Character Skinning

15-864 Advanced Computer Graphics

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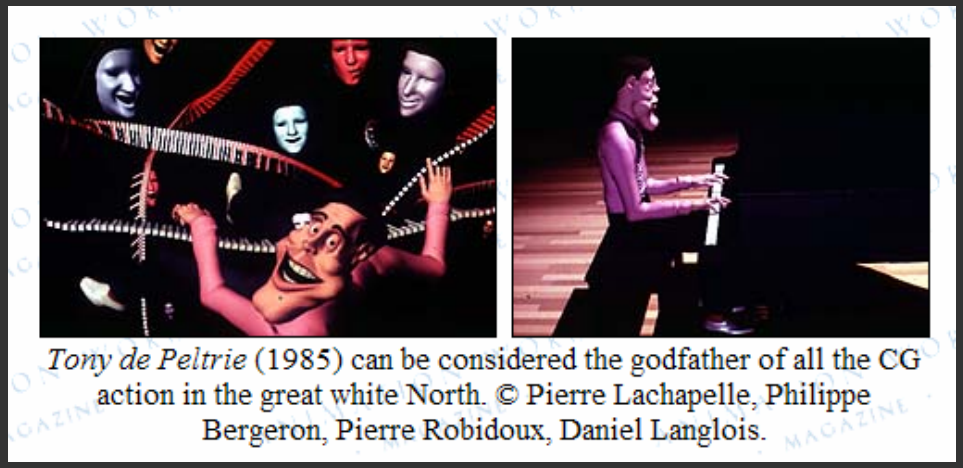
Overview

- Shape interpolation
- Skinning basics; Linear blending
- Pose Space Deformation
  - EigenSkin hardware implementation
- Multi-weight Enveloping

Shape Interpolation

- or “blend shapes”
- Widely used for facial animation



Tony de Peltrie (1985) can be considered the godfather of all the CG action in the great white North. © Pierre Lachapelle, Philippe Bergeron, Pierre Robidoux, Daniel Langlois.

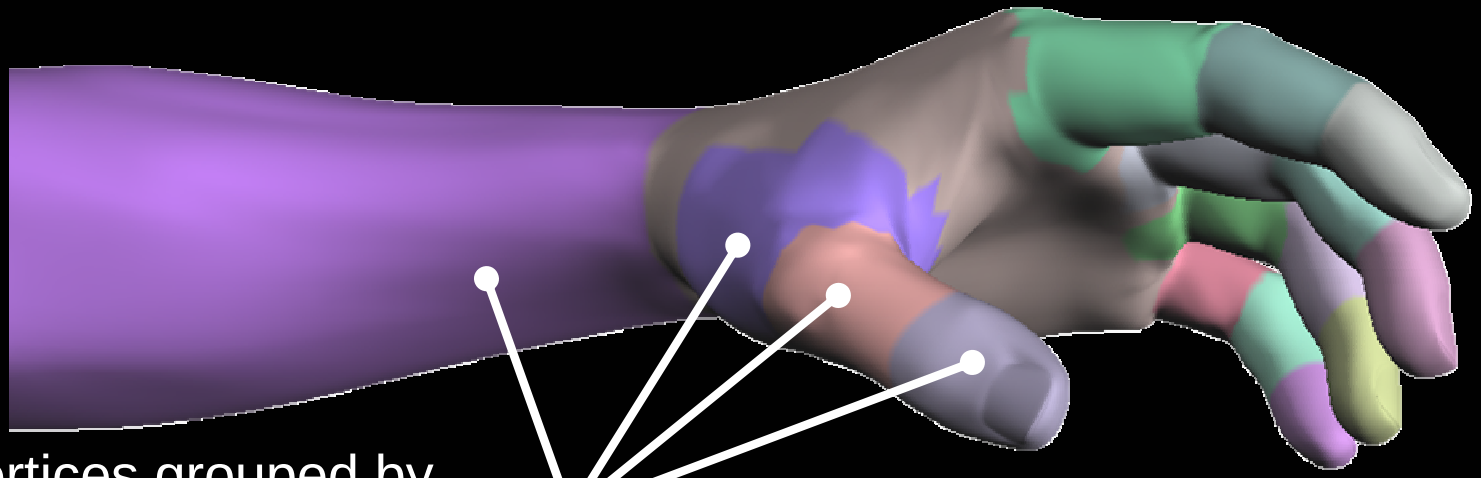
- Sliders control shape contributions
- Problems:
  - Shapes are not independent
  - Interpolation artifacts
  - Bad for articulation

Most common skinning method…

- Many names…
  - Skeleton-subspace deformation (SSD)
  - linear blending
    - linear (vertex,transform,…) blending
  - skinning
    - matrix palette skinning
  - enveloping
  - etc.
- Very simple approach
- Common skinning assumption: sequence of static poses dependent on skeleton joint angles, …

