AC 2007-2362: A LEARNING TOOL TO ASSIST IN ANIMATION OF BIPEDAL WALK CYCLES

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A Learning Tool to Assist in Animation of Bipedal Walk Cycles

Abstract

This paper studies the activity of bipedal walking with the objective of describing procedural techniques to automate this process. The main problem this paper explores is how to mathematically characterize the relationships and motion of different limbs involved in the process of walking and to represent realistic and natural walk cycles. Other issues discussed are possible variations to create different types of walk cycles. The results have been used to implement and develop a learning tool to assist students in the creation of animated walk cycles.

This paper is reporting on the methods used to create a practical computer-assisted tool to show and teach students how walk cycles get affected by different parameters without having to learn every facet of their complicated 3D animation applications. The results can also be applied to many different areas of visualization, such as architectural and virtual reality environments, where human or bipedal models are involved.

The Need

Students learning to animate a bipedal walking animation are faced with the necessity of doing several things, successfully, at the same time to make any sort of believable walk cycle: (1) setting and managing key frames on dozens to hundreds of channels, (2) maintaining the weight and proportionality of their character, and (3) setting and maintaining the correct timings of the different elements in the walk cycle. The first task, setting and managing key frames, needs to be accomplished before the remaining two tasks can be successfully completed. Managing all of the necessary key frames is the first primary obstacle in creating a walk cycle, and it is primarily a technical and managerial, or work flow, task. Once students are somewhat adept at this, they can begin to concentrate on steps (2) and (3). The goal of this learning tool is to make it possible for beginning students can work on all three at once. The learning tool attempts to take the technical complexity out of animating a walk cycle and replace it with a smaller, manageable, number of easy-to-use sliders, so the student can concentrate on timing, weight, and proportionality. This won't replace the need to be able to deal with the great number of keys developed when keyframing a walk cycle, but it will enable a student to work on both the style of a walk at the same time they are learning to master the technical skills necessary to accomplish this on their own.

One of the primary goals of this tool is that students of animation can produce walks that aren't necessarily accurate. They can experiment with walk cycles that are exaggerated, and stylized to learn about what parameters of an accurate walk cycle can be pushed beyond their normal boundaries to produce walks that generate personalities.

With further development, this learning tool could become more of a production-oriented process as well. Since the mechanics of a walk cycle are present and are customizable in this tool, it could be used as a tool for quickly generating a variety of walk cycles. This would be especially applicable for characters that were not the focus, but rather background or crowd characters.

Structure and Mechanics

Our character is a traditional bipedal structure. We have made no accommodations for the fingers or toes, but have added bones and controls for the clavicles, neck, and hips. The figure walks in place as though on a treadmill. From the waist up, the bone setup is very common with a series of bones for the spine and neck, and one bone apiece for the head and each articulated bend in the arm. The legs have been simplified from some sort of reverse foot setup that would be considered typical, to just hip, knee, heel, and ball joints. The extra complexity present in almost any flavor of the usual reverse foot setup wasn't necessary in this case since the character is only walking, and only in one direction. There is no need, for instance, for the character to be able to make the motions of crushing out a cigarette with the ball and toe of the foot in a swivel motion. Our character is walking down the X axis as in Figure 1.

