Complex movement patterns of a bipedal walk

Objectives

After completing this lesson, you will be able to:

- Describe the complex movement patterns of a bipedal walk.
- Describe the biomechanics of walking and how to apply this knowledge to animating a walk cycle.

Description

This lesson is the first in the series to introduce animating a character. Walking is a good place to start, as it involves learning about timing, weight shifts and articulation of the foot with the ground. We are all experts at walking, yet animating a believable walk cycle is a surprising challenge.

Learning Outcomes

Students will understand the biomechanics of walking and be able to apply this knowledge to animating a walk cycle.

Introduction

Animating a walk cycle is deceptively complex. It is important to understand the motor pattern of a walk, and how a character’s body weight shifts through space during the phases of the walk. This sense of weight is key to understanding all character animation and is an essential component of believable characters. In this section, you explore patterns of body coordination that support walking motion, and stylistic variations that will help you create fluid and believable animated walking. As you develop your animation skills, you will explore naturalistic integration of walking with other activities, as well as uniqueness, character personality, and stylized movement.

How Walking Begins

Figure 1: Walk cycle poses

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Most babies begin to walk somewhere close to their first birthday. At that stage of motor development, a baby has evolved through six patterns of total body connectivity:

- The breath pattern is the root of life and movement, and is the foundation of rhythm. It reflects thought and emotion.
- The core-distal pattern connects the core, or navel center to the limbs, head, and tail. The limbs find their connection to each other through the core.
- Head-tail connectivity is about the internal support of the spine, the relationship of the head and tail in spinal movement, and the full three-dimensional mobility of the spine.
- The upper-lower pattern is about the support, yield/push, and locomotive ability of the lower body, and the goal-oriented reach/pull of the upper body.
- Body-half connectivity is about the two sides of the body. One half can stabilize, while the other is mobile.
- The cross-lateral pattern is about the diagonal connectivity of the upper-right to lower-left, and upper-left to lower-right. It facilitates full three-dimensional movement.

Each stage of development integrates with the next, which means that by the time we are walking we are using a complex, rhythmic coordination of body patterns to achieve locomotion through space. These patterns are operative at a very primitive level of our brains, such that walking becomes automatic and integrated with locomotive intent.

The three axes of spinal rotation present in walking come from upper-lower, body-half, and cross-lateral patterning. Babies begin crawling because they want to reach an object in their environment. Body-half and cross-lateral patterning are developed through the stages of crawling first on the belly, then on hands and knees. In body-half crawling, the arm and leg on the same side either flex or extend together, and the spine curves in an arc sideward, bringing the head and tail closer to each other on one side of the body.
In cross-lateral motion, the spine twists around its vertical axis. An example is when right arm and left leg move towards each other, creating a diagonal fold across the body from left arm to right leg.

Upper-lower patterning is the beginning of movement that changes levels. Actions such as being on hands and knees, pushing weight from knees to hands or from hands to knees, jumping the feet forwards to the hands, and so on, all serve to differentiate upper from lower, and shift weight between upper and lower. Babies practice this pattern extensively as they prepare to start walking. This pattern involves spinal rotations going forwards and backwards.
Intent towards a goal in space also develops push-reach-pull patterns, which are present through crawling, upper-lower patterning, and walking. In belly crawling, a baby initiates with a reach, as well as a push from the toes. As the push phase reaches its conclusion, the reach with the arm becomes a pull to gain further distance.
In walking, the push-reach-pull pattern is present in the legs: the forward leg reaches, and begins the pull phase by connecting the heel to the ground—the foot pulling the body forwards. At the same time, the back leg is pushing off through the toes.

The arm swing completes the cross-lateral coordination needed for walking. In a sense, the oppositional swing of the arm can be considered a shadow of the arm reach needed for crawling, as it no longer has spatial intent.

In her book *Making Connections: Total Body Integration Through Bartenieff Fundamentals*, which is about developmental patterning, Peggy Hackney summarizes walking as follows:

The propulsion of the body weight through space can be most effectively accomplished through beginning the intent to forward action in the lowest part of the pelvis; supporting the intent with a push through the grounded leg, sequencing through the internal core, letting the arm get the message and providing counterbalance cross-laterally, while at the same time reaching forward with the free leg to accept the weight. (Hackney, p. 23)
Weight – Being Vertical, Coping with Gravity

Animated characters are not physical beings in the real world—they are only a series of images. This means that animators create the illusion of weight through how the character is manipulated frame by frame. The illusion of weight fulfills two important factors: the physical material of the character or object, and the character’s inner intent and sense of themselves in relationship to gravity. Weight in character animation is about how we use our intent to mobilize our body mass.

Think for a moment about what it feels like to wake up in the morning, lie in bed for a few minutes, and then finally get out of bed to begin your day. Most of us would love nothing more than to lay in bed and drift back to sleep! Yet, responsibilities require you to resist the urge to give in to gravity—you must eventually mobilize your weight and energize your body for that mobility. This gives you a sense of how intent energizes you to move the mass of your body.

