Animation

- Making things alive/Making them move
- Traditional Animation
  - Interpolating between key frames
- Kinematics
- Dynamics
- Motion Capture
- Behaviors

Traditional Cel Animation

- Film runs at 24 frames per second (fps)
  - That's 1440 pictures to draw per minute
  - 1800 fpm for video (30fps)
- Productions issues:
  - Need to stay organized for efficiency and cost reasons
  - Need to render the frames systematically (render farms)
- Artistic issues:
  - How to create the desired look and mood while conveying story?
  - 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

(Pollard http://graphics.cs.cmu.edu/nsp/course/15-462/Fall04/slides/25-animII.pdf)

Traditional Animation: The Process

- Story board
  - Sequence of drawings with descriptions
  - Story-based description
- Key Frames
  - Draw a few important frames as line drawings
    - For example, beginning of stride, end of stride
- Inbetweens
  - Draw the rest of the frames
- Painting
  - Redraw onto acetate *Cels*, color them in

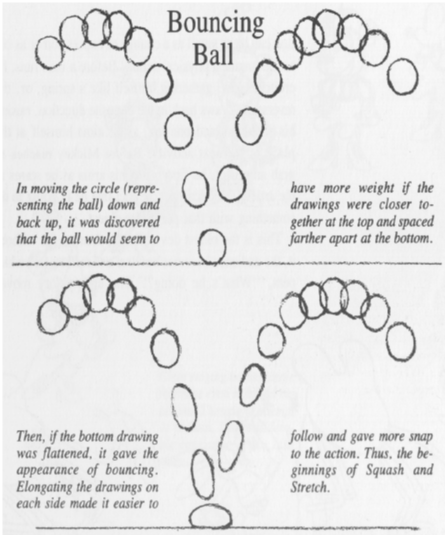
(Pollard http://graphics.cs.cmu.edu/nsp/course/15-462/Fall04/slides/25-animII.pdf)

Layered Motion

- It's often useful to have multiple layers of animation
  - How to make an object move in front of a background?
  - Use one layer for background, one for object
  - Can have multiple animators working simultaneously on different layers, avoid re-drawing and flickering
- Transparent acetate allows multiple *layers*
  - Draw each separately
  - Stack them together on a copy stand
  - Transfer onto film by taking a photograph of the stack

(Pollard http://graphics.cs.cmu.edu/nsp/course/15-462/Fall04/slides/25-animII.pdf)

Squash and Stretch

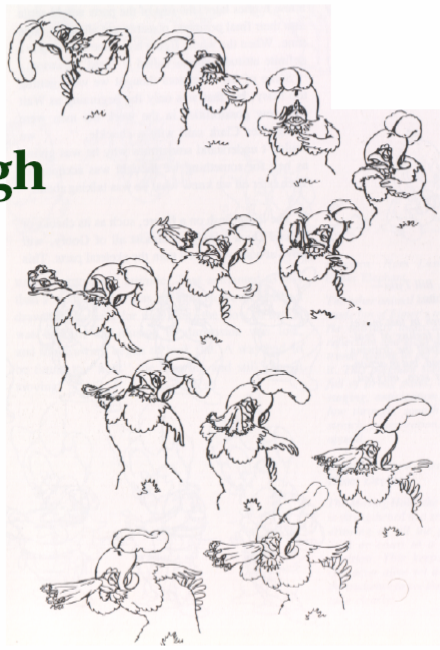


(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/principles.pdf)

Anticipation

(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/principles.pdf)

Follow Through



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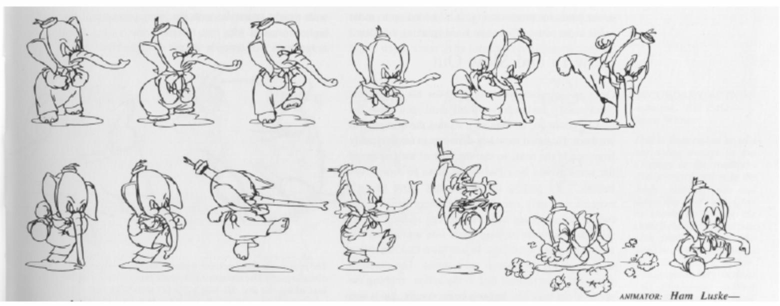
Follow Through



(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/principles.pdf)

Cartoon Laws of Physics

Authorship Unknown

Cartoon Law I

Any body suspended in space will remain in space until made aware of its situation. Daffy Duck steps off a cliff, expecting further pastureland. He loiters in midair, soliloquizing flippantly, until he chances to look down. At this point, the familiar principle of 32 feet per second per second takes over.

