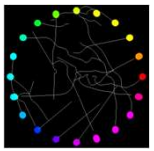
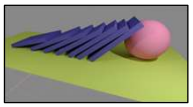
Animation





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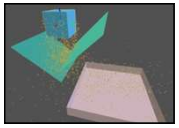
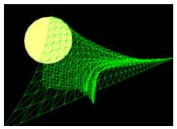
Mike Bailey
mjb@cs.oregonstate.edu





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1

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?

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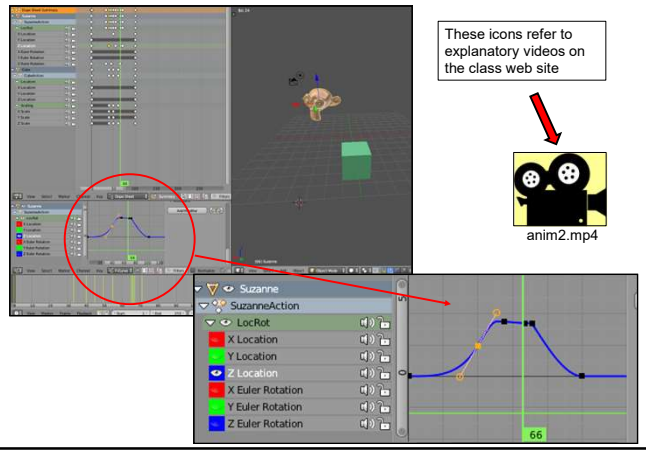
2

Keyframe Animation



These icons refer to explanatory videos on the class web site

anim2.mp4

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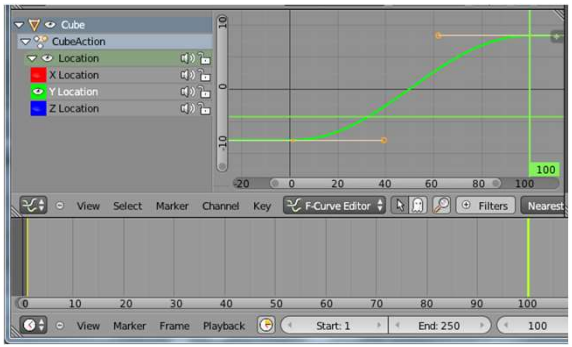
3

Keyframe Animation

Blender:



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4

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 );
    }
}
```

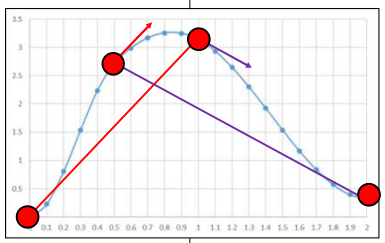
Declare one class per parameter you are animating. Here it wants to interpolate and animate the x-location of something.

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

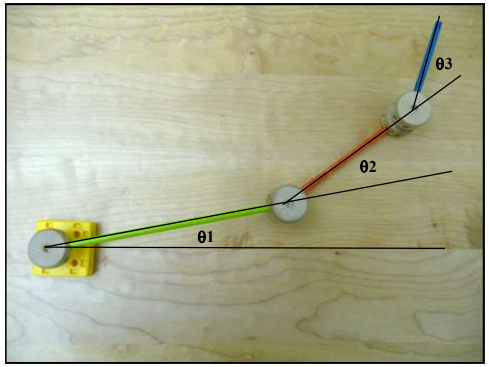
Using the System Clock in Display( ) for Timing


```
#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

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

9



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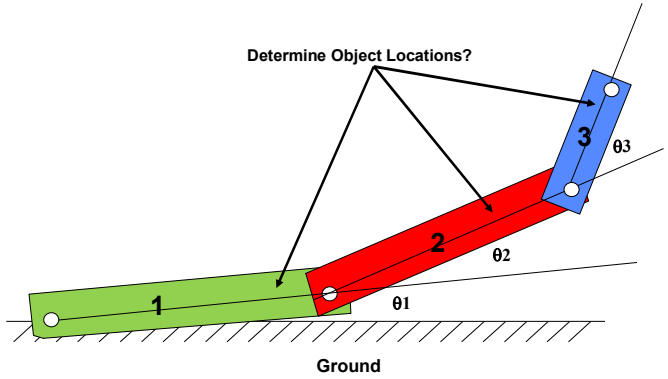
9

