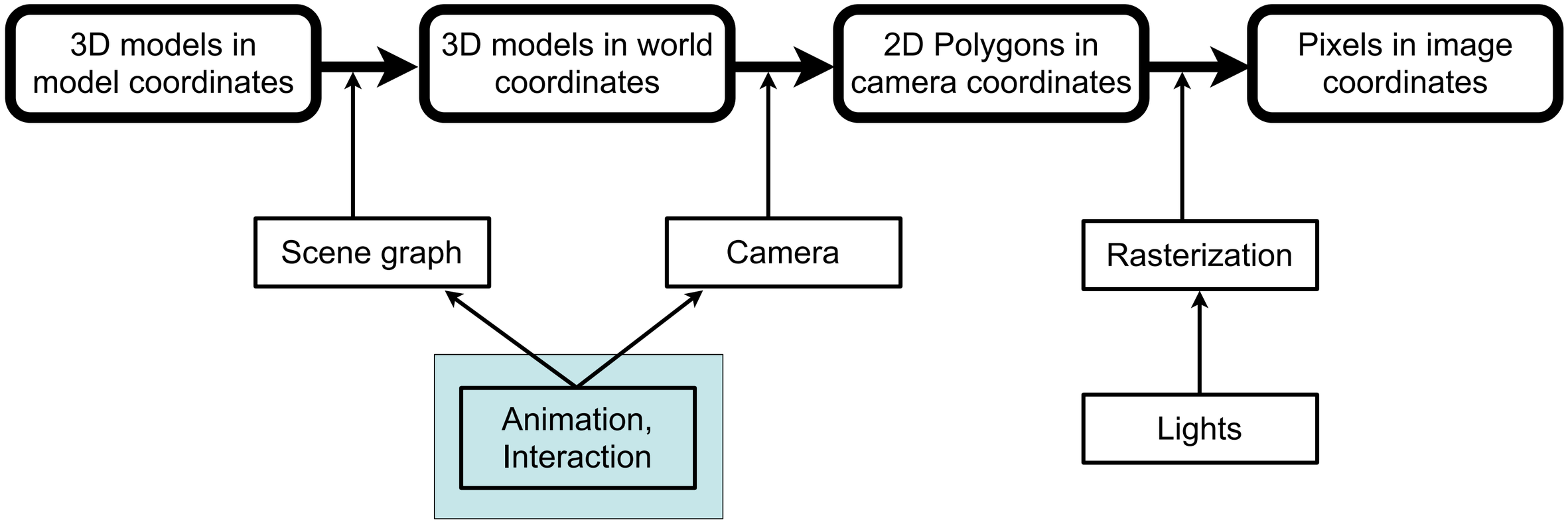
The 3D rendering pipeline (our version for this class)



Chapter 8 - Animation

- Animation before the time of 3DCG
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Animation == bring to life

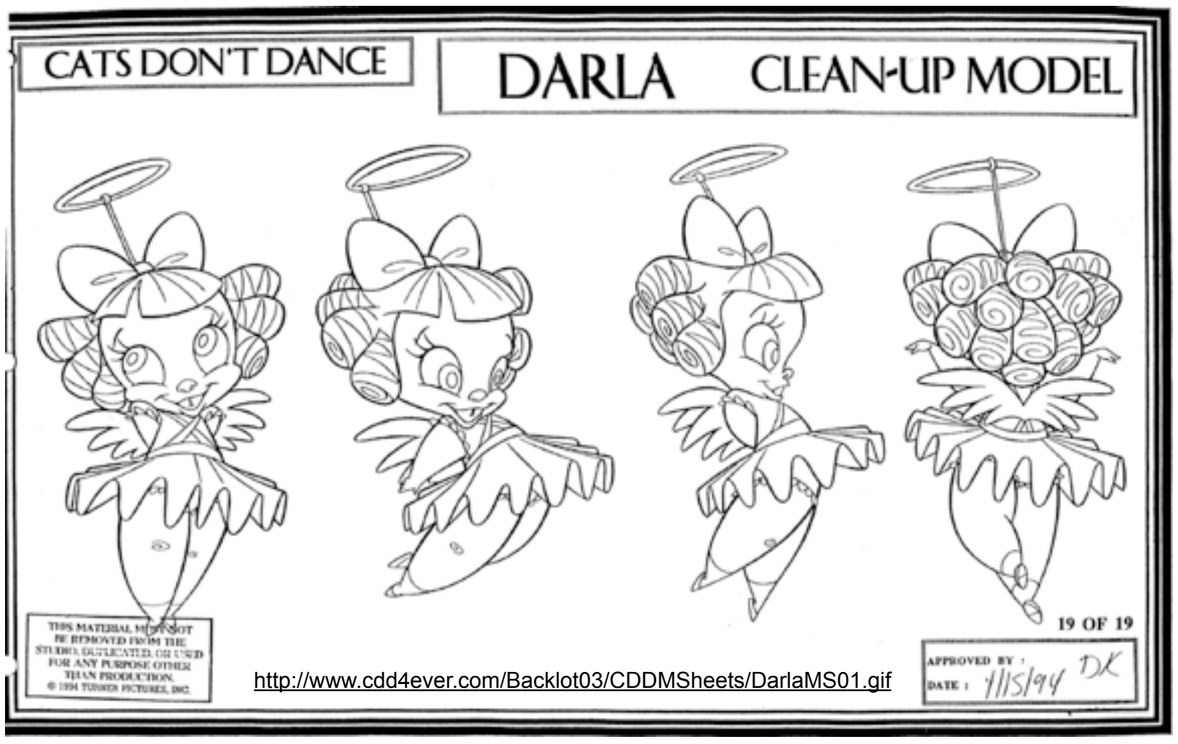
- Generally any kind of **moving** graphics
  - flipbooks
  - cartoon films
  - computer animation
- Sequence of single images
  - Movie: 24, TV: 30, Comp.: up to >100/sec.
- Impression of movement >6 fps (???)
- 3D animation most often at video frame rates

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

http://germanblogs.de/pub/germanblogs/digitallife/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



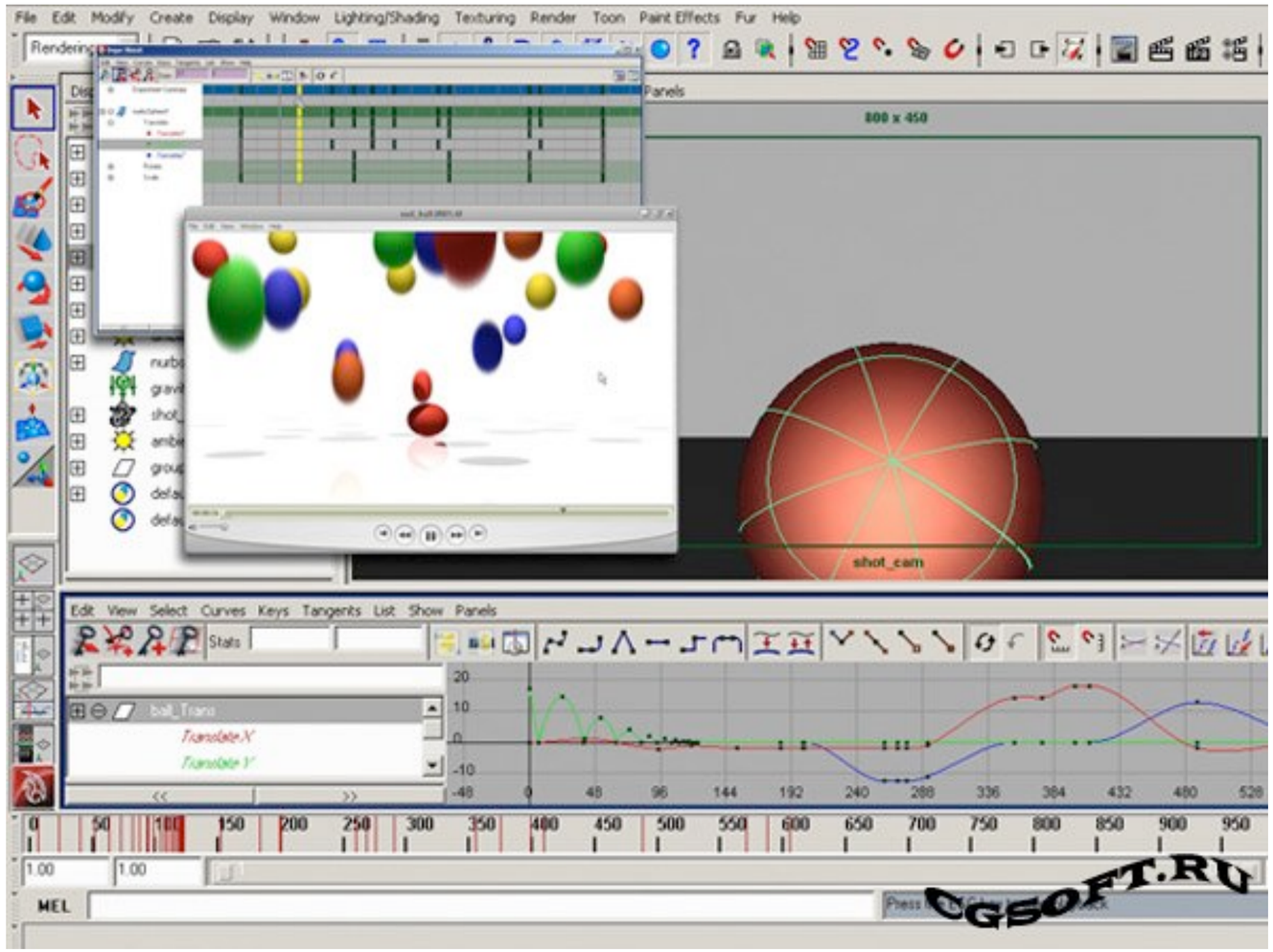
http://www.cdd4ever.com/Backlot03/CDDMSheets/DarlaMS01.gif

