Tutorial 9.1: Animating a Bouncing Ball

I've had several students go to interviews with a studio, and the studio – after the interview – performs a brief skills test. The test was, "So, you're tool is Maya? Ok, cool. Over there on that machine is Maya. Please animate a nicely bouncing ball. We'll be back in 10 minutes to see how you're doing."

The reason for this is simple. There are a lot of important animation principles going on with a bouncing ball – most critically, the idea of Squash & Stretch. It's the veritable flour sack (the movement test of many early 2D animators) of 3D animation. So let's see what we can do.

1. Step 1: Create a new scene and in this scene create a polygon plane for the ground and a polygon sphere for the ball (Fig. 9.1).

2. Step 2: Move the axis to the bottom of the ball. In the side View Panel, select the sphere and the hold d and then v down (d to move the object's axis and v to snap to a vertex), and move the axis of the sphere to the very bottom of the ball.

d and v

AXIS = PIVOT POINT

Why?

The default manipulator is in the middle of the sphere, which means that when the sphere squashes the bottom of the sphere would lift off the ground (it will scale from the middle of the sphere). What needs to happen is that the sphere should squash from the bottom of the sphere (where the sphere will contact the ground), so we need to move the sphere's axis there.

3. Step 3: Snap the sphere to sit right on the ground. In the side View Panel, hold x (snap to grid) and move the sphere up so that it's sitting right on the ground (Fig. 9.2).

Why?

Sometimes, close is good. But when animating something walking or hopping, "close" isn't good enough. That ball needs to really hit the ground – not pass through it, not float above it – but be right on the ground. The same would go for feet if the character was walking. This is where snapping to grid or vertices becomes very valuable.

4. Step 4: Freeze transformations. Select the sphere and choose Modify > Freeze Transformations.

FREEZE TRANSFORMS

Why?

We've moved the sphere from where it was first created. This means that it has dirty transforms (likely Translate Y = 1). This means that to get the sphere back on the ground, we need to get Translate Y to exactly 1 (and remember that this happens to be the value for this situation). A more intuitive method is to just have the sphere be a Y = 0 when it is on the ground. By freezing the transformations, we tell the sphere to make this position its origin. After this, if we ever want to be sure that the sphere is on the ground, we can just enter 0 in the Channel Box for its Translate Y.

5. Step 5: Set the Animation preferences. Do this by choosing Windows > Settings/Preferences > Preferences. In the left of the Preferences window, look for the Settings section and click on the Time Slider section beneath that. Then, change the Playback Speed to Real-Time (24 fps). Click the Save button to save changes and close the window.

Why?

Maya, by default is a bit of a show off. When an animation is played, it plays every frame as fast as it can. While this might show how great Maya can handle information, it's useless for animators attempting to find timing. By changing this Playback Speed to Real-Time, Maya will play the frames back at 24 frames per second. If it can play it back faster than that – it'll restrain itself and still only show 24 fps.

Of course, the bad part of this is that if the scene is too complicated for Maya to playback at 24 fps, it will start dropping frames to keep the playback speed. Luckily for us, we won't be working with a scene that is complicated enough for that to be a problem.

BOUNCING BALL

6. Step 6: Set a keyframe at frame 1 for the sphere. Do this by selecting the sphere and hitting s.

Why?

It seems like nothing happens, but if you look at the Time Slider, there will be a red line on frame 1 (assuming that the Current Time Marker is at frame 1) indicating that this is a keyframe.

This first keyframe is important as it lets Maya know "this is where the animation should start, and the shape of the sphere before it starts deforming."

7. Step 7: Animate the squash with a keyframe at frame 8. To do this, first move the Current Time Marker to frame 8. Then, with the Scale Tool, first scale the sphere down in Y only by dragging on the green cube handle. Then, scale the sphere up in all directions by dragging on the middle light blue cube. Finally, be sure and hit s to set the key (Fig. 9.4).

Why?

To make a ball believably hop on its own accord, we must take hints from how a person would hop. The first thing a person does when hopping is compress the muscles that will provide the upward thrust – he squashes.