Forward Kinematics: Transformation Hierarchies

10



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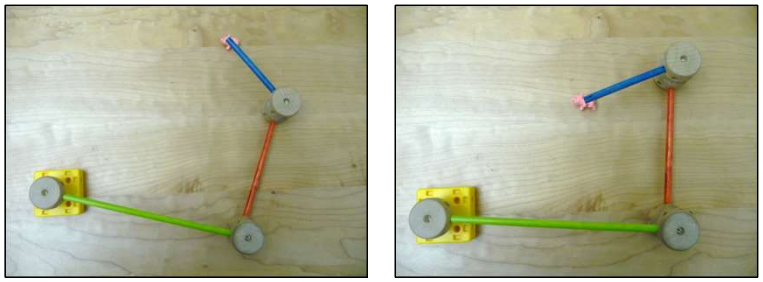
10

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

11



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! ☺

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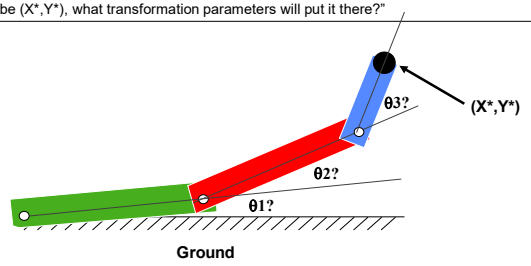
11

Inverse Kinematics (IK)

12

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?"



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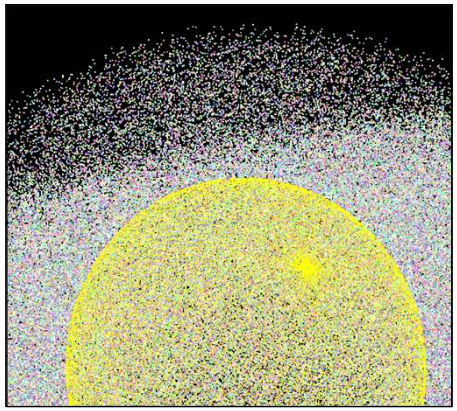
12

Particle Systems:
A Cross Between Modeling and Animation?

13



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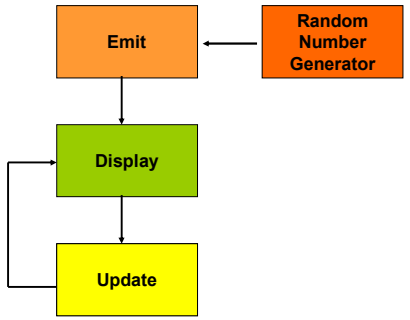
13

Particle Systems:
A Cross Between Modeling and Animation?

14

The basic process is:



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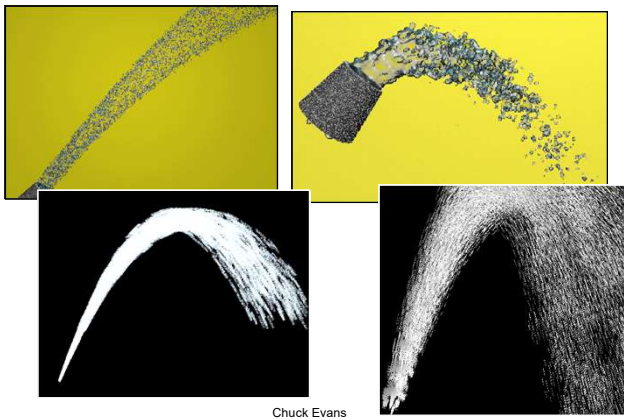
14

