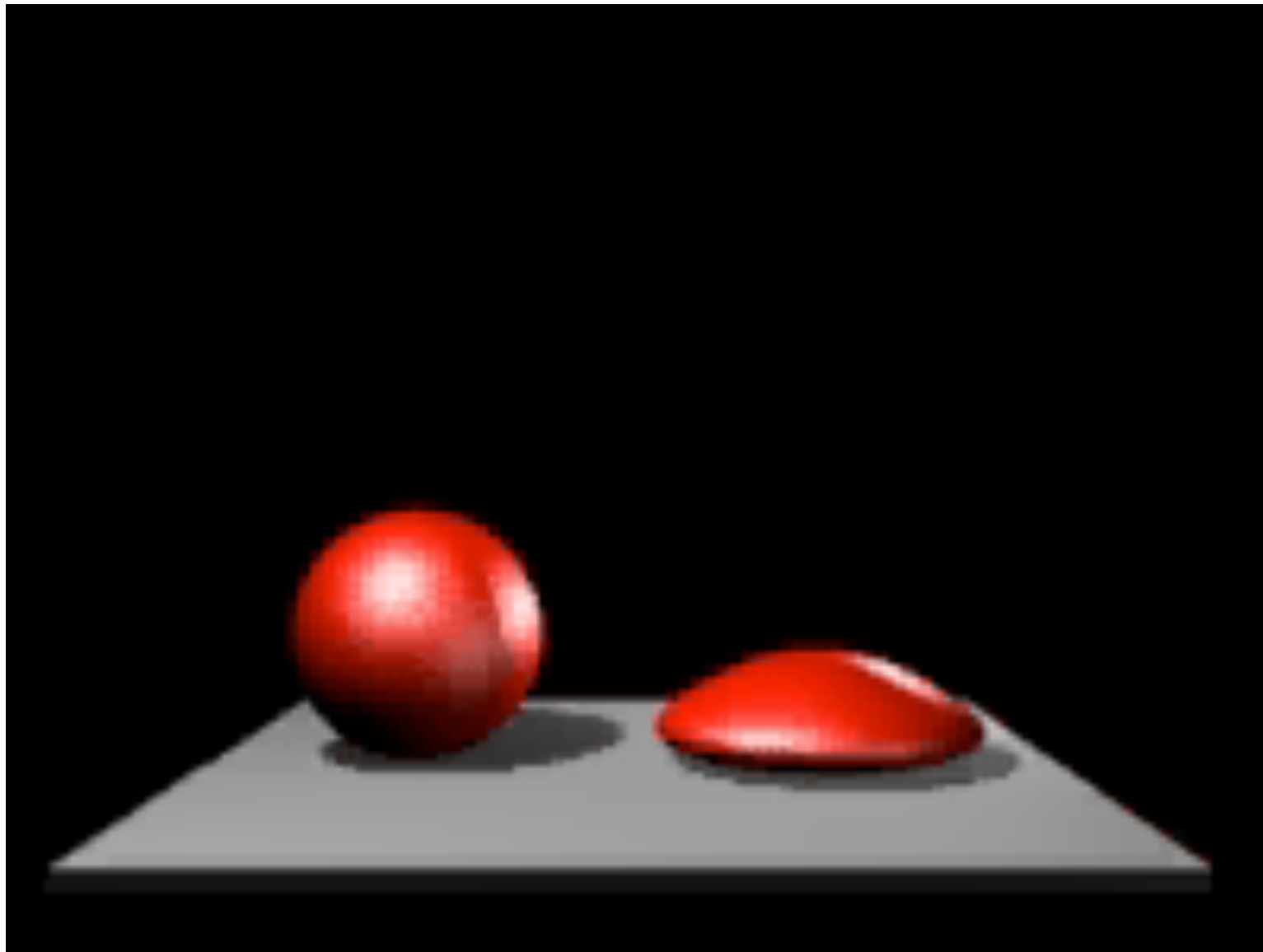
Exaggeration



- Motions come across more pointedly when exaggerated
- Light exagg. = only emphasizing the motion
- Strong exagg. = cartoon-like appearance