But it's not enough just to make the sphere get squattier. There is an important concept in animation called "Conservation of Volume," which focuses on the amount of material that is in an object remaining constant regardless of how it deforms. If this sphere were a balloon and we pressed down on the top, the amount of air within the balloon wouldn't change, it would just reshape. This means that as the sphere gets shorter in Y, it has to get wider (fatter) in X and Z.

8. Step 8: Animate the stretch at frame 12. Do this by moving the Current Time Marker to frame 12 and then use the Scale Tool again to scale the sphere tall (with the green cube handle), and then very skinny (with the blue cube handle). Hit s to set the key (Fig. 9.5).

Why?

This is the second half of the critical Squash & Stretch principle. As a person jumps, he uncoils those compressed muscles and stretches out to a long pose *before* lifting off the ground. This explosion of energy happens much faster than the squash (this is happing over four frames here).

Notice that we are also still working with Conservation of Volume. As the sphere gets really tall, he needs to get really skinny.

9. Step 9: Set the keyframe for the top of the hop. To do this, move the Current Time Marker to frame 24. Use the Move Tool and move the sphere up into the air along the Y axis to where you figure the top of the hop would be (I'm using Y = 8). Then, in the Channel Box, change the Scale X, Y, and Z values to 1. Hit s to set the key (Fig. 9.6).

Why?

One of the advantages of freezing the transformations as we did earlier is that when the ball needs to get back to regular size (Scale), we can just set the Scale X, Y, and Z to 1 in the Channel Box and we're there.

In other news, in this step, we are both moving and scaling, but hitting s once will set the keys for Scale and Position (and Rotation too, by the way, even though we aren't changing this).

10. Step 10: Increase the visible frames to 48. Do this with the Range Slider by dragging the right end of it out to fill the entire 48 frames.

11. Step 11: Set the keyframe for the landing. To do this, we'll explore a little bit different method. This keyframe on the landing will look very similar to the keyframe where the sphere leaves the ground (frame 12). Move the Current Time Marker to frame 12 and then right-click-hold on it and choose Copy. Then, move the Current Time Marker to frame 36 and again right-click-hold and choose Paste > Paste (Fig. 9.7).

Why?

This is frequently a problem for students. They know that when the character hits the ground, they squash. The important detail here is that it's *because* the character hits the ground that he squashes. This means that the moment the ball touches the ground, it still needs to be stretched. It'll squash in just a bit.

This method of copy and pasting keyframes can help speed time up and generate some nice consistency across the animation. It turns out that Maya's copy/paste mechanism is really deep and can be really complex. But for this situation, the standard method shown in step 11 works great.

Step 12: Copy and paste the squash keyframe to frame 40. Copy the key at frame 8 and paste it into frame 40.
Step 13: Copy and paste the rest key from frame 1 to frame 48.
Step 14: Play the animation. Do this with the VCR looking controllers in the Time Slider or by hitting Alt-v (Alt-v will also stop the playback).

Refining Animation

Well, it's moving. And it's got squash and stretch happening. But it's still a long way from plausible or appealing. This is the nature of animation – at least for me. My first pass is almost always wrong – or at least not right.

This is where the power of the computer as an animation tool starts to emerge. We're not tied into the choices of timing or position, and in fact, we can change things in a hurry.

Overwriting Keys

The first way we're going to look at editing animation is to simply write over an existing keyframe. This is pretty easy; just move the Current Time Marker to a frame that already has a key, make changes and when s is hit again, this new key will replace the old one.

Step 15: Make the hop higher. To do this, move the Current Time Marker to frame 24 (the top of the hop). Use the Move Tool to move the sphere higher (say Y = 12). Hit s to overwrite the keyframe.

The Graph Editor will always show the time (by frames) across the X axis. The Y axis will be values that change depending on what attribute is selected. For instance, if Translate Y is selected, the Y values represent centimeters (the default Maya unit). But, if Rotate Y is selected, the Y values represent degrees.

One key thing that is a little different here is that to move a key either in time (by shifting it along the X axis) or in value (by shifting it along the Y axis) requires you to first be in the Move Tool (hit w on the keyboard) and then middle-mouse-dragging.