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 8 - Animation

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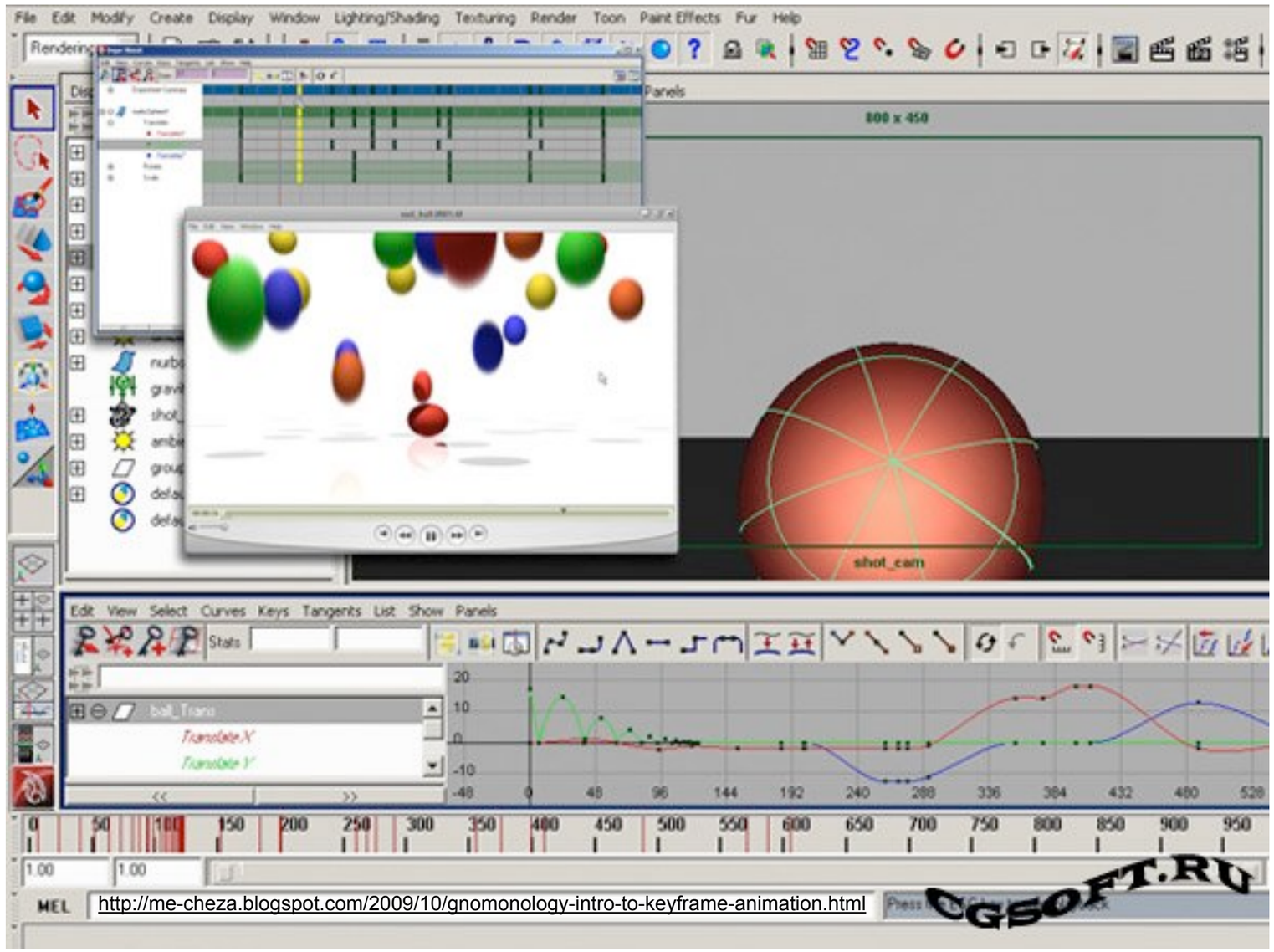
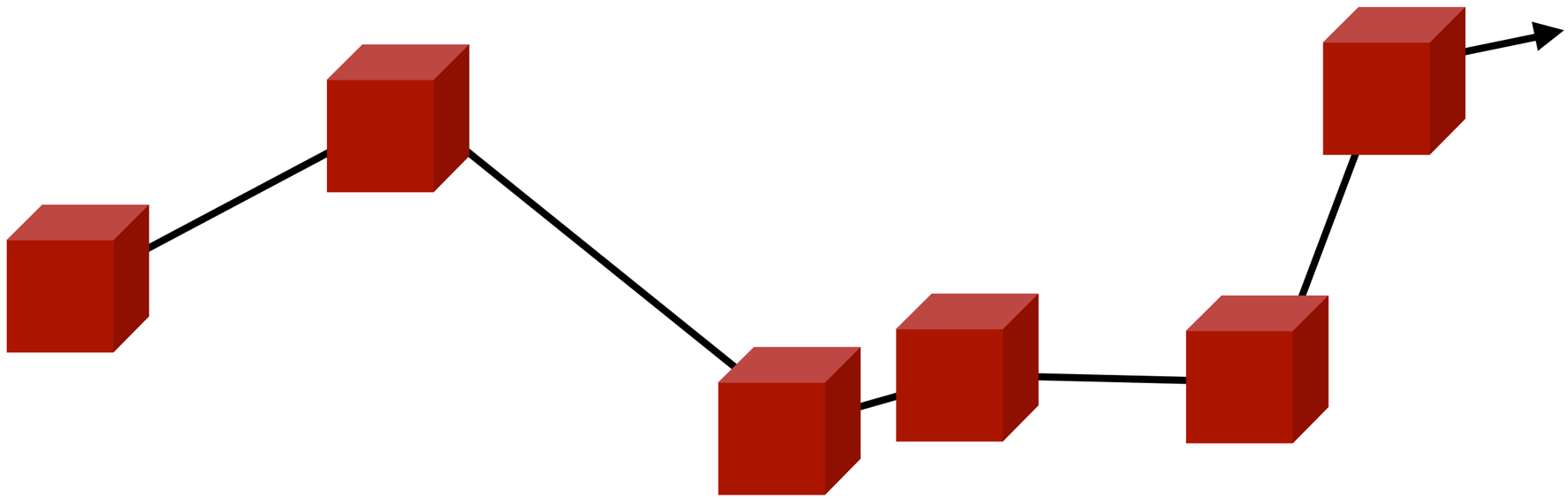
Keyframing

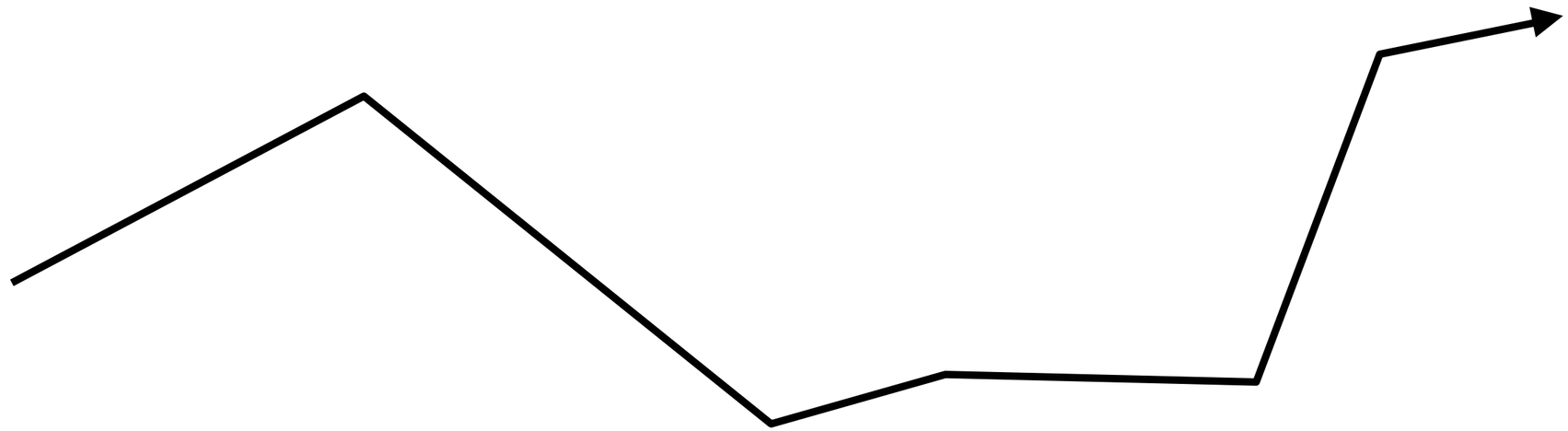
- Define certain parameters of the scene for certain frames
  - not all in every keyframe
  - also known from other authoring systems (e.g. Flash, MS Expression Blend)
  - also applied in purely textual programming and scripting languages (e.g. XAML, JavaFX)



