CSC418 Computer Graphics

- Animation Principles
- Keyframe Animation

Principles of Traditional Animation

- Developed largely during the early days of the Disney studio
- Great reference: The Illusion of Life: Disney Animation by Frank Thomas and Ollie Johnston

Principles of Traditional Animation

From “Principles of Traditional Animation Applied to 3D Computer Animation” by John Lasseter, SIGGRAPH 87

1. Timing
   - Space actions to show mass and personality of characters
2. Slow In and Out
   - Spacing of inbetween frames to achieve subtlety of timing and movement
3. Anticipation
4. Follow Through and Overlapping Action
5. Arcs
   - Visual path of action

Principles of Traditional Animation

6. Secondary Action
   - Action of an object resulting from the motion of another action
7. Squash and Stretch
8. Straight Ahead Action and Pose-To-Pose Action
9. Staging
   - Present an idea so that it is unmistakably clear
10. Exaggeration
11. Appeal

What can be animated?

- Lights
- Camera
- Articulated figures
- Deformable figures
- Clothing
- Skin/muscles
- Wind/water/fire/smoke
- Hair
- ***Any variable***
- Given the right time scale, most things…

Keyframing in Cel Animation

Key frames

- Key poses of an animation sequence
- Show important story element or pose
- Drawn by lead or senior animator
- Capture the general impact of a scene

In-betweens

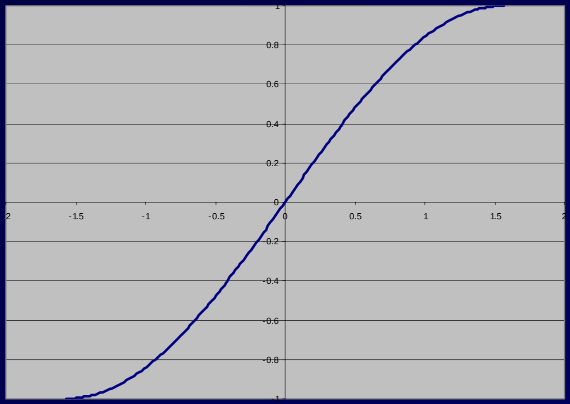
- All the cels drawn “in-between” the key frames
- Complete the flow of the motion
- Normally drawn by junior artist, an “in-betweener”
- “in-betweener” may also clean up the keyframes

Keyframing in Computer Animation

- Based on same idea as in cel animation
- Animator specifies keyframes
- Computer interpolates between them to create in-between frames
- Early keyframe system developed by Burtnyk and Wein working at NFB

Interpolation

- Linear variation of control variables
- Cubic splines
- Ease-in ease-out curves
  - E.g. sine based

