Computer animation
Hair

“A Survey on Hair Modeling: Styling, Simulation, and Rendering,” K. Ward, F. Bertails, T.-Y. Kim S. Marschner, M.-P. Cani, M. Lin

Shape – handle various hair styles

Motion – dynamic grouping and splitting of hair clusters, collision of hairs, seconday motion due to head motion

User Control – over hair style, properties

Properites – coarse v. fine, dry v. wet, stiff v. loose, oily v. clean, hair strand types

Shape – handle various hair styles

Distribute strands

Create hair styles

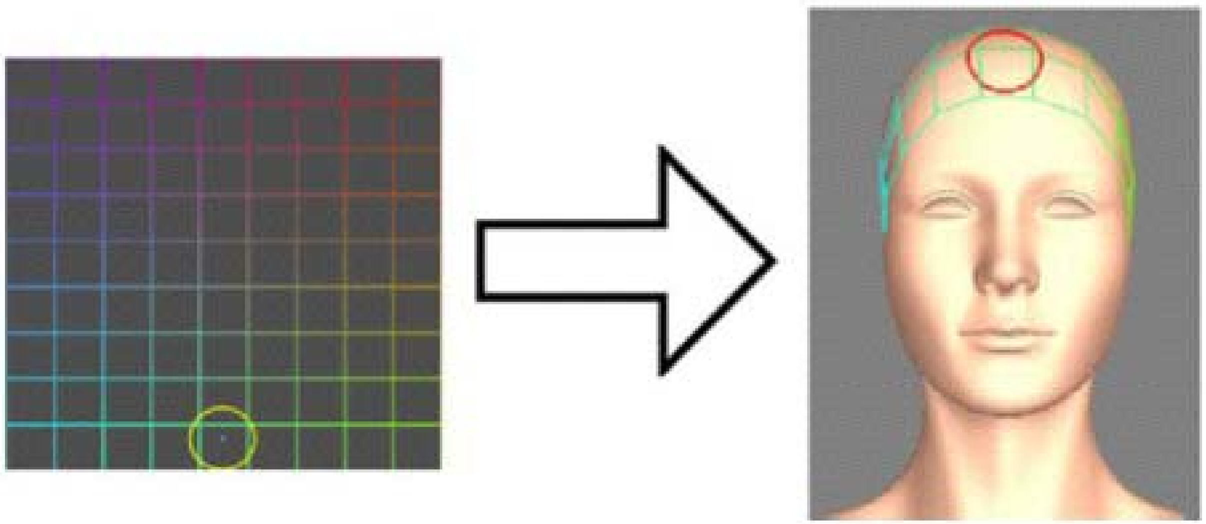

Fig. 1. 2D square patch wrapped onto the 3D model by the method of Kim *et al*. [9].

Distribute strands

Fig. 2. Modeling hair using NURBS surfaces [16] (left). The Thin Shell Volume [19] (right)

Conform strands to head

Fig. 3. The cluster hair model [20] [21]