Squash and Stretch

- Soft objects are squashed when they hit an obstacle and stretch when released.
- All objects are soft to *some* extent
- Again: exaggeration creates a cartoon-like appearance



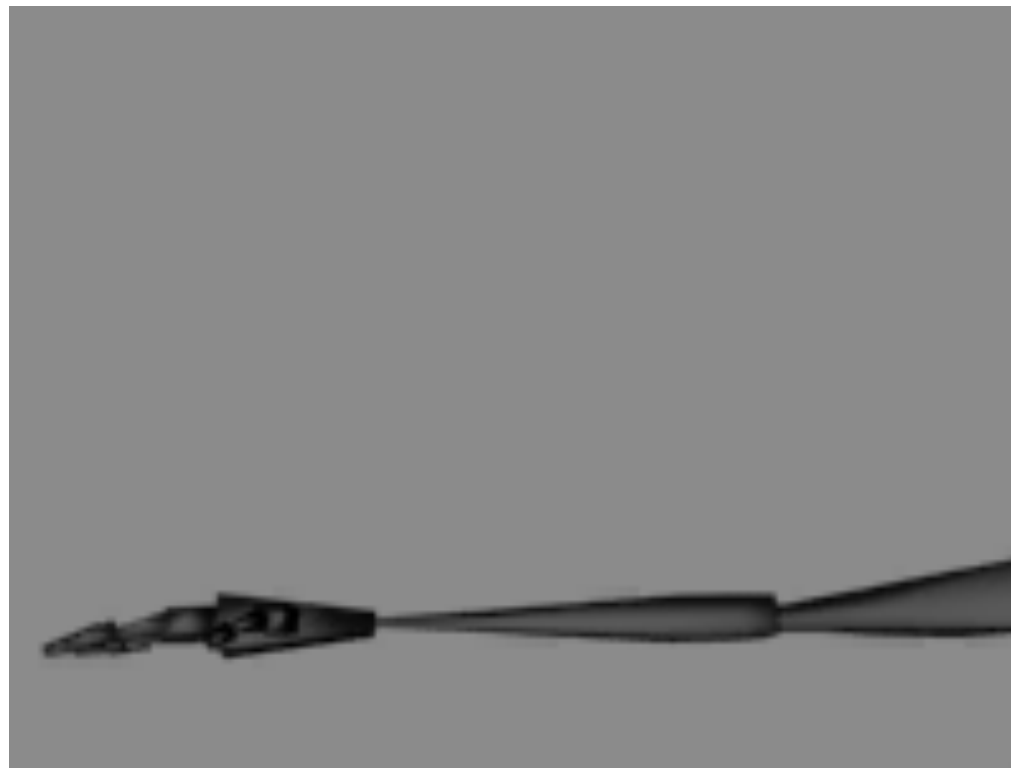
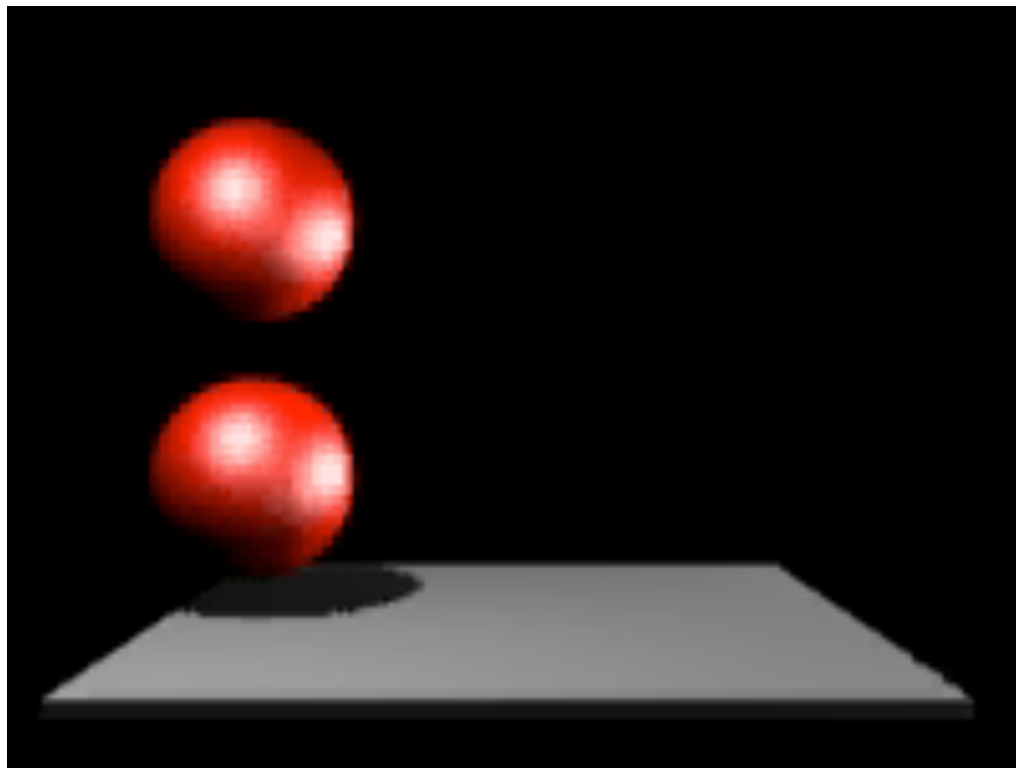
Secondary Action