Skeleton-Subspace Deformation

$$\tilde{v}_i = \left(\sum_{b \in B_i} w_{ib} T_b \right) v_i$$



Vertices grouped by common bone influences
Groups are arbitrary

Weights are arbitrary
- Defined by an artist
- Function of vertex-bone distances

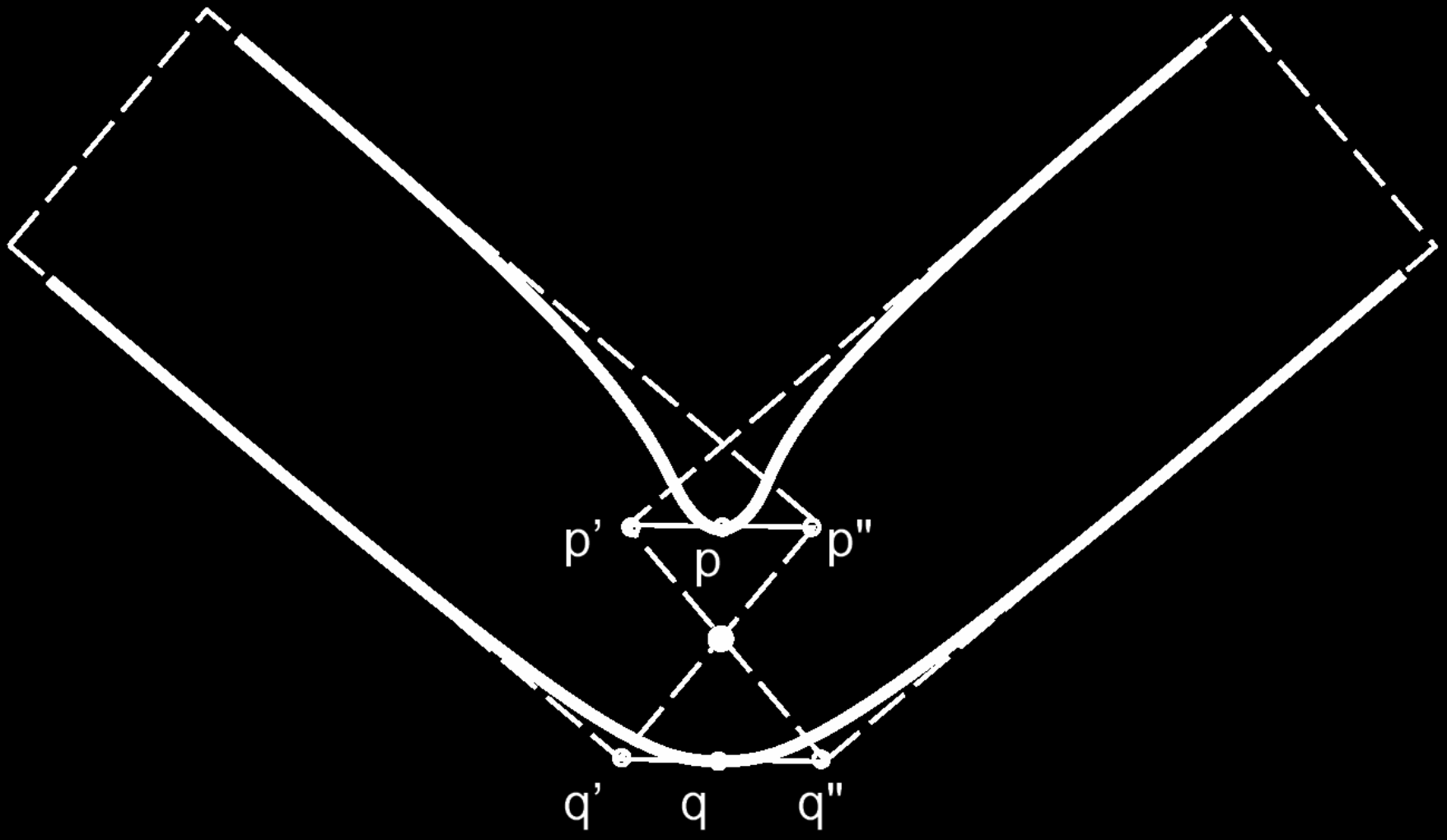


Figure 1: The skeleton subspace deformation algorithm. The deformed position of a point p lies on the line $p'p''$ defined by the images of that point rigidly transformed by the neighboring skeletal coordinate frames, resulting in the characteristic 'collapsing elbow' problem (solid line).

SSD Pros/Cons

- Pros:
  - easy, fast, and supported in hardware
- Cons:
  - Range of deformations is limited
    - Hence “skeleton-subspace deformations”
    - Unsuitable for more general deformations
  - Buckling, poor behavior, limited expression

SSD Limitations

Figure 2: The ‘collapsing elbow’ in action, c.f. Figure 1.

SSD Limitations

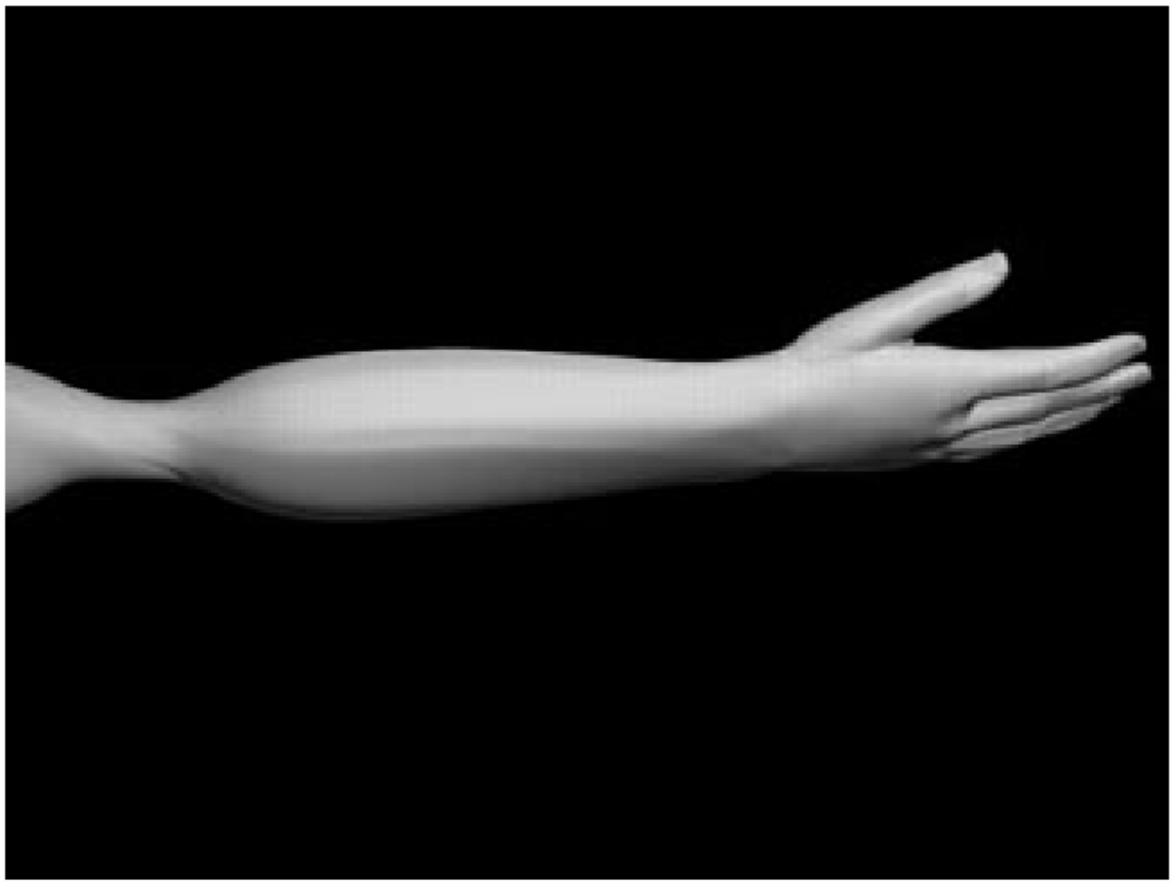


Figure 3: The forearm in the 'twist' pose, as in turning a door handle, computed by SSD. As the twist approaches 180° the arm collapses.

(But it’s fast…) Hardware Implementation

- OpenGL/DirectX support
- Vertex program implementation
- Each vertex deformed independently
- Per-vertex memory:
  - position, normal, bone weights/indices, …
- Constant memory:
  - bone transforms, …

Indexed matrix skinning of a running jester. Executing a single static display list renders each jester instance. Each vertex contains a position, a normal, 2D texture coordinate, and 4 matrix index/weight pairs. The vertex program uses relative addressing to transform and weight each vertex position and normal by its appropriate matrix set. The animation is accomplished by varying matrices stored as program constants. Credit: Sebastien Domine.

Erik Lindholm, Mark J. Kilgard, and Henry Moreton, A User-Programmable Vertex Engine, Proceedings of ACM SIGGRAPH 2001. pp. 149-158, 2001.

Pose Space Deformation

- J. P. Lewis, Matt Cordner and Nickson Fong, **Pose Space Deformations: A Unified Approach to Shape Interpolation and Skeleton-Driven Deformation**, *Proceedings of ACM SIGGRAPH 2000*. pp. 165-172, 2000.

- Optimized graphics hardware implementation:
  - Paul G. Kry, Doug L. James and Dinesh K. Pai, **EigenSkin: Real Time Large Deformation Character Skinning in Hardware**, *ACM SIGGRAPH Symposium on Computer Animation.* pp. 153-160, 2002.
  - EigenSkin slides…

Multi-Weight Enveloping

- Idea: Instead of interpolating all the data, …
  Fit a simple/fast skinning model

- Xiaohuan Corina Wang and Cary Phillips, **Multi-Weight Enveloping: Least-Squares Approximation Techniques for Skin Animation**, *ACM SIGGRAPH Symposium on Computer Animation*. pp. 129-138, 2002.