Work with clusters of hair strands

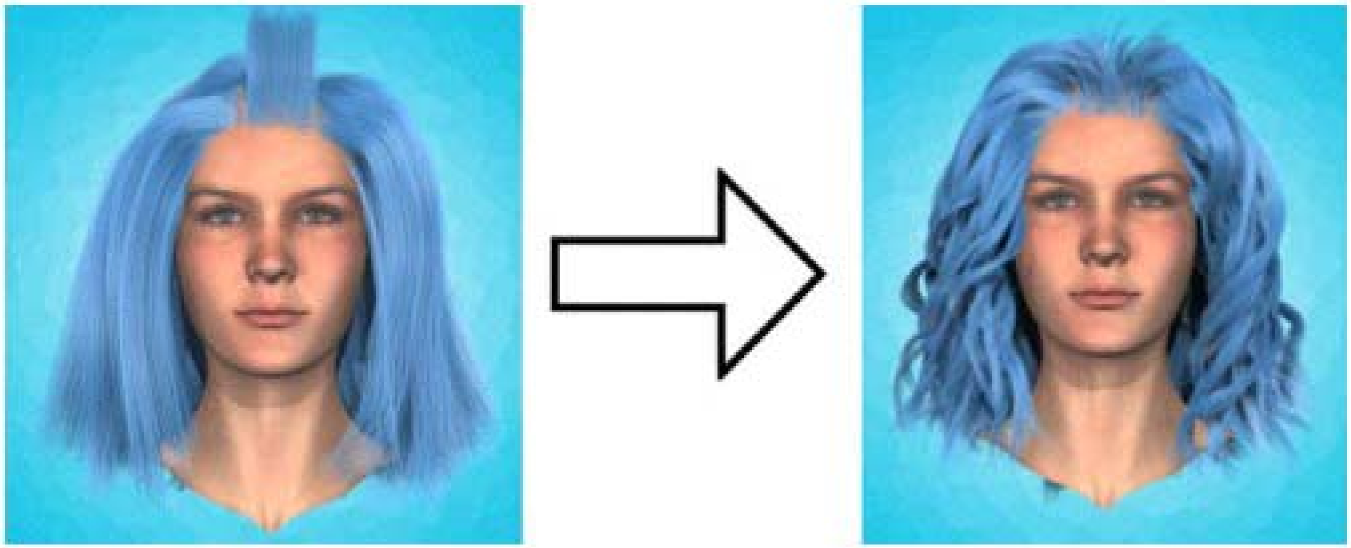

Fig. 4. Multiresolution hairstyling [9]

Multi-resolution techniques

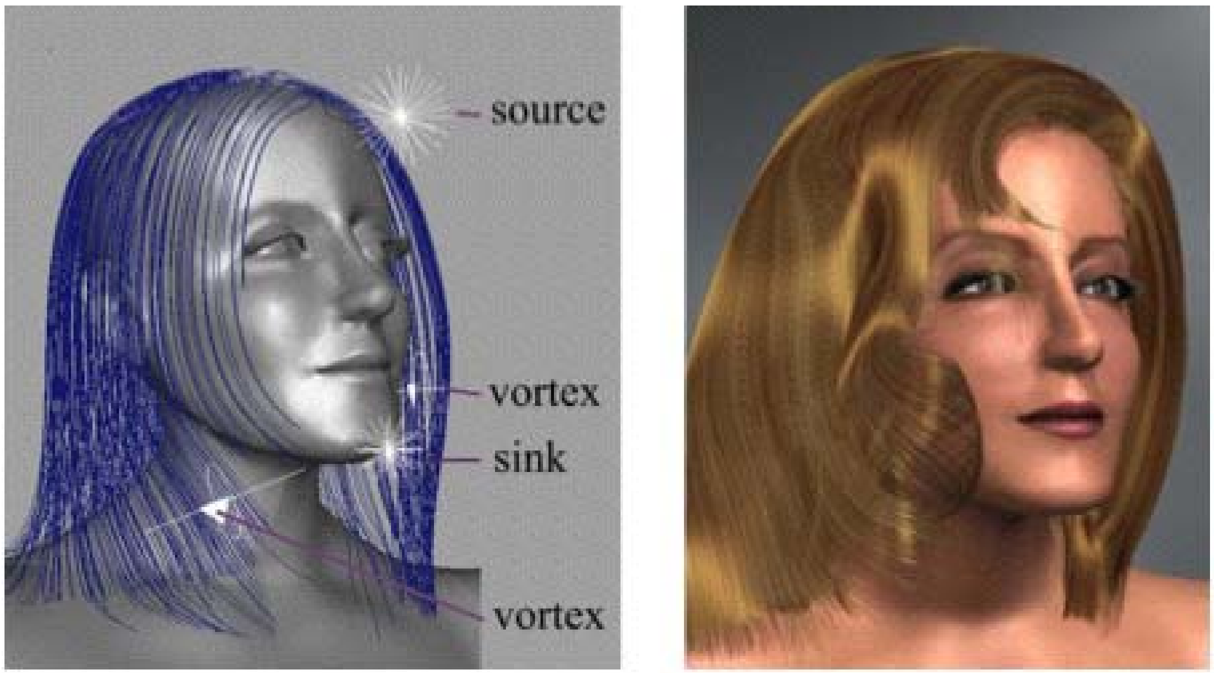

Fig. 5. Modeling hair using a fluid fbw [24]

Use fluid flow to define hair strand ‘paths’