- Secondary story/character/movement in the background
- Should not overpower main action
- Creates a counterpoint to the main action
- Can be used for running gags, Eastereggs
- Can create ironic side notes
- Can emphasize atmosphere
- Example:
 - fingers on the table
 - Figure in the background



Follow Through and Overlapping Action

- Same as anticipation, but at the end of an action
- Object goes past its resting point and then comes back to where it would normally be.
- Again: exaggeration creates a cartoon-like appearance

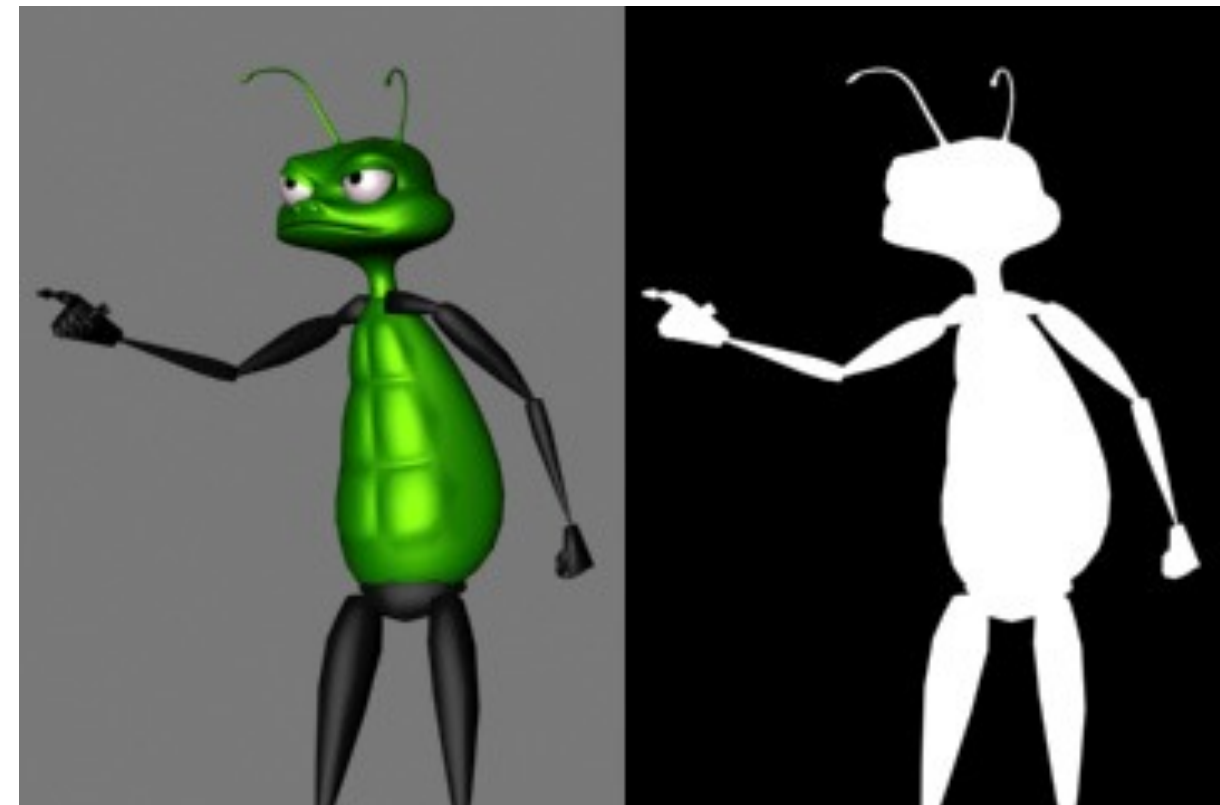
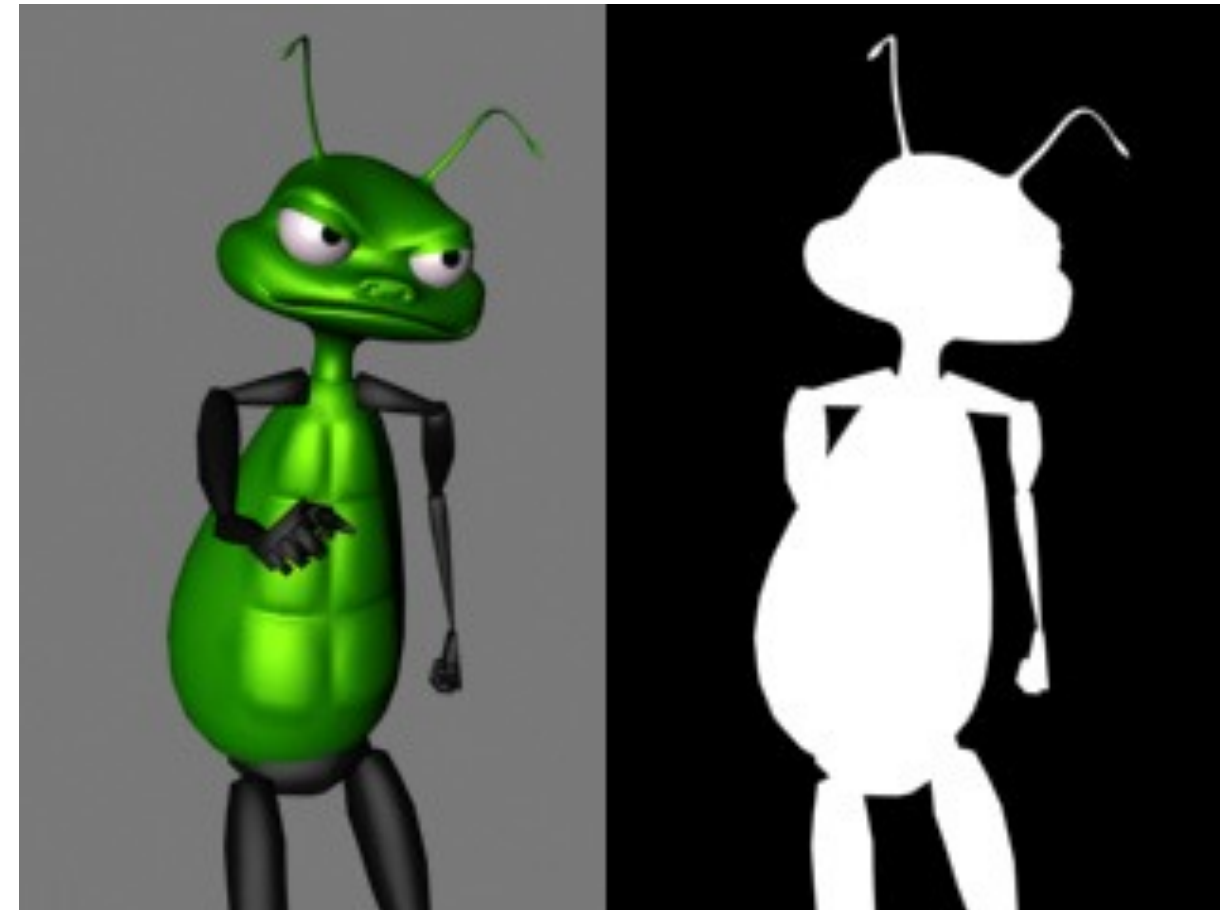


