Rendering is the process of giving motion to your geometric modes. 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?
- Am I willing to "fake" the physics to get the objects 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 website.

**Blender:**

Forward Kinematics:

- Change Parameters – Connected Things Move
- (All Tinker Toy users understand this)

Forward Kinematics: Transformation Hierarchies

Determine Object Locations?
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! 😊

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?"

Particle Systems: A Cross Between Modeling and Animation?

The basic process is:
1. Emit
2. Random Number Generator
3. Display
4. Update

Particle Systems Examples

Chuck Evans
Particle Systems Examples

The Lion King (2019) -- Disney

A Particle System to Simulate Colliding Galaxies in Cosmic Voyage

Particles Don’t Actually Have to Be “Particles”

Animating using Rigid-body Physics

Newton’s second law:
force = mass * acceleration
or
acceleration = force / mass

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

fluid.avi
$D_0 = \text{unloaded spring length}$

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

$k = \text{spring stiffness} \in \text{Newtons/meter or pounds/inch}$

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

\[ F = k (D - D_0) \]

This is known as Hooke's Law.

**“Lumped Masses”**

**Simulating a Bouncy String**

**Placing a Physical Barrier in the Scene**

**Animating the Physics of a Mesh of Springs**

**Simulating a Bouncy String**

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

\[ m\ddot{x} + cx + kx = 0 \]

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

\[ m\ddot{x} + cx + kx = \sum F \]
Increasing the Stiffness

Stiffness = 3

Stiffness = 6

Increasing the Repulsion Coefficient

Repulse = 10

Repulse = 30

Functional Animation

Motion Capture as an Input for Animation

Motion Capture is for Faces Too

Tron I –
They probably should have used physics, but didn’t
Sidebar: DIY KeyTime Animation

A C++ class can do it all for you

class Keytimes:
    void AddTimeValue( float time, float value );
    float GetFirstTime( );
    float GetLastTime( );
    int GetNumKeytimes( );
    float GetValue( float time );
    void PrintTimeValues( );

DIY KeyTime Animation

using namespace std;

int main( int argc, char *argv[] )
{
    Keytimes Xpos;
    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( );
    }
    ...
}

DIY KeyTime Animation

using the System Clock for Timing in Display( )

#define MSEC 10000 // i.e., 10 seconds

Keytimes Xpos;

int main( int argc, char *argv[] )
{
    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.;
        if( nowTime < 10.0 )
        {
            // draw the object
        }
    }
    ...
}