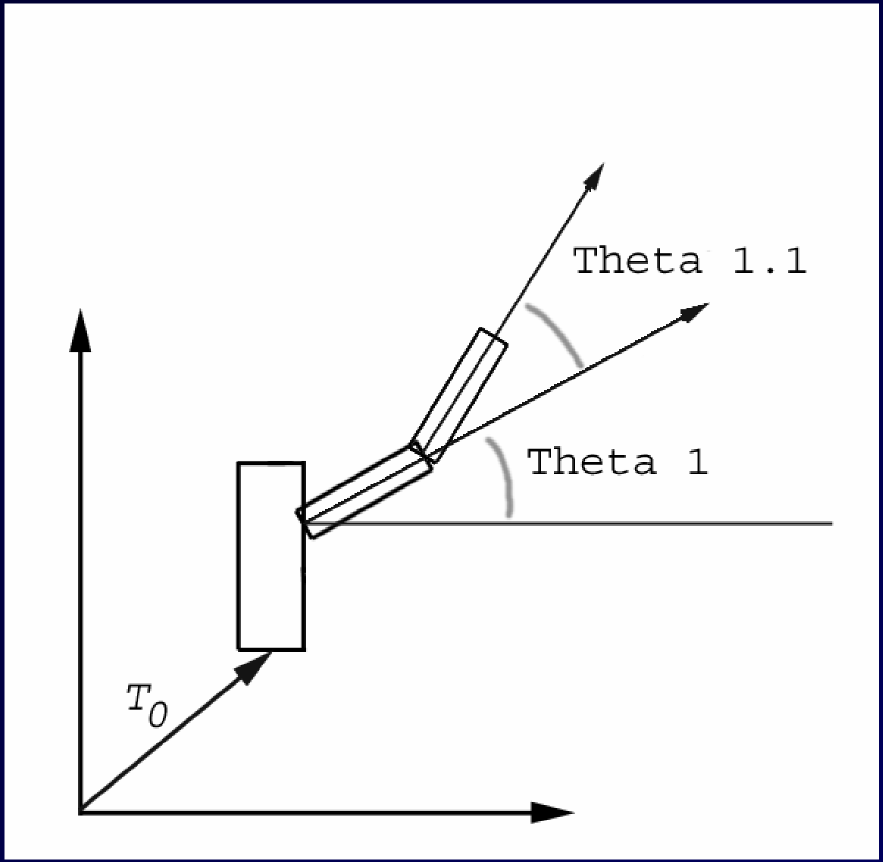


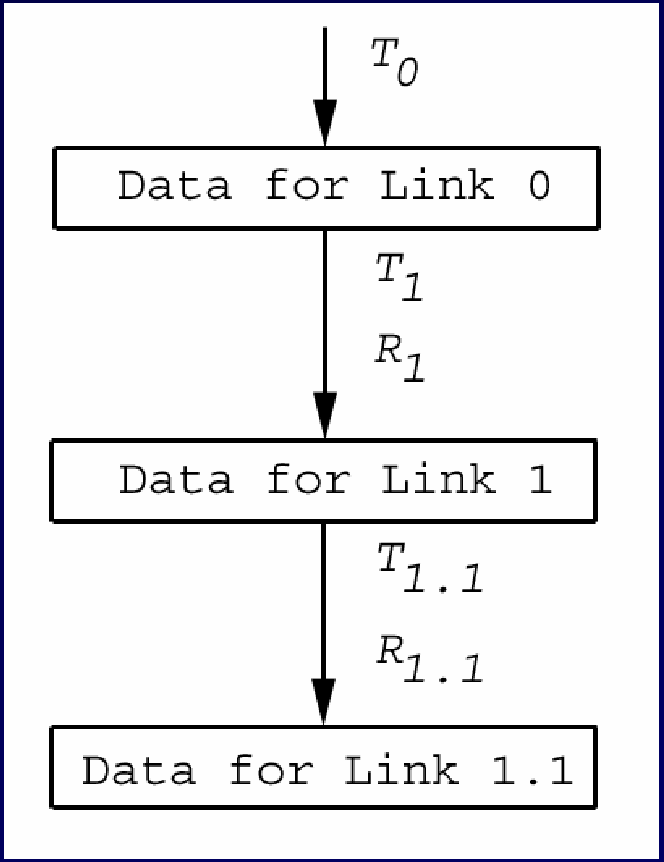
- Track a path in space
- Arc length reparmaterization, velocity curves to control timing

Articulated Figures

- Represented as a hierarchy of transformation matrices
- Root node specifies world coordinates of figure (usually at hip)
- Joints normally have 1, 2 or 3 rotational degrees of freedom (DOF)
- 3 dof
  - Gimbal joint (locks)
  - Ball joint (quaternions)

More on Joint Hierarchies





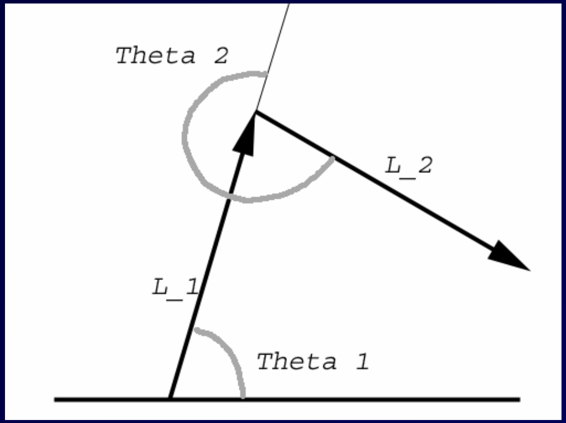
$$V'_1 = T_0 \bullet T_1 \bullet R_1(\theta_1) \bullet V_1$$

$$V'_{1.1} = T_0 \bullet T_1 \bullet R_1(\theta_1) \bullet T_{1.1} \bullet R_{1.1}(\theta_{1.1}) \bullet V_{1.1}$$

Forward and Inverse Kinematics

- Kinematics: The study of motion when only position and velocity are considered.
- Forward Kinematics
  - Position is specified by setting value for each dof
  - Hard to achieve world space constraints
  - Movement flow (relatively) easy to control
- Inverse Kinematics
  - Specify world space constraints that one or more parts of the skeleton must achieve
  - Solve for joint angles to achieve these
  - Good for meeting world space constraints (!), but movement flow can be a problem
  - Most skeletons are highly redundant, so problem is underconstrained

Forward and Inverse Kinematics



- Consider the above two joint, planar arm. Forward kinematics gives:

$$x = l_1 \cos\theta_1 + l_2 \cos(\theta_1 + \theta_2)$$

$$y = l_1 \sin\theta_1 + l_2 \sin(\theta_1 + \theta_2)$$

- Inverting these equations gives the inverse kinematics equations:

$$\theta 2 = \cos^{-1} \frac{(x^2 + y^2 - l_1^2 - l_2^2)}{2 l_1 l_2}$$

$$\theta_1 = \frac{-(l_2 \sin\theta_2) x + (l_1 + l_2 \cos\theta_2) y}{-(l_2 \sin\theta_2) y + (l_1 + l_2 \cos\theta_2) x}$$

What makes IK interesting?

- For real characters, most IK problems are highly underconstrained
- System is redundant
- Subspace of solutions satisfies constraints
- What solutions satisfy animator’s goals?

What more is there to animation?

Coming later to a lecture hall near you…

- Physical simulation
- Spring Mass systems
- Motion Capture
- Behavioral Animation

Now…

- Videos!

3D Transformations

- Going from 2D to 3D
- What is special about rotations?
- Composition and inversion of transforms
- Scene Graphs
- Change of basis