Particle Systems Examples

15



Chuck Evans

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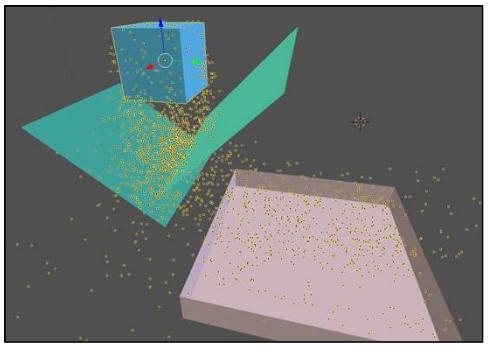
15

Particle Systems Examples

16



particles.mp4

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Particle Systems Examples

17

17

Particle Systems Examples

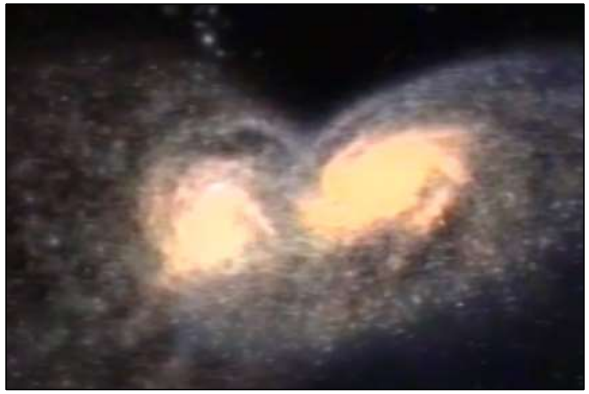
18

The Lion King (2019) -- Disney

18

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

19



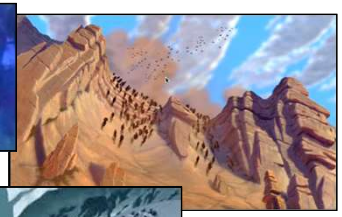
Cosmic Voyage

19

Particles Don't Actually Have to Be "Particles"

20

Avatar



The Lion King

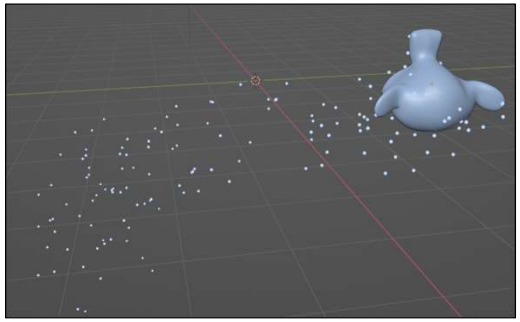
Mulan

20

Multiple Animation Techniques Can Be Combined

21

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



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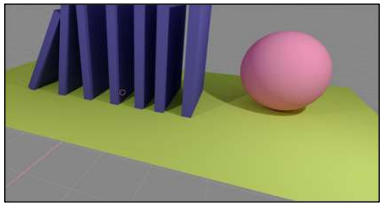
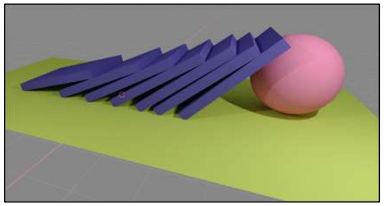
Animating using Rigid-body Physics

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

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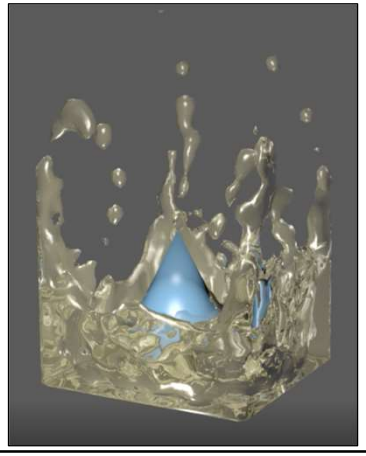
In order to make this work, you need to supply physical properties such as mass, center of mass, moment of inertia, coefficients of friction, coefficients of restitution, etc.