Keyframing the Position

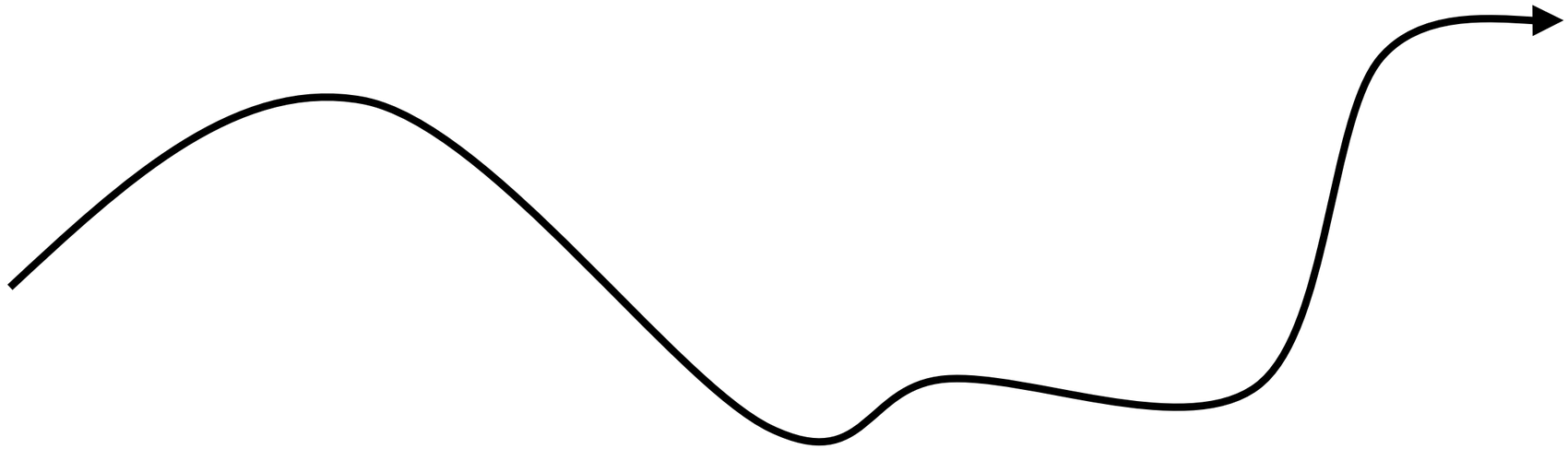


Linear Interpolation



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

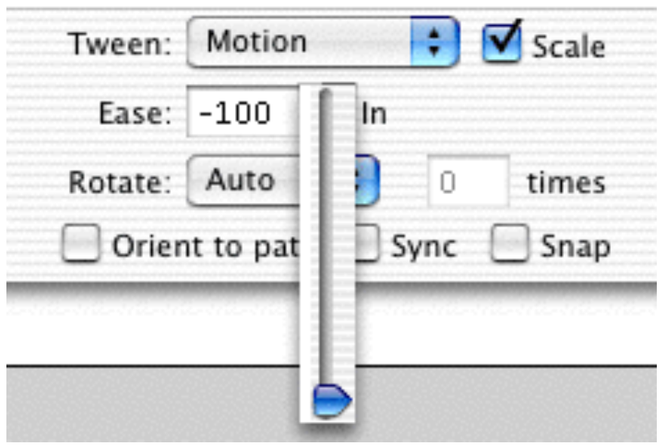
Spline Interpolation (Non-Linearity in Space/Value)



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

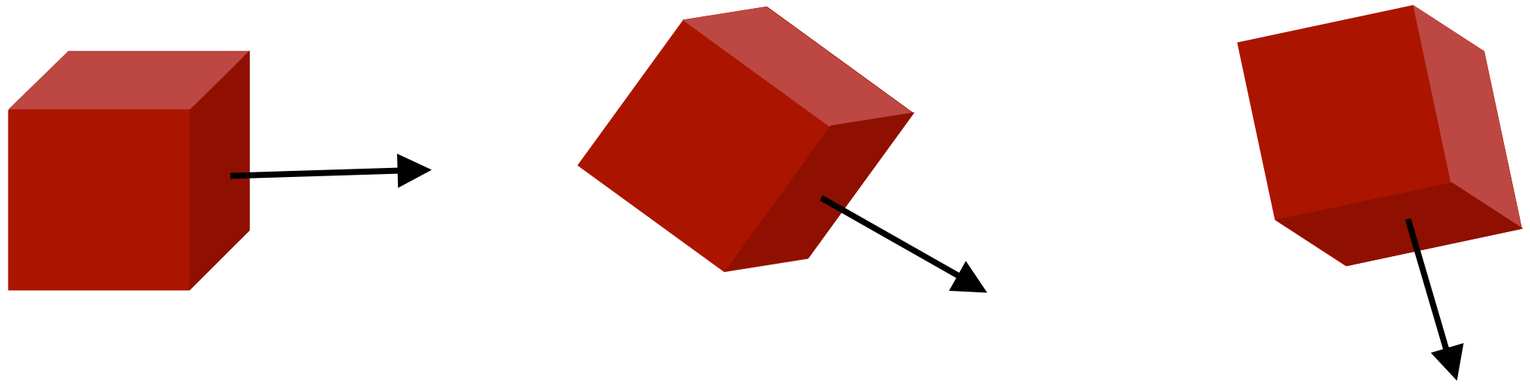
Non-Linearity in Time

- 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)



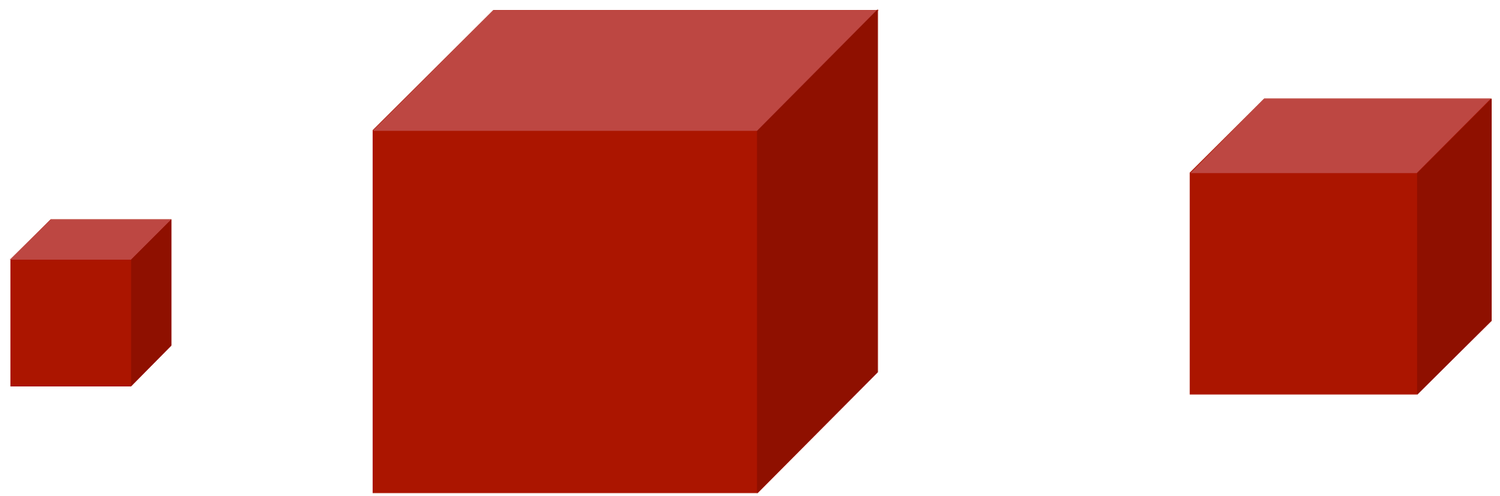
Ease in parameter
in Flash motion tweens

Keyframing the Orientation

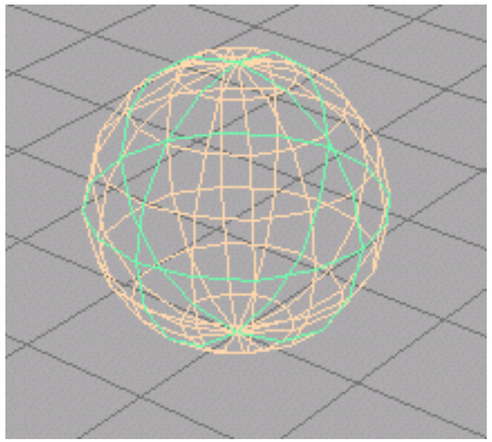
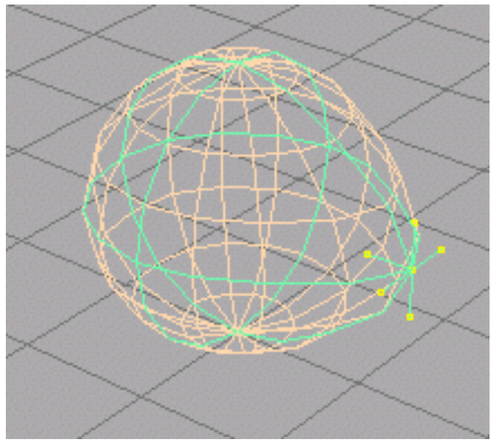
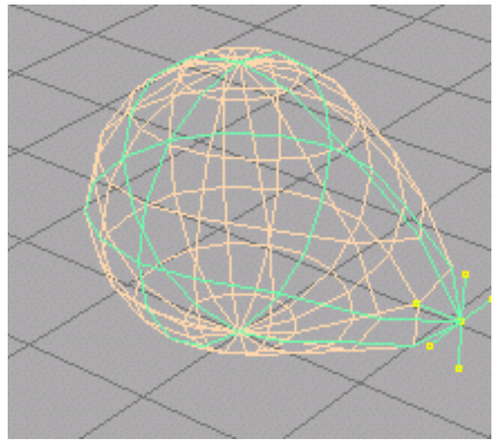


- Choose rotation axis
- interpolate angle about this axis
- or: shortest path on the unit sphere

Keyframing the Size

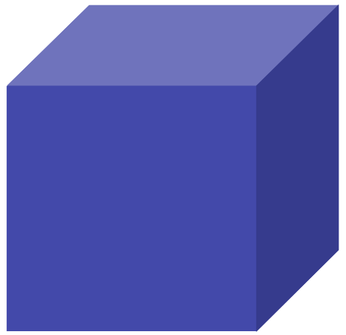


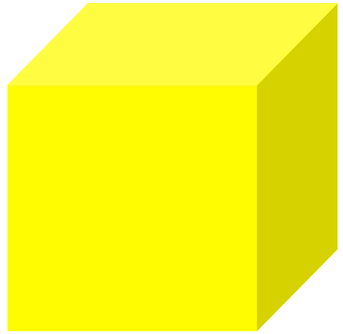
Keyframing Mesh Deformation

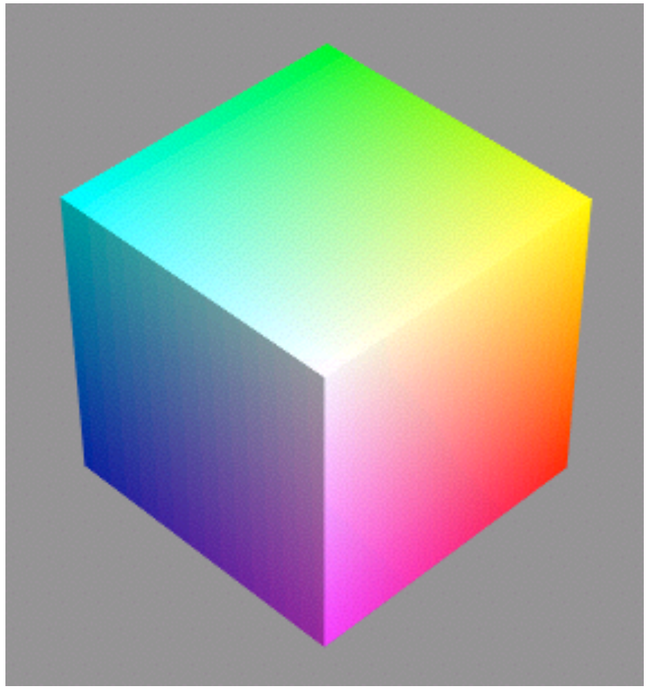
- Grab a control point
- Keyframe its position
- Deform the polygon mesh accordingly

