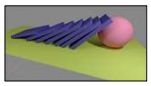
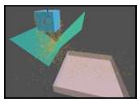
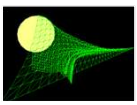
Animation



Oregon State University
Mike Bailey
mjb@cs.oregonstate.edu





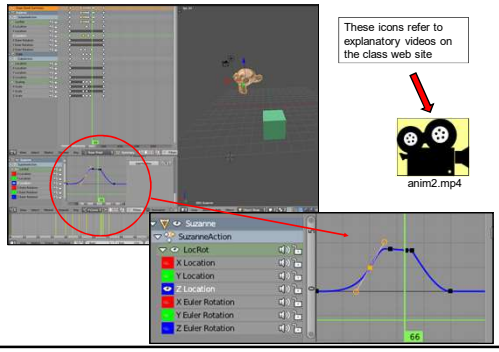
This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Animation

Animation is the process of giving motion to your geometric models. Before animating, there are questions you need to ask first:

- Why am I doing this?
- Do I want the animation to obey the real laws of physics? Partially? Which elements?
- Am I willing to "fake" the physics to get the objects to *want* to move in a way that I tell it?
- Do I have specific key positions I want the objects to pass through no matter what?
- Do I want to simply record the motion of a real person, animal, etc., and then play it back?

Keyframe Animation

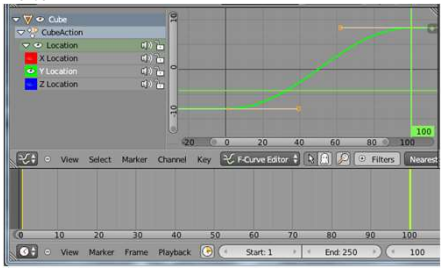


These icons refer to explanatory videos on the class web site

anim2.mp4

Keyframe Animation

Blender:



Here's Some Code that Lets You Create DIY Keyframe Animations

For my own work, instead of *Key Frames*, I like specifying *Key Times* better. And, so, I created a C++ class to do it for you.

```
class Keytimes:

        void    AddTimeValue( float time, float value );
        float   GetFirstTime( );
        float   GetLastTime( );
        int     GetNumKeytimes( );
        float   GetValue( float time );
        void    Init( );
        void    PrintTimeValues( );
```


Instead of Key *Frames*, I Like Specifying Key *Times* Better

```
Keytimes Xpos;

int
main( int argc, char *argv[ ] )
{
    Xpos.Init( );
    Xpos.AddTimeValue(  0.0,  0.000 );
    Xpos.AddTimeValue(  2.0,  0.333 );
    Xpos.AddTimeValue(  1.0,  3.142 );
    Xpos.AddTimeValue(  0.5,  2.718 );
    fprintf( stderr, "%d time-value pairs:\n", Xpos.GetNumKeytimes( ) );
    Xpos.PrintTimeValues( );

    fprintf( stderr, "Time runs from %8.3f to %8.3

    for( float t = 0.; t <= 2.0; t += 0.1 )
    {
        float v = Xpos.GetValue( t );
        fprintf( stderr, "%8.3f\t%8.3f\n", t, v );
    }
}
```

Declare one class per parameter you are animating. Here it wants to interpolate and animate the x-location of something.

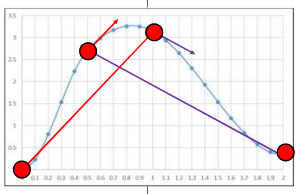
Key-Time pairs (Time and Xlocation) can be specified in any order

Just to demonstrate, this for-loop runs through a collection of time values and looks up the interpolate x-location at those values. Normally you would get the time from the system clock.