Straight Ahead and Pose-To-Pose Action

- Define pose frame by frame from start to end
- Not sure where it will end until done
- Useful for fine tuning motions
- Define start pose and end pose
- Interpolate poses inbetween
- Leads to well defined key frames
- Useful for tweaking the timing

Staging

- Make action and objects understandable
- Show actions one at a time
- position objects to maximize silhouette
- Combine effects to convey a consistent message



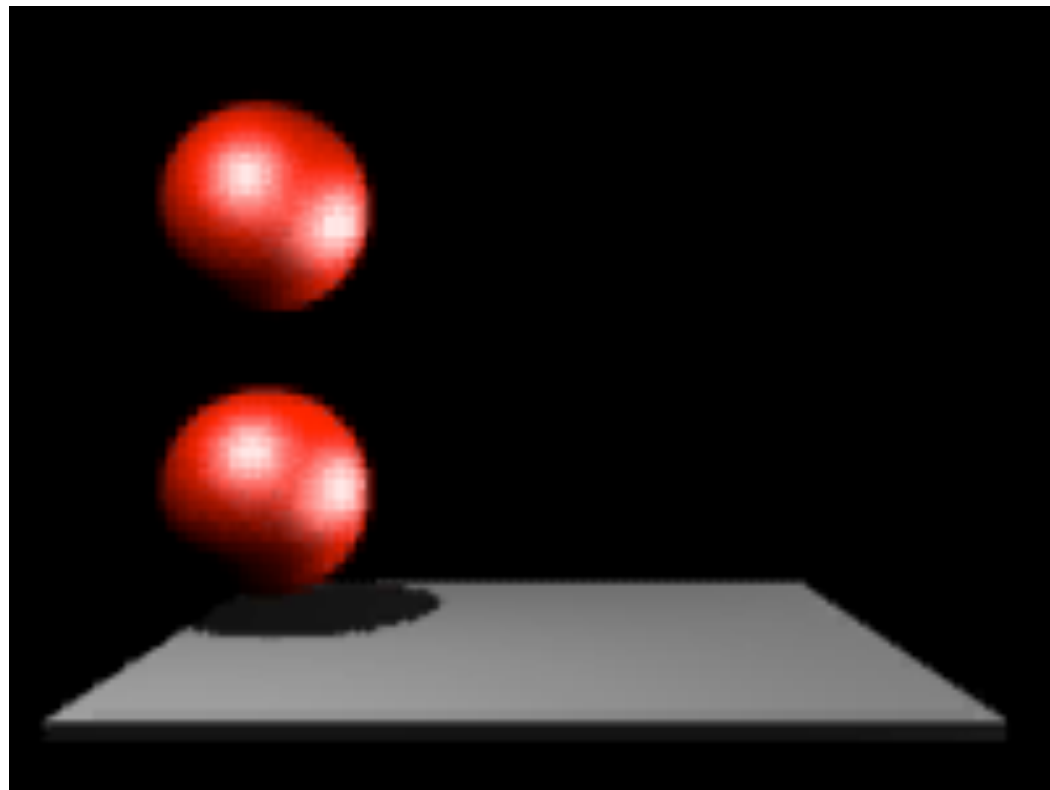
Non-Symmetrical Posing and Performing

- Asymmetrical compositions are more interesting
- Nature is almost never *perfectly* symmetric
- Image diagonal can convey atmosphere