Keyframing the Color

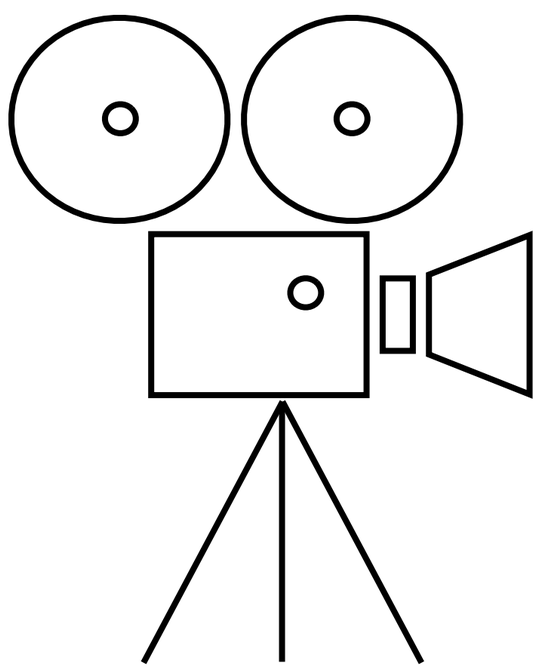




- Can be done in RGB or HSV color space
- what‘s between yellow and blue then??
- RGB: _____ HSV: _____

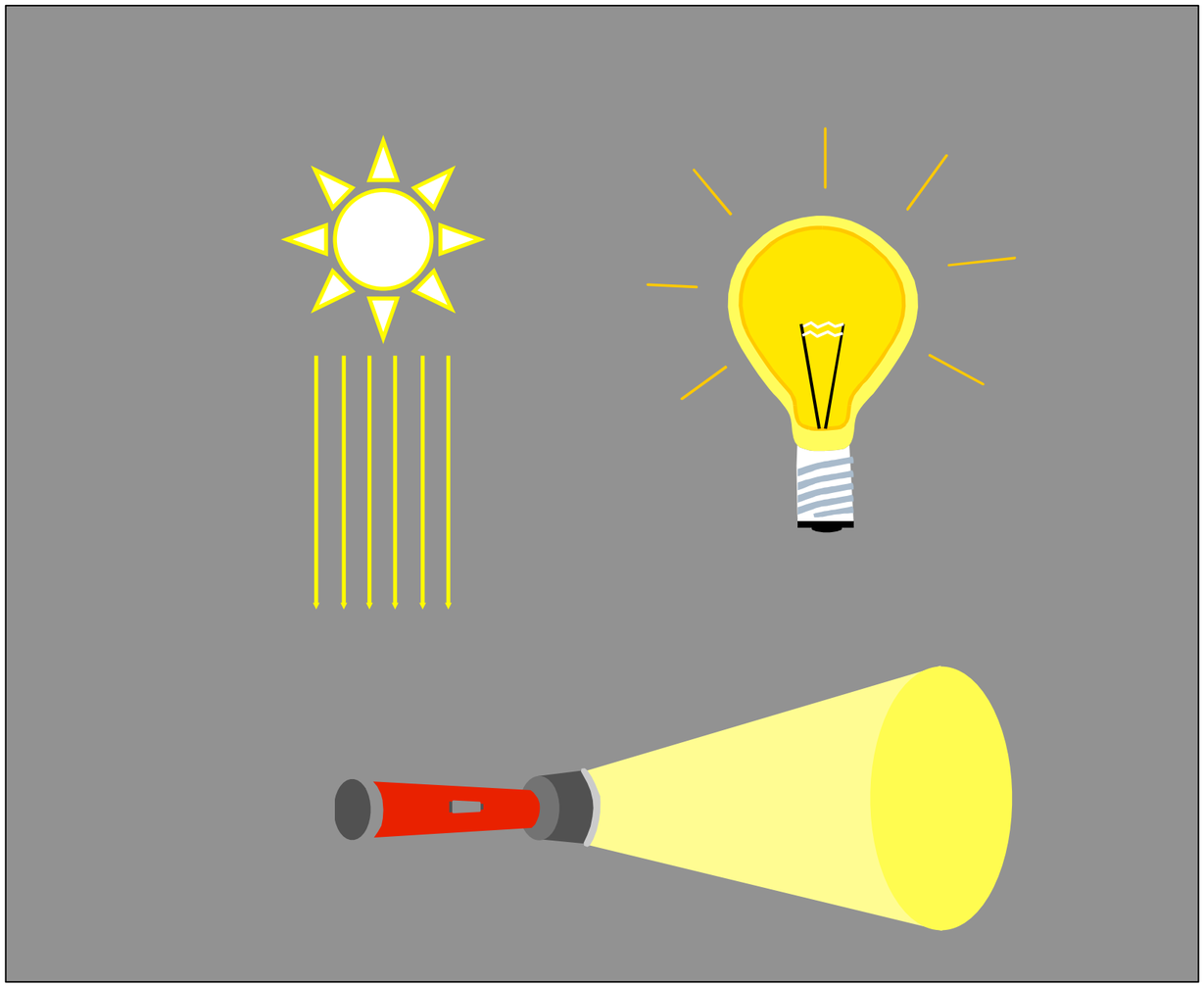


Keyframing the Virtual Camera



- 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

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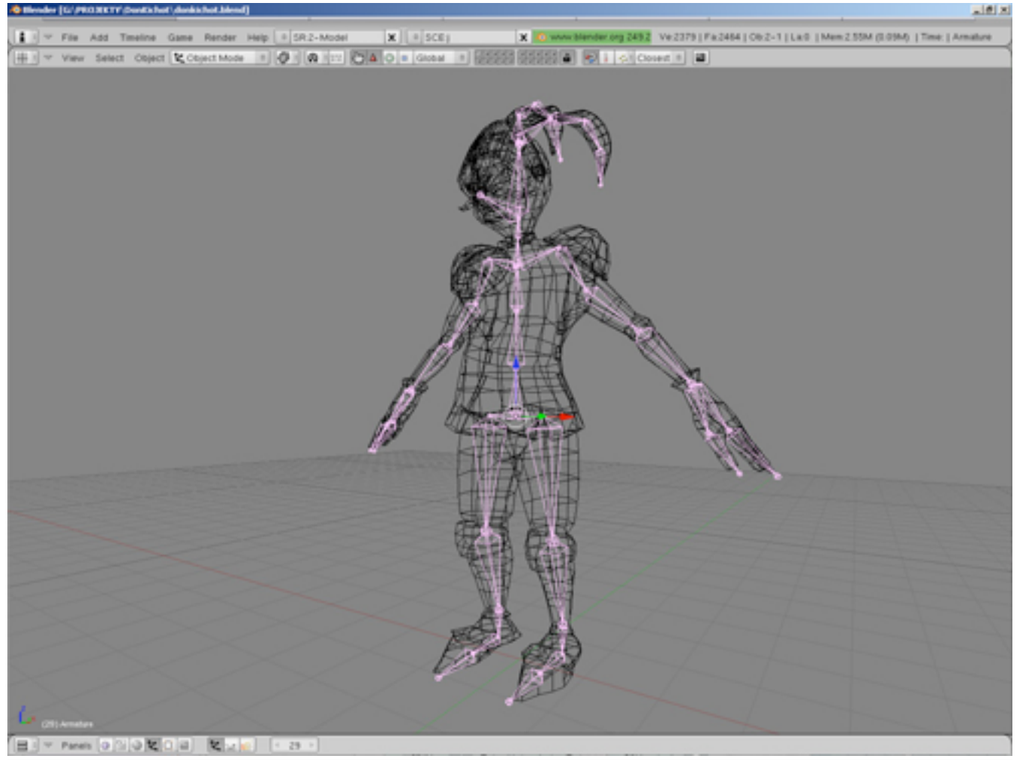
Bone animation

- 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

http://www.gamecask.com/news/animation.jpg



http://www.3dluvr.com/clisk3d/anims.htm

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


http://cache.kotaku.com/assets/resources/2007/08/gollumserkis.jpg


http://www.yourdictionary.com/computer/motion-capture

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)

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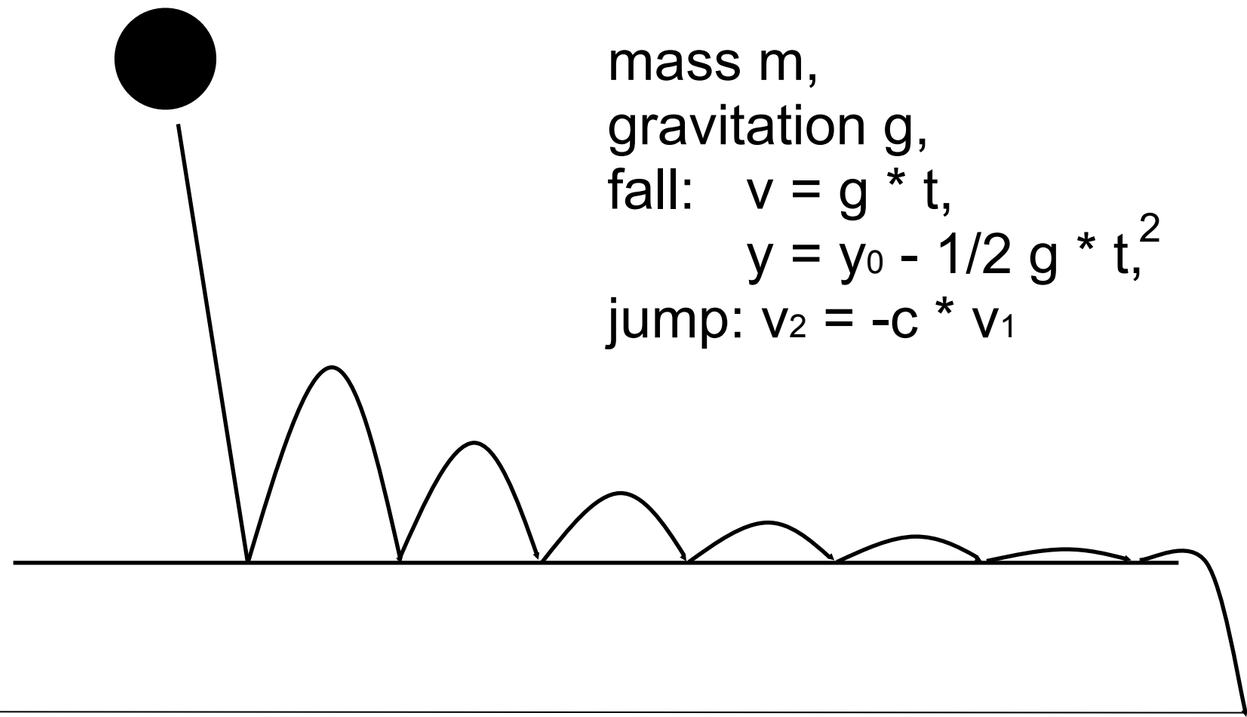
Physics simulation