Instead of Key *Frames*, I Like Specifying Key *Times* Better

```
( 0.00,  0.000)
( 0.00,  0.000)  ( 2.00,  0.333)
( 0.00,  0.000)  ( 1.00,  3.142)  ( 2.00,  0.333)
( 0.00,  0.000)  ( 0.50,  2.718)  ( 1.00,  3.142)  ( 2.00,  0.333)
4 time-value pairs
Time runs from   0.000 to   2.000
  0.000      0.000
  0.100      0.232
  0.200      0.806
  0.300      1.535
  0.400      2.234
  0.500      2.718
  0.600      2.989
  0.700      3.170
  0.800      3.258
  0.900      3.250
  1.000      3.142
  1.100      2.935
  1.200      2.646
  1.300      2.302
  1.400      1.924
  1.500      1.539
  1.600      1.169
  1.700      0.840
  1.800      0.574
  1.900      0.397
  2.000      0.333
```

= the originally-specified key-time pairs



Oregon State University Computer Graphics

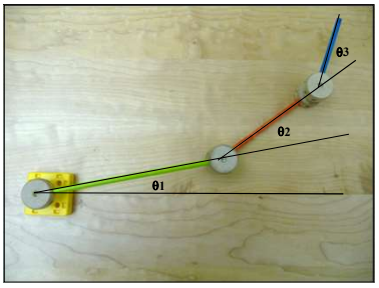
Using the System Clock in Display( ) for Timing

```
#define MSEC      10000                    // i.e., 10 seconds
Keytimes Xpos, Ypos, Zpos;
Keytimes ThetaX, ThetaY, ThetaZ;

. . .

if( AnimationIsOn )
{
        // # msec into the cycle ( 0 - MSEC-1 ):
        int msec = glutGet( GLUT_ELAPSED_TIME ) % MSEC;

        // turn that into a time in seconds:
        float nowTime = (float)msec / 1000.;
        glPushMatrix( );
                glTranslatef( Xpos.GetValue( nowTime ), Ypos.GetValue( nowTime ), Zpos.GetValue( nowTime )
};
                glRotatef( ThetaX.GetValue( nowTime ), 1., 0., 0. );
                glRotatef( ThetaY.GetValue( nowTime ), 0., 1., 0. );
                glRotatef( ThetaZ.GetValue( nowTime ), 0., 0., 1. );
                << draw the object >>
        glPopMatrix( );
}
```

Number of msec in the animation cycle

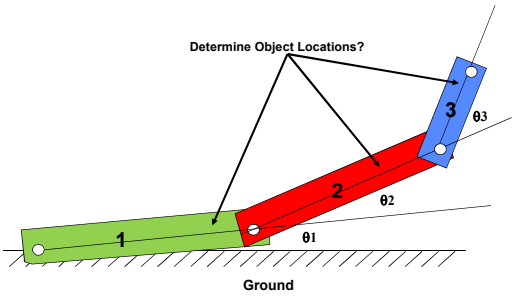
Oregon State University Computer Graphics

Forward Kinematics: Change Parameters – Connected Things Move (All children understand this)



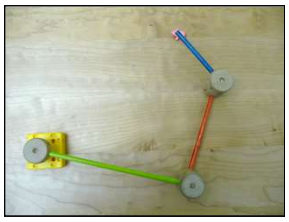
Oregon State University Computer Graphics

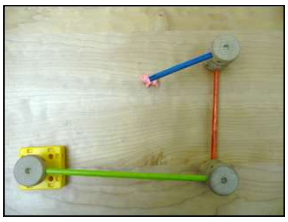
Forward Kinematics: Transformation Hierarchies



Oregon State University Computer Graphics

Inverse Kinematics (IK): Things Need to Move to a Particular Location – What Parameters Will Make Them Do That?





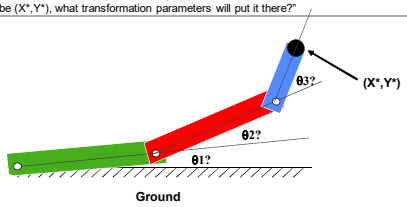
Of course, there will always be target locations that can *never* be reached.
Think about that spot in the middle of your back that you can never scratch! ☺

Oregon State University Computer Graphics

Inverse Kinematics (IK)

Forward Kinematics solves the problem "if I know the link transformation parameters, where are the links?".

