Animation – A broad Brush

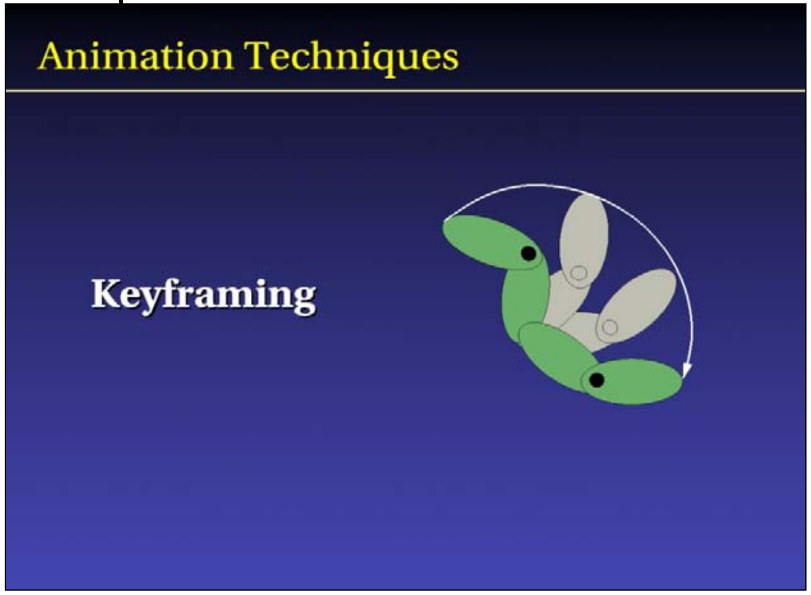
Traditional Methods
- Cartoons, stop motion

Keyframing
- Digital inbetweens

Motion Capture
- What you record is what you get

Simulation
- Animate what you can model (with equations)

Computer Animation



Animation Techniques

Keyframing

Keyframing

Traditional animation technique

Dependent on artist to generate ‘key’ frames

Additional, ‘inbetween’ frames are drawn automatically by computer

Keyframing

How are we going to interpolate?

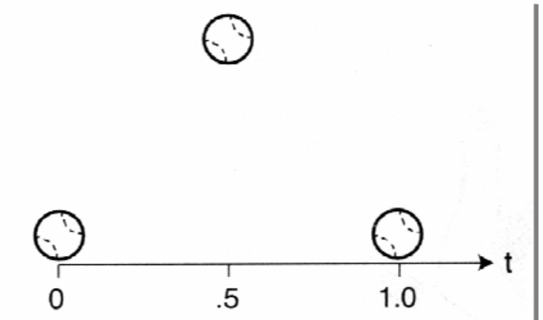
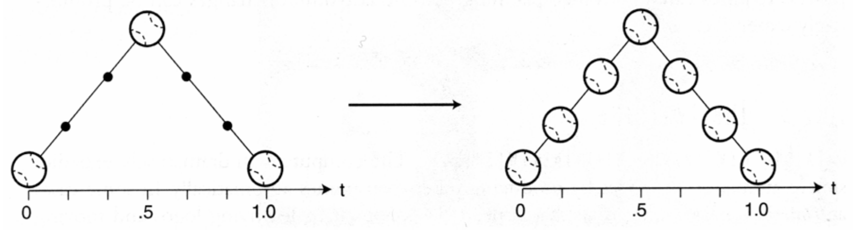


Figure 10.4 **Three keyframes.** Three keyframes representing a ball on the ground, at its highest point, and back on the ground.

From “The computer in the visual arts”, Spalter, 1999

Linear Interpolation

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).



Simple, but discontinuous velocity

Nonlinear Interpolation

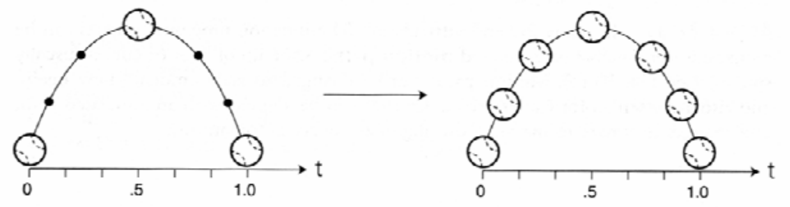


Figure 10.9 **Inbetweening with nonlinear interpolation.** Nonlinear interpolation can create equally spaced inbetween frames along curved paths. The ball still moves at a constant speed. (Note that the three keyframes used here and in Fig. 10.10 are the same as in Fig. 10.4.)