- 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

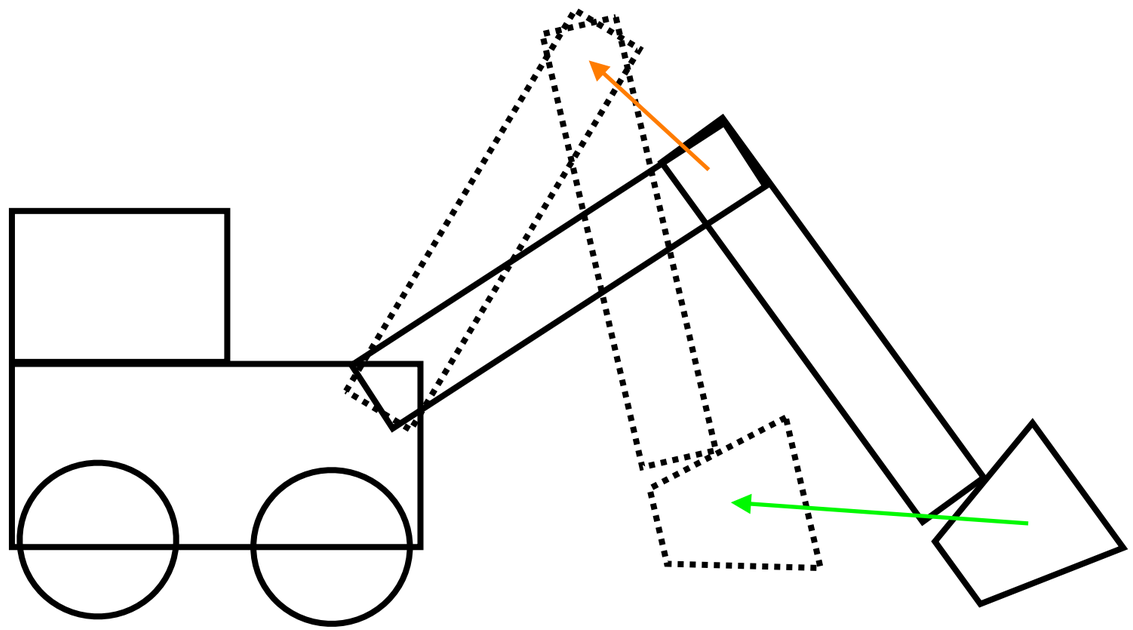
- Two examples
  - Inverse kinematics
  - Particle systems



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

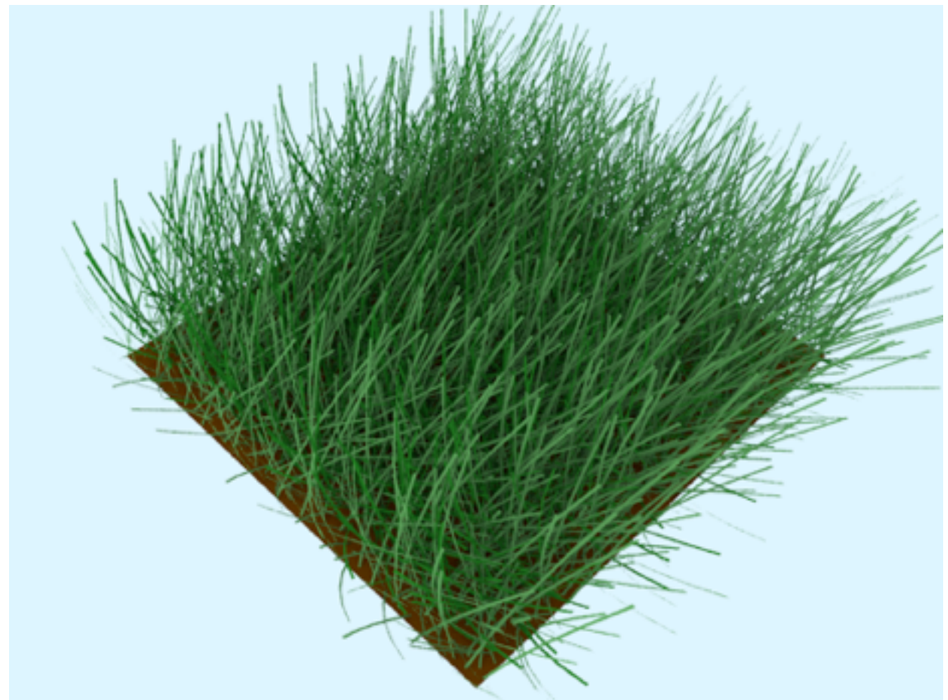
- Used for various phenomena
  - dust, explosions
  - fire
  - grass, hair, fur

- 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.cgtutorials.com/oneadmin/_files/linksdir/1685_Create_fire_effects_with_particle_system.jpg

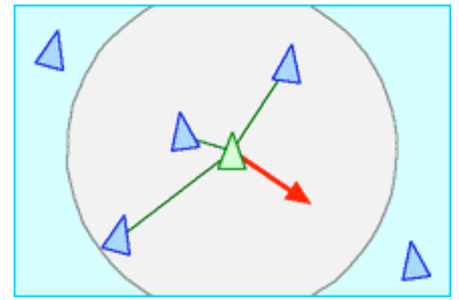
http://www.blender3darchitect.com/wp-content/uploads/2009/07/blender-3d-yafaray-realistic-grass.png

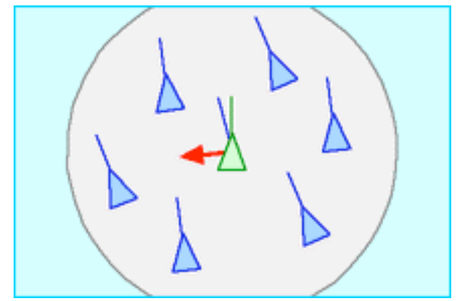


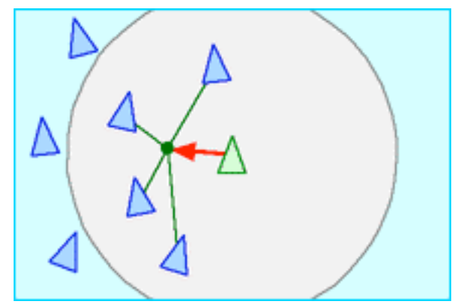
AI Example: Flocks, Herds, Schools

- 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)

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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

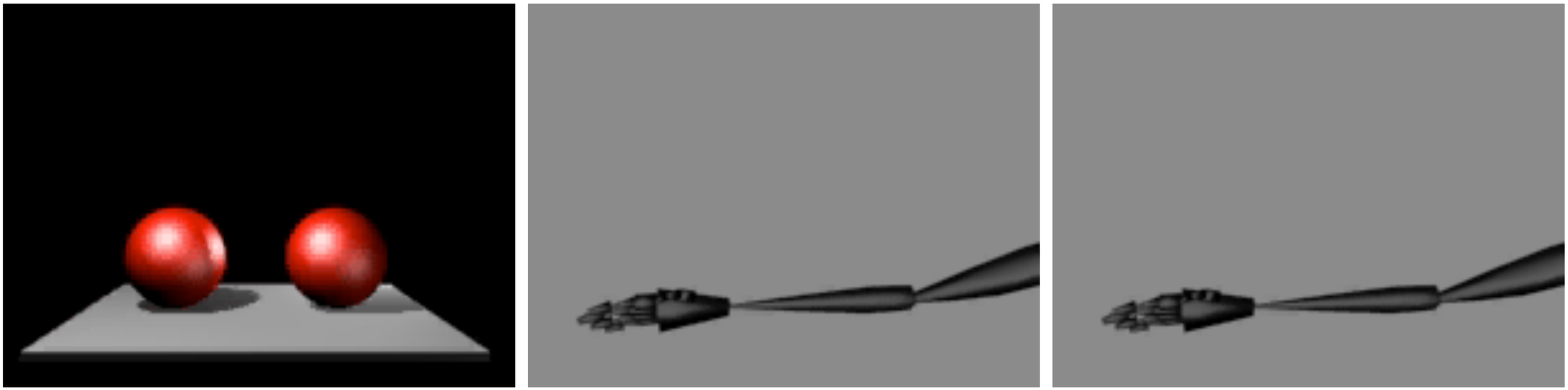
Timing

- 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."