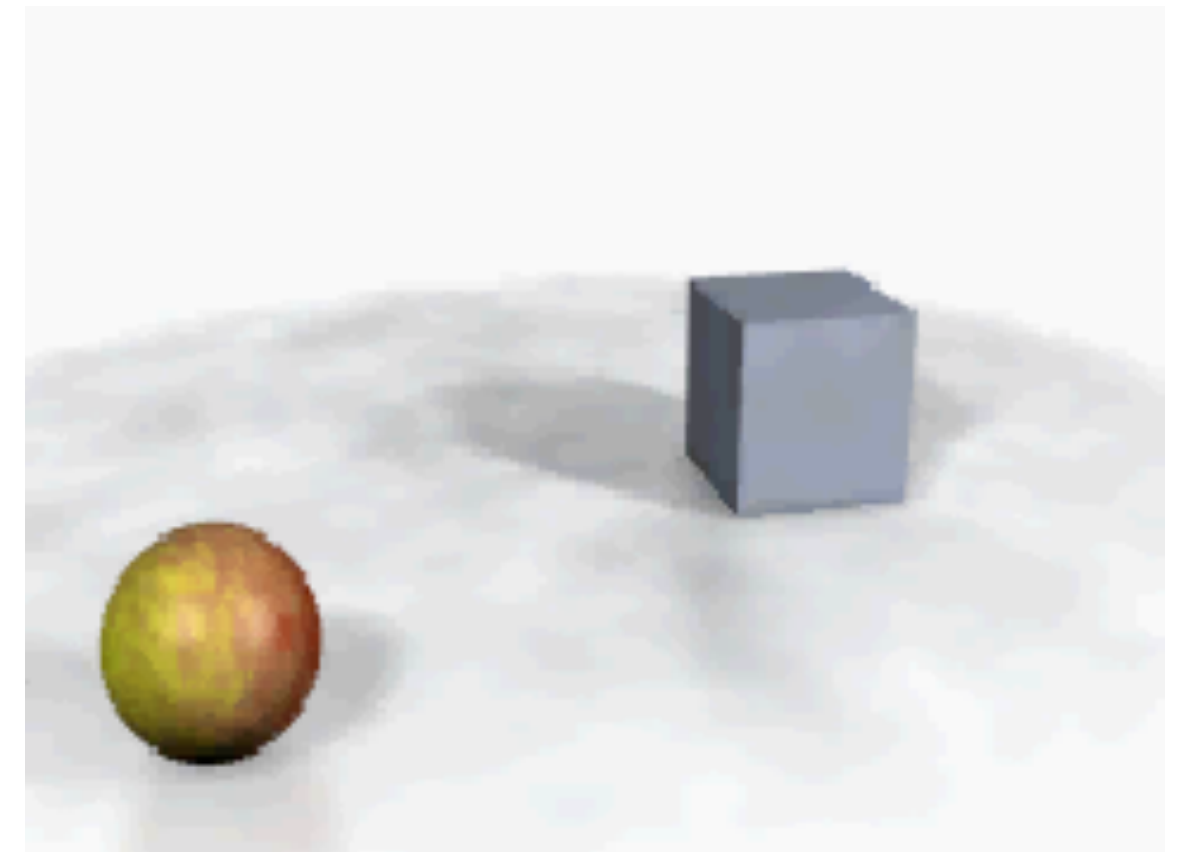
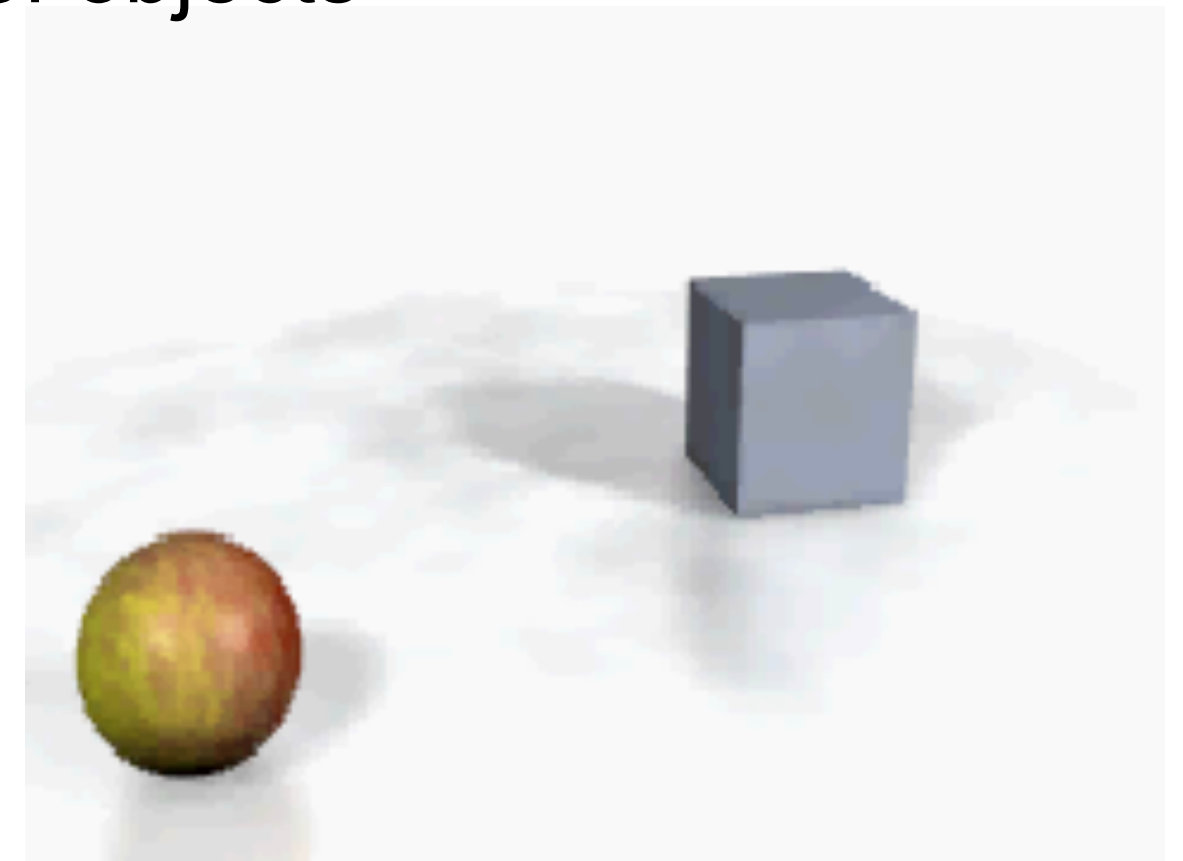