MWE Goals

- It should handle fanciful creatures whose motion cannot readily be described with muscles and bones.
- It should be able to approximate the look of an anatomically-based simulation system, but at interactive display rates.
- It should be able to serve as the underlying deformation on top of which a physically-based simulation system can add inertial effects of jiggling and shaking.
- It should be able to "learn" from existing good examples of how the skin should move.

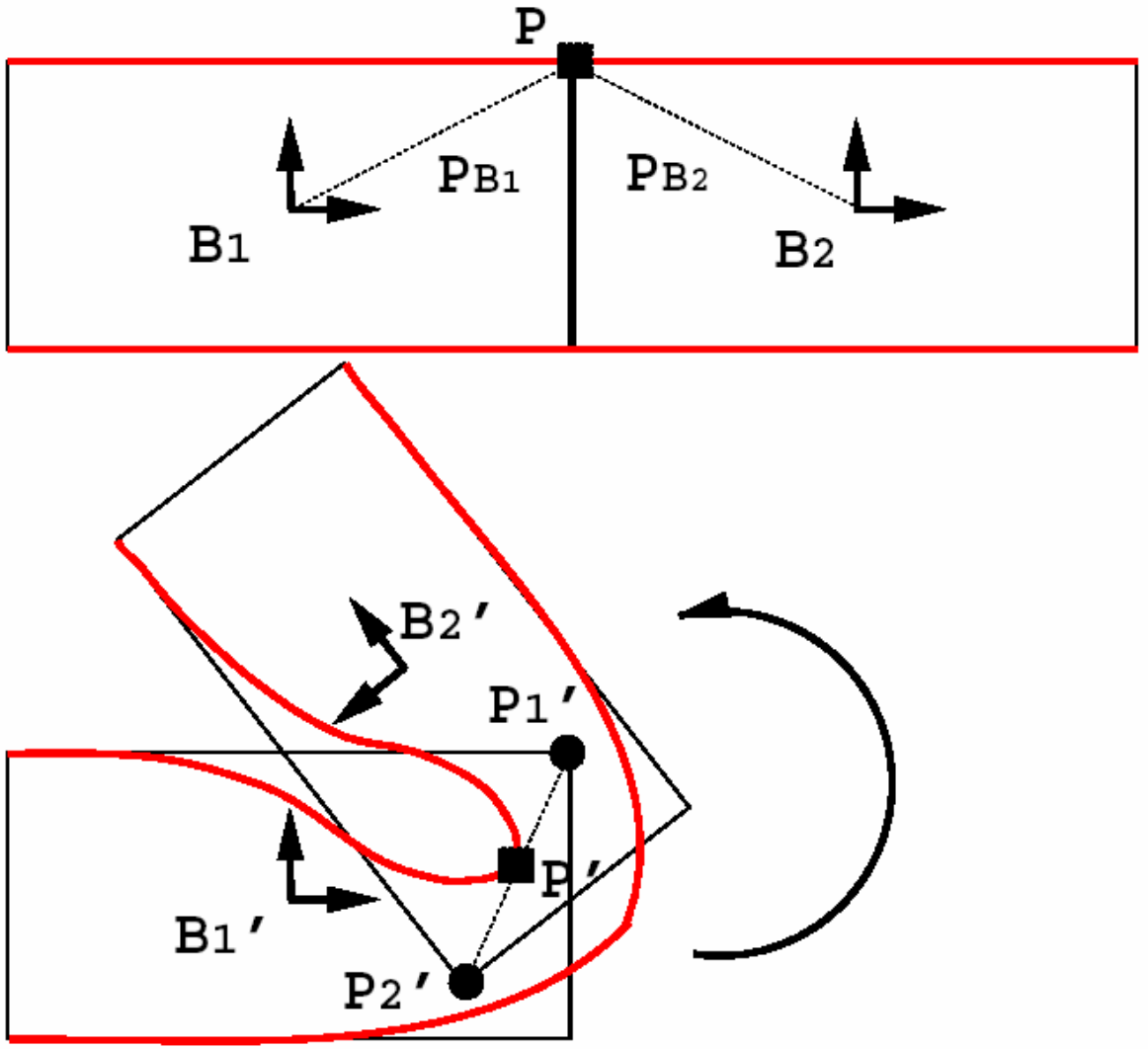
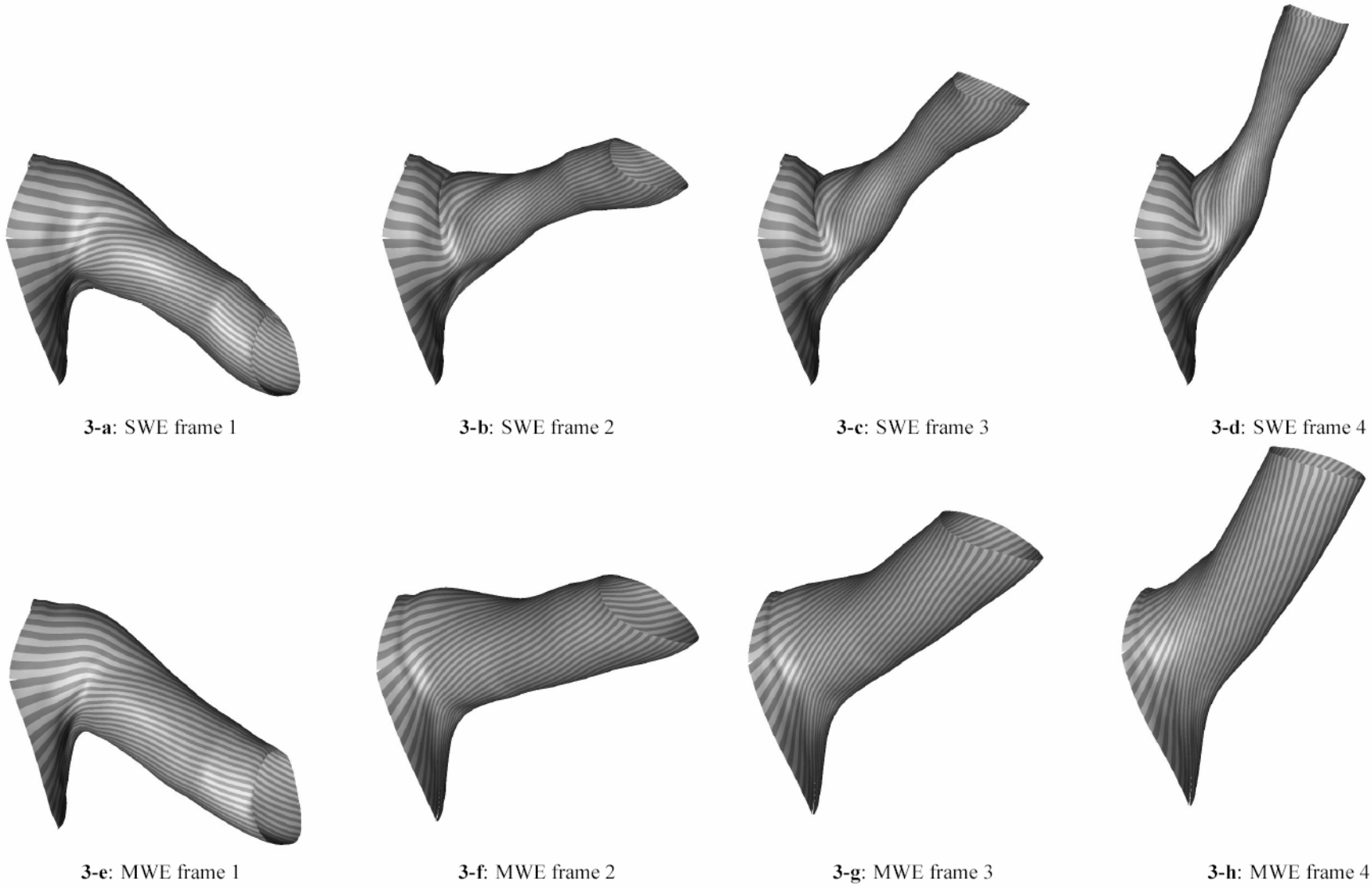


Figure 2: Single-Weight Enveloping. The top figure shows two skin surfaces (red) enveloped to two coordinate frames, B_1 and B_2, at the rest position. The bottom figure shows how the skin (red) deforms as the angle between B_1 and B_2 changes, with $w_1 = w_2 = 0.5$.