Some people describe walking as controlled falling forwards. It is essential to think of walking as a continuous, flowing weight shift, both forwards and lateral (side to side). The lateral weight shift is often overlooked, and is critical to achieving a believable walk. Try looking in a full-length mirror as you balance on one leg, and you will see the lateral weight shift right away. Your pelvis shifts to the side of the supporting leg, otherwise you would topple over!

Babies initially “waddle” using the body-half pattern with a wide stance. As they gain stability and fluidity their stance narrows, enabling them to take longer steps. From left to right, these images show chronological development of a baby walking. In the first image, she stabilizes herself in space by holding her hands forwards. Later on, she walks with a body-half pattern, lifting her left arm and leg together. Finally, with more practice, she walks with cross-lateral patterning, swinging the left arm forward with the right foot.
Planes of Rotation for Parts of the Body

When you animate a walk cycle, you inevitably pose and set keyframes for every part of the body. It can seem daunting at first to pose the body and track all of its motion via function curves. While animation software treats body part rotations as movement around the X, Y or Z axes, thinking in terms of rotational planes (instead of axes) for walking motion, it provides a conceptual tool to help you plan your animation and create smooth cycling motion.

Figure 9: Planes of the body: Vertical, Sagittal and Horizontal

Note:

Vertical, sagittal, and horizontal are anatomical terms for the three-dimensional planes of the body. In a majority of 3D software programs, these planes correspond to the XY, YZ, and ZX planes, respectively.

- The vertical plane separates the front and back of the body. Movement in the vertical plane involves rotation about the Z axis.
- The sagittal plane separates the two halves of the body. Movement in the sagittal plane involves rotation about the X axis.
- The horizontal plane divides the body into upper and lower. Movement in the horizontal plane involves rotation about the Y axis.

In walking motion, the arm/hand and leg/foot rotations are mostly in the sagittal plane. The opposition of the arms and legs in the sagittal plane creates a spinal twist in the horizontal plane.
As the pelvis moves through space, it goes forwards, up and down in the sagittal plane. It also rotates in all three planes. The most observable rotation is in the vertical plane. During the phase when the character is fully on one leg, the weight-bearing side of the pelvis is tilted up, with the free side tilted down. With each lateral weight shift, this rotation switches sides. The shoulders rotate in counterbalance to the pelvis, creating rotation in the vertical plane along the entire spine.

The pelvis also rotates forwards and backwards in the sagittal plane. In a natural style walk, this rotation can be quite subtle, but in exaggerated styles such as a sneak, both the pelvis and spine take on pronounced sagittal rotation.

**Stylizing the Walk**

Once you get the basics of the walk cycle down, stylization is all about varying the amount of rotations, as well as subtle timing offsets. The range of rotations in a walk cycle varies greatly from one character to the next. In general, a natural walk cycle has a relatively limited range, and cartoon walks are broader. The character’s design and proportions will basically lead you to create poses that work graphically in terms of staging, and dynamically in terms of creating smooth walking motion.
Thinking in terms of planes is a broad guideline, yet subtle variations will help you stylize your animation. For example, to walk purely in the sagittal plane is actually very unnatural. Most people walk with a slight turnout, which begins as an outward rotation of each thigh in the horizontal plane. (Do not make the mistake of turning the feet out only—turnout starts in the hip joint!)

You can also consider arm swings that turn in towards the midline, or outwards, at the start or end of the swing. With the spine and pelvis, experiment with exaggerating rotation in one or more planes and see how the results affect your character’s style.

As you animate, always be in the habit of viewing your walk from multiple viewports, especially the perspective view. Because the sagittal plane is such a dominant aspect of walking, animators tend to work from a side viewport, or profile view, to do most of the posing. Avoiding this tendency will free you to explore more subtle rotations that bring complexity and individual style to your walk.
In his book *Acting for Animators*, Ed Hooks talks about power centers—leading with a part of the body (Hooks, pp. 64-65). The leading part is, metaphorically, where that person is “coming from,” usually the head, chest, pelvis, or feet. Power centers characterize an overall body attitude—a habitual posture that movement emerges from and returns to, and is closely related to the head-tail pattern, described earlier. Working with the concepts of power centers and habitual postures bring noticeable expression and individual style to your character’s walk.

**Summary**

At some point in your lives, you have all learned how to walk! Yet, learning how to *animate* a walk can make you feel surprisingly uncoordinated. This lesson discussed the developmental process of walking, which gives you a deeper understanding of why walking works the way it does. Weight shift is the most important aspect of the walk. If you work towards making this believable, the rest of your walk cycle animation will organize itself around the strength of your weight shifts. The practice you gain with animating weight via walk cycles will translate into all your character animation as creating the illusion of materiality, personality, and intent in the character.

**References**