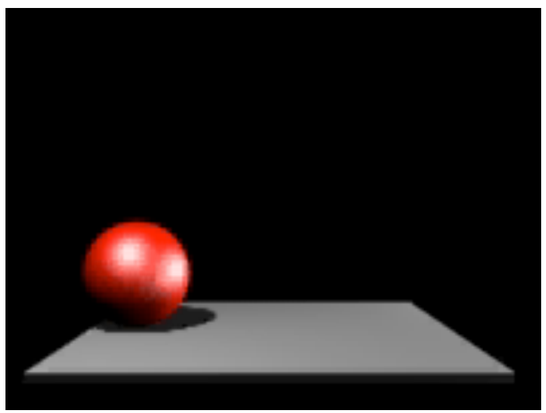
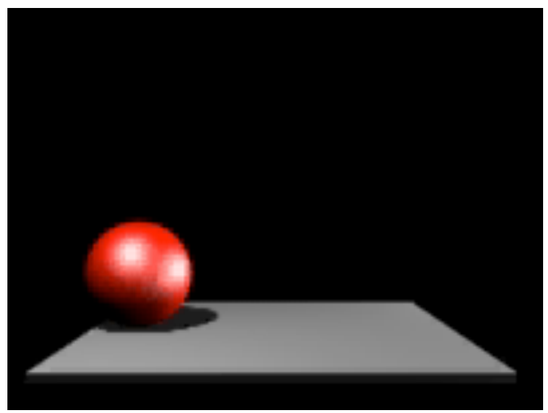
Ease In and Out (or Slow In and Out)

- 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



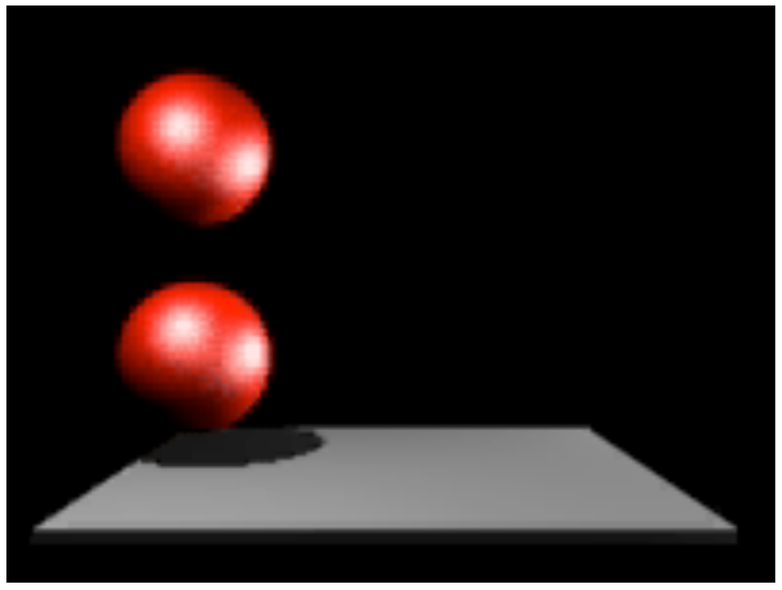
Arcs

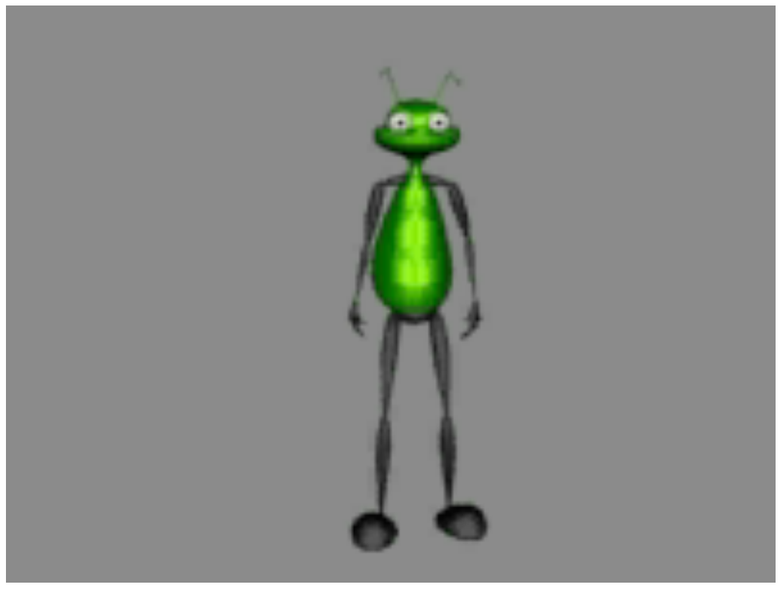
- Many motions in nature happen in arcs.
- Linear motions only in machines
- Motion in arcs look more natural on characters