3-a: SWE frame 1 **3-b**: SWE frame 2 **3-c**: SWE frame 3 **3-d**: SWE frame 4

3-e: MWE frame 1 **3-f**: MWE frame 2 **3-g**: MWE frame 3 **3-h**: MWE frame 4

Figure 3: This example illustrates a tight-fitting shirt with stripes around the shoulder and upper arm area. From left to right the arm is rotated up and twisted toward the front. **3-a** to **3-d** is the SWE deformation based on Equation (1): **3-d** exhibits typical collapsing problem around the shoulder area and the "candy-wrapper" problem around the middle of the upper arm. **3-e** to **3-h** is the MWE deformation computed from only two poses: **3-e** and **3-h** are poses provided by the artist and **3-f** and **3-g** are the MWE results applied on new poses.

5 The MWE Skinning Process

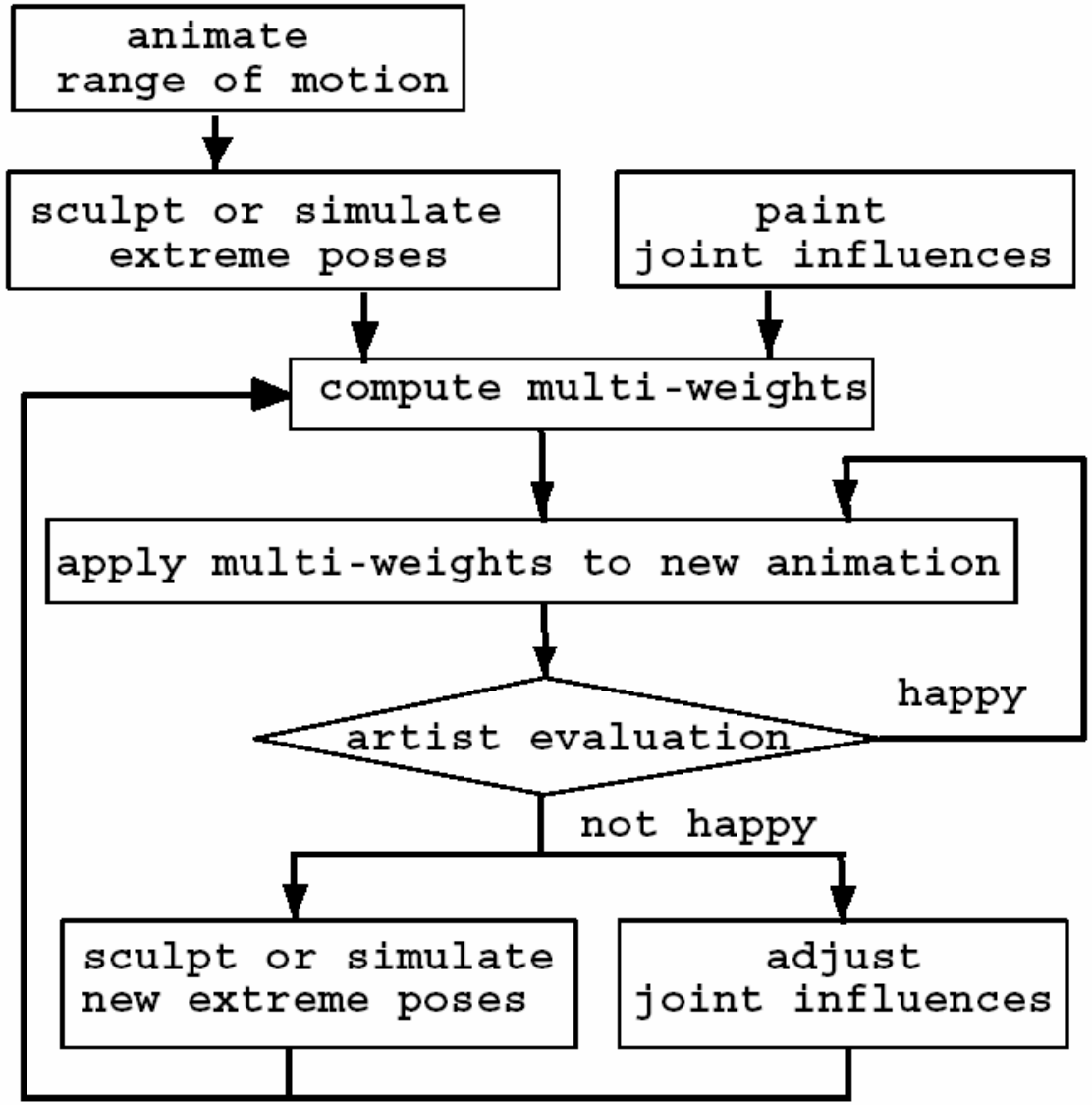
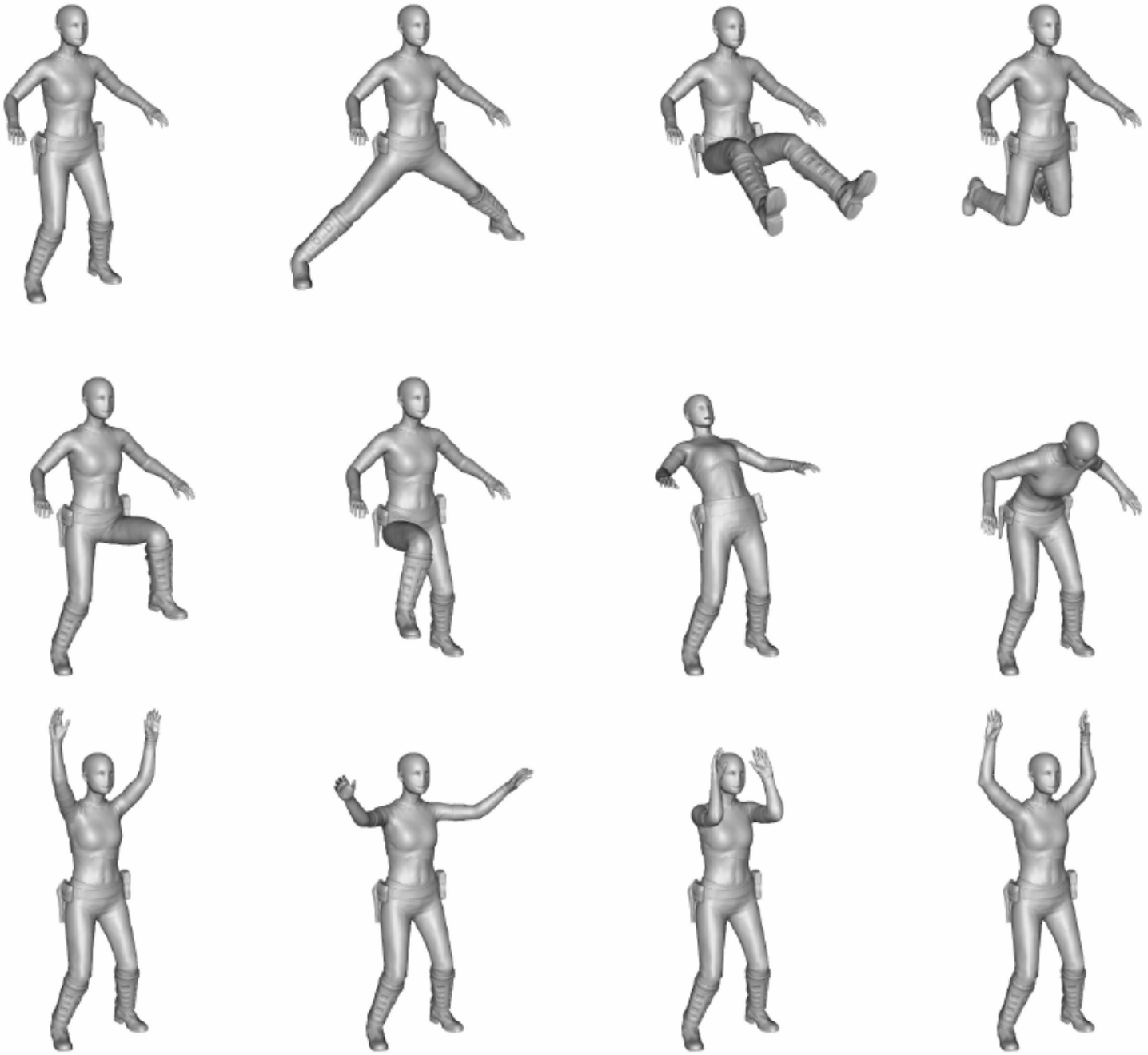