Animating using Fluid Physics

23



fluid.avi

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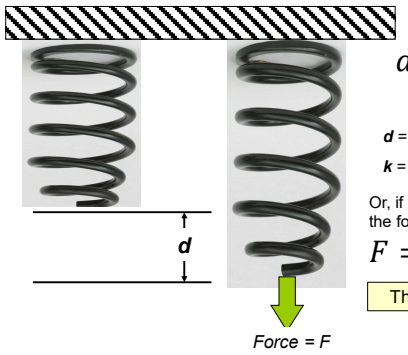
Animating using Physics

24



$$d = \frac{-F}{k}$$

d = ***spring displacement*** in inches

k = ***spring stiffness*** in pounds/inch

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

$$F = -kd$$

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

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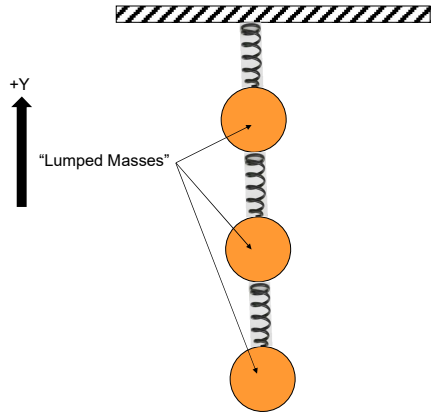
Why the minus sign? Because a spring's force acts in a direction opposite the displacement. In other words, a spring's force tries to correct its displacement.

Animating using the Physics of a Mesh of Springs

25



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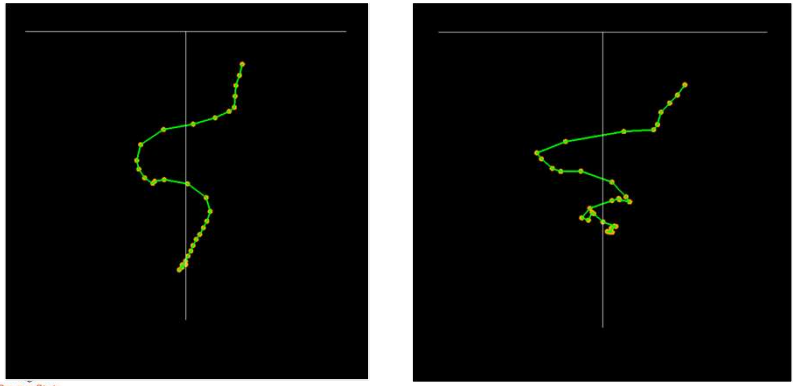
25

Simulating a Bouncy String or a Chain

26



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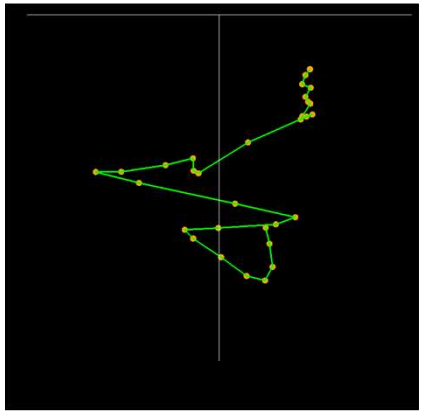
26

Simulating a Bouncy String or a Chain

27



string.mp4

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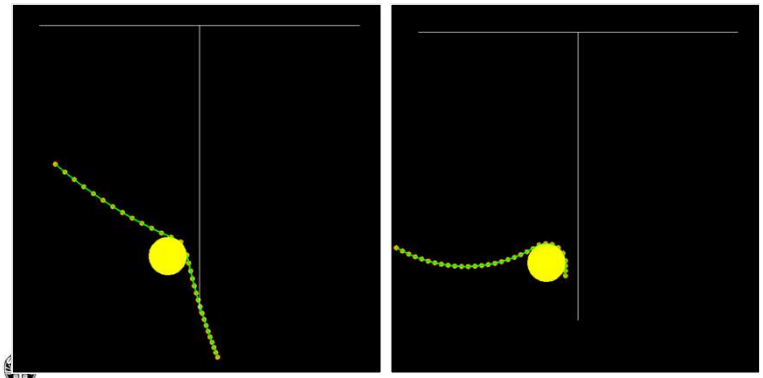
27