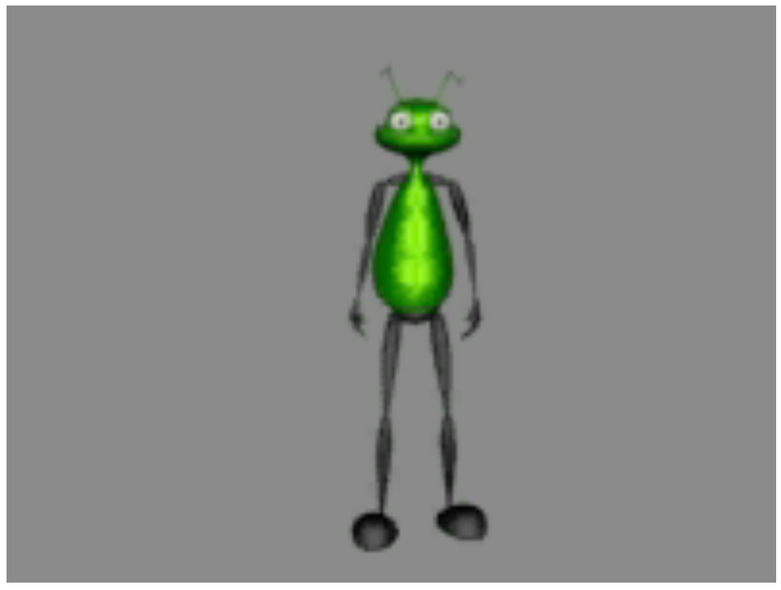



Anticipation

- 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





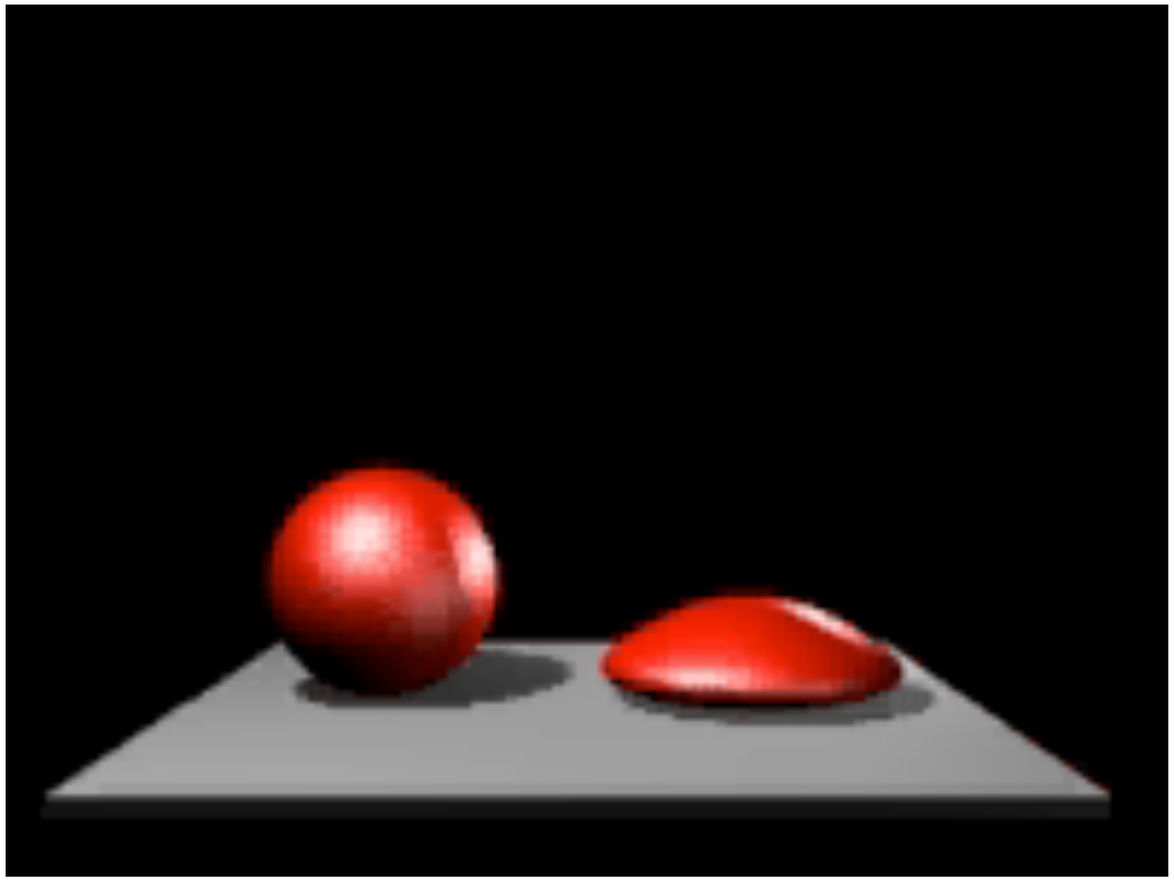


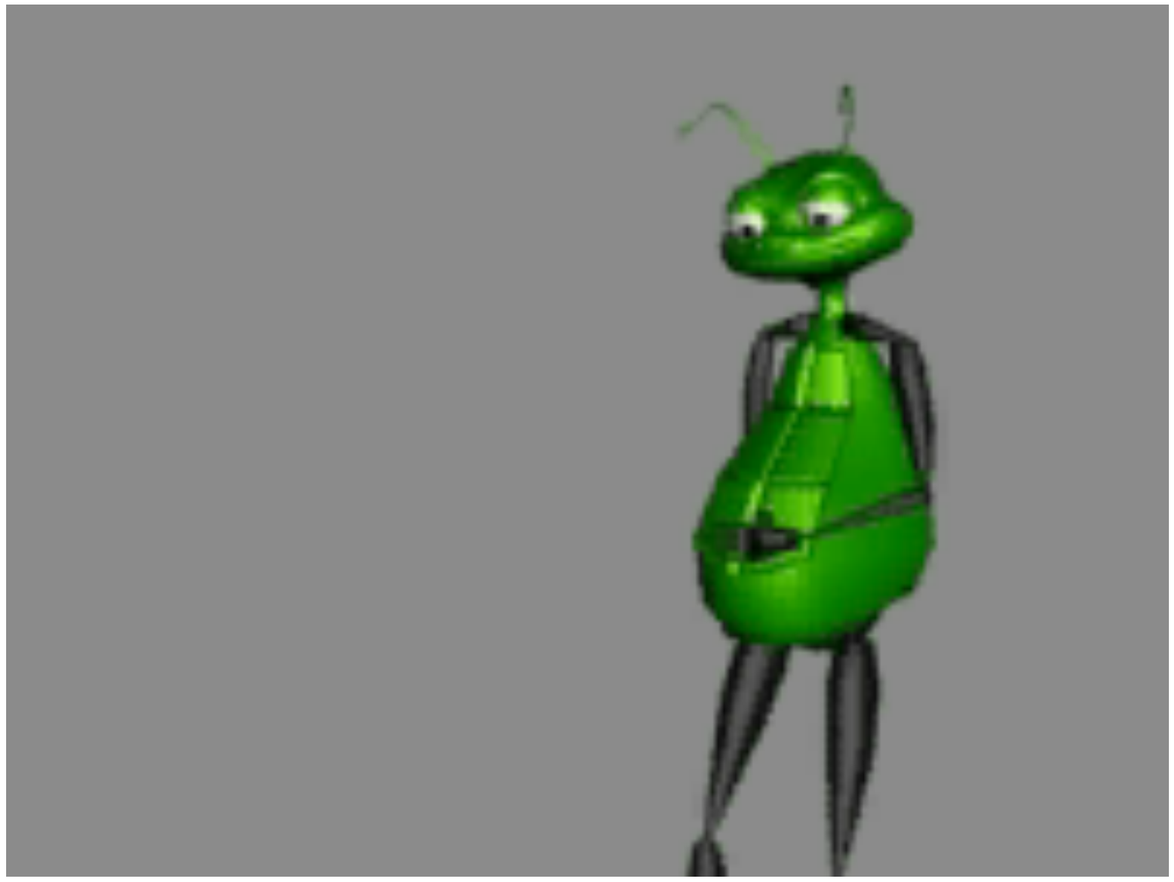
Exaggeration

- 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





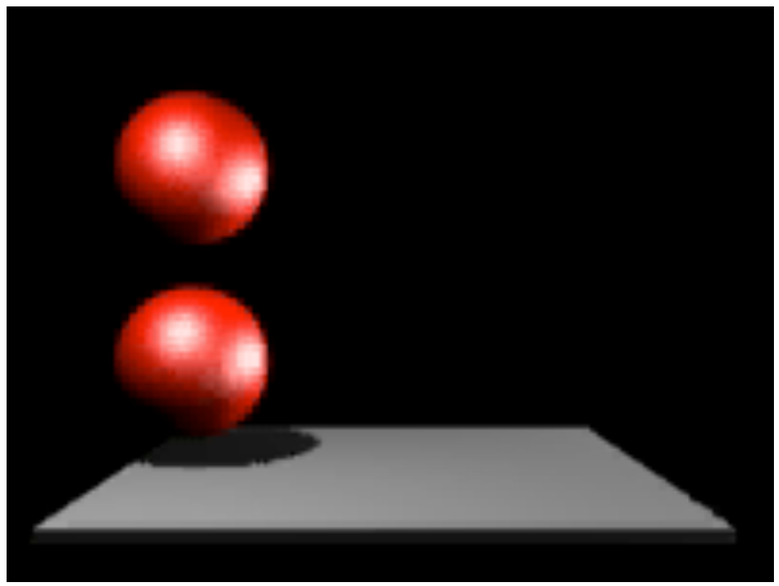
Secondary Action

- Secondary story/character/movement in the background
- Should not outpower 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