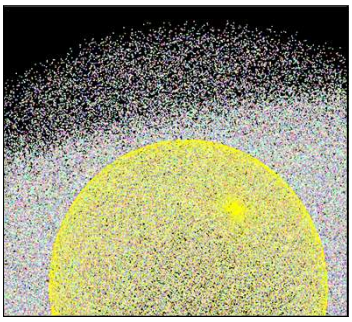
Inverse Kinematics (IK) solves the problem "If I know where I want the end of the chain to be (X*,Y*), what transformation parameters will put it there?"



Oregon State University Computer Graphics

Particle Systems: A Cross Between Modeling and Animation?

13



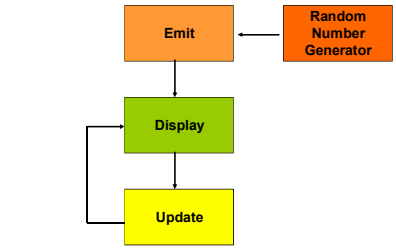
Oregon State University Computer Graphics

mjb – September 11, 2023

Particle Systems: A Cross Between Modeling and Animation?

14

The basic process is:

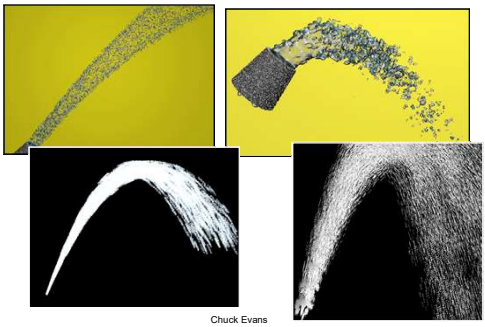


Oregon State University Computer Graphics

mjb – September 11, 2023

Particle Systems Examples

15



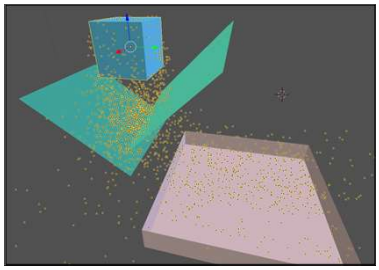
Chuck Evans

Oregon State University Computer Graphics

mjb – September 11, 2023

Particle Systems Examples

16



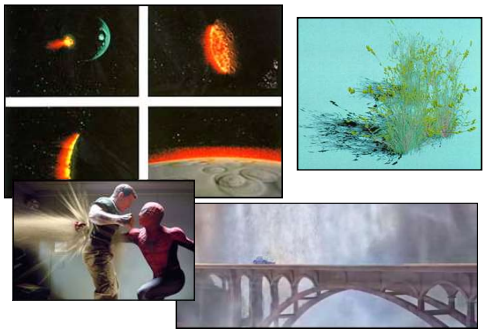
particles.mp4

Oregon State University Computer Graphics

mjb – September 11, 2023

Particle Systems Examples

17



Oregon State University Computer Graphics

mjb – September 11, 2023

Particle Systems Examples

18

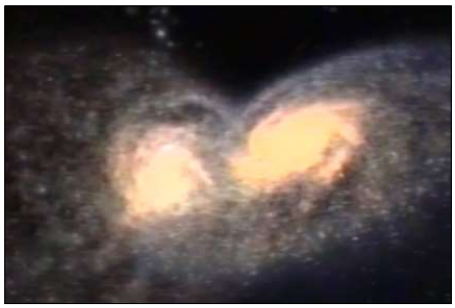
The Lion King (2019) -- Disney

Oregon State University Computer Graphics

mjb – September 11, 2023

A Particle System to Simulate Colliding Galaxies in *Cosmic Voyage*

19



Cosmic Voyage

Oregon State University Computer Graphics

mjb – September 11, 2023

Particles Don't Actually Have to Be "Particles"

20

Avatar

The Lion King

Mulan

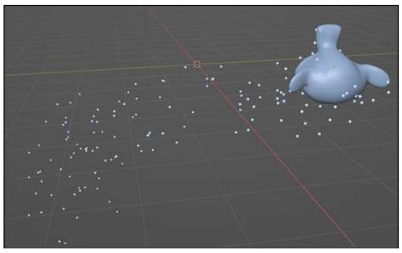
Oregon State University Computer Graphics

mjb – September 11, 2023

Multiple Animation Techniques Can Be Combined

21

A Particle System coming from a moving keyframed object in Blender:

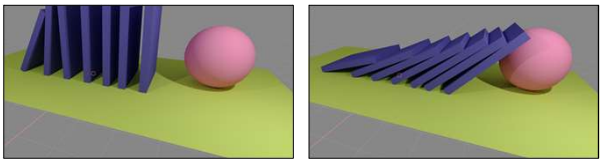


Oregon State University Computer Graphics

mjb – September 11, 2023

Animating using Rigid-body Physics

22



Newton's second law:

force = mass * acceleration

or

$\ddot{x} =$ acceleration = force / mass

$$x(T) = \iint_{t=0}^{t=T} \ddot{x}\,dt \approx \sum \sum \ddot{x}\,\Delta t$$

dominos.mp4

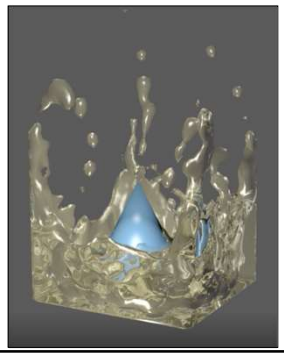
Oregon State University Computer Graphics

In order to make this work, you need to supply physical properties such as mass, center of mass, moment of inertia, coefficients of friction, coefficients of restitution, etc.

mjb – September 11, 2023

Animating using Fluid Physics

23



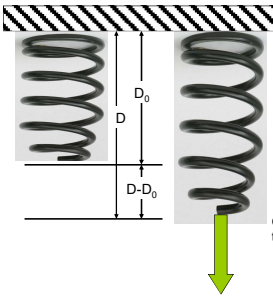
fluid.avi

Oregon State University Computer Graphics

mjb – September 11, 2023

Animating using Physics

24



D_0 = unloaded spring length

$$(D - D_0) = \frac{F}{k}$$

k = ***spring stiffness*** in Newtons/meter or pounds/inch

Or, if you know the displacement, the force exerted by the spring is:

$$F = k\left(D - D_0\right)$$

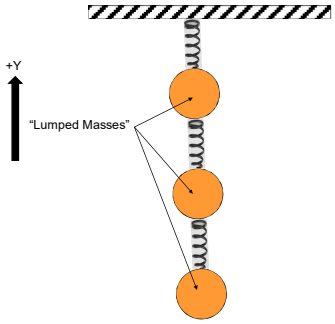
This is known as **Hooke's Law**

Oregon State University Computer Graphics

mjb – September 11, 2023

Animating using the Physics of a Mesh of Springs

25

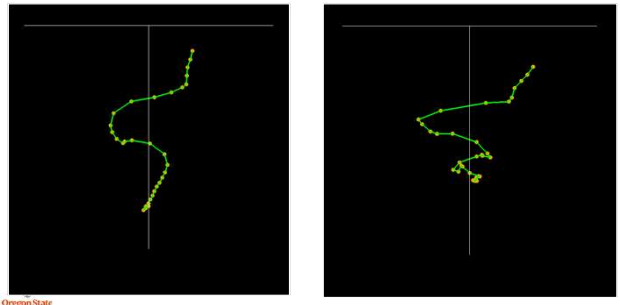


Oregon State University Computer Graphics

mjb – September 11, 2023

Simulating a Bouncy String

26

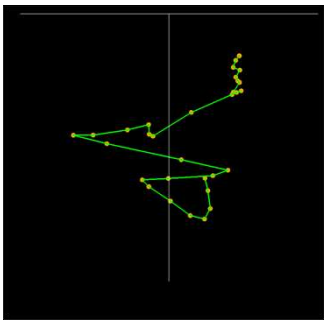


Oregon State University Computer Graphics

mjb – September 11, 2023

Simulating a Bouncy String

27



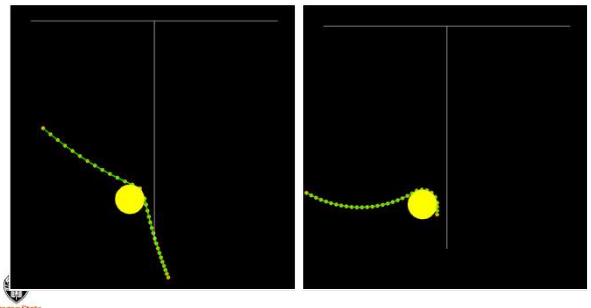
string.mp4

Oregon State University Computer Graphics

mjb – September 11, 2023

Placing a Physical Barrier in the Scene

28

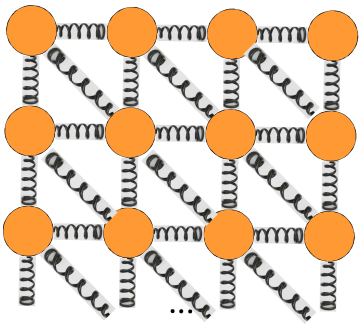


Oregon State University Computer Graphics

mjb – September 11, 2023

Animating Cloth

29

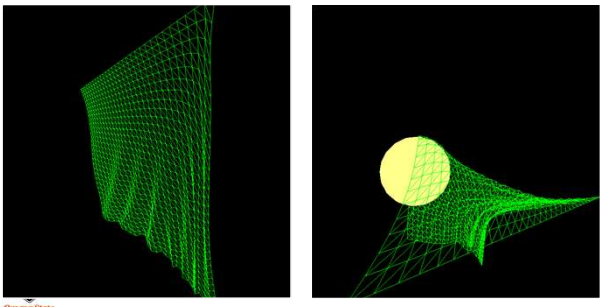


Oregon State University Computer Graphics

mjb – September 11, 2023

Cloth Examples

30

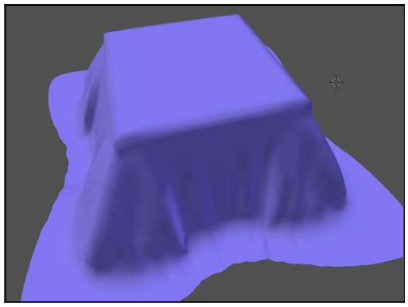


Oregon State University Computer Graphics

mjb – September 11, 2023

Cloth Example

31



cloth.mp4

Oregon State University Computer Graphics

mjb – September 11, 2023

Cloth Example

32

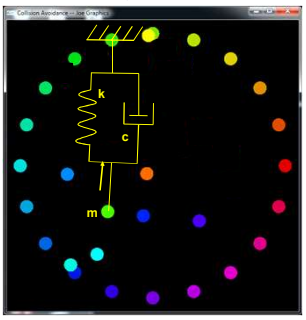
Geri's Game, Pixar

Oregon State University Computer Graphics

mjb – September 11, 2023

Functional Animation: Make the Object *Want* to Move Towards a Goal Position

33



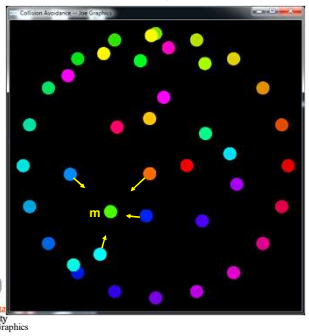
$$m\ddot{x} + c\dot{x} + kx = 0$$

Oregon State University Computer Graphics

mjb – September 11, 2023

Functional Animation: While Making it Want to Move Away from all other Objects

34



$$m\ddot{x} = \sum F_{repulsive}$$

Repulsion Coefficient

$$F_{repulsive} = \frac{C_{repulse}}{d^{Power}}$$

Distance between the boundaries of the 2 bodies

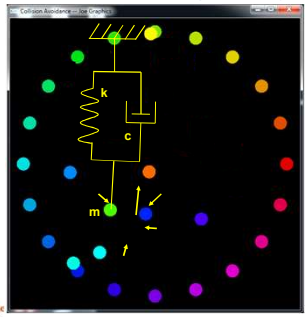
Repulsion Exponent

Oregon State University Computer Graphics

mjb – September 11, 2023

Total Goal – Make the Free Body Move Towards its Final Position While Being Repelled by the Other Bodies