Placing a Physical Barrier in the Scene

28



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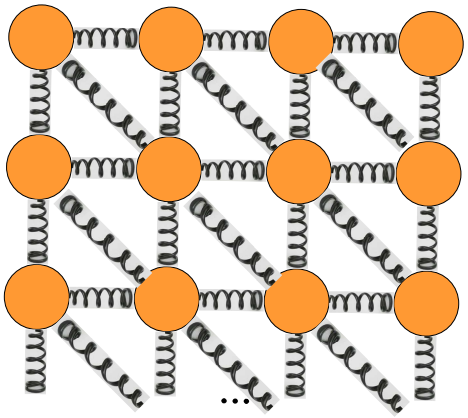
28

Animating Cloth

29



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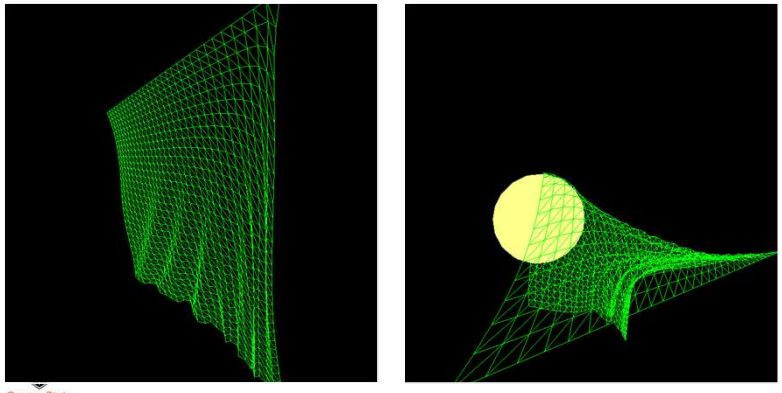
29

Cloth Examples

30



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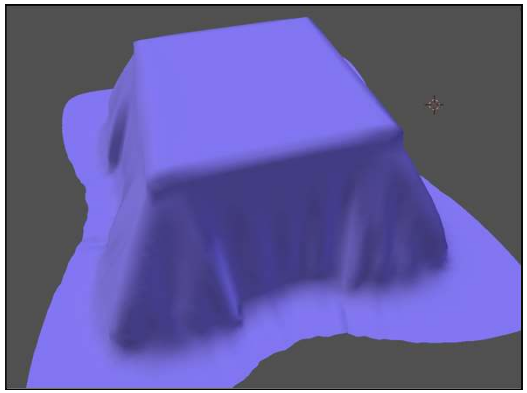
30

Cloth Example

31



cloth.mp4

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31

Cloth Example

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Geri's Game, Pixar

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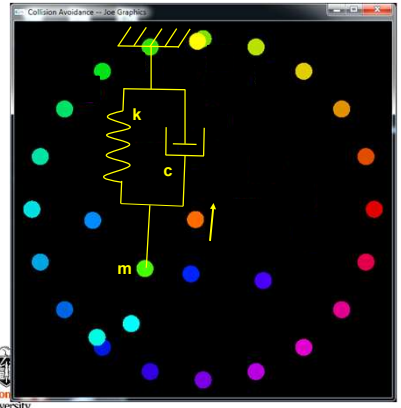
32

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

33



Newton's second law:
force = mass * acceleration
or
$\ddot{x}$ = acceleration = force / mass

$$\ddot{x} = \frac{-c\dot{x} - kx}{m}$$

- The ***k*** is an imaginary spring.
- The ***c*** is an imaginary "damper", which you can think of as a shock absorber which absorbs energy. (Your car has these to soften bouncing.)