Smooth ball trajectory and continuous velocity, but loss of timing

Easing

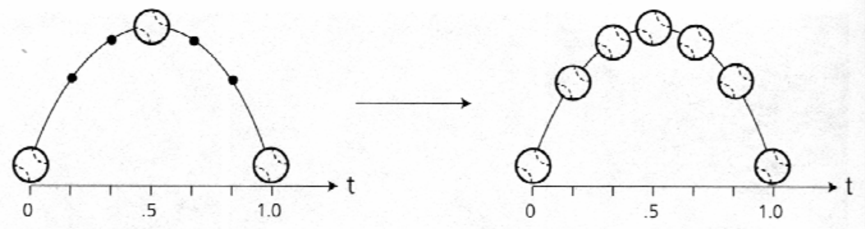
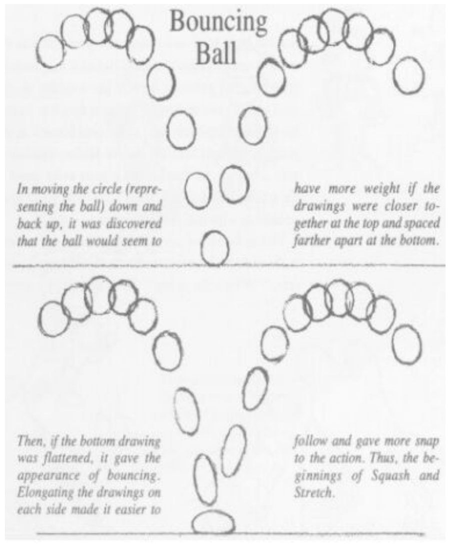


Figure 10.10 **Inbetweening with nonlinear interpolation and easing.** The ball changes speed as it approaches and leaves keyframes, so the dots indicating calculations made at equal time intervals are no longer equidistant along the path.

Adjust the timing of the inbetween frames. Can be automated by adjusting the stepsize of parameter, t.

Style or Accuracy?

- **Interpolating time captures accuracy of velocity**
- **Squash and stretch replaces motion blur stimuli and adds life-like intent**



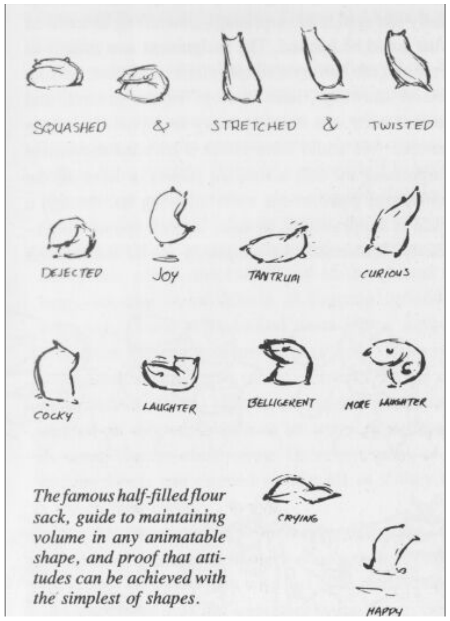
In moving the circle (representing the ball) down and back up, it was discovered that the ball would seem to have more weight if the drawings were closer together at the top and spaced farther apart at the bottom.

Then, if the bottom drawing was flattened, it gave the appearance of bouncing. Elongating the drawings on each side made it easier to follow and gave more snap to the action. Thus, the beginnings of Squash and Stretch.