Step 16: Make the hop still higher through Graph Editor manipulation. The height of the bounce is defined by the Translate Y values. With the sphere selected, in the Graph Editor, click on the Translate Y in the left side list of attributes (this will show only the keys for Translate Y). Swap to the Move Tool (hit w on the keyboard). Select the key that represents the top of the hop. Hold Shift down and middle-mouse-drag the key up to around Y = 16 (Fig. 9.9).

> **Why?**
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> Holding the Shift key down makes sure you are only moving the Translate Y value and not moving the keyframe in time as well.

Anatomy of a Curve

The Graph Editor is about curves. Being able to read the curves and manipulate those curves is what makes this tool powerful. Consider the following curves (Fig. 9.10).

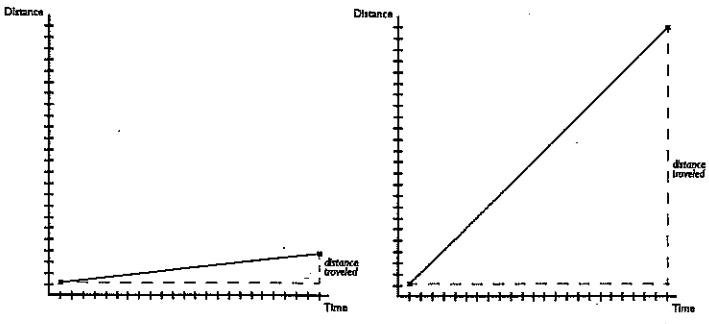

FIG 9.10 Various curves and their meaning.

These curves represent a Translate curve within the Graph Editor. Again, the X axis shows time and the Y axis shows distance. In both the curves, notice that the movement happens over the same amount of time, but the one in the left travels a far shorter distance than that in the right. This means that the graph on the right shows an object traveling much faster. Steeper curves represent faster movement.

Now, to continue on with this, check out the curves in Fig. 9.11.

In these two examples, the two keyframes are in identical locations. The difference is how Maya is interpolating between the two. In both the cases, I've split up the time into two equal halves. Notice that in the image on the left, the distance traveled is a lot more over the first half of the time covered than in the second half. This means that this object shoots off in a hurry and then eases to a stop.

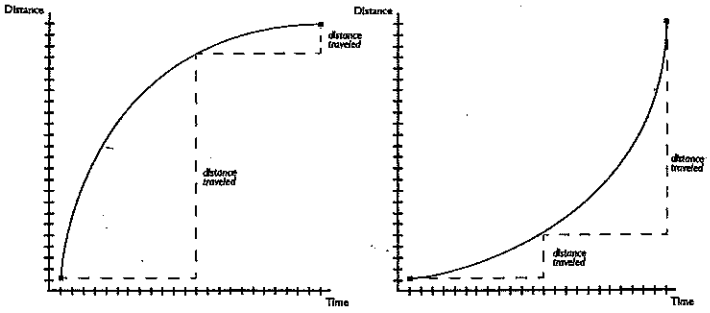

FIG 9.11 Again, two animation curves as they would appear in the Graph Editor.

Conversely, the image on the right shows a curve in which the distance traveled over the first half of the time covered is very little compared to that traveled over the second half of the time. This is an object that travels very slowly at first and speeds up as it goes.

The funny thing about those two graphs is that the keyframes themselves are identical – it's all about how that curve goes between the two. Clearly, controlling that curve makes a big difference in the movement of an object.

Of particular interest are the two highlighted areas at frames 12 and 36. Frame 12 is where the sphere leaves the ground and frame 36 is where it touches down again. Notice that before frame 12 and after frame 36, the line is flat – meaning that the sphere does not move in Y at all (which is what it should be doing). The problem is that at frame 12, the curve is flat going out of the key. And then again, in frame 36, the curve is very flat coming into frame 36. This means that at the frames immediately following lift off (frame 12) – when the sphere has exerted enough force to lift it off the floor (an *explosive* amount of energy), it is traveling very slowly. Likewise, at frame 36, when the sphere has been falling the farthest, it suddenly – right before hitting the ground – slows down. Both are just plain wrong.

What should be happening is a very sharp vertical curve coming off of frame 12 and a very sharp vertical curve coming into frame 36. To do this, we need to be able to control the tangents – and specifically to break them.