Vector field

Constraints for complex hair styles

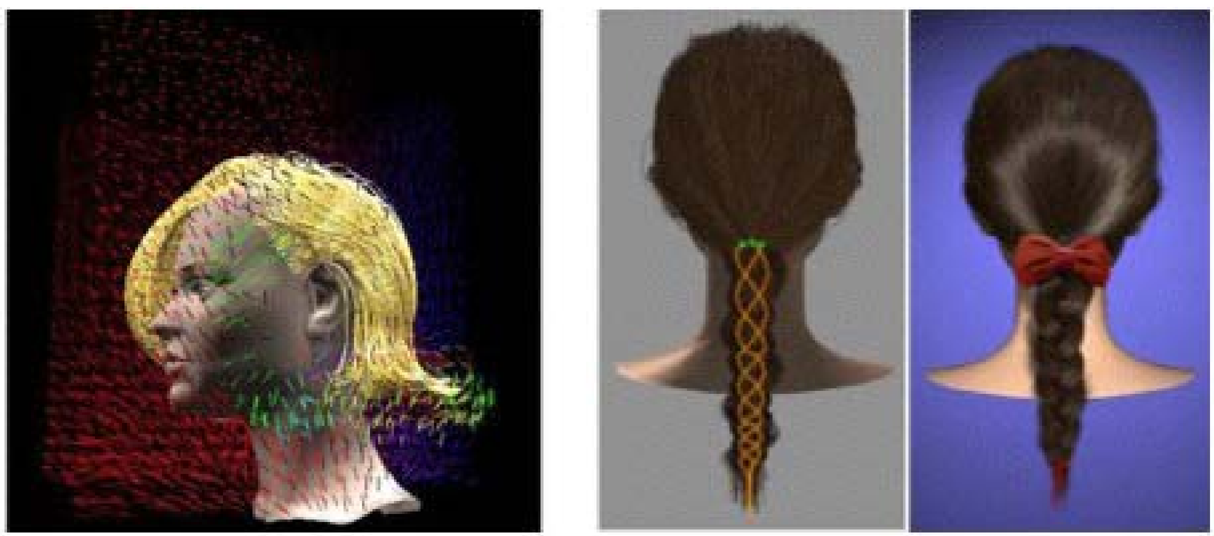

Fig. 6. A styling vector field [8] (left) and constraint-based hairstyling [13] (right)

From photographs

Capture local orientations

Fig. 7. Hair capture from photographs [28]

Comparison of shaping techniques

	Hair Shapes	User Control	Manual Time
Gen. Cylinders	flexible	high	slow
Surfaces	limited to straight	high	fast
Physical Volumes	limited, details hard	cumbersome	medium
Photos	limited, must exist	none	fast
Sketches	limited, details hard	medium	fast

TABLE I

Procedurally generate style
Pseudo-random
Semi-automatic

Fig. 8. Waves and curls procedurally generated by Yu [8] (left) and Choe *et al*. [13] (right)

Fig. 9. A real ringlet (left), and a synthetic one (right) automatically generated by the physically-based method of Bertails *et al*. [6]

Physically based method

Energy minimization

Hair dynamics

Fig. 10. Comparison of hair (a) dry and (b) wet [33].

Allow common hair solon operations

Wetting, Blow-drying, etc.

Hair simulation

Mechanics: curl, elasticity, cross section

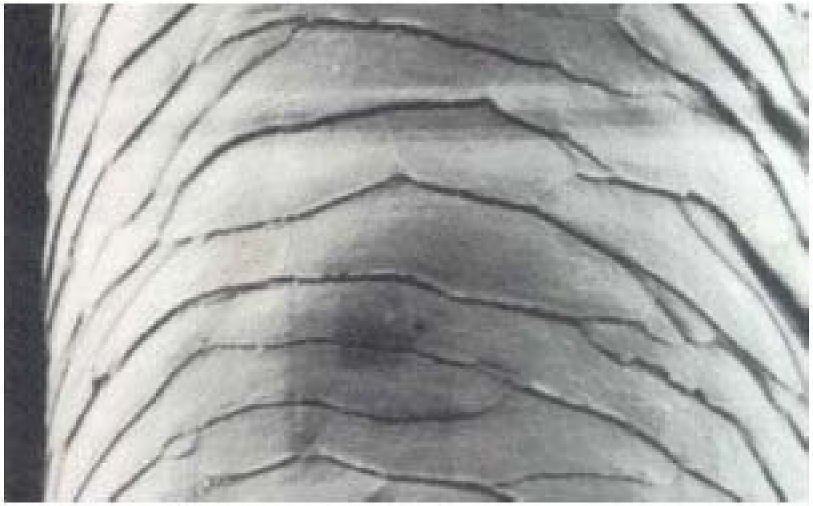

Fig. 11. An electron micrograph of a hair fiber that shows the structure of the outer cuticle surface, which is composed of thin overlapping scales [4].