Traditional Motivation

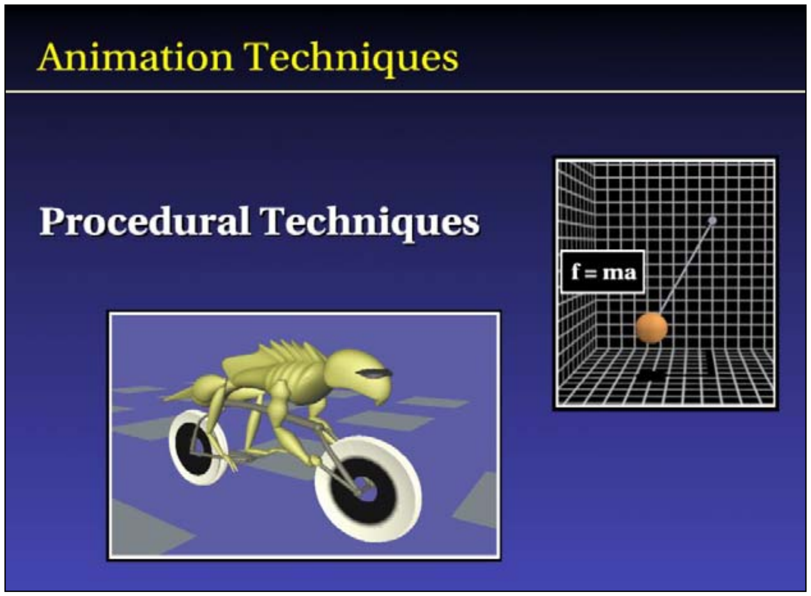
Ease-in and ease-out is like squash and stretch

Can we automate the inbetweens for these?



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.

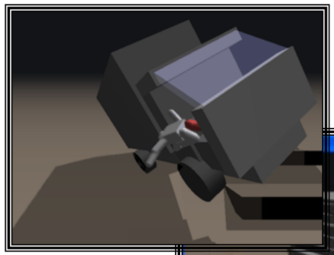
"The Illusion of Life, Disney Animation"
Thomas and Johnson



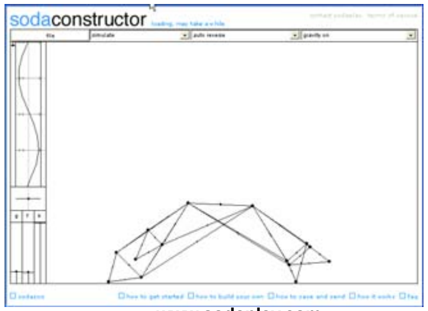
Animation Techniques

Procedural Techniques

Procedural



http://jet.ro/dismount



www.sodaplay.com

Examples

Inanimate video game objects

- GT Racer cars
- Soapbox about why this is so cool

Special effects

- Explosions, water, secondary motion
- Phantom Menace CG droids after they were cut in half

Procedural Animation

- Very general term for a technique that puts more complex algorithms behind the scenes
- Technique attempts to consolidate artistic efforts in algorithms and heuristics
- Allows for optimization and physical simulation

Procedural Animation Strengths

- Animation can be generated 'on the fly'
- Dynamic response to user
- Write-once, use-often
- Algorithms provide accuracy and exhaustive search that animators cannot

Procedural Animation Weaknesses

- We're not great at boiling human skill down to algorithms
  - How do we move when juggling?
- Difficult to generate
- Expensive to compute
- Difficult to force system to generate a particular solution
  - Bicycles will fall down

Particle Systems

❑ **Particle systems provide a powerful framework for animating numerous similar elementary "objects" at the same time. Those objects are called particles. Using a lot of particles with simple physics allow us to model complex phenomena such as:**
  - Fireworks
  - Waterfalls
  - Smoke
  - Fire
  - Flocking
  - Clothes, etc.

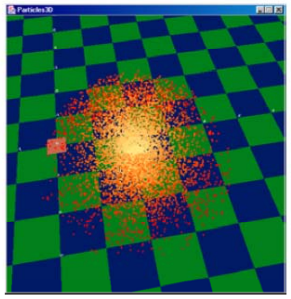


Figure 1. A Particle System of Points.

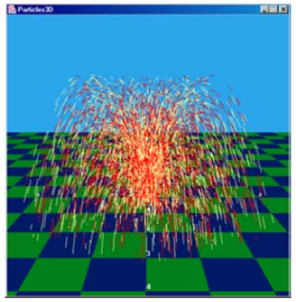


Figure 2. A Particle System of Lines.