Cartoon Law II

Any body in motion will tend to remain in motion until solid matter intervenes suddenly. Whether shot from a cannon or in hot pursuit on foot, cartoon characters are so absolute in their momentum that only a telephone pole or an outsize boulder retards their forward motion absolutely. Sir Isaac Newton called this sudden termination of motion the stooge's surcease.

Cartoon Law III

Any body passing through solid matter will leave a perforation conforming to its perimeter. Also called the silhouette of passage, this phenomenon is the specialty of victims of directed-pressure explosions and of reckless cowards who are so eager to escape that they exit directly through the wall of a house, leaving a cookie-cutout-perfect hole. The threat of skunks or matrimony often catalyzes this reaction.

Cartoon Law IV

The time required for an object to fall twenty stories is greater than or equal to the time it takes for whoever knocked it off the ledge to spiral down twenty flights to attempt to capture it unbroken. Such an object is inevitably priceless, the attempt to capture it inevitably unsuccessful.

Cartoon Law V

All principles of gravity are negated by fear. Psychic forces are sufficient in most bodies for a shock to propel them directly away from the earth's surface. A spooky noise or an adversary's signature sound will induce motion upward, usually to the cradle of a chandelier, a treetop, or the crest of a flagpole. The feet of a character who is running or the wheels of a speeding auto need never touch the ground, especially when in flight.

Cartoon Law VI

As speed increases, objects can be in several places at once. This is particularly true of tooth-and-claw fights, in which a character's head may be glimpsed emerging from the cloud of altercation at several places simultaneously. This effect is common as well among bodies that are spinning or being throttled. A `wacky' character has the option of self-replication only at manic high speeds and may ricochet off walls to achieve the velocity required.

Cartoon Law VII

Certain bodies can pass through solid walls painted to resemble tunnel entrances; others cannot. This trompe l'oeil inconsistency has baffled generations, but at least it is known that whoever paints an entrance on a wall's surface to trick an opponent will be unable to pursue him into this theoretical space. The painter is flattened against the wall when he attempts to follow into the painting. This is ultimately a problem of art, not of science.

Cartoon Law VIII

Any violent rearrangement of feline matter is impermanent. Cartoon cats possess even more deaths than the traditional nine lives might comfortably afford. They can be decimated, spliced, splayed, accordion-pleated, spindled, or disassembled, but they cannot be destroyed. After a few moments of blinking self pity, they reinflate, elongate, snap back, or solidify. Corollary: A cat will assume the shape of its container.

Cartoon Law IX

Everything falls faster than an anvil.

Cartoon Law X

For every vengeance there is an equal and opposite revengeance. This is the one law of animated cartoon motion that also applies to the physical world at large. For that reason, we need the relief of watching it happen to a duck instead.

Cartoon Law Amendment A

Cartoon Law Amendment B

The laws of object permanence are nullified for "cool" characters. Characters who are intended to be "cool" can make previously nonexistent objects appear from behind their backs at will. For instance, the Road Runner can materialize signs to express himself without speaking.

Cartoon Law Amendment C

Explosive weapons cannot cause fatal injuries. They merely turn characters temporarily black and smoky.

Cartoon Law Amendment D

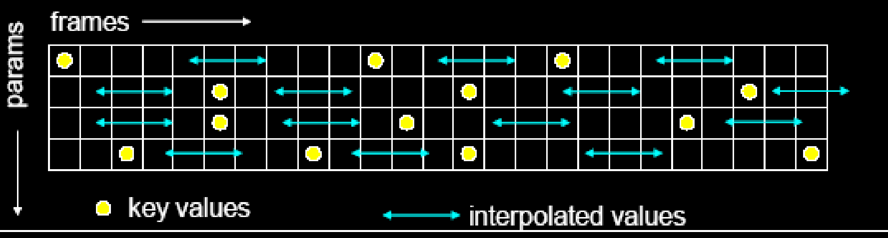
Gravity is transmitted by slow-moving waves of large wavelengths. Their operation can be witnessed by observing the behavior of a canine suspended over a large vertical drop. Its feet will begin to fall first, causing its legs to stretch. As the wave reaches its torso, that part will begin to fall, causing the neck to stretch. As the head begins to fall, tension is released and the canine will resume its regular proportions until such time as it strikes the ground.