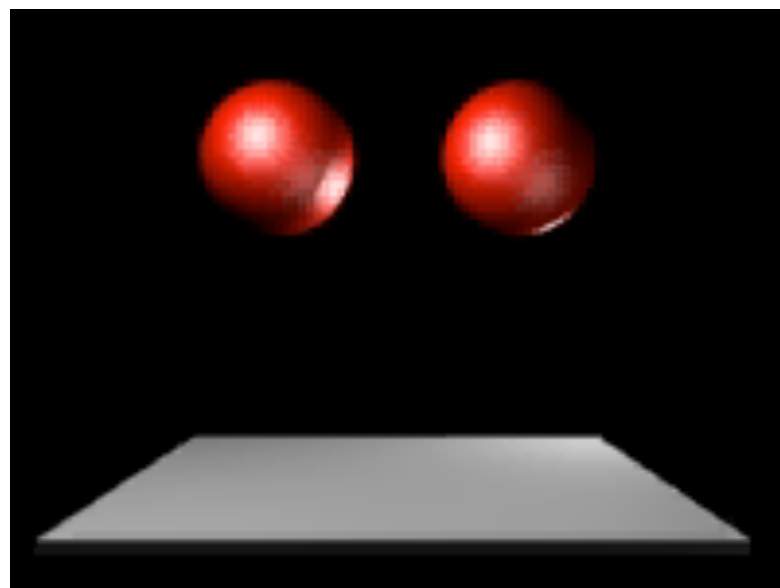
Snap