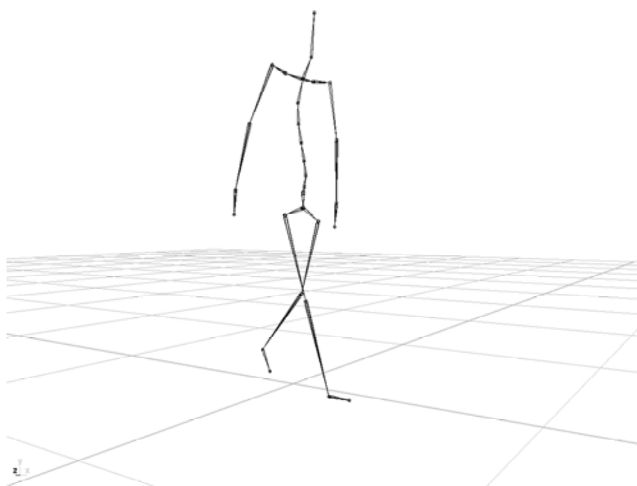


Figure 1

The legs are driven by inverse kinematics (IK) and the upper body, from the hips upward, is driven by forward kinematics (FK). The legs are moved from a controller at the ankles. Moving this one control moves the thighs, calves, and foot of the character as is typical with an IK control. This is a common setup for animated, bipedal, legs. This control also has rotation attributes that allow for the foot to rotate left and right, as well as up and down. In this first version of the learning tool, there is no accommodation for aiming the knees in or out. This places all of the control for the lower body in one controller for each leg.

The lower body also has a stretchy system built into the legs. This enables a greater variety and styles of strides. The stretchy IK has become commonplace in animation setups for a few reasons: it helps in the animation process by taking away a fixed leg length limit, it can reduce and eliminate joint "snapping" when the joint has reached its rotation limit, and it enables you to use this setup on characters that don't have a completely fixed form. This stretchiness is controlled indirectly by several of the attributes in the learning tool.

The upper body has controls for the rotation of every joint. When any joint is rotated, all of its dependent joints are affected. For instance, if the upper back is rotated, the neck and shoulder joints move, or when the upper arm is rotated, the lower arm and wrist are all affected. This is a standard parent-child relationship with every joint that is further out from the core of the body is affected by the one being rotated. There are no positional transforms for the upper body, just rotation. Translating joints will lead to stretching and there is no stretchy functionality built into the upper body.

Of all the controls, only the foot controls have anything other than procedural animation controlling their motions. The foot control uses constraints in addition to scripting control. The constraints help aim the foot correctly, or control its rotation, during the walk cycle. These two types of controls work in conjunction with each other.

There are no boundaries on any of the controls. The character can be pushed far enough that it will break or give distorted results. For instance, the feet are able to rise higher than the hips, or the head even.

The Principles of Animation

This tool is also aimed at making students familiar with some of the principles of character animation, namely timing and motion, and overlapping action.[1] With this tool it is entirely possible to create dreadful character animation. Even though the tool is relatively simple to use, your results will be unsatisfactory if your sense of what an animated walk cycle should look like is unsophisticated. The basic principles of character animation still apply to the extent they can be affected with the controls. The controls give you the ability to set the timing on every facet of the character in relation to the basic walking rhythm. For instance, the bobbing of the hips can be moved forward or backward in time in relation to the rest of the body, as can anything else. By adjusting these motions in time, you will create the overlapping action that starts to distinguish a better animation.

One of the characteristics of human animation is that animated joints tend to move in arcs.[2] Linear motion, both linear speed and linear position, is very much characteristic of a machine. When people act and move as though they were a machine, they are moving linearly in position and speed. From a complete standstill, they will start moving at speed without any ease-in, or gradual acceleration, and they'll stop just as suddenly. The position of their end joints (hands and feet) will move in a straight line from one position to another. As we'll discuss below, all of this character's motion is based upon a looping curve that generates smooth motion, with gradual starts and stops.

Procedural Animation

To make this animation tool customizable for different situations and applications, all of the animation parameters are based upon Time. Time, in this case, is defined as:

$$Time = Frame/Frame\ Rate$$

This allows the tool to function correctly at different frame rates that are common in different applications (i.e., 24 frames per second for film, 30 frames per second for video, 15 frames per second for some computer-based applications). It also allows the tool to function at negative frame numbers, should that be necessary.

The primary cycle upon which the whole walk is based is: sin(time). You can see the graph of this function in Figure 2. This function several qualities that lend itself to our walk cycle:

1. The function is cyclical.
2. The function can be offset in time by adjusting Time, i.e., sin(time-2). You can see the graph of this in Figure 3.
3. The function can be sped up or slowed down by compressing or expanding Time, i.e., sin(time*2). You can see the graph of this in Figure 4.
4. The function is smooth and without sudden jumps in values. Just like the parts of a walk cycle are smooth and fluid, the functions behind the cycle should be smooth and fluid.