Step 17: Weight the Tangents. To do this, select the sphere and then in the Graph Editor click on the Translate Y attribute. Hit f to frame this curve. Click on the green curve in the graph area. Choose Curves > Weighted Tangents.

Select the curve.

Curves menu
Weighted Tangents

> **Why?**
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> The handles will change a little bit in the Graph Editor. The tangent handles themselves will get slightly larger circles on their ends. But importantly, they will no longer be the same length going in and out of the anchor (take a close look at the tangent handles at frames 12 and 36 for example).

Must click on a Keyframe to select all tangents.

Step 18: Free the Tangent Weights. To do this, with the Translate Y curve still selected, choose Keys > Free Tangent Weight.

Tangents menu → Tangents > Free Tangent Weight

> **Why?**
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> The handles will change in appearance again. The end of the tangent handles will appear as squares. This means that now these handles can be grabbed and shortened or lengthened.

Step 19: Add some extra hang time. At the very top of the hop the sphere's upward energy is giving way to gravity. This is the point where the speed of the sphere in Y will be the slowest. To help pump this up, we'll make the curve flatter at the apex. To do this, marquee drag around one of the tangent handles for the key at frame 24 (at the top of the hop). Using the Move Tool, and while holding Shift down, middle-mouse-drag the tangent handle outward (Fig. 9.14).

> **Why?**
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> So now the curve coming in and out of that key is flat, meaning that the sphere is traveling very slowly through the frames before and after this key.

Tips and Tricks

Selecting things in the Graph Editor can be a little tricky. Get used to using the marquee-select (dragging across the curve or key you want to select). It's different than simply clicking on a curve or key; and for our purposes will actually expose the things we need to adjust.

Step 20: Explode off the ground. Do this by breaking the tangents at frame 12. To make this happen, marquee-select the key at frame 12 (all this is done within the Graph Editor). Then, choose Keys > Break Tangents. Marquee-select the handle on the right and middle-mouse drag it straight up (Fig. 9.15).

Tangents > Break Tangents

Step 21: Repeat for the key at frame 36 (Fig. 9.16).

To manipulate tangents, first the keyframe must be selected. When this is done, the keyframe will highlight yellow and the tangents will highlight pink. Now here's where it gets a little clumsy. By default, the curves that Maya builds in the Graph Editor use Locked, Non-weighted Tangents. What this means is that the tangent handles are the same length for every anchor (non-weighted) and are unable to be lengthened (locked). We want to be able to grab ahold of those tangent handles and bend them in all directions and change their lengths to really have control over how those curves -- and thus the motion -- work coming in and out of keyframes. Let me show you why (Fig. 9.13).

Bouncy Ball due on Feb 20th

Step (20): Explode off the ground.

Why?

A unified tangent means that the two handles on either side of the tangent are connected. So when one handle is grabbed, the other side stays straight in line -- as though they were two ends of a stick. In this case, we want there to be a clear, sharp break at the key. So breaking the tangents allows us to alter one handle without changing the other. By moving this tangent straight up, the curve going out of the key at frame 12 becomes very sharp, which means that the speed will be very fast; the sphere will be exploding off the ground with enough energy to overcome the force of gravity.

Tangents > Break Tangents

Step (21):

Repeat Step 20 for Keyframe at 36 — the ball lands on ground — hits the ground —

Why?

The sphere will travel faster the farther it falls (until it reaches terminal velocity). It should be traveling the fastest right before it hits the ground. This means that the Graph Editor's curve should be the most vertical going into the frame 36. Breaking the tangent and making it vertical does just that.

(22) Step 22: Play the animation. Do this back in the View Panel with the Time Slider. You should see an immediate difference.

Conclusion

Pretty cool, huh? The animation of that sphere should immediately feel more lifelike and like it has real weight. This comes from effective Graph Editor work and knowing what the curve should look like.

In my university classes 7 out of 10 times, the problems with assignments turned in can be solved with further work in the Graph Editor. It can sometimes feel "unartistic" to be mired deep in Graph Editor curves, but an animator who is comfortable in the Graph Editor produces better animation faster and more efficiently. Make the Graph Editor your friend.

(1) Constructing the Stage and the Ball 22:19

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The Fundamentals: The Talented Ball

(2) Creating a Curtain 10:22

(3) Duplicating Curtains 6:56