Hand Crafted

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Extended Abstract

In [Bloomenthal and Shoemake] *convolution surfaces*, an implicit modeling technique based upon three dimensional convolution, was applied to *skeletal primitives* (see [Bloomenthal and Wyvill]) to simulate a human arm. We present here the use of skeletal primitives and convolution surfaces for the modeling of a human hand. We begin with a review of the arm model, which consists of five 'muscles,' blended together and each represented by a planar polygon, diagrammed in Figure 1.

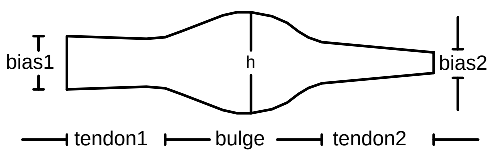

Figure 1: Individual Muscle and Parameters.

The five polygons, arranged as in Figure 2, were individually convolved with a windowed Gaussian kernel, and then summed. The surface was taken as the set {**P**} such that $F(\mathbf{P}) = \sum CS_i(\mathbf{P}) - c = 0$, where c is a positive constant and $CS_i(\mathbf{P})$ is the value at point **P** of the *i*-th convolution primitive.

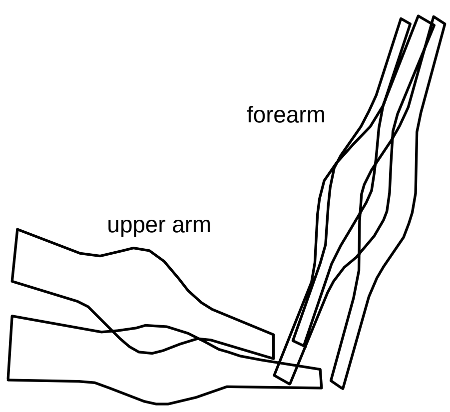

Figure 2: Arm Muscles.

Each convolution surface is evaluated independently, and, because of the superposition property of convolution, the sum of individual convolution surfaces does not produce unwanted bulging. Consider the convolution of a primitive with a filter kernel; this yields an iso-surface valued from (a normalized) 1 on the primitive to 0 when the distance to the primitive is greater than the kernel size. When the primitives are contiguous, the resulting implicit surface contains no bulge. The problem of bulging in implicit modeling is discussed in [Middleditch and Sears]; [Rockwood] presents an elegant solution that, however, requires interdependent evaluation of the primitives.

The arm is a collection of relatively amorphous muscles. We achieve greater definition in the hand by representing the bones of the palm and fingers with contiguous primitives. An additional primitive represents the muscle near the thumb, two sets of contiguous primitives represent the veins in the back of the hand, and five sets of contiguous primitives represent the tendons.

Modeling the human hand has interested numerous researchers. [Thompson *et al*] simulates the mechanical aspects of the hand by manipulating the position and orientation of bones; an overlying skin is not, however, produced. [Gourret *et al*] models the hand as a deformable surface overlying a bone structure; the surface is parametrically defined and deformed according to forces acting upon the hand. [Forsey and Bartels] introduces a sophisticated method for controlling parametric surfaces that allows the automatic creation of surfaces from articulated, contiguous skeletons; inclusion of bulges from disjoint primitives is considered in [Forsey].

Unlike implicit techniques, parametric techniques must explicitly account for surface topology. For example, as the thumb muscle contracts, the topology of the vertex network of the surface may change. Such changes are easily accomodated within an implicit modeling system. This is an issue not only for models whose shape changes, but also for the design of new models: parametric systems must carefully attend to the topology of the resulting surface.

As shown in Figure 3, the skeletal primitives of the hand include:

palm bones: a contiguous set of 15 triangles,
finger bones: a contiguous set of 48 triangles,
tendons: five sets of connected line segments, 10 in total,
veins: two sets of connected line segments, 11 in total,
muscle (adductor pollicis): one line segment,

resulting in a total of 85 convolution surface primitives.

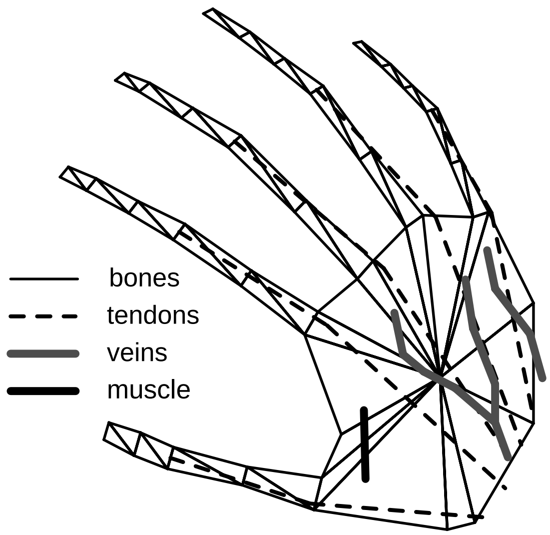

Figure 3: Hand Skeleton.

The triangles that constitute the skeleton beome oblong upon convolution. This oblong quality is only an approximation to the bone and muscle within a finger, and the smooth encasing by skin.

The user does not directly define these primitives, however; rather, each finger is specified by two Euler angles and the amount of grip at each of its two (one for the thumb) joints. Even this level of control may be unnecessarily complex; [Wilhelms] has proposed methods whereby joint angles may be derived from goal oriented specifications. Alternatively, finger parameters may be read directly from special purpose input devices.

The following page displays individual and summed convolution surfaces that constitute the hand. At the upper left are the fingers in isolation; at the upper right are the tendons in isolation. The middle left shows the palm and the middle right shows the veins and the thumb muscle. At the lower left is the combination of palm and fingers, and at the lower right is the complete hand, consisting of fingers, palm, muscle, tendons, and veins.

We hope these images demonstrate that a design environment utilizing convolution surfaces can create complex, well-behaved shapes by simply adding/deleting, positioning/orienting, and scaling/proportioning individual skeletal primitives.

We have yet to animate the hand to observe its articulated behavior. A number of issues are expected to arise, including the prevention of unwanted blending between individual convolution surfaces; for example, when two fingers approach each other, they should not blend.

Additional aspects of the model concern realism. The easily controlled blending of individual convolution surfaces facilitates the design of the macro structure of the hand. Highly realistic models also require micro details such as nails, wrinkles, and creases. We hope to investigate these details in the future.

References

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