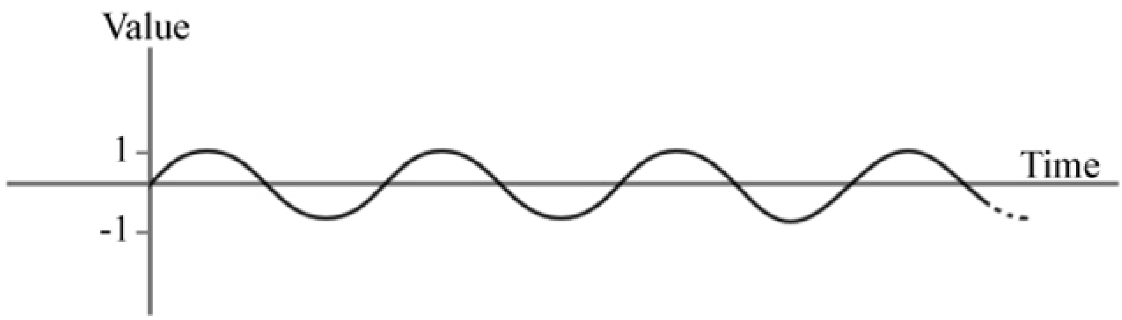


Figure 2. The graph of: sin(time).

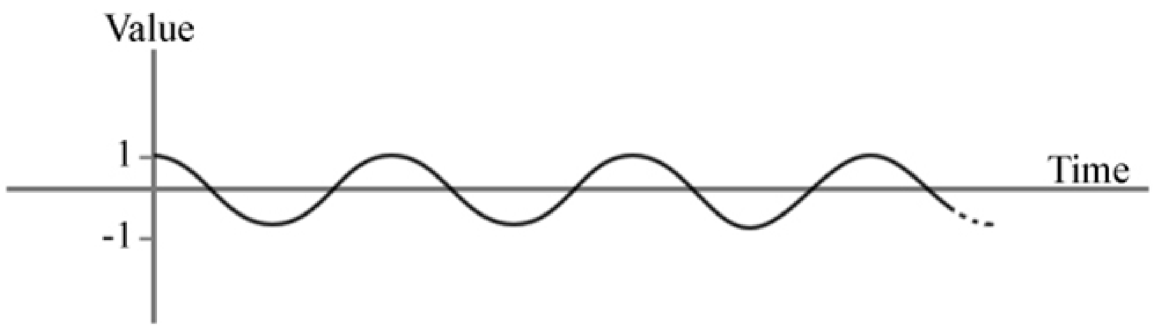


Figure 3. Offsetting the cycle. The graph of: sin(time-2).

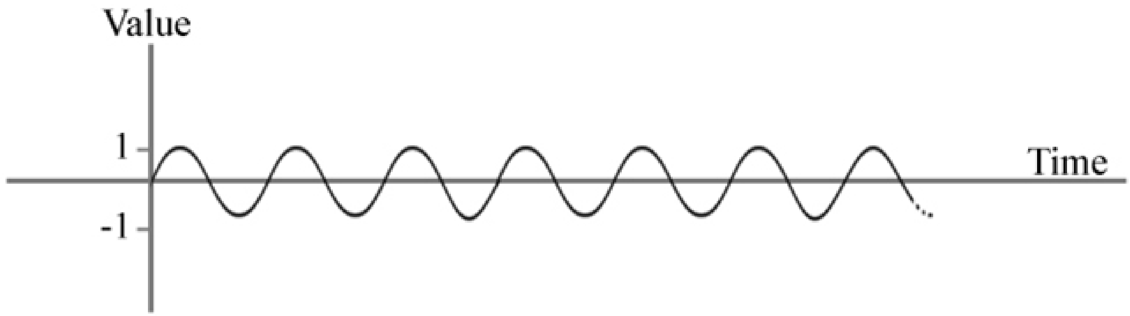
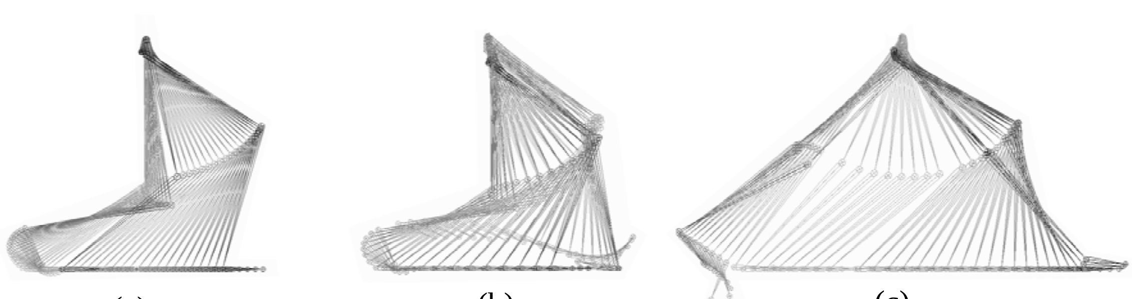