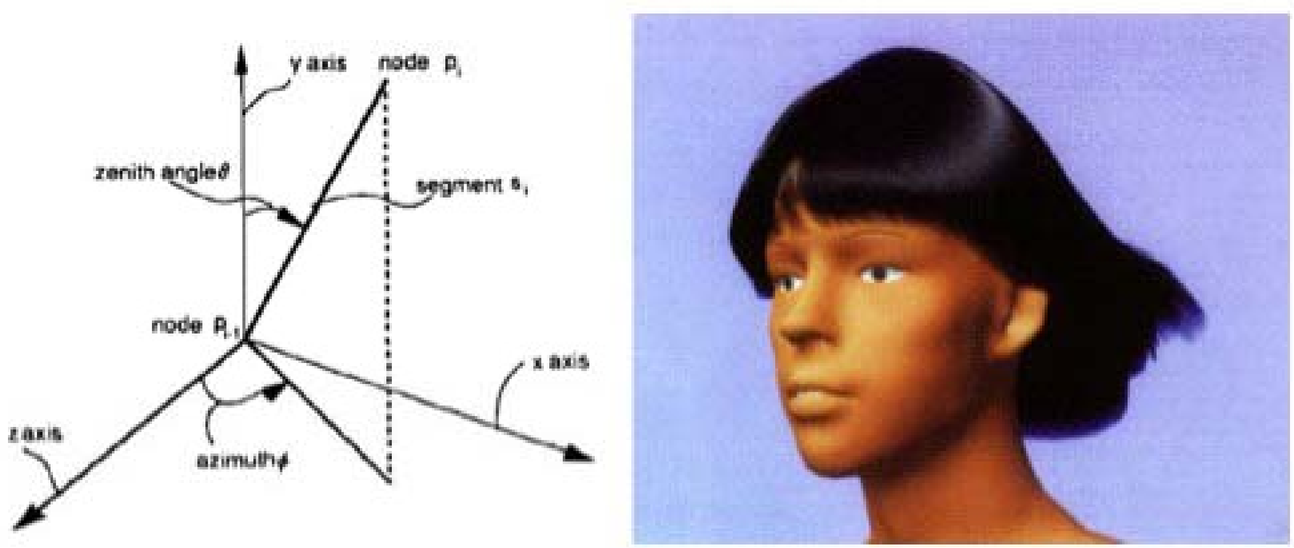

Fig. 12. Left: the polar coordinate system for a hair segment. Right: simulating individual hair strands using one dimensional projective equations for dynamics [3].