- Quick and abrupt motions
- Only a few frames long
- Convey something that happens abruptly
- Can be emphasized by sound



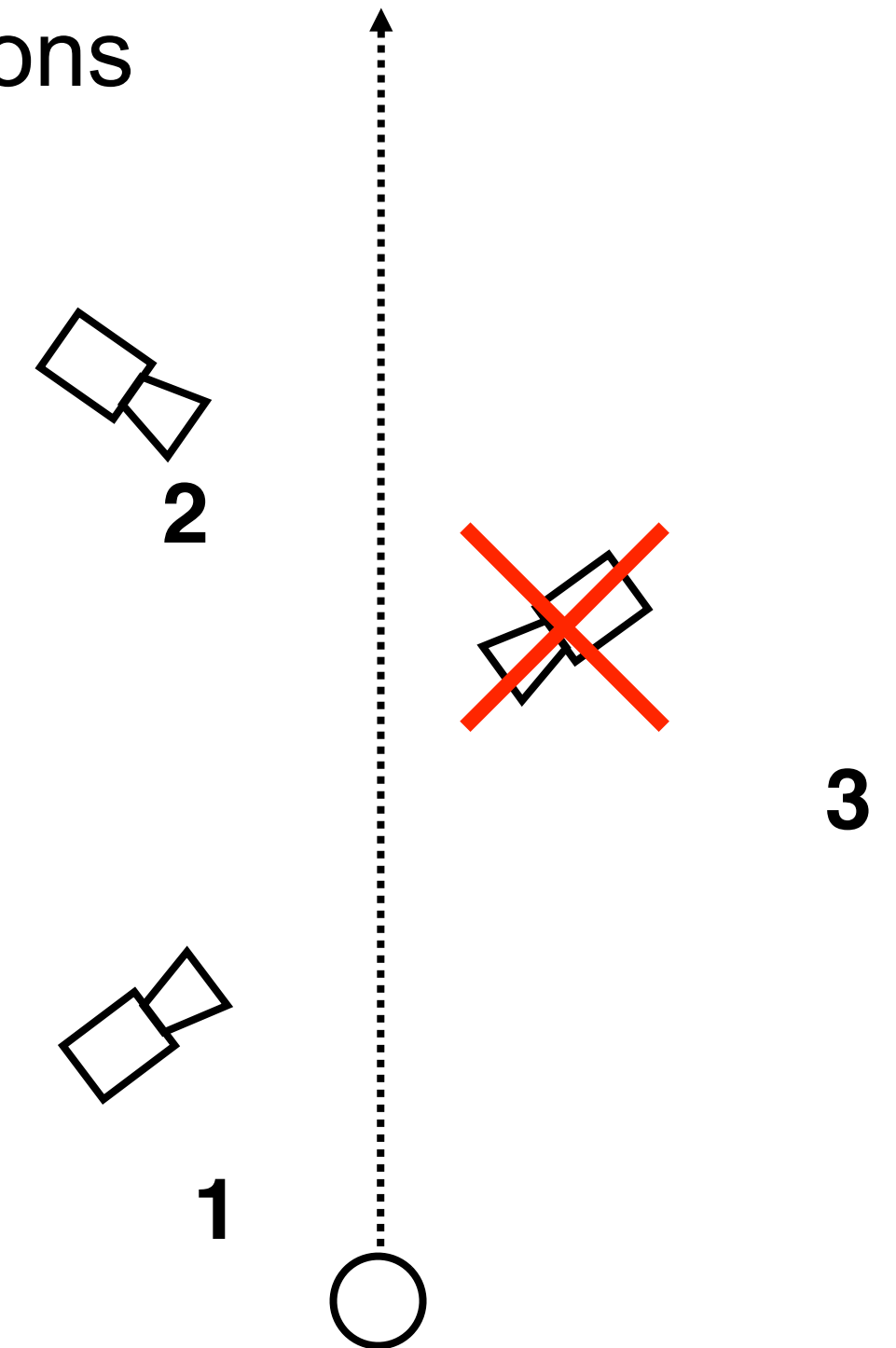
Weight

- Imitate physical behavior to convey the weight of objects
- Heavy objects accelerate slowly
- Light objects bounce higher
- Heavy objects push light ones aside



Line Crossing Error

- Camera must not cross the line of motion
- Otherwise will be perceived as 2 different motions
- Fix: cut a different scene in between
- not particular to 3D animation!



Appeal, Personality

- Appeal is anything the audience likes to see
- Can be quality of charm, design, simplicity, movements, communication
- Create believable personalities
 - Consistency in pose, facial expression, communication, behavior
- Image from „ferdinand the bull“
- Disney, 1938..

<http://www.ultimatedisney.com/images/w-z/wdac-v6-03.jpg>



Pixar: For the Birds (2008)