Figure 6: Flow Chart of the MWE Skinning Process

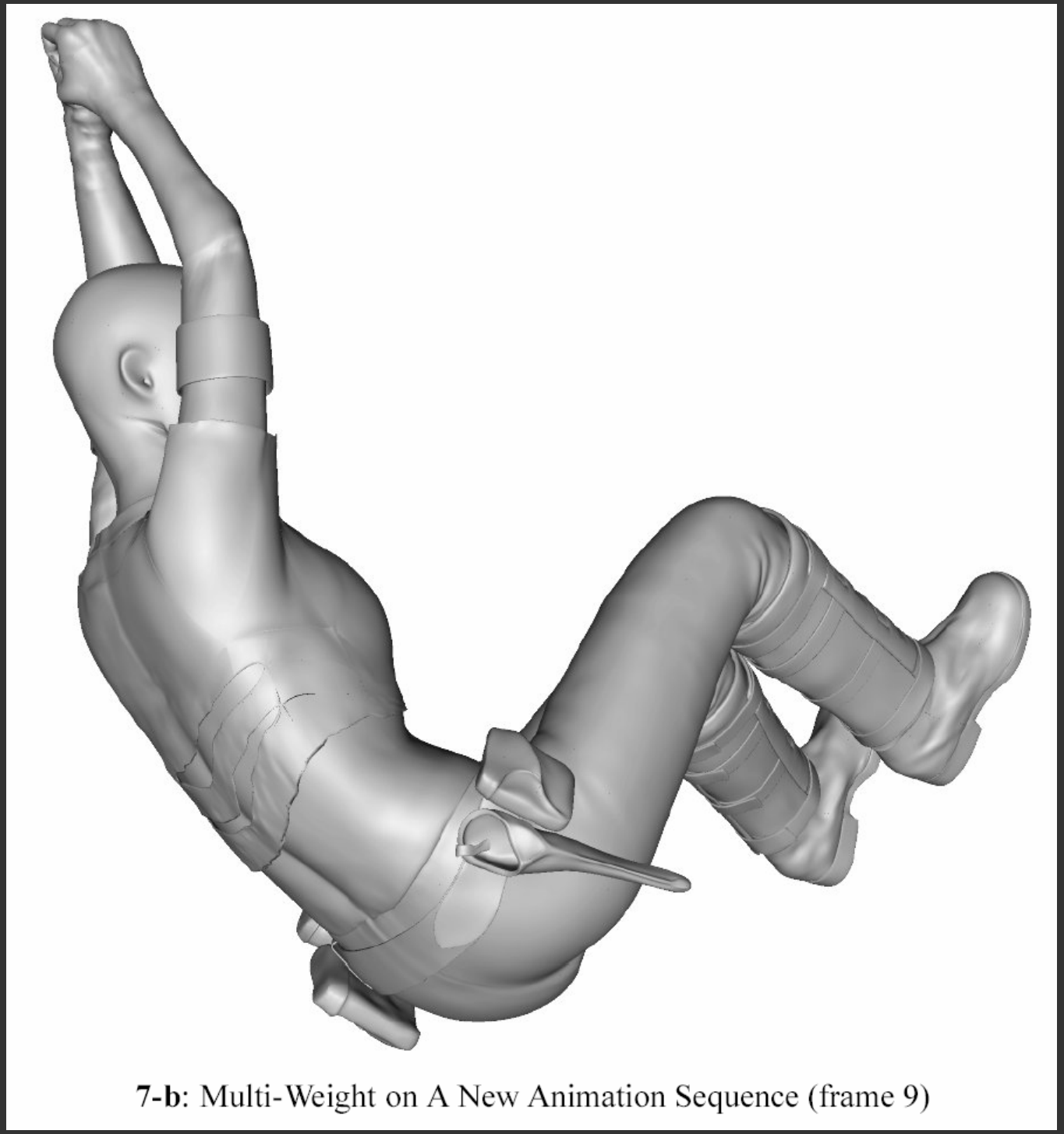
1-a: Training Exercise

1-b: New Animation Sequence

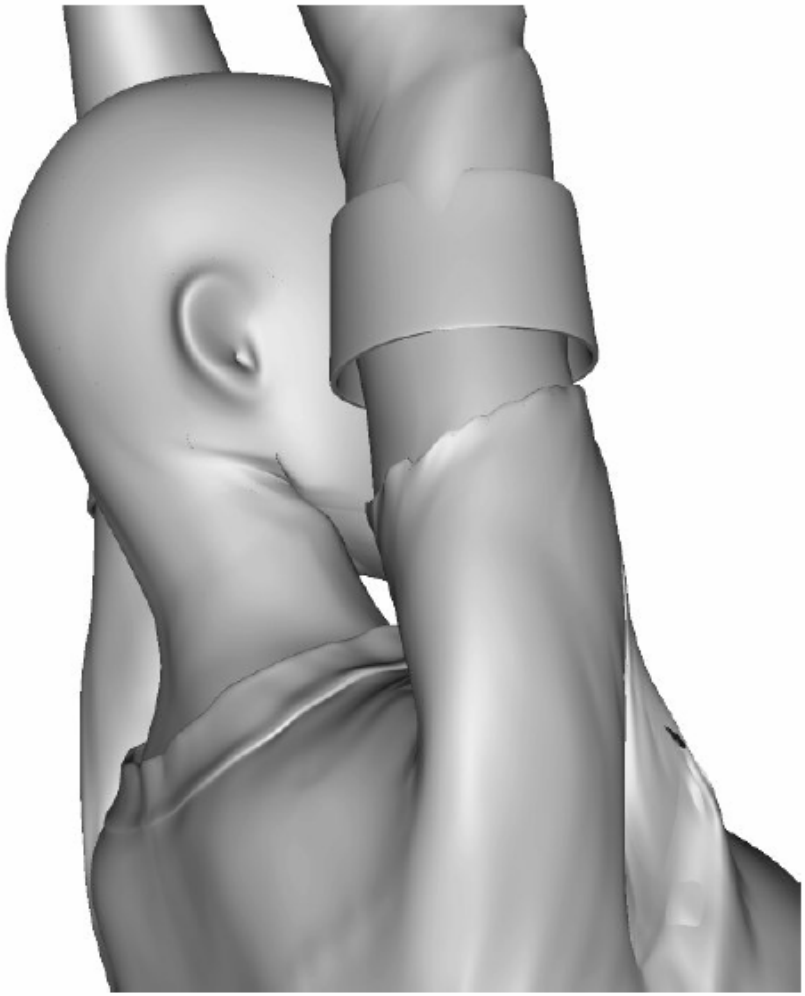
Figure 1: The multi-weight enveloping skinning process solves for a set of weights that approximate the movement of skin in a training exercise. The result is that the skin movement in the training exercise is generalized so that it applies well to other sequences of animation. **1-a** shows some example poses from a training exercise. **1-b** shows some frames from a new animation sequence.



