Principles of Traditional Animation Applied to 3D Computer Animation

Introduction

Many of the principles of traditional animation were developed in the 1930's at the Walt Disney studios. These principles were developed to make animation, especially character animation, more realistic and entertaining. These principles can and should be applied to 3D computer animation.

Principles of Traditional Animation

The following principles were developed and named:

1. Squash and Stretch- defining the rigidity and mass of an object by distorting its shape during an action
2. Timing and Motion- spacing actions to define the weight and size of objects and the personality of characters
3. Anticipation- the preparation for an action
4. Staging- presenting an idea so that it is unmistakably clear
5. Follow Through and Overlapping Action- the termination of an action and establishing its relationship to the next action
6. Straight Ahead Action and Pose-to-Pose Action- The two contrasting approaches to the creation of movement
7. Slow In and Out- the spacing of the in-between frames to achieve subtlety of timing and movement
8. Arcs - the visual path of action for natural movement
9. Exaggeration- Accentuating the essence of an idea via the design and the action
10. . Secondary Action- the action of an object resulting from another action
11. . Appeal- creating a design or an action that the audience enjoys watching

Personality in character animation is the goal of all of the above.

Squash and Stretch

When real objects move only totally rigid ones, e.g., a chair, remain rigid in motion. Living creatures always deform in shape in some manner. For example, if you bend your arm, your bicep muscles contract and bulge out. They then lengthen and disappear when your arm straightens out. The squashed position shows the form flattened out and the stretched position shows the form extended. An important rule is that the volume of the object should remain constant at rest, squashed, or stretched. If this rule is not obeyed, then the object appears to shrink when squashed and to grow when stretched.

A classic example is a bouncing ball, that squashes when it hits the ground and stretches just before and after. The stretching, while not realistic, makes the ball appear to be moving faster right before and after it hits the ground.

When an object squashes or stretches, it appears to be made of a pliable material, if it doesn't then it appears rigid. Objects that are partially pliable and partially rigid should have only the pliable parts deform.

A hinged object can squash and stretch without deforming, e.g. Luxo, jr.

These deformations are very important in facial animation, since they show the flexibility of the skin and muscle and also the relationship between the different facial parts. In very early animation, a character chewing something only moved its mouth and it appeared unrealistic. A later innovation was to have the entire face moving with the mouth motion, thus looking more realistic. This can be exaggerated for effect. A broad smile or frown similarly involves more than the mouth

This can also be used in the rapid motion of objects. If motion is slow, then the objects overlap between frames and the eye smoothes out the motion. But if the motion is too fast, such that there is no object overlap, then the eye sees separate images and the object appears to strobe. A solution is to stretch the object to retain the overlap and smooth motion.

Squash and stretch can be accomplished by differential scaling in 3D Keyframe systems. Be sure to conserve volume, i.e., a stretch in one direction, (X) must be accompanied by a squash in the other directions (Z,Y). Also, the direction of the stretch should be along the direction of motion so a rotational transformation may be required.

Timing and Motion

The speed of an action, i.e., timing, gives meaning to movement, both physical and emotional meaning. The animator must spend the appropriate amount of time on the anticipation of an action, on the action, and on the reaction to the action. If too much time is spent, then the viewer may lose attention, if too little, then the viewer may not notice or understand the action.

Timing can also affect the perception of mass of an object. A heavier object takes a greater force and a longer time to accelerate and decelerate. For example, if a character picks up a heavy object, e.g., a bowlng ball, they should do it much slower than picking up a light object such as a basketball. Similarly, timing affects the perception of object size. A larger object moves more slowly than a smaller object and has greater inertia. These effects are done not by changing the poses, but by varying the spaces or time (number of frames) between poses.

Motion also can give the illusion of weight. For example, consider a ball hitting a box.

Timing can also indicate an emotional state. Consider a scenario with a head looking first over the right shoulder and then over the left shoulder. By varying the number of inbetween frames the following meanings can be implied:

- No in-betweens - the character has been hit by a strong force and its head almost snappedd off
- One in-betweens - the character has been hit by something substantial, .e.g., frying pan
- Two in-betweens - the character has a nervous twitch
- Three in-betweens - the character is dodging a flying object
- Four in-betweens - the character is giving a crisp order
- Six in-betweens - the character sees something inviting
- Nine in-betweens - the character is thinking about something
- Ten in-betweens - the character is stretching a sore muscle

Anticipation

An action occurs in three parts:

1. the preparation for the action - this is **anticipation**
2. the action
3. the termination of the action

Anticipation can be the anatomical preparation for the action, e.g., retracting a foot before kicking a ball. It can also be a device to attract the viewer's attention to the proper screen area and to prepare them for the action, e.g., raising the arms and staring at something before picking it up, or staring off-screen at something and then reacting to it before the action moves on-screen. An example of this is the opening scene of Luxo, jr.. The father is looking off-screen and then reacts to something. This sets up the viewers to look at that part of the screen so they are prepared when Luxo, jr. hops in from off-screen.

A properly timed anticipation can enable the viewer to better understand a rapid action, e.g., preparing to run and then dashing off-screen.

Anticipation can also create the perception of weight or mass, e.g., a heavy person might put their arms on a chair before they rise, whereas a smaller person might just stand up.

Staging

Staging is the presentation of an idea so that it is clear. This idea can be an action, a personality, an expression, or a mood. The key idea is that the idea is made clear to the viewer.