Hair strand
chain of rigid links v. spring-dampers

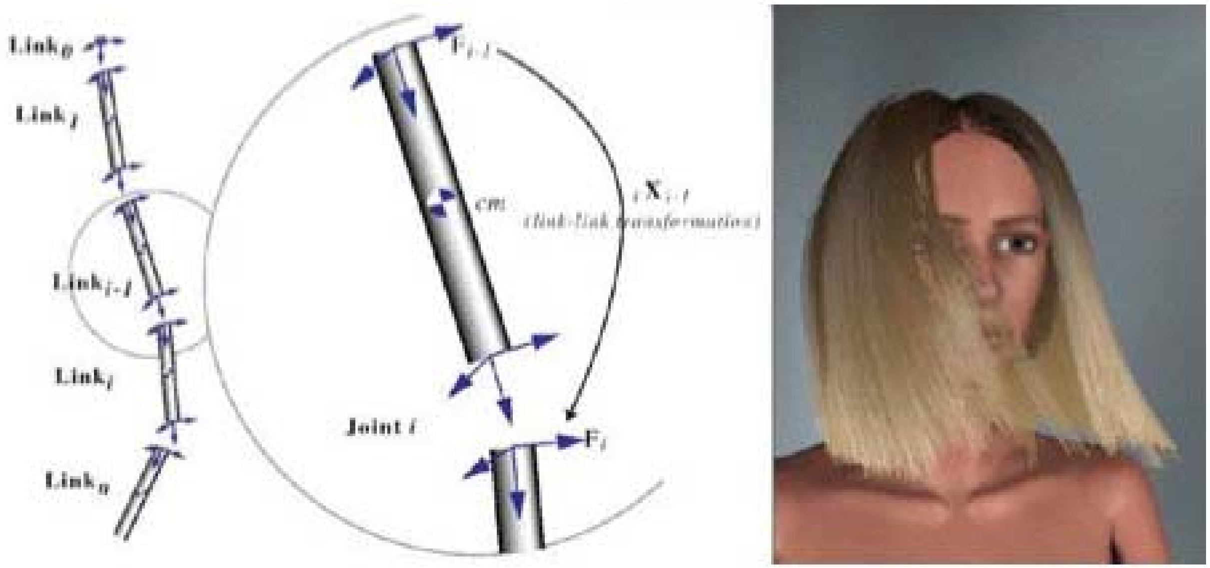

Fig. 13. (left) Hair strand as a rigid multi-body serial chain [41] (right) Simulation of hair blowing in the wind using fluid flow.

Comparison of simulation techniques

	Mass-springs	Projective dynamics	Rigid multi-body serial chain	Dynamic Super-Helices
Bending	yes	yes	yes	yes
Torsion	no	no	yes	yes
Non-stretching	no	yes	yes	yes
Curliness	no	no	no	yes
Constraints	easy	tricky	tricky for hard	tricky for hard

Fig. 14. (left) Particles defining hair, line segments indicate direction (right) Animation of hair with head shaking [10].

Particle physics
Fluid dynamics

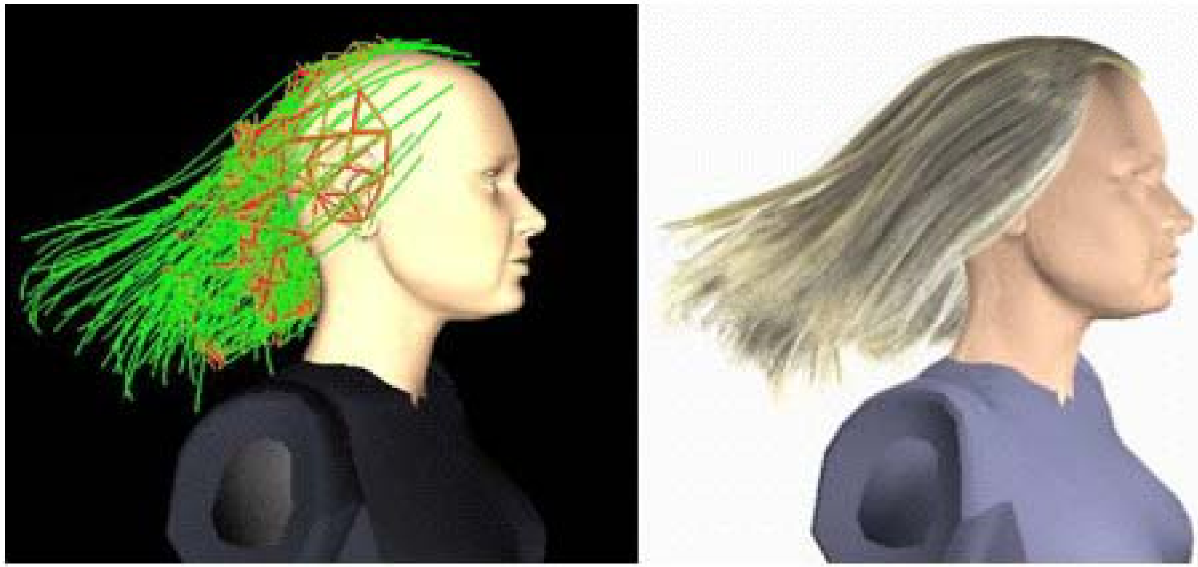

Fig. 15. (left) Sparse hair model with static links and (right) Rendered image of interpolated dense hair model [32].