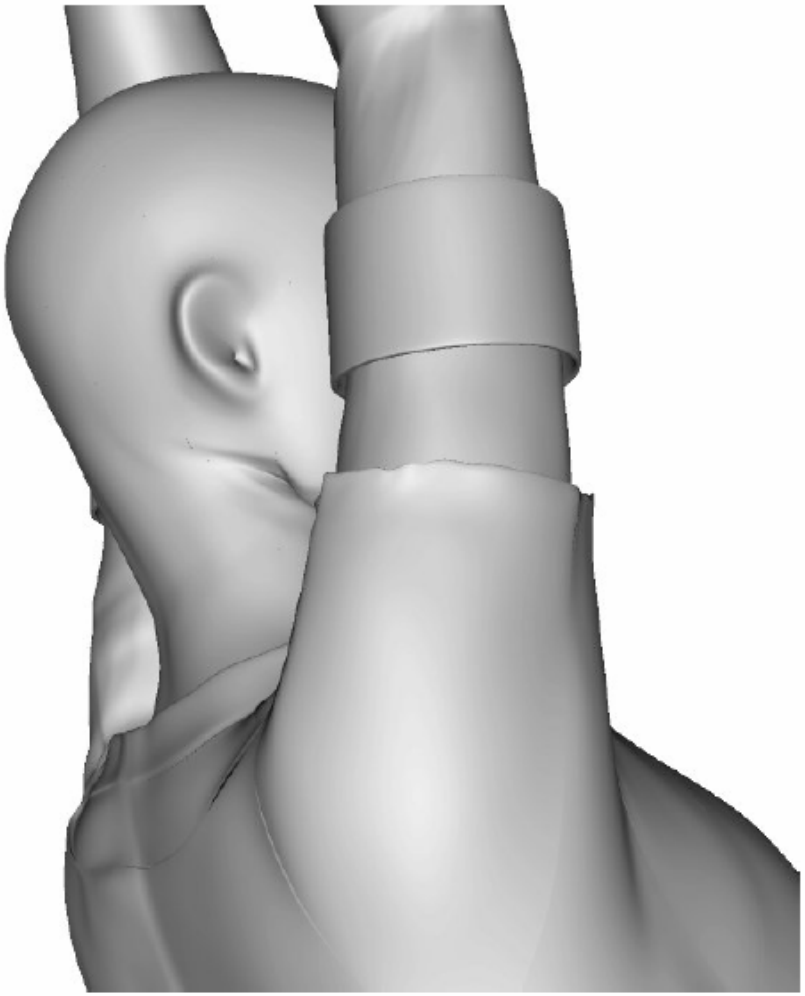
7-a: Training Exercise for the Human Creature



7-b: Multi-Weight on A New Animation Sequence (frame 9)

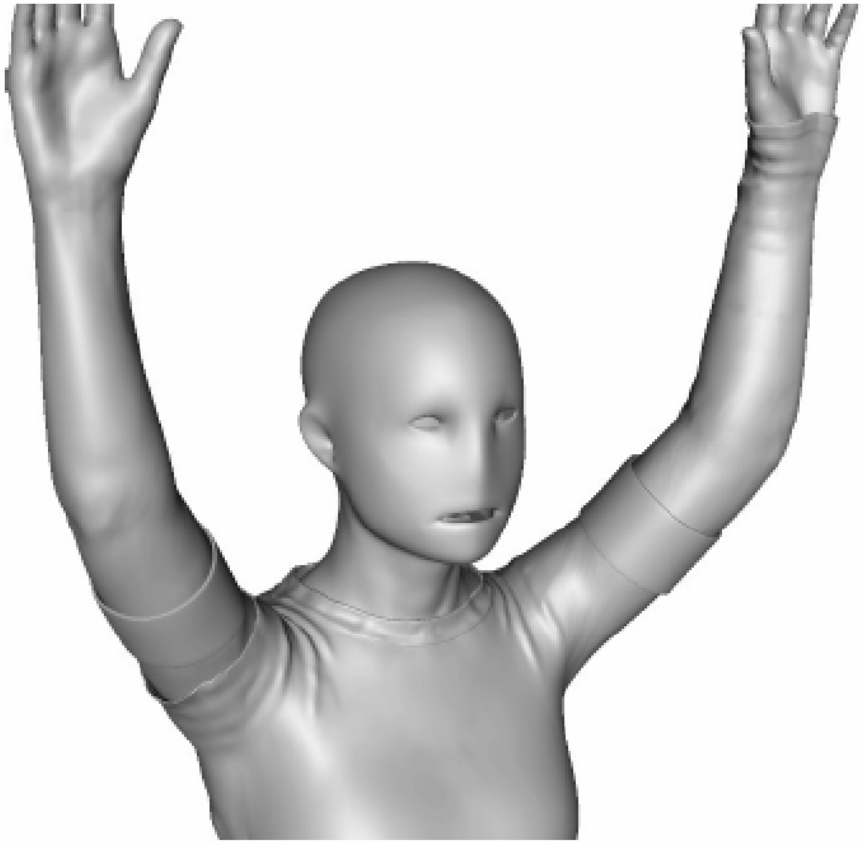


7-c: Single-Weight. It exhibits typical collapsing and crunching artifacts.

