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? Oh, cool, over there on that machine is Maya. Please animate a nicely bouncing ball. Well 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 laws of Squash & Stretch. It's the movement arc of many early 2D animators of 3D animation. So let's see what we can do.

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).

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 snap to a vertex) and move the axis of the sphere to the very bottom of the ball.

Step 3: Snap the sphere to all right on the ground, in the side View Panel, hold w to snap and move the sphere up so that it's sitting right on the plane (Fig. 9.2).

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

Step 5: Set the Animation preferences. Do this by choosing Windows > Settings/Preferences > Preferences. In the left of the Preferences window, look for the Animation 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?
- The default manipulator is the middle of the sphere, which means that when the sphere squashes the bottom of the sphere would be right off the ground (it will scale from the middle of the sphere). What happens in a square is that the sphere should squash from the bottom of the square (where the contact with the ground), so we need to move the sphere's axis there.

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

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 the artist know "This is where the animation should start, and the shape of the sphere before it starts deforming!"

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 n 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—hence, the squats.
- The squats are usually only made to make the muscle get squatter. There is an important concept in animation called "Contraction and Expansion," which focuses on the amount of material that is in an object remaining constant regardless of how it deforms. If this were a balloon and we pressed down on the top, the amount of air within the balloon would not 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.

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 n to set the key (Fig. 9.5).

Why?
- This is the second half of the critical Squash & Stretch principle. As a person jumps, he heeds those compressed muscles and stretches out to a long pose before landing on the ground. This explosion of energy happens much faster than the squash (this is happening over four frames here).
- Notice that we are also still working with Conservation of Volume. At the sphere gets really tall, it needs to get really skinny.

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 so where you figure the top of the hop would be (I'm using Y = 0). Then, in the Channel Box, change the Scale X, Y, and Z values to 1. Hit n 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 n once will set the keys Scale and Position (and Rotation too, by the way, even though we aren't changing this).

Why?
- By default, Maya is a bit of a show off. When an animation is played, it plays every frame at face it is. 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 — I'll restrain myself and only show 24 fps.

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.

Why?
- This is frequently a problem for students. They know that when the character hits the ground, they squish. The important detail here is that it's because the character hits the ground that he squishes. This means that the moment the ball touches the ground, it still needs to be stretched. It'll squish 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.

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Step 12: Copy and paste the squash keyframe to frame 40. Copy the key at frame 8 and paste it in frame 48.
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: Modes or by hitting Alt+V (Alt+V will also stop the playback).

Refining Animation
Well, it's moving. And it's getting squash and stretch happening. But it's still a long way from pleasant 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've not tied it to 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 it's 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), right 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 X is selected, the Y values represent centimeters (the default Maya unit). If, however, Translate 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), you must first be in the Move Tool (hit t on the keyboard) and then middle-mouse-dragging.

Step 16: Make the hop 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 X in the left side list of attributes (this will show all the keys for Translate X). Switch to the Move Tool (hit t 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).

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).

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

These curves represent a Translate curve within the Graph Editor. Again, the X axis shows time and the Y axis shows distance. In both 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. Steep curves represent faster movements.

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 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.

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. 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, the sphere has moved enough force to lift it off the floor (on average). It is traveling very slowly. It's even, if at frame 36, when the sphere has been lifting the furthest. It suddenly — right before hitting the ground — slows down, both are just plain wrong.

What should be happening is a very steep 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 t to frame this curve. Click on the green curve in the graph area. Choose Curve > Weighted Tangents.

Why?
The handles will change a little bit in the graph editor. The tangent handles themselves will get slightly larger closer on their axis. 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).

Most click on a keyframe to select all tangents.

Why?
The handles will change in appearance again. The end of the tangent handles will appear as squiggles. This means that 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 going away to gravity. This is the point where the speed of the sphere in Y will be the slowest. To help push this up, we'll make the curve flatter at the apex. To do this, marquee select around one of the tangent handles for the key at frame 24 (at the top of the hop). Using the Move Tool, while holding Shift down, middle-mouse-drag the tangent handle outward (Fig. 9.14).

Why?
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 do this, Pausing break the tangents 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).
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 clumpy. By default, the curves that Maya builds in the Graph Editor are 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 each of these 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 A11).

Step 28: 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 steep, 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 29:
Repeat Step 20 for keyframe at 36
the ball lands on 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.

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

Conclusion
Pretty cool, huh? The animation of that sphere should immediately feel more realistic 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 "unfair" to be relied upon the 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) Construct the Stage and the Ball 22:19
2) Creating a Curtain 10:22
3) Duplicating Curtains 6:36

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The Fundamentals: The Talented Ball