http://www.canalred.info/public/Fondos_Pantalla/Cine y Tv/Scrat - Ice Age.jpg

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



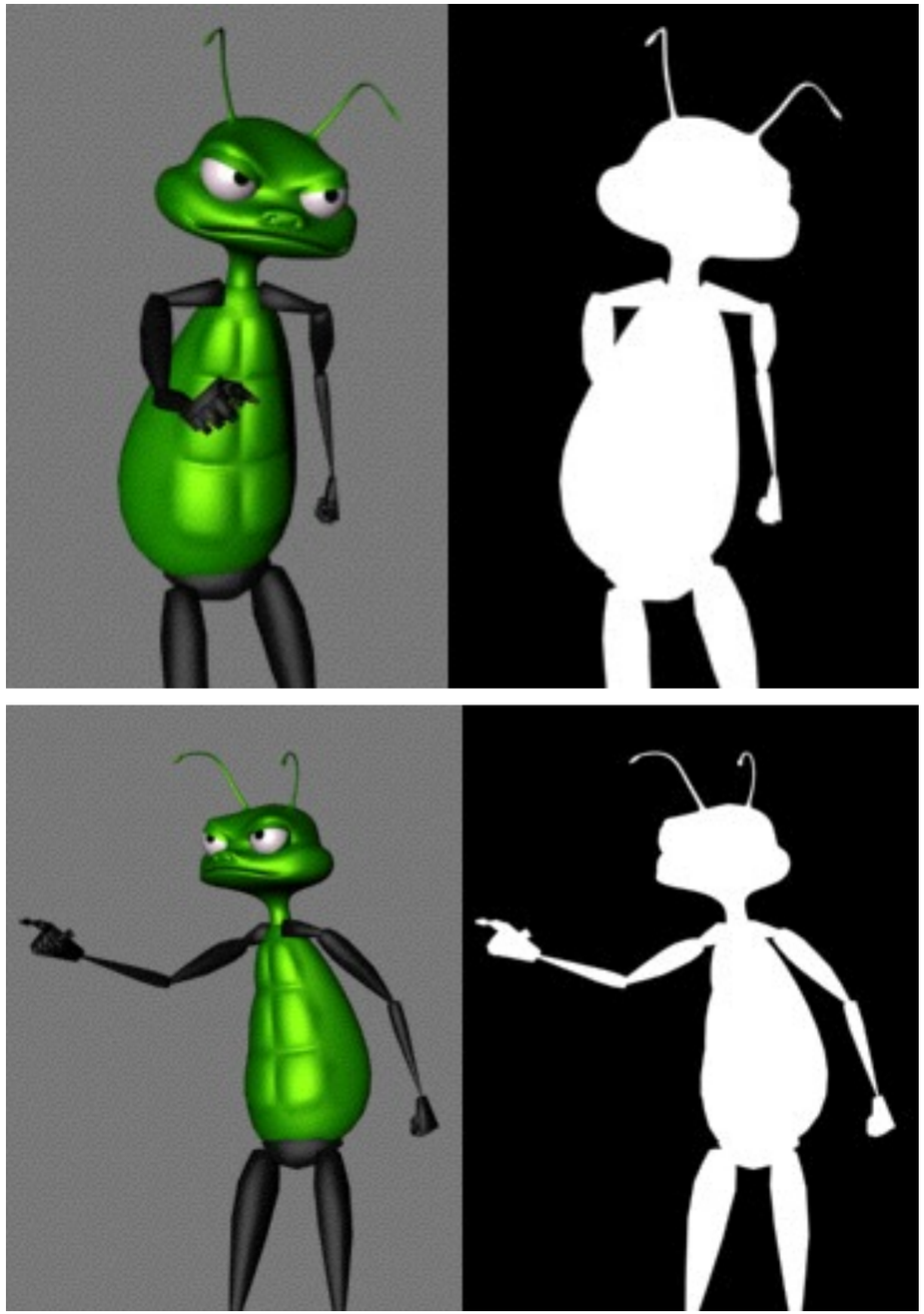
Straight Ahead and Pose-To-Pose Action

- 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

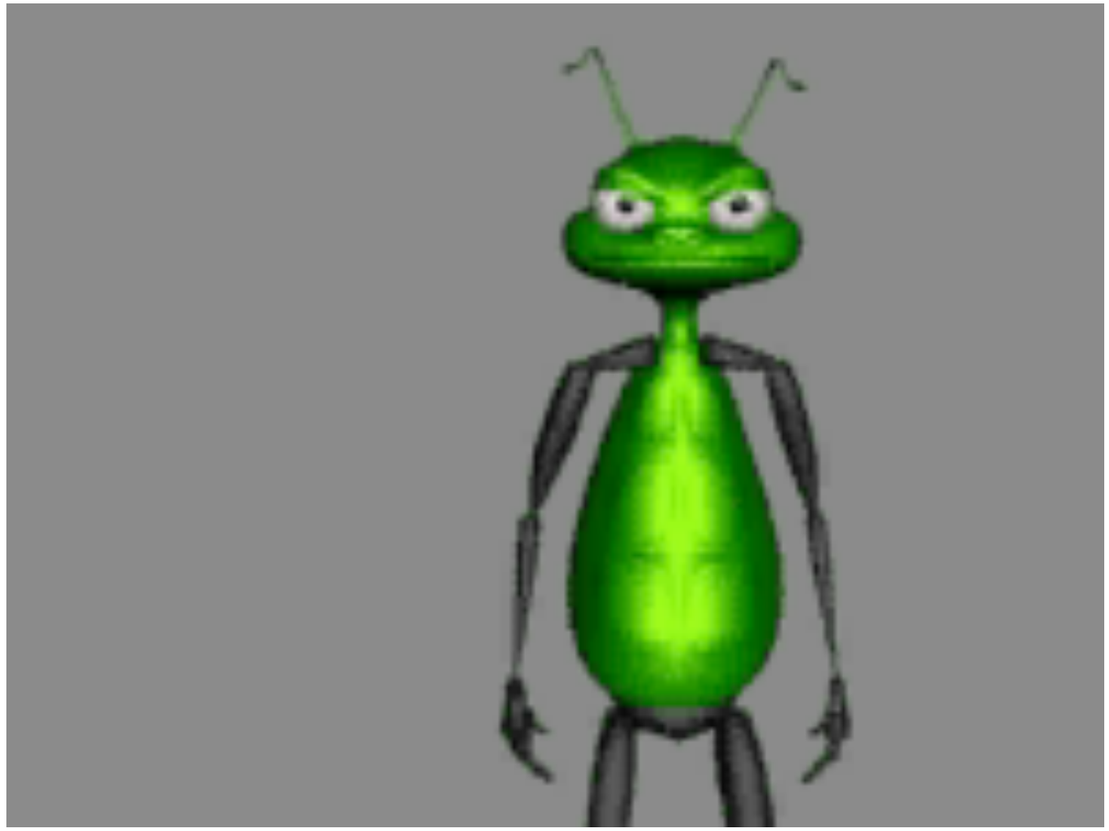
Staging

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



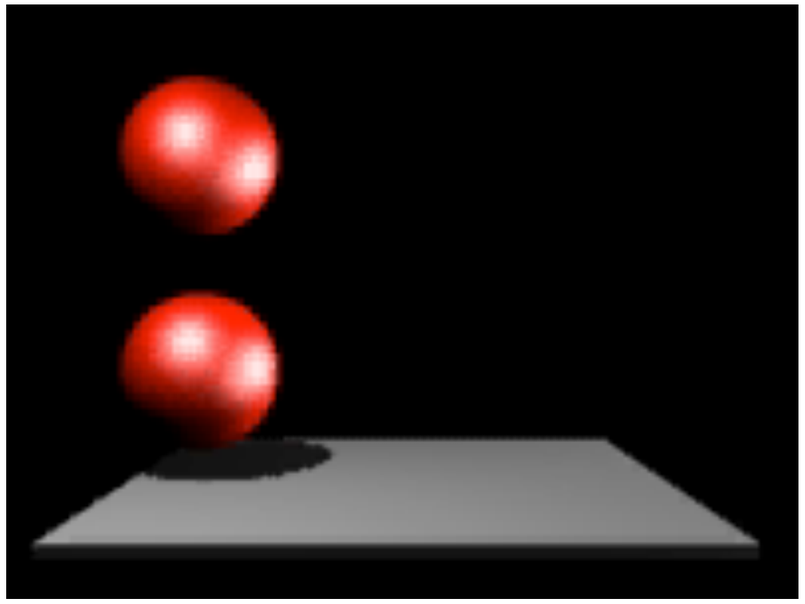
Non-Symmetrical Posing and Performing

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



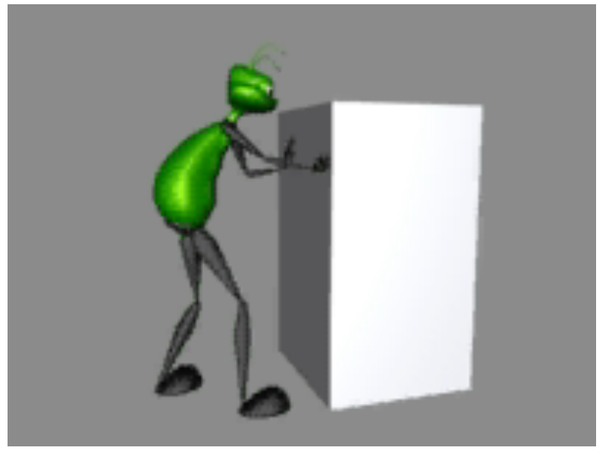
Snap

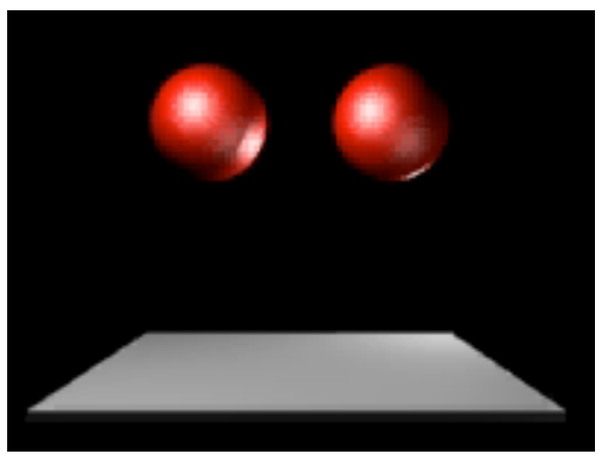
- Quick and abrupt motions
- Only a few frames long
- Convey something that happens abruptly
- Can be emphasized by sound

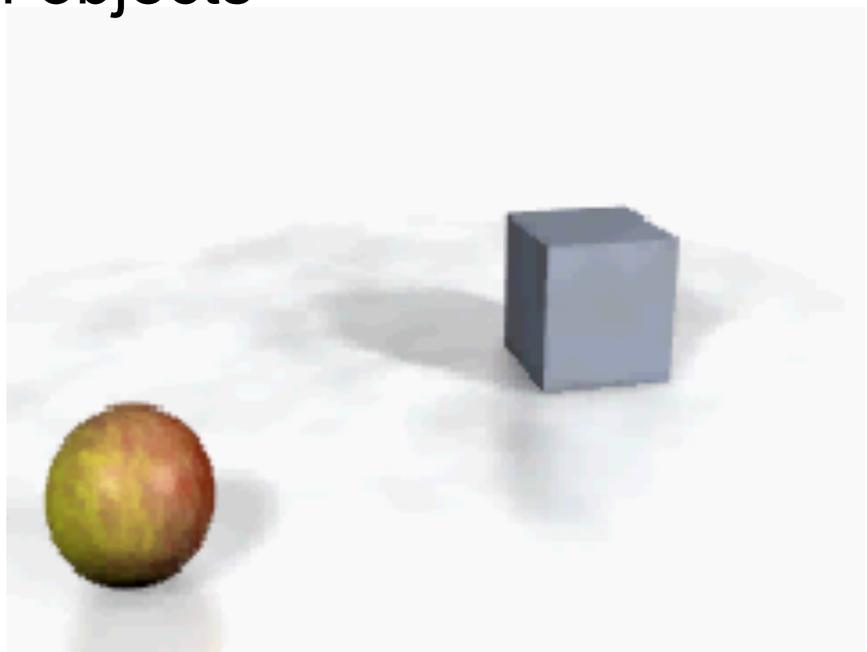


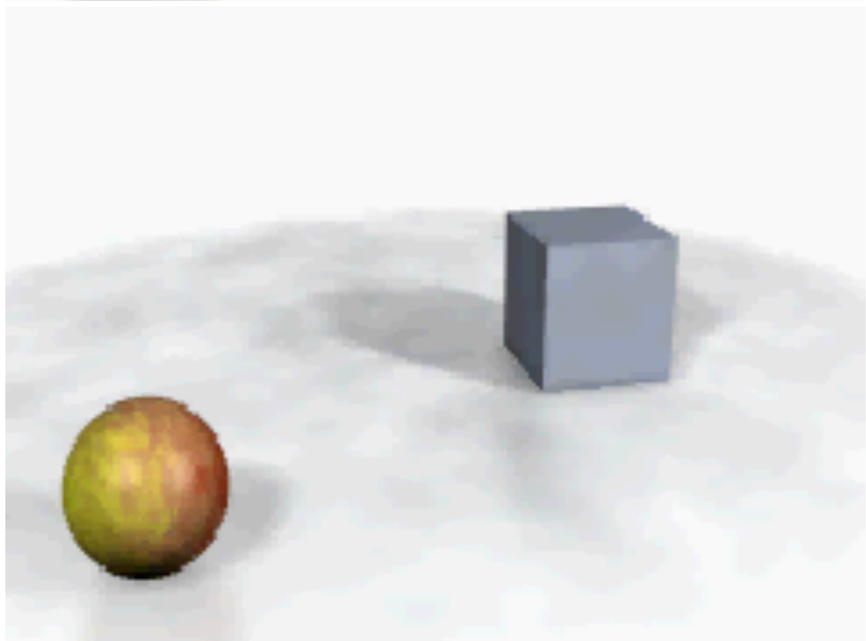
Weight

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





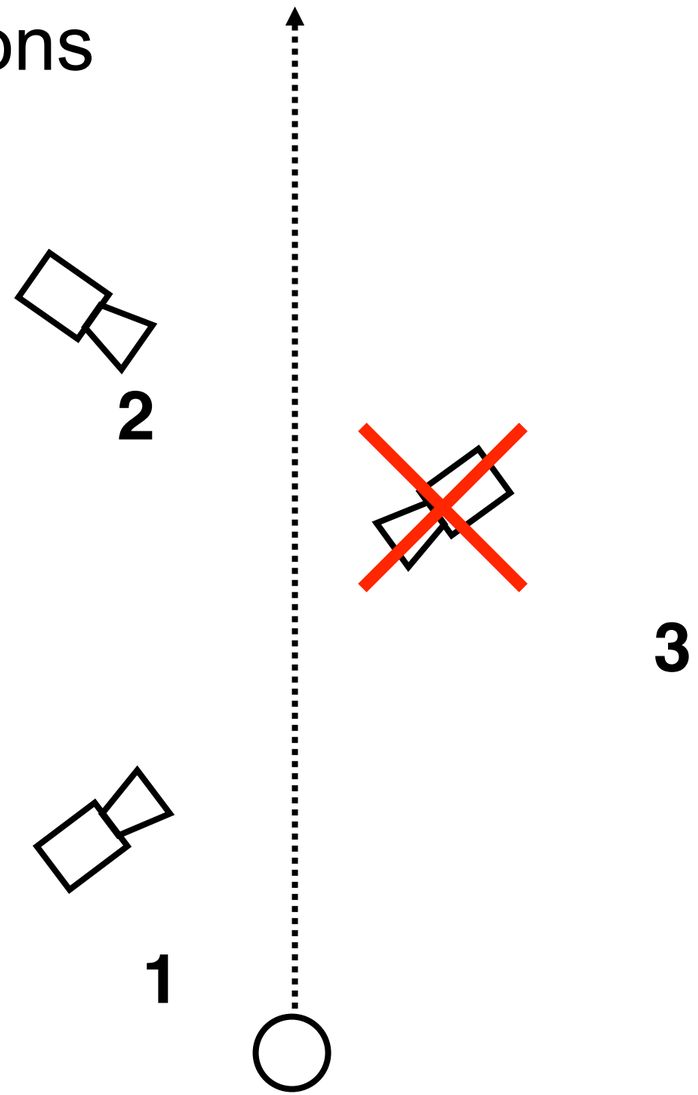




Line Crossing Error

- 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)