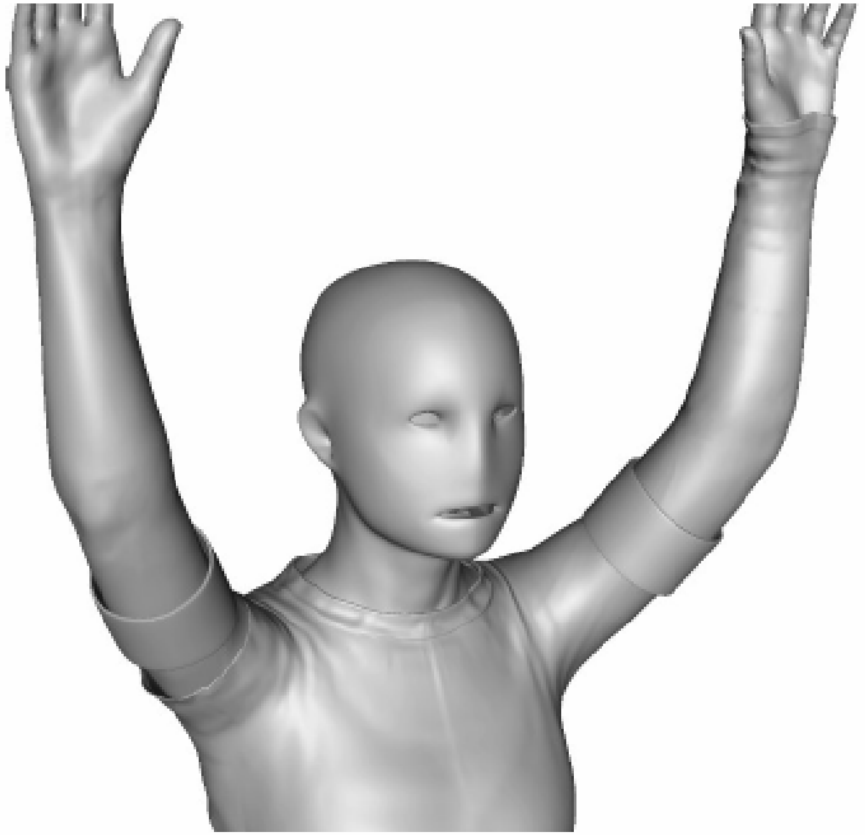


7-d: Multi-Weight. It shows a smooth shoulder with proper volume.

Figure 7: Multi-weight Skinning on the Human Creature



10-a: One of the 16 Input Poses



10-b: Multi-Weight on This Pose

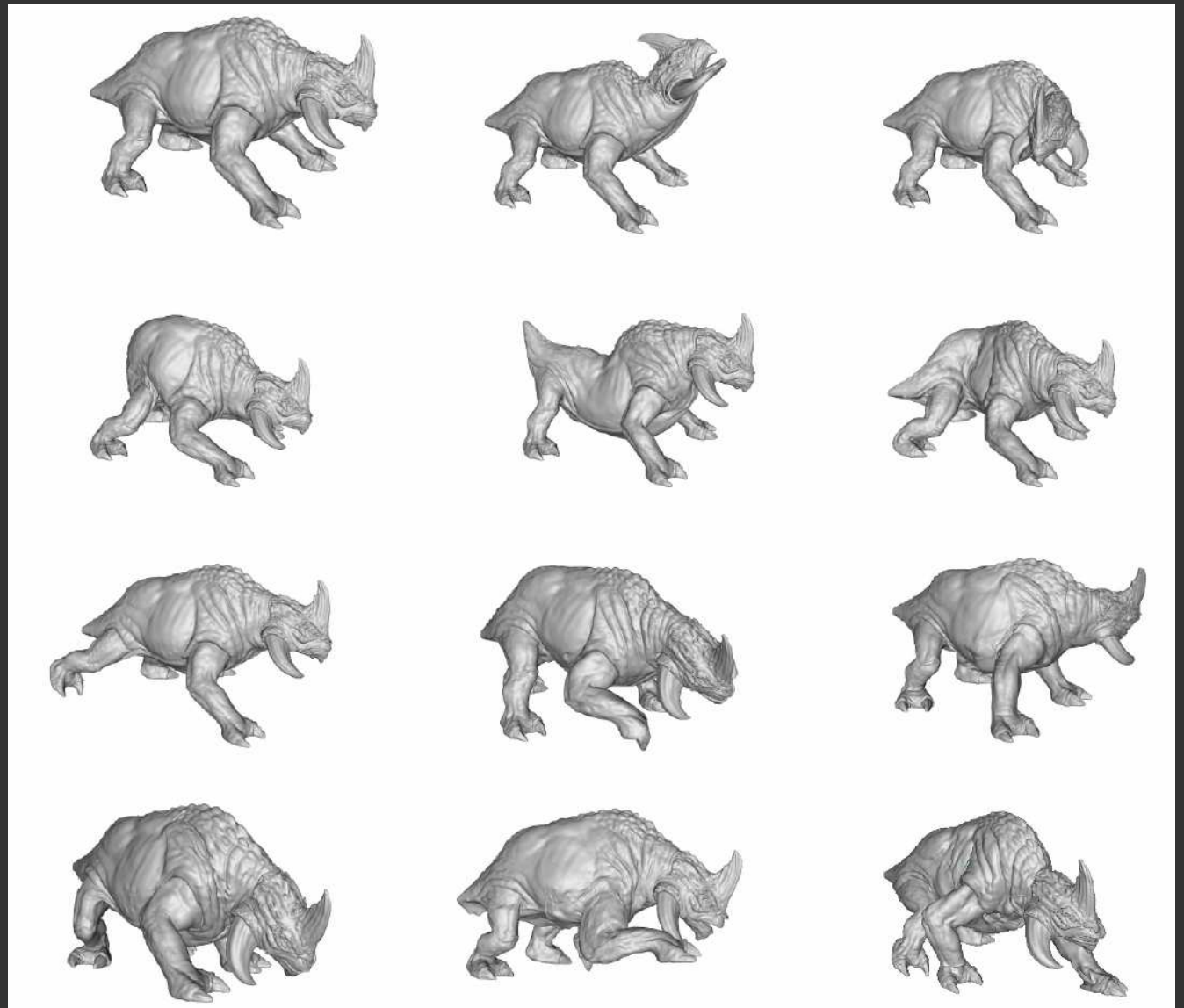


Figure 8: Example of Training Poses for the Animal Creature. Some poses are from the training exercise and some are from additional training animation sequences.