Use guide strands for animation
Then interpolate for dense hair model

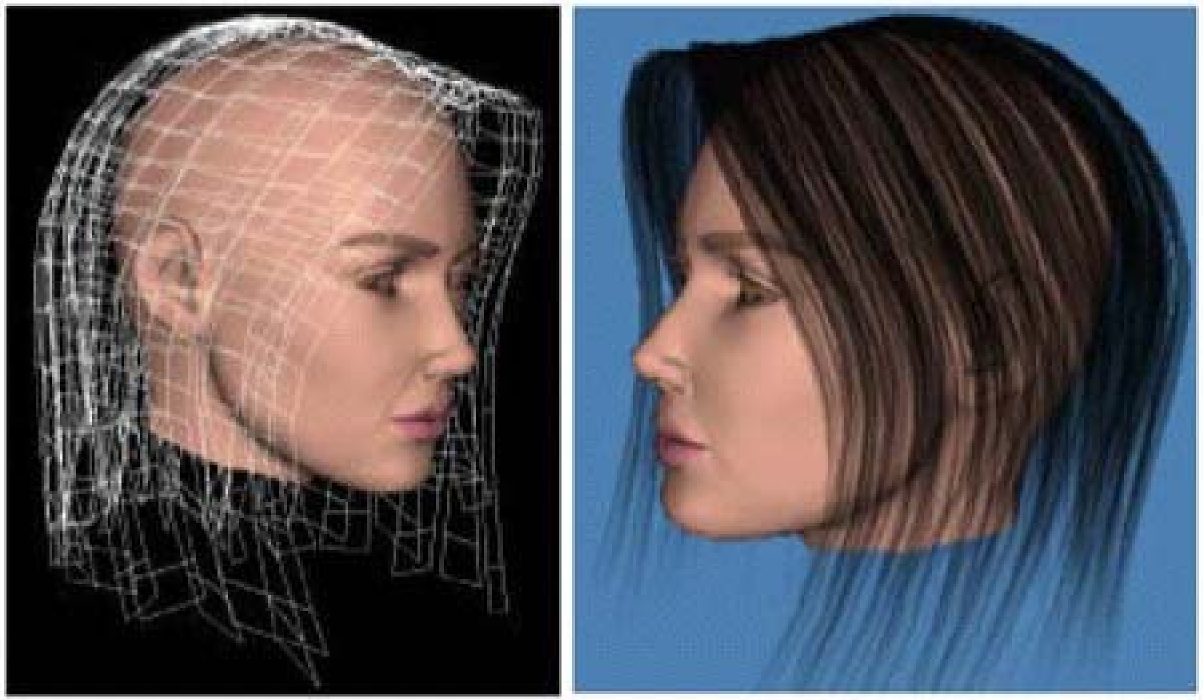

Fig. 16. Hair strips as an approximate hair model [16].

Hair strips to represent hair clusters

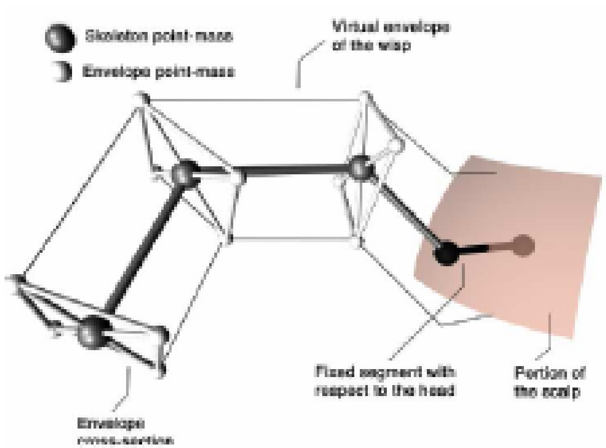

Fig. 17. Elements defining a deformable volumetric wisp [12].

Fig. 18. The layered wisp model [12] (bottom) captures both continuities and discontinuities observed in real long hair motion (top).

