Skinning and Rigging

⇒ Specific Problem
⇒ General Problem

Controls ➔ geometry / appearance
  ↓
  rig
  everything might change

[Vertex Animation]

Arbitrary code for rig
Arbitrary controls
  - need convenient, compact, expressive, constrained, ...
  - could model at every frame
How to leverage artist?
  ➔ define geometry / appearance for a pose
Pixar clay models
  how many poses? ➔ at some point, they are animated

Rigging - arbitrary code to create geometry + appearance

Usually - data driven
  a model
  a subset of models
  other hints
parameter -
  good controls vs. ...
Easy case # Blend Shapes

Linear blends

\[ \text{params} = \text{weighty (abstract)} \]
\[ \text{alternatives beyond weights least squares} \]
\[ \text{why works for faces} \]

Simplicial complex modeling

why not for articulated figures

Special Case #2

Hierarchical Skeletons

Single "Skin"

Fundamental limits (eyes glow when hit 96 mod)
Possibly deduced complex effects
Biceps based on bend (but not weight)
May want to layer an extra controls/effects
Still could have arbitrary complexity

Binding Pose < inside of shin

Simplest Version: Rigid Skin

Each vertex = 1 coordinate system

Single skins will crack < or weird stuff @ connection
Blend - each point in multiple coordinate systems
weights
$$w_1 M_1 x + w_2 M_2 x$$

notice
$$\left( w_1 M_1 + w_2 M_2 \right) x$$

So common no one claims to have invented it
- smooth shinning
- skeletal subspace deformation
- linear blend shinning
- matrix pallete shinning
- matrix pallette issues
- only a few weights
- locality for efficiency

Why good?
- Easy
- Hardware
- Range of effects
- Just set w (control)
- Uniform

Problems?
- Where to get w? (painting, guessing, ....)
  hard to know what effects can/can't be achieved
- bad effects (collapse, squish, candy wrapper, ....)
- math is dubious (linear combinations of matrices)
  certainly doesn't preserve rigidity
  not even the same center
- might use wired, non-local effects
  artists do trial and error
Using Linear Skinning

Review Problems

→ Simple Problem
Matrix "Optimization" (palleting)

1) Come up w/ weights (Skeleton Embedding)

   Based on geometric analysis (heuristics)
   - distance to bone ← attach through space
   - heat equation (diffusion) Bran i Popovic
   - other hacks and heuristics

   No real way to know how well it works w/o heuristics
   Easy to get to 90%
   Hard to get fancier effects

2) Example based (MG)

   \[ x' = W_i M_i x \]

   suppose you know more poses
   (each pose has \( M_i \))
   mesh \((x')\) for each pose

   linear least squares solution
   too many poses
   too few poses
   poses out of "subspace"

   Note: "last pose" is exact ← why make it special?
   opt \( x \) as well
   Bi - Linear optimization
Other observations
- introduce new bones (and see if they are useful)
  half angles
  procedural radial scaling (for bulges)
  never came up w/ principled way to add new ones

\[ X = w_i M_i M_i^{-1} V_i \]

- limit number of non-zeros in \( w_i \)
- determine potential influence by rigidity
- compactness of bell in local coordinates

Multi-Weight Enveloping (weight per bone)

Add normals as constraints too

Skinning Mesh Animations
- Find \( M \) as well
- Cluster triangles that have similar rotations

Related (but unsolved?) problem:
- pose estimation + skinning (done for animation reconstruction)
Pose Space Deformation

1. Do LBS (he called it SSD) & Actually does RIGIO!
2. At some pose, add a correction
3. At poses not in z, interpolate corrections

Rigid skinning gives a clear coordinate system

Radial basis functions to interpolate in pose space