Cartoon Law Amendment E

Dynamite is spontaneously generated in "C-spaces" (spaces in which cartoon laws hold). The process is analogous to steady-state theories of the universe which postulated that the tensions involved in maintaining a space would cause the creation of hydrogen from nothing. Dynamite quanta are quite large (stick sized) and unstable (lit). Such quanta are attracted to psychic forces generated by feelings of distress in "cool" characters (see Amendment B, which may be a special case of this law), who are able to use said quanta to their advantage. One may imagine C-spaces where all matter and energy result from primal masses of dynamite exploding. A big bang indeed.

Keyframing Basics

- Despite the name, there aren't really keyframes, *per se.*
- 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



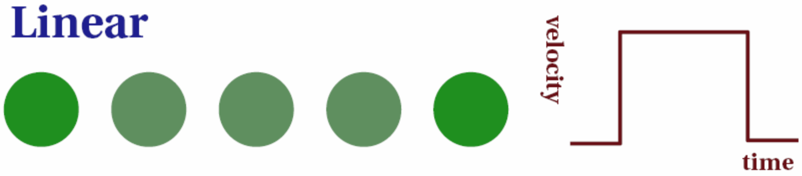
(Pollard http://graphics.cs.cmu.edu/nsp/course/15-462/Fall04/slides/25-animII.pdf)

Interpolating Key Frames

- Can use B-spline/Bezier interpolation curves to interpolate position
- Goals: local control, smooth motion, robustness
- Challenging to maintain the right balance between interpolated position and timing (controlling velocity and acceleration)– almost an art

(Varshney)

Linear



Ease in/ Ease out

(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/)

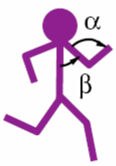
Keyframing: Issues

- 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

(Pollard http://graphics.cs.cmu.edu/nsp/course/15-462/Fall04/slides/25-animII.pdf)

Interpolating rotations

Kinematics –– the study of motion without regard to the forces that cause it.



Forward: $A = f(\alpha, \beta)$

draw graphics

Inverse: $\alpha, \beta = f^{-1}(A)$

specify fewer degrees of freedom

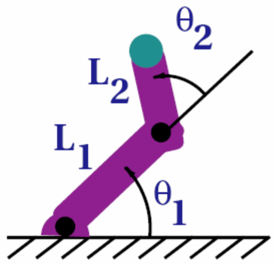
more intuitive control of dof
- pull on hand
- glue feet to the ground

(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/)

Forward Kinematics

$$x = L_1 \cos\theta_1 + L_2 \cos(\theta_1 + \theta_2)$$

$$y = L_1 \sin\theta_1 + L_2 \sin(\theta_1 + \theta_2)$$



$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} \quad \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} \quad \end{bmatrix} = \begin{bmatrix} \text{rot } \theta_1 \end{bmatrix} \begin{bmatrix} \text{trans } L_1 \end{bmatrix} \begin{bmatrix} \text{rot } \theta_2 \end{bmatrix} \begin{bmatrix} \text{trans } L_2 \end{bmatrix}$$

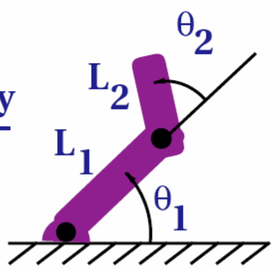
(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/)

Inverse Kinematics

$$\theta_2 = \cos \frac{(x^2 + y^2 - L_1^2 - L_2^2)}{2 L_1 L_2}$$

$$\theta_1 = \frac{-(L_2 \sin\theta_2)x + (L_1 + L_2 \cos\theta_2)y}{(L_2 \sin\theta_2)y + (L_1 + L_2 \cos\theta_2)x}$$

$$\theta = f^{-1}(x)$$



(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/)

(Terzopoulos)

Physics-based Animation

- Advantages:
  - Mimics real life more closely
  - Simple to program
- Disadvantages
  - Exact parameters difficult to discern
  - Sometimes *cartoonish* look and feel is preferable to realism

(Varshney)

Physics-based Animation

- Ideally suited for:
  - Large volumes of objects – wind effects, liquids, …
  - Cloth animation/draping
- Underlying mechanisms are usually:
  - Particle systems
  - Mass-spring systems
- Typically solve ordinary or partial differential equations using iterative methods with some initial/ending boundary values and constraints on conservation of mass/energy/angular momentum