10-c: One of the 344 Input Poses

10-d: Multi-Weight on This Pose

Figure 10: Multi-weight Approximates the Input Poses

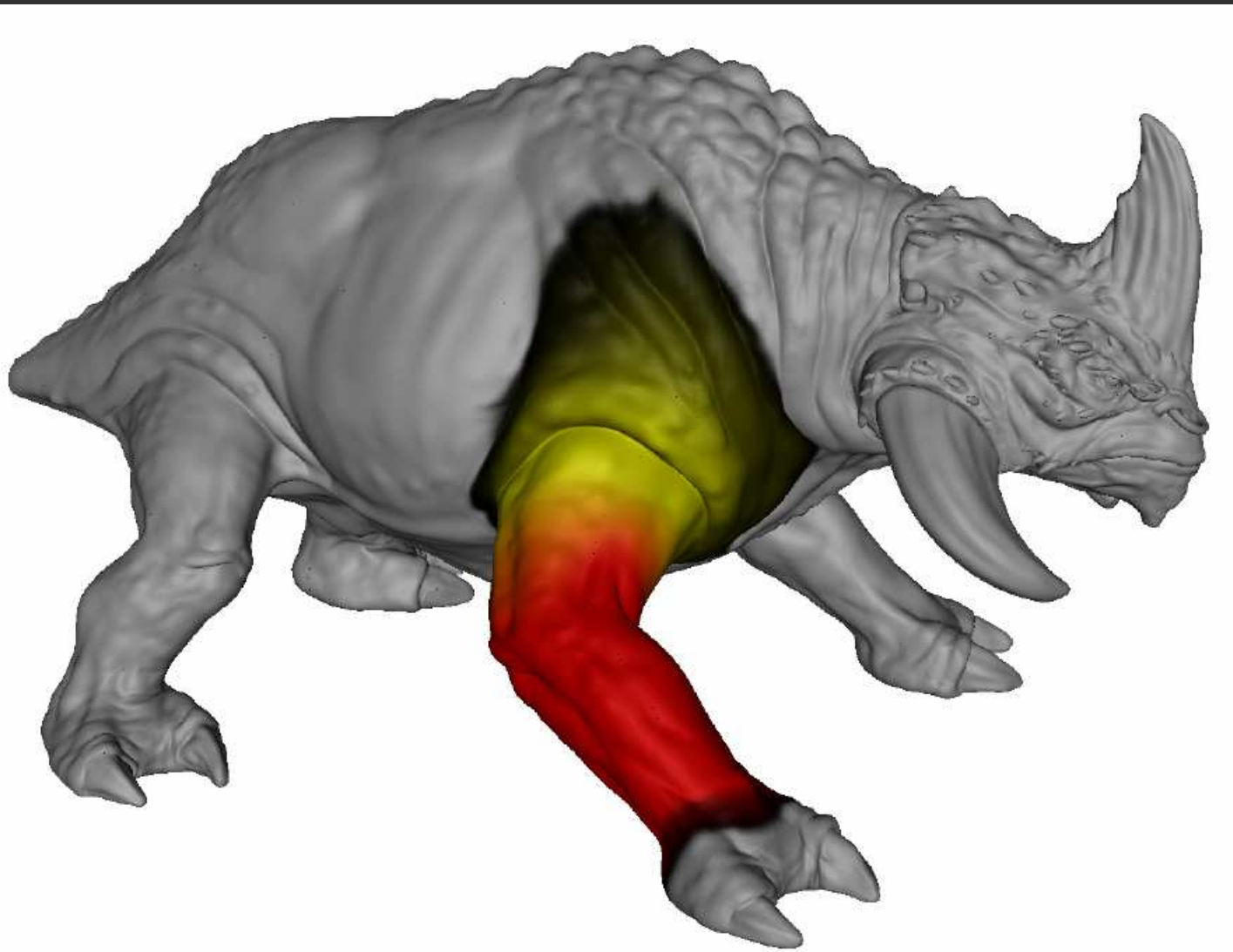
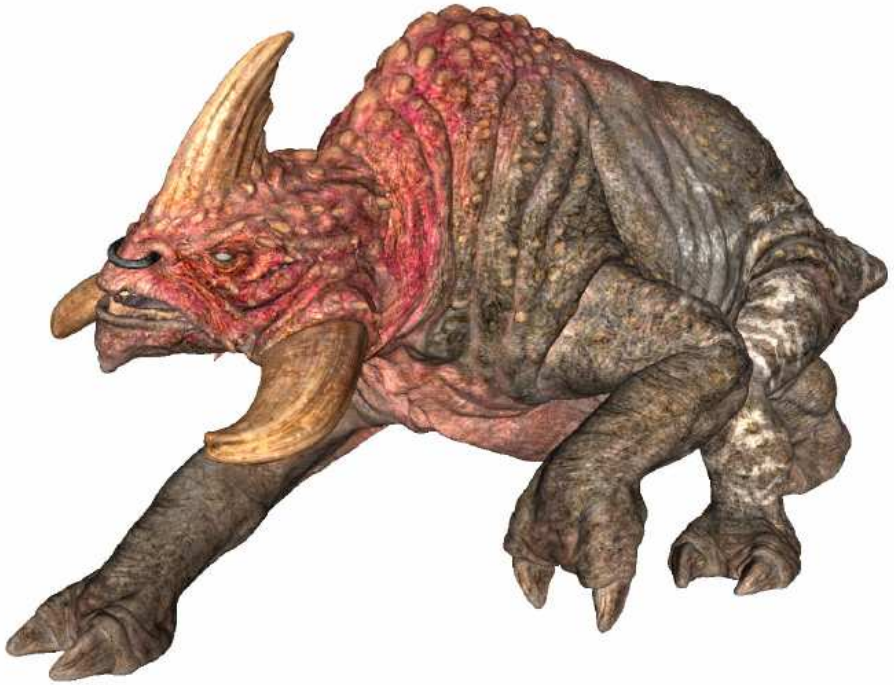
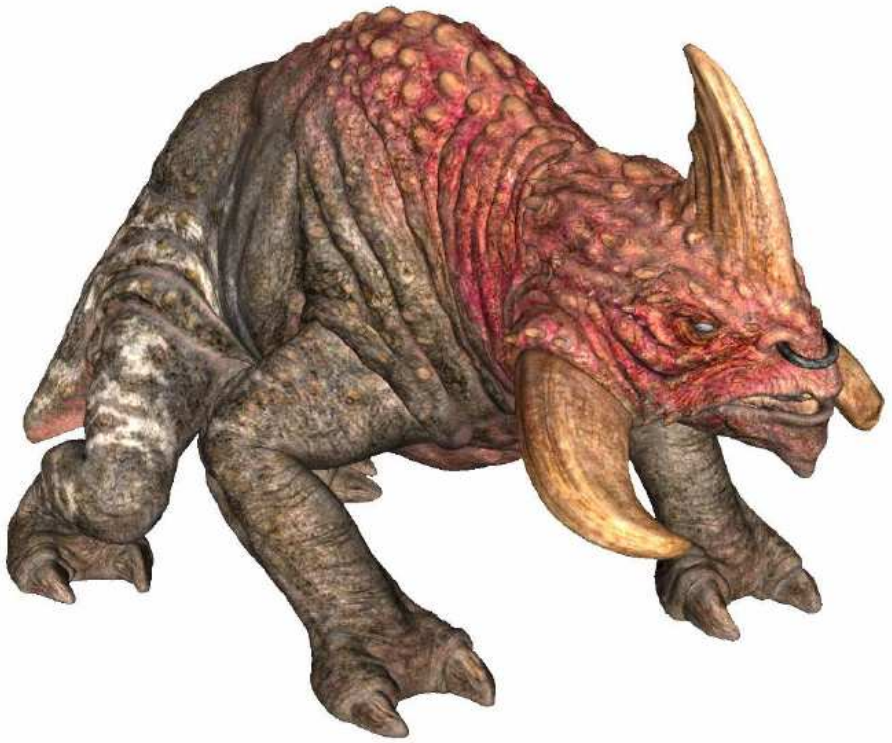


Figure 4: Color coded influences maps from two bones on the animal creature. The yellow area for the upper leg and the red area for the lower leg. The darker the area, the smaller the influence.



9-a: Multi-Weight on A New Animation Sequence (frame 42)



9-b: Multi-Weight on Another New Animation Sequence (frame 17)

Figure 9: Multi-weight Skinning on the Animal Creature

Outline of Remaining Classes

March

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

April

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

Presentations?

No class (SIGGRAPH papers meeting)

Radiometry; Global Illumin.

Project proposal due

Solving the Rendering Equation

Project progress report

Photon Mapping assignment due

Image based rendering; aliasing; …

Projects due: **May 2**

Project Proposal (due Apr 1 in class)

- 2 pages or less
- Prefer SIGGRAPH style LaTeX formatting
  - http://www.siggraph.org/publications/instructions
- Proposal structure:
  1. Abstract
  2. Introduction (What, why, related work)
  3. Details of approach
  4. Proposed work (incrementally defined)
     1. Will do (core material)
     2. Hope to do (time-permitting)
     3. Ultimately would like to do (if 1 & 2 get done)
  5. Summary of proposed contributions
  6. Use graphbib for References:
     http://www.siggraph.org/publications/bibliography