An important objective of staging is to lead the viewers eye to where the action will occur so that they do not miss anything. This means that only one idea at a time occur, or else the viewers may be looking at the wrong thing. So, the main object should be contrasted in some way with the rest of the scene. A good example is motion, since the eye is drawn to motion in an otherwise still scene. In a scene with everything moving, the eye is drawn to a still object.

The animator must use different techniques to ensure that the viewer is looking at the correct object at the correct time. For example, in Luxo, jr. The Father appears first, and so is the center of attention. Then the son bounds in, moving rapidly, so the center of attention shifts to him. At a certain point the son stops and looks up at the father, refocusing the attention on the father.

In the early days at Disney all characters were black and white, with no gray. All action was shown in silhouette (to the side), because if a character moved its black arm in front of its black body it would disappear, so the action had to be against the white background. The Disney animators realized that even without this technological limitation action was more clearly visible in silhouette.

Even with modern color 3D graphics, silhouette actions are more clearly delineated and thus to be preferred over frontal action. An example would be a character waking up and scratching its side, it is easier to understand what it is doing than if it scratched its stomach.

Follow Through and Overlapping Action

Follow through is the termination part of an action. An example is in throwing a ball - the hand continues to move after the ball is released. In the movement of a complex object different parts of the object move at different times and different rates. For example, in walking, the hip leads, followed by the leg and then the foot. As the lead part stops, the lagging parts continue in motion.

Heavier parts lag farther and stop slower. An example is in the antennae of an insect - they will lag behind and them move quickly to indicate the lighter mass.

Overlapping means to start a second action before the first action has completely finished. This keeps the interest of the viewer, since there is no dead time between actions.

Here is a quote about overlapping from Walt Disney:

"*It is not necessary for an animator to take a character to one point, complete that action completely, and then turn to the following action as if he had never given it a thought until after completing the first action. When a character knows what he is going to do he doesn't have to stop before each individual action and think to do it. He has it planned in advance in his mind.*"

Straight Ahead Action and Pose-to-Pose Action

Straight Ahead Action in hand drawn animation is when the animator starts at the first drawing in a scene and then draws all of the subsequent frames until he reaches the end of the scene. This creates very spontaneous and zany looking animation and is used for wild, scrambling action.

Pose-to-Pose Action is when the animator carefully plans out the animation, draws a sequence of poses, i.e., the initial, some in-between, and the final poses and then draws all the in-between frames (or another artist or the computer draws the inbetween frames). This is used when the scene requires more thought and the poses and timing are important.

This is similar to keyframing with computer graphics but it must be modified slightly since the inbetweens may be too unpredictable. For example, objects or parts of objects may intersect one another. Computer keyframing can take advantage of the hierarchical model structure of a complex object. Different parts of the hierarchy can be transformed at different keyframes. For example, in a jump, translation keyframes can be set for the entire model in the X and Z directions. Then other rotation or translation keyframes can be set for portions of the model, e.g., the legs and arms.

Slow In and Out

This refers to the spacing of the inbetween frames at maximum positions. It is the second and third order continuity of motion of the object. Rather than having a uniform velocity for an object, it is more appealing, and sometimes more realistic, to have the velocity vary at the extremes. For example, a bouncing ball moves faster as it approaches or leaves the ground and slower as it approaches leaves its maximum position. The name comes from having the object or character "slow out" of one pose and "slow in" to the next pose.

This is usually achieved by using splines to control the path of an object. The various spline parameters can be adjusted to give the required effect. In 3D Studio this is controlled by the parameters Ease To and Ease From in the Key info window (from the Track info window). When these are zero, there is a constant velocity in either direction, i.e., to/from the keyframe. When Ease To is set to a higher value, the motion is faster as it leaves the previous keyframe and slows as it approaches the current keyframe. When Ease From is set to a higher value the motion is slower leaving the current keyframe and speeds up as it approaches the next keyframe. The tick mark spacing shows the velocity with closer tick marks indicating a slower rate and spaced out ones indicating a faster rate.

Examples:

- Ease To/From both set to 0 (bounce0.flc)
- Ease To/From both set to 50 (max value)(bounce1.flc)

There are other potential problems with spline controlled movements. Because of the nature of splines, there may be an overshoot effect, For example, look at box1.flc. The upper box was keyframed to just touch the top of the bottom box, but because of the properties of the spline curve, it overshoots and goes into the lower box. There are three other parameters that control the approach to/from keyframes. These are discussed below.

Tension

Tension controls the overall shape of the spline curve.

Continuity equally affects the angles at which the spline enters and leaves the keyframe.

Bias affects the overshoot or undershoot of the motion through the keyframe.

Arcs

Arcs - the visual path of action for natural movement

Exaggeration

Exaggeration does not mean just distorting the actions or objects arbitrarily, but the animator must carefully choose which properties to exaggerate. If only one thing is exaggerated then it may stand out too much. If everything is exaggerated, then the entire scene may appear too unrealistic.

Secondary Action

This is an action that directly results from another action. It can be used to increase the complexity and interest in a scene. It should always be subordinate to and not compete with the primary action in the scene. An example might be the facial expression on a character. The body would be expressing the primary action while the expression adds to it. Another example would be the trailing electrical cord of Luxo, jr.

Appeal

Appeal means something that the audience will want to see. This is equivalent to charisma in a live actor. A scene or character should not be too simple (boring!) or too complex (can't understand it). One principle to achieve this is to avoid mirror symmetry. Asymmetry tends to be more interesting and appealing.

Personality

The objective of the principles previously discussed are to give the characters in an animation a personality that appeals to the viewers. The different principles should be applied in a fashion to produce a consistent personality. This means that the animator must have a good idea of the desired personality before beginning the animation.