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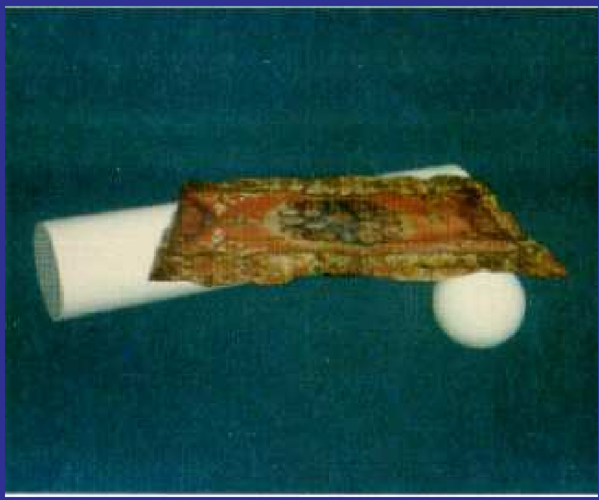

(Terzopoulos, Platt, Barr and Fleischer, SIGGRAGH '87)

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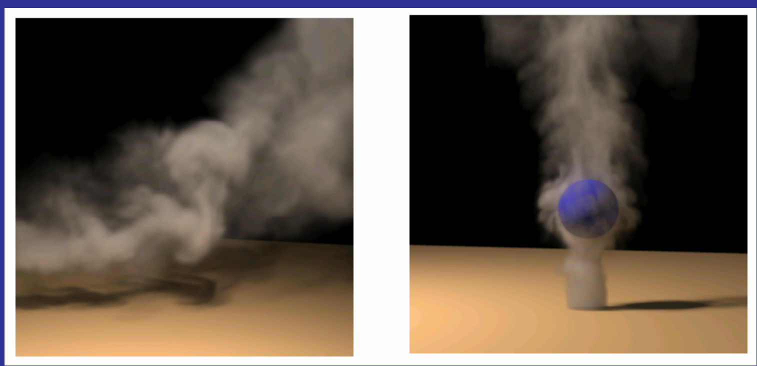
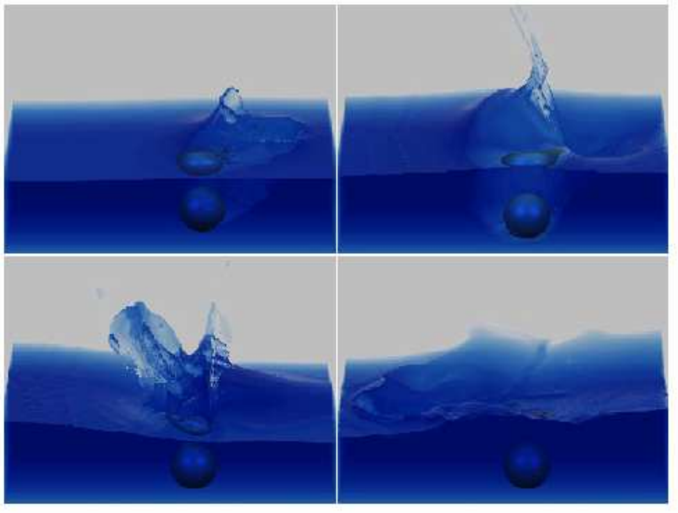
Examples



Images from Fedkiw, Stam, Jensen, SIGGRAPH 2001

Examples



Images from Foster & Fedkiw SIGGRAPH 2001

Examples

Image courtesy Simon Premoze, Univ. of Utah

Physically real motion

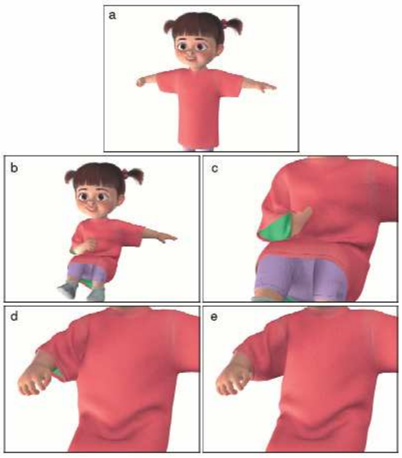


Figure 10: (a) Starting pose. (b) Arm moves in tightly. (c) Close-up view of (b) with right arm invisible. Note how the arm position forces cloth to intersect both itself and the body. (d) Without GIA, a cloth/cloth intersection persists as the arm pulls out, snagging the sleeve. (e) The same frame as (d), but using GIA, the cloth doesn't snag as the arm pulls out.