35



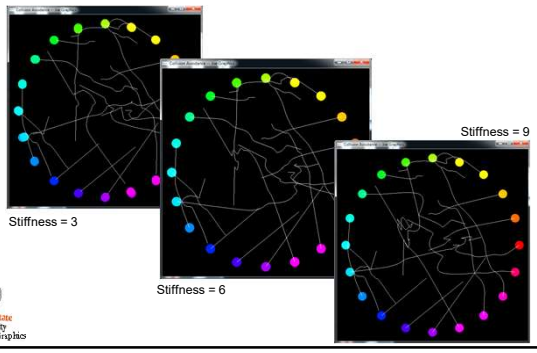
$$m\ddot{x} + c\dot{x} + kx = \sum F$$

Oregon State University Computer Graphics

mjb – September 11, 2023

Increasing the Stiffness

36

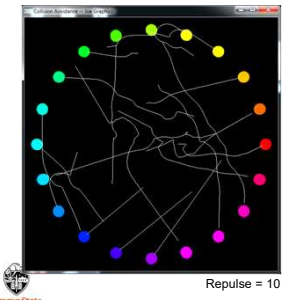


Oregon State University Computer Graphics

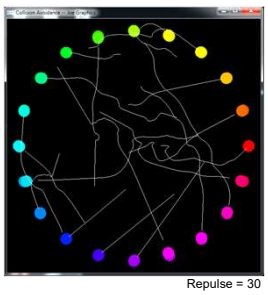
mjb – September 11, 2023

Increasing the Repulsion Coefficient

37



Repulse = 10



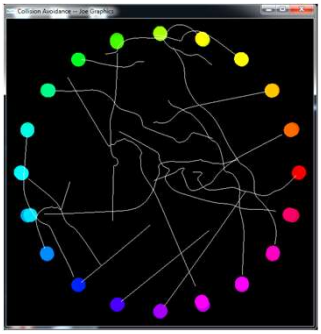
Repulse = 30

Oregon State University Computer Graphics

mjb – September 11, 2023

Functional Animation

38



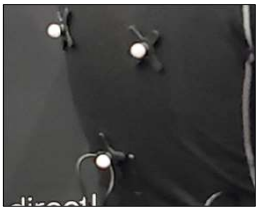
avoid.mp4

Oregon State University Computer Graphics

mjb – September 11, 2023

Motion Capture ("MoCap") as an Input for Animation

39



Natural Point

Oregon State University Computer Graphics

mjb – September 11, 2023

Motion Capture is for Hands and Faces Too

40

Natural Point

Oregon State University Computer Graphics

mjb – September 11, 2023

Even Animals can be MoCapped

41

My cats would never have put up with this…

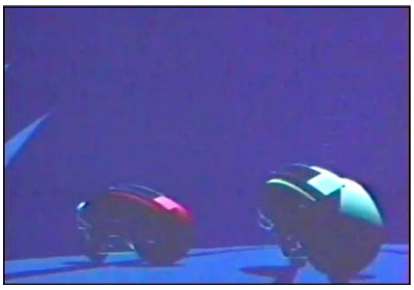
https://www.youtube.com/watch?v=zyq_LQrHpoo

Oregon State University Computer Graphics

mjb – September 11, 2023

Tron I – They probably should have used physics, but didn't

42



MAGI

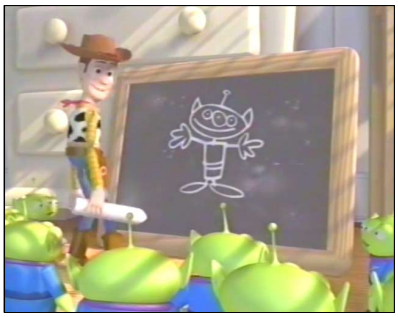
Oregon State University Computer Graphics

mjb – September 11, 2023

Card Trick

Rob Russ

Pixar Animated Shorts



Pixar