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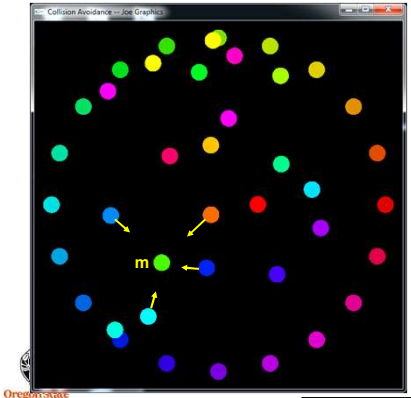
33

Functional Animation:
Setup Imaginary Physics to Make the Object *Want* to Move Away from all other Objects

34



Newton's second law:
force = mass * acceleration
or
$\ddot{x}$ = acceleration = force / mass

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

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

Repulsion Coefficient

Distance between the boundaries of the 2 bodies

Repulsion Exponent

This isn't from a book. I just made this up. It seemed like a good idea.

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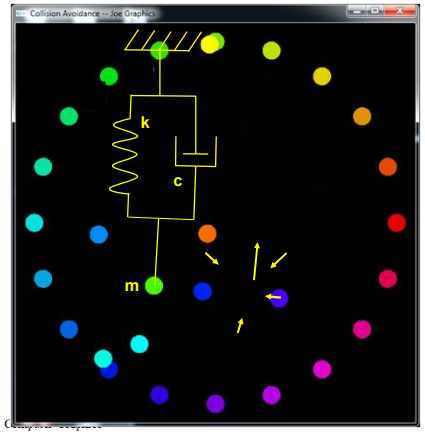
34

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

35



Newton's second law:
force = mass * acceleration
or
$\ddot{x}$ = acceleration = force / mass

$$\ddot{x} = \frac{-c\dot{x} - kx + \sum F_{repulsive}}{m}$$

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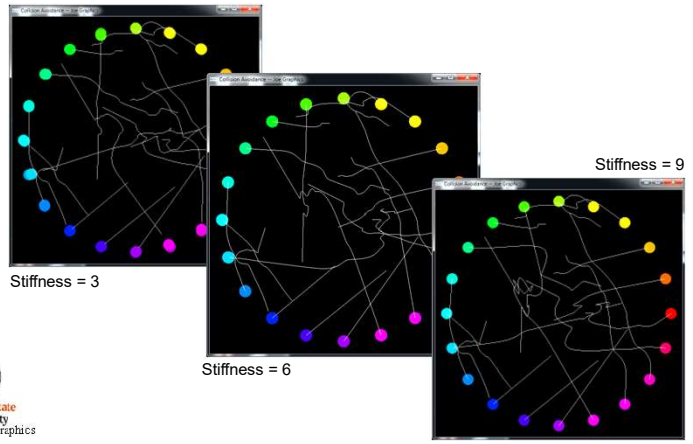
35

Increasing the Stiffness

36



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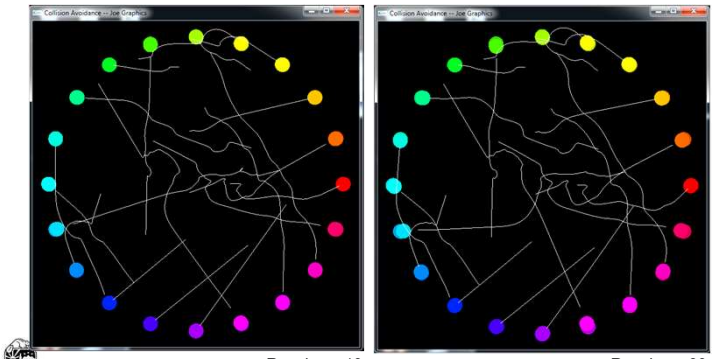
Increasing the Repulsion Coefficient