(http://mrl.nyu.edu/~dt/)

What is Motion Capture?

capture of motion of (human) actor
- whole body
- upper body
- face

more generally...

one way of using a physical device to control animation
- puppeteering
- exoskeletons
- discrete sensors on actors

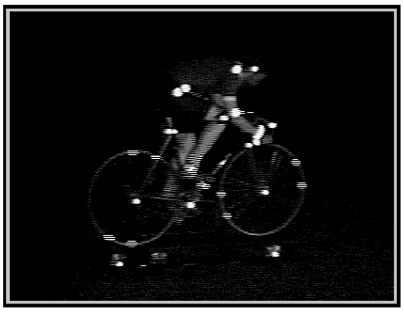
(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/)

Technology––optical

passive reflection––Peak

hand or semi–automatically digitized
time consuming

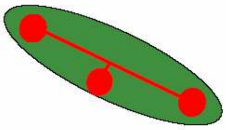
no glossy or reflective materials
tight clothing
occlusion of markers by props or limbs
higher frames/second



(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/)

Technology--optical

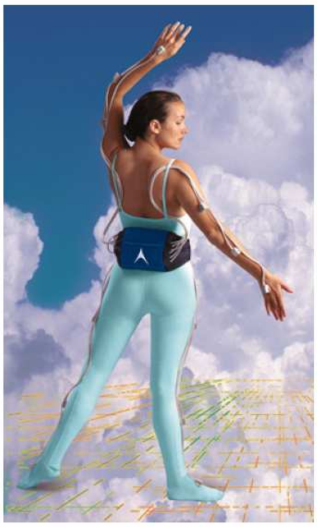
- passive reflection--Acclaim, Motion Analysis,...
- automatically digitized
- 240 Hz
- not real-time
- 3 markers/body part for 6 dof
- 2+ cameras for 3d position data
- ~$100K



(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/)

Technology--magnetic

- electromechanical transducers
  - Ascension flock of birds
  - Polhemus Fastrak
- limited range/resolution
- pigtail (new wireless system)
- metal in the environment
  - (treadmill, rebar!)
- no identification problem
- 6 dof information
- realtime
- low frequency: 30 to 120 Hz
- few markers: 10-20
- $40K

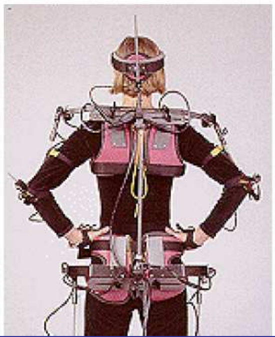


(Hodkins, http://www.cc.gatech.edu/classes/cs8113a_98_spring/)

Technology--mechanical

exoskeleton + angle sensors
Analogous

pigtail
no identification problem
realtime
high frequency: 500Hz
not range limited
fit
rigid body approximation



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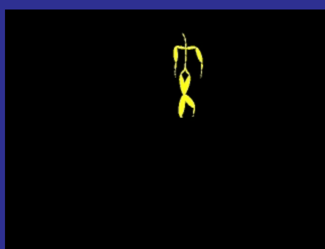
Motion Capture

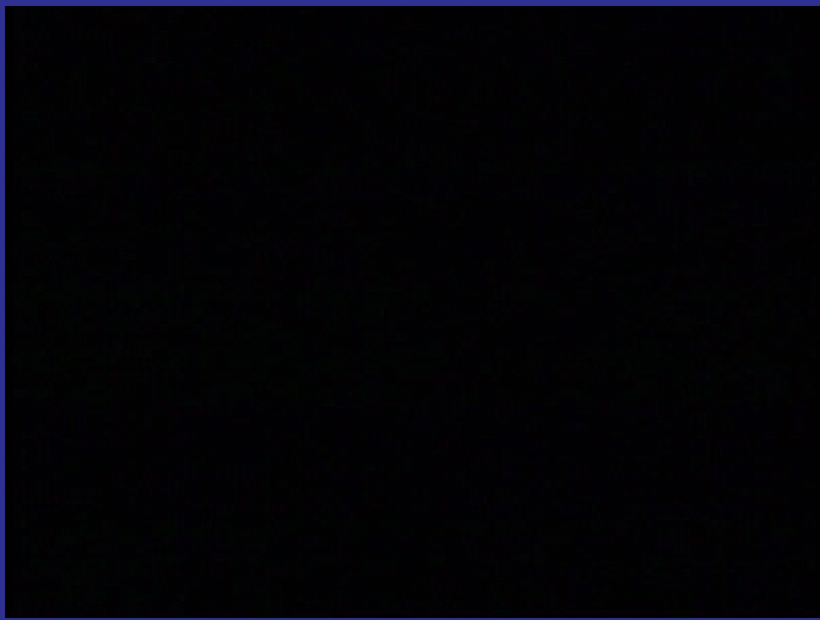


http://mocap.cs.cmu.edu/search.php?subjectnumber=%&motion=%

Behaviors

(Terzopoulos)

(Terzopoulos)



(Terzopoulos)