Level of detail representation for animation

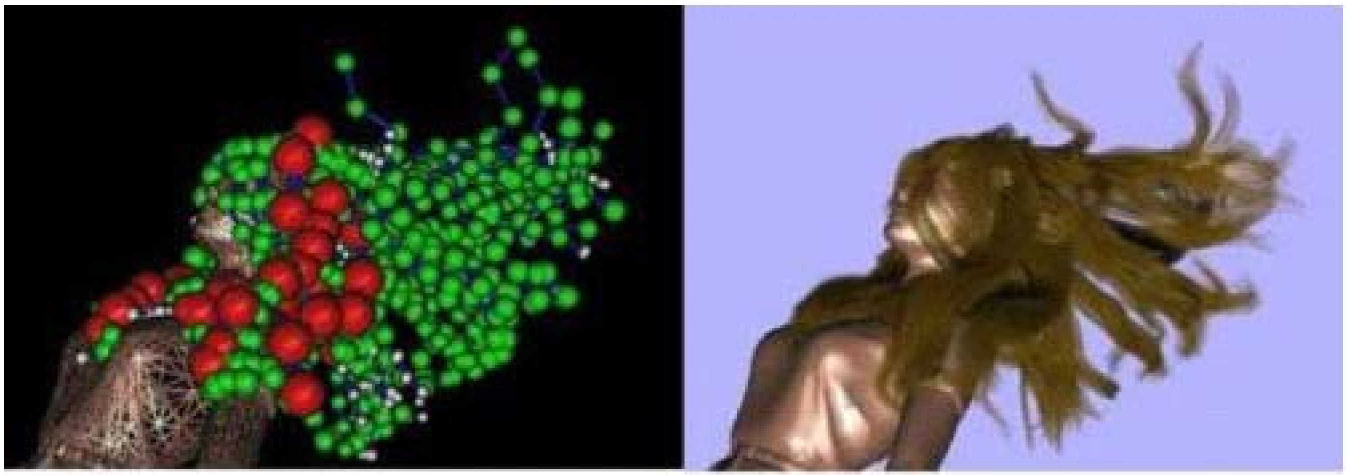

Fig. 20. Illustration of the AWT on long hair (left) and its final rendered version (right) [40].

Adaptive clusters, merge and split

Hair rendering

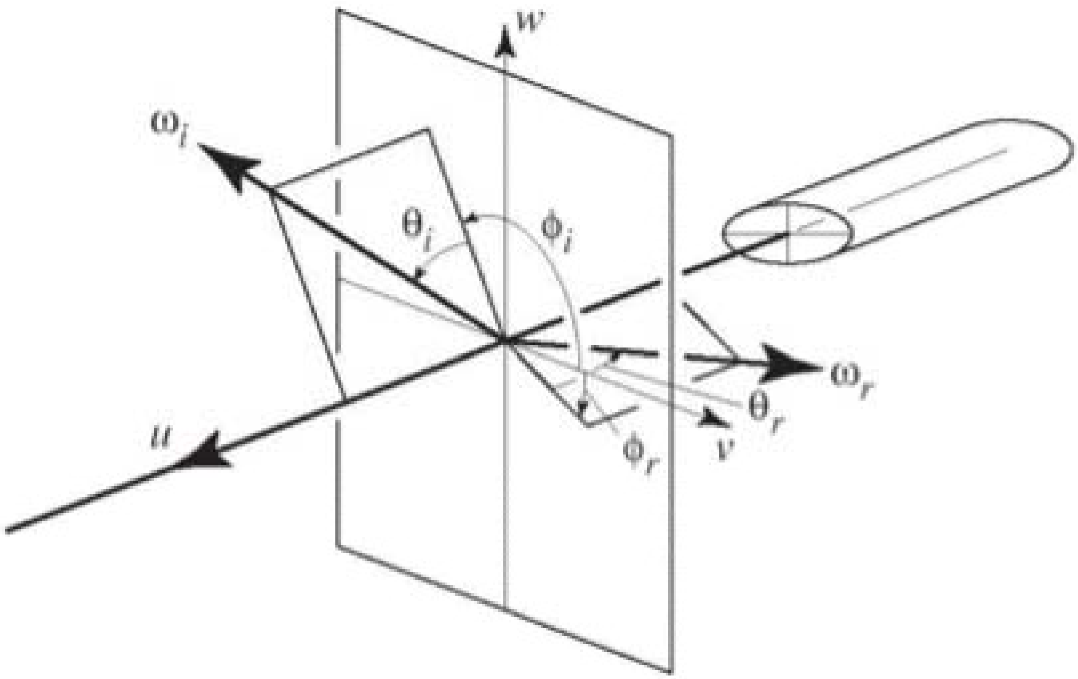

Fig. 21. Notation for scattering geometry

Fig. 22. Comparison between Kajiya's model (left), Marschner's model (middle) and real hair (right).

Fig. 23. Importance of self-shadowing on hair appearance. (left) Shadows computed using Deep Shadow Maps [75] compared to (right) No shadows. Images courtesy of Pixar Animation Studios.

