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The digital fur in "Cats and Dogs" requires fully CG animals to be seamlessly intercut with their live-action cat, dog, and mouse counterparts. Realistically groomed, animated, and rendered fur is essential to achieving this effect for various types of fur coats. The ninja cats have short sleek hair closely matted against the skin. In contrast, the villainous Mr. Tinkles is a Persian with long and fluffy plumes. Not only must these animals talk, but the furry cast must also perform martial arts and operate tools and machinery such as drills, guns, and log-loaders.

GROOMING

We begin with a partition of the polygonal skin geometry. The "element normal" and "uv" parameters define a spatially and temporally consistent field of coordinate systems providing for precise local positioning and grooming control. Spline-based control hairs are rooted onto the skin surface through density maps or modified through direct modeling. An interactive 3D fur grooming tool sculpts and grooms the control hair geometry based on global and texture-based parameters such as length, scruffiness, and curvature. The same tool is used to control additional attributes of the instantiated fur. Noise controls generate the irregularity necessary for a natural appearance. Efficient clumping is achieved by correlating the hundreds of thousands of hairs using a clump-control image. Hairs are assigned to various coats such as a thick, dark undercoat, or a sparse set of specular hairs.

ANIMATION

As geometry, the control hairs can fully utilize the transformation tools in our proprietary animation program. For example, blend shapes target specific emotions. Control is added to constrain the hairs to the surface of the deforming skin. Specialized dynamics modules are written to support concepts such as cohesion and collision using the hair root and tip connectivity.

RENDERING

Each hair strand is converted by the renderer into a polygonal ribbon representing a generalized cylinder traveling along a Catmull-Rom spline. The ribbon, automatically oriented to squarely face the camera, consists of trapezoidal segments whose density depends on hair length and curvature, as well as camera distance. This arrangement minimizes the hair's polygon count while maintaining frame-to-frame coherence.

The true geometric normals of a hair ribbon are useless for shading. Instead, we use the hair's tangent vectors, which are easily obtained from its spline path. We chose the cylinder-based shading model originally presented by Kajiya and Kay. It produces realistic shading that is free of aliasing and correctly handles backlighting, the phenomenon where edge hair lights up when placed between the light and camera.

The gradual self-shadowing by layers of semi-transparent hair is essential to a photo-realistic render. To capture this, we compute a normal vector and depth value for each hair control point. These define an imaginary sphere that encloses the control point. The distance along any direction from this point to the sphere surface represents the amount of hair material that shadows the control point.

To obtain the self-shadowing normals and depth values, all hair control points are inserted into a voxel grid. A ray-marcher then determines, in each voxel, the ray that escapes the point cloud while encountering the fewest points along the way. We specially mark voxels containing skin polygons, so as to prevent rays from escaping through the skin. After computing the normal and depth values at each voxel, we interpolate them over all the control points. The resulting self-shadowing accurately portrays hair clumping and bald spots.