*Figure 4. Compressing the cycle. The graph of: sin(time*2).*

Most of the motions in the walk cycle are based upon permutations of this one function. In "Walking Patters of Normal Men," Murry et. al. gathered data about the walk cycles of men ranging in age and height, but no so much in weight.[3] Much of this data shows the visibly sinusoidal nature of the movements of the body in a walk cycle, particularly the transforms. The rotations of some body elements are somewhat sinusoidal, with alternating peaks in the wave differing in height. This is primarily in the leg joints where we are controlling the motion with IK, rather than specifying the joint rotations explicitly. For these reasons we started with sin(time) as our basic building block. There are no hard set keyframes or limits upon any of the attributes.

Application

Each leg is controlled with IK at the heel of the foot. The X translate (the character is walking down the X axis) is controlled by the expression: (sin(time*speed))*stride where "speed" and "stride" and user settings for the speed of the cycle and the length of the stride respectively. Figure 5 shows the results of using these controls in a series of animated snapshots, each covering 60 frames. In the following examples we are working at 30 frames per second, so the elapsed time in each snapshot is 2. Version (a) is the default setting and shows a partial stride with very smooth motion. Version (b) shows the results of doubling the speed of the cycle. The snapshot covers the animation of the entire stride. Version (c) shows the results of multiplying the length of the stride 2.5 times, at the original speed. The legs are stretched a bit and the control for ball of the foot is past its working range. You can see the visible errors at the extremes of the step where the foot picks up and where it lands.



(a) (b) (c)

Figure 5

When any settings are used for the spine, they also affect the arms. When any settings are used for the arms, they affect the wrist. This is how traditional FK works; any change in a joint affects all of the joints further down the parent-child chain. So after using random settings on the spine and arms, there is a certain amount of uncontrollability about what happens at the end of the arms. Figure 6 shows the motion paths of the wrist joint on our character after all of the settings on the spine and arms were adjusted randomly, but without going far out of range. The left wrist is on top and the right wrist is on the bottom and the three views are, in order: top, side, and front. The results are smooth arcs of motion that characterize human animation. They also show that nothing in the chain of bones has any angular motion since it would show up here.

