Fundamentals of Computer Animation

Principles of Traditional Animation

How to create maximum impact
Early animators worked from scratch to analyze and improve upon silence live action films.
Conventional Animation

- Draw each frame of the animation
  - great control
  - tedious
- Reduce burden with cel animation
  - layer
  - keyframe
  - inbetween
  - cel panoramas (Disney’s Pinocchio)
  - ...

ACM © 1997 “Multiperspective panoramas for cel animation”
A multiperspective panorama incorporates many perspectives into a single locally coherent image. A moving window slides across the panorama, selecting frames for the animation.
Computer-Assisted Animation

• **Keyframing**
  – automate the inbetweening
  – good control
  – less tedious
  – creating a good animation still requires considerable skill and talent

• **Procedural animation**
  – describes the motion algorithmically
  – express animation as a function of small number of parameters
  – Example: a clock with second, minute and hour hands
    • hands should rotate together
    • express the clock motions in terms of a “seconds” variable
    • the clock is animated by varying the seconds parameter
• Physically Based Animation
  – Assign physical properties to objects
    (masses, forces, inertial properties)
  – Simulate physics by solving equations
  – Realistic but difficult to control

• Motion Capture
  – Captures style, subtle nuances and realism
  – You must observe someone do something
Computer Animation

FIGURE 3. Squash & stretch in Luxo Jr.’s hop.

ACM © 1988 “Spacetime Constraints”
Animators first draw key drawings, follow by inbetween drawings to keep the continuity of action in shape and form.
Describe motion of objects as a function of time from a set of key object positions. In short, compute the inbetween frames.
Computer Animation as Animation

Lassiter, John
"Principles of Traditional Animation Applied to 3D Computer Animation,“
SIGGRAPH '87, pp. 35-44.
(check web site)

Thomas, F. and Johnson, O.,
"The Illusion of Life,"
Abbeville Press, 1981.
Simulating Physics

1. Squash & Stretch
2. Timing
3. Secondary Actions
4. Slow In & Slow Out
5. Arcs

The visual path of action for natural movement Motion in straight lines is not organic. Most human motion happens on curved trajectories or arcs.
Simulating Physics → 1. Squash & Stretch

defining the rigidity and mass of an object by distorting its shape during an action
Simulating Physics → 1. Squash & Stretch

- **Squash**: flatten an object or character by pressure or by its own power

- **Stretch**: used to increase the sense of speed and emphasize the squash by contrast
Simulating Physics → 1. Squash & Stretch

• Here is an example where the ball on the right has been stretched and so looks more "natural".
Squash and stretch

- Human bodies squash and stretch when performing different actions.
- Heavier characters squash more than thin ones.
- Squashing and stretching gives the character a sense of weight.
Characters move at different speeds

- Tall guys move slowly than short guys

- Fat characters slower than thin ones.

- Small characters will have to take more steps to keep up with taller characters.
Simulating Physics → 2. Timing

• Timing affects weight:
  – Light object move quickly
  – Heavier objects move slower

• Timing completely changes the interpretation of the motion. Because the timing is critical, the animators used the draw a time scale next to the keyframe to indicate how to generate the in-between frames.

Spacing actions to define the weight and size of objects and the personality of characters
• If the ball rebounds from the box, and the box is unmoved, we have the illusion that the box is much heavier than the ball

• If the ball knocks the box aside, then the effect is that the box is much lighter than the ball
Simulating Physics → 3. Secondary Actions

The action of an object resulting from another action
• A secondary action is an action that results directly from another action.
• Important in heightening interest and adding a realistic complexity to the animation.

The secondary action of Luxo Jr's forward motion is the rippling of his power cord.
Secondary action

- A secondary action is like a chain reaction.
- Secondary actions are a beat behind the main action.
Simulating Physics → 4. Slow In & Slow Out

- The spacing of the inbetween frames to achieve subtlety of timing and movement.

- 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.
• The ball on the left moves at a constant speed with no squash/stretch.

• The ball in the center does slow in and out with a squash/stretch.

• The ball on the right moves at a constant speed with squash/stretch.
* Visual path should be an arc
  – Rather than a straight line

* Can be a problem for typical computer methods:
  – Fast movement = straight lines

* Solution:
  – Use independent curves for position interpolation and speed control
Designing Aesthetic Actions

1. Exaggeration
   Accentuating the essence of an idea via the design and the action

2. Appeal
   Creating a design or an action that the audience enjoys watching

3. Follow Through/Overlapping Action
   Follow through is the termination part of an action. Overlapping establishes the next action's relationship by starting it before the first action has completely finished. This keeps the interest of the viewer, since there is no dead time between actions.
3. Follow Through
Follow through

• Follow through is when a secondary action runs its course.
• For example the pooch with long ears leans forwards and stop but the ears continue swinging back and forth.
Effective Presentation of Actions

1. Anticipation
The preparation for an action

2. Staging
Presenting an idea so that it is unmistakably clear.

This idea can be an action, a personality, an expression, or a mood.

An important objective of staging is to lead the viewers eye to where the action will occur so that they do not miss anything.
Anticipation

• An action breaks down into:
  – Anticipation
  – Action
  – Reaction

• Anatomical motivation: a muscle must extend before it can contract. Prepares audience for action so they know what to expect. Directs audience’s attention. Amount of anticipation can affect perception of speed and weight.
Anticipation-1-17 Frames
Anticipation-2- 3 to 10 Frames
Anticipation-3- 3 Frames
1. **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.

2. **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.
Interpolation

• Many parameters can be interpolated to generate animation
  – Position
  – Color
  – Orientation
  – Shape
  – Camera
  – ….
• More complicated inbetweening will require a more complicated model of animated object and simulation
Interpolation

- Interpolating splines are smooth curves that interpolate their control points.
- Perfect for keyframe animation.
- Typically, time is directly associated with the parameter value, controlling speed.

Keyframes

Animation
• Anything can be keyframed and interpolated
  – Position, Orientation, Scale, Deformation, Patch Control Points (facial animation), Color, Surface normals…

• Special interpolation schemes for things like rotations
  – Use *quaternions* to represent rotation and interpolate between quaternions

• Control of parameterization controls speed of animation
Animation of a Juggler

use of:
- overlapping action,
- anticipation
- follow-through techniques

• The clown is tossing the ball with his right hand in cel 7*, catching it with his left in cel 5, and transferring it back to the right hand in cel 3.
• The cycle has only one toss and catch, yet the clown is juggling two balls, because at least one ball is always held.
• Can you see the anticipation and follow-through used in each action?
• Little touches like the tapping foot and the loose hat add a lot of life to the piece.
Use in Computer Games

- Use of:
  - Ease-in/out
  - Timing
  - Overlapping action,
  - Anticipation
  - Follow-through techniques