37



Repulse = 10 Repulse = 30

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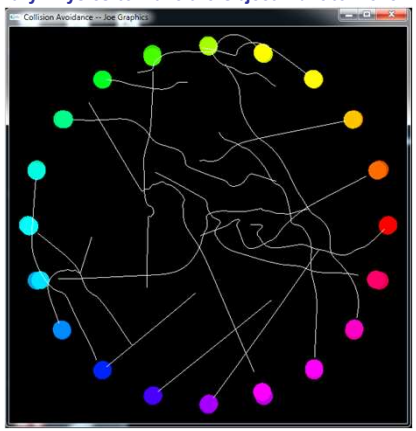
37

Functional Animation: Setup Imaginary Physics to Make the Object *Want* to Move Like We Want it To

38



avoid.mp4

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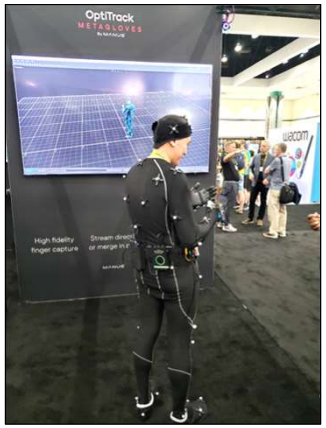
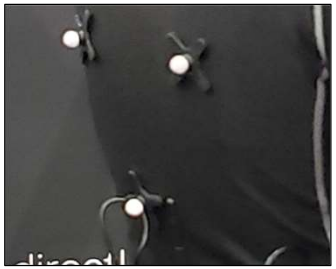
38

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

39





Natural Point

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Motion Capture is for Hands and Faces Too

40

Natural Point

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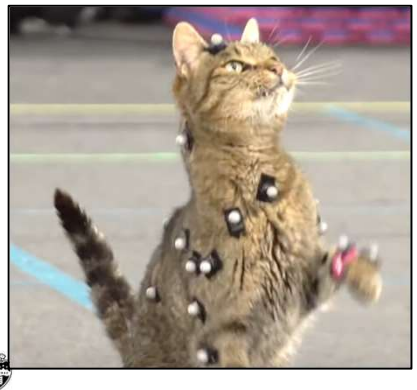
40

41

Even Animals can be MoCapped



My cats would never have put up with this…

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

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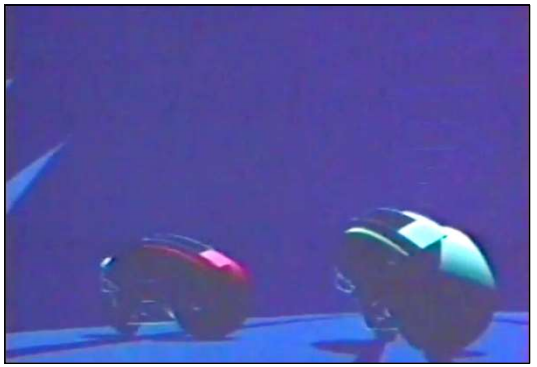
Tron I –
They probably should have used physics, but didn't



MAGI

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Card Trick

Rob Russ

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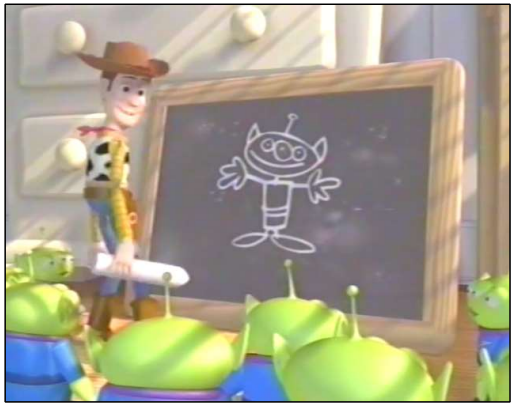
Pixar Animated Shorts



Pixar

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