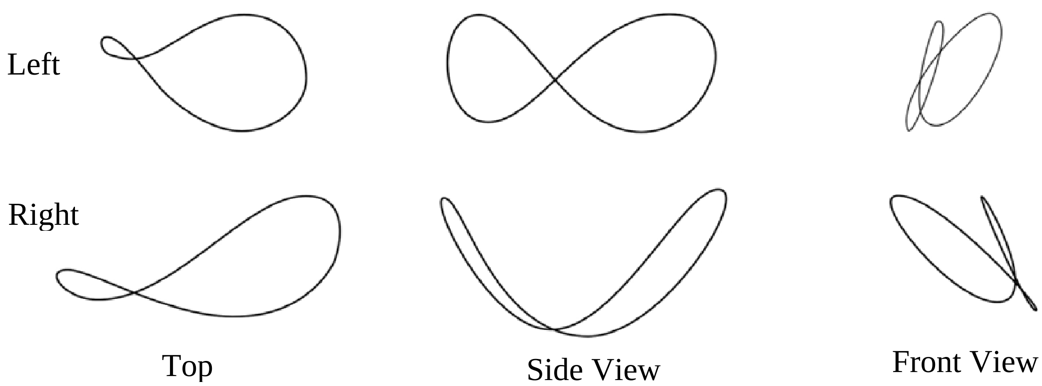


Figure 6

The relationship between the hips and the feet, or the weight, is one of the strong determinants of the style of the walk. Even leaving the feet the same, just changing the hips in position or in time has a large effect on how the walk is perceived. Positional offsets are available for the feet and the hips, or root or the character. In Figure 7, you can see the results of changing just the position of the root (the arms are hidden for clarity). In each figure, the feet are in the same position, and at the same part of the walk cycle, but the positional offset of the root has changed. This changes the relationship between the root and the feet, visually changing where the weight of the character is. This positioning has a strong effect on the look of the walk cycle.

Figure 7

In addition to varying the position of the root in 3D space, you can also reposition it in time, which we're referring to as an offset. The root bobs up and down in a cycle that has the same elapsed time as the foot gait, but its timing within that gait can vary. Figure 8 shows how changing the offset, the timing, affects the walk. The legs in each variation are unchanged, as is their place in the walk cycle. The positional offset of the root is also unchanged. The only element to change is the timing of the bobbing of the root; from left to right the bobbing goes from peaking at the stride's extension to being at its lowest point during the stride's extension.

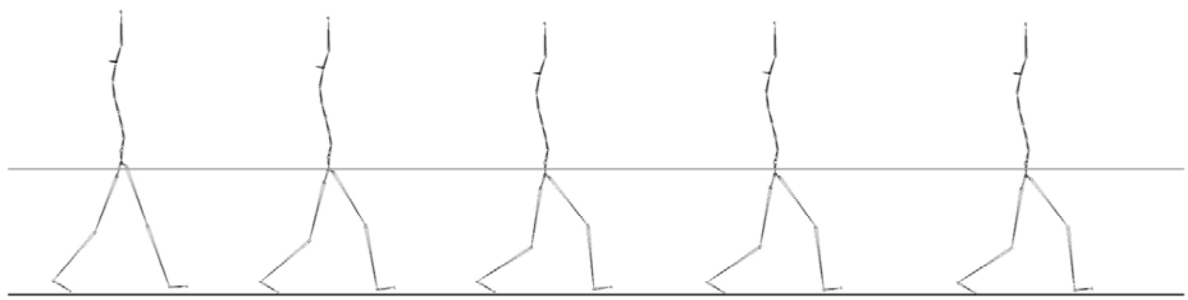


Figure 8

Since it can be challenging to present animations in a printed, non-temporal form, some sample animations have been posted for viewing. You can see samples of animated walk cycles created with this tool, and the settings used to create and alter the cycles. These examples are there more to show variety than any particular style of walking. The web address is http://faculty.etsu.edu/fitzgemr/walkCycle

Further Work

This tool needs to have an easy-to-use interface developed so that students are quickly at ease with its functions. Since part of the goal of this exercise is to make it simple and intuitive for students to generate walk cycles, the interface needs to present the complexities of the code in a logical and understandable fashion. It also needs to be of such a nature that the lessons learned from using it are transferable to the tools in their 3D application.

Having stated that the interface needs to stay uncomplicated, there can be more development on the tool so that users can differentiate parameters on the right and left sides of the character. As of the time of this writing, the character has the same attributes on each side. Also there is room for more development in having more control over the basic shape of the cycle. While the function sin(time) that drives most of the animation is very rounded and smooth, it would add another level of sophistication to be able to sharpen up some aspects of that curve. This could add a enormous variety to the walk cycles possible and allow the students to sharpen their skills even more.

Aside from the tool itself, testing needs to be done now that the tool is in some sort of usable state. While the controllable attributes feel correct to the authors, there's no way to accurately predict the reactions of students. So it's envisioned that several rounds of testing will need to take place, probably in spring of 2007.

Currently the tool runs within Maya as a series of expressions to control motion. Ideally, in the future this can be made into a stand-alone application to make it more platform- and application-independent. This would give it a broader appeal and place the emphasis on learning to animate walk cycles generally, rather than in a specific 3D application.

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Further Reading

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