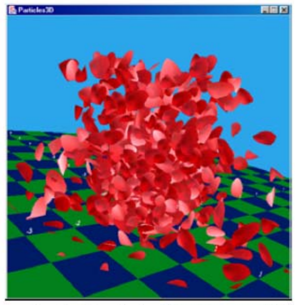


Figure 3. A Particle System of Quads.

Introduction

Typical Particle system animation routine

```
ParticleSystem()
1.  Animate a particle System
2.   While animation not finished
3.       Do Delete expired particles
4.           Create new particles
5.           Simulate Physics
6.           Update particle attributes
7.           Render particles
```

Particle

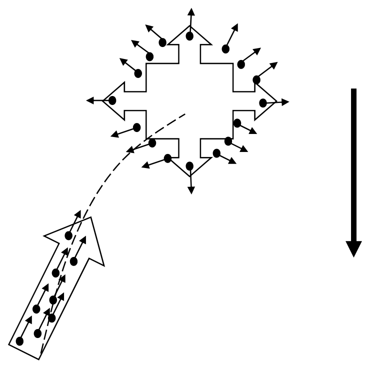
A particle is described by physical body attributes, such as:

Mass, Position, Velocity, Acceleration, Color, Life time.

```
typedef struct                          // Create A Structure For
Particle
{         bool     active;              // Active (Yes/No)
          float    life;                      // Particle Life
          float    fade;                      // Fade Speed
          float    r;                         // Red Value
          float    g;                         // Green Value
          float    b;                         // Blue Value
          float    x;                         // X Position
          float    y;                         // Y Position
          float    z;                         // Z Position
          float    xi;                        // X Direction
          float    yi;                        // Y Direction
          float    zi;                        // Z Direction
          float    xg;                        // X Gravity
          float    yg;                        // Y Gravity
          float    zg;                        // Z Gravity
}
particles; // Particles Structure
```

```
initAll(){
    for(int i = 0; i <= MAX_PARTICLES; i++){
        Particles[i].x = rand() % WORLD_WIDTH;
        Particles[i].y = rand() % WORLD_HEIGHT;
        Particles[i].z = rand() % WORLD_DEPTH;}}
initEntity(int index){
    Particles[index].x = rand() % WORLD_WIDTH;
    Particles[index].y = rand() % WORLD_HEIGHT;
    Particles[index].z = rand() % WORLD_DEPTH;}
render(){
    for(int i = 0; i <= MAX_PARTICLES; i++){
        draw_rain_texture(Particles[i].x, Particles[i].y, Particles[i].z);        }}
update(){
    for(int i = 0; i <= MAX_PARTICLES; i++)   {
        Particles[i].y =- (rand() % 2) - 2.5;
        if (collisiondetect(Particles[i]))  { initEntity(i);  }
    }}
```

Example - Firework



During the explosion phase, each particle has its own mass, velocity and acceleration attributes modified according to a random, radially centered speed component.

During the rocket phase, all particles flock together. The speed of the particles inside the illusory rocket is determined by the initial launch speed to which we subtract the influence of gravity

Physics

$F = m*a$

$a = F/m$

$a = g = 9.81$ m/s

$a(t + dt) = - gz$ where z is upward unit vector

$v(t+dt) = v(t) + a(t)\, dt$

$x(t+dt) = x(t) + v(t)dt + ½\, a(t^2)dt$

Particle system - Applications

Using this general particle system framework, there are various animation effects that can be simulated such as force field (wind, pressure, gravity), viscosity, collisions, etc.

Rendering particles as points is straightforward, but we can also draw tiny segments for giving the illusion of motion blur, or even performing ray casting for obtaining volumetric effects.

The QuadParticles Class

Although many particle systems can be modeled with points and lines, moving to quadrilaterals (quads) combined with textures allows many more interesting effects.

The texture can contain extra surface detail, and can be partially transparent in order to break up the regularity of the quad shape.

A quad can be assigned a normal and a Material node component to allow it to be affected by lighting in the scene.

The only danger with these additional features is that they may slow down rendering by too much. For example, we want to map the texture to each quad (each particle), but do not want to use more than one QuadArray and one Texture2D object.

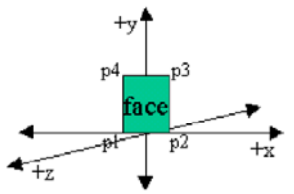


Figure 8. Initial Quad Position.

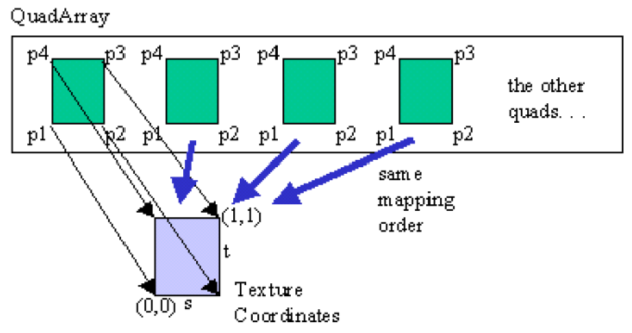


Figure 9. Mapping Quads to the same Texels.

Forces

A = F/m

- Particle masses won't change
- But need to evaluate F at every time step.
- The force on one particle may depend on the positions of all the others

Forces

Typically, have multiple independent forces.

- For each force, add its contribution to each particle.
  - Need a force accumulator variable per particle
  - Or accumulate force in the acceleration variable, and divide by m after all forces are accumulated

Forces

Example forces

- Earth gravity, air resistance
- Springs, mutual gravitation
- Force fields
  - Wind
  - Attractors/Repulsors
  - Vortices

Forces

Earth Gravity

- f = -9.81*(particle mass in Kg)*Y

Drag

- f = -k*v

Uniform Wind

- f = k

Forces

Simple Random Wind

- After each timestep, add a random offset to the direction

Noisy Random Wind

- Acts within a bounding box
- Define a grid of random directions in the box
- Trilinear interpolation to get f
- After each timestep, add a random offset to each direction and renormalize

Forces

Attractors/Repulsors

- Special force object at position x
- Only affects particles within a certain distance
- Within the radius, distance-squared falloff
  - if |x-p| < d

```
        v = (x-p)/|x-p|
        f = $\pm k/|x|^2 * x$
  else
        f = 0
```

- Use the regular grid optimization from lecture

Emitters

What is it?!

- Object with position, orientation
- Regulates particle "birth" and "death"
- Usually 1 per particle system
  - More than 1 can make controlling particle death inconvenient

Emitters

Regulating particles

- At "birth," reset the particle's parameters
  - Free to set them arbitrarily!
- For "death," a few possibilities
  - If a particle is past a certain age, reset it.
  - Keep an index into the particle array, and reset a group of K particles at each timestep.
- Should allocate new particles only once!
  - Recycle their objects or array positions.

Emitters

Fountain

- Given the emitter position and direction, we have a few possibilities:
  - Choose particle velocity by jittering the direction vector
  - Choose random spherical coordinates for the direction vector

Demo

- http://www.delphi3d.net/download/vp_sprite.zip

Rendering

Spheres are easy but boring.

- Combine points, lines, and alpha blending for moderately interesting effects.

Render oriented particle meshes

- Store rotation info per-particle
- Keep meshes facing "forward" along their paths
- Can arbitrarily pick "up" vector

Rendering

Render billboards

- Want to represent particles by textures
- Should always face the viewer
- Should get smaller with distance
- Want to avoid OpenGL’s 2d functions

Rendering

Render billboards (one method)

- Draws an image-plane aligned, diamond-shaped quad
- Given a particle at p, and the eye’s basis (u,v,w), draw a quad with vertices:
  - q0 = eye.u
  - q1 = eye.v
  - q2 = -eye.u
  - q3 = -eye.v
- Translate it to p
- Will probably want alpha blending enabled for smoke, fire, pixie dust, etc. See the Red Book for more info.

Simulation Loop Recap

A recap of the loop:

- Initialize/Emit particles
- Run integrator (evaluate derivatives)
- Update particle states
- Render
- Repeat!

Particle Illusion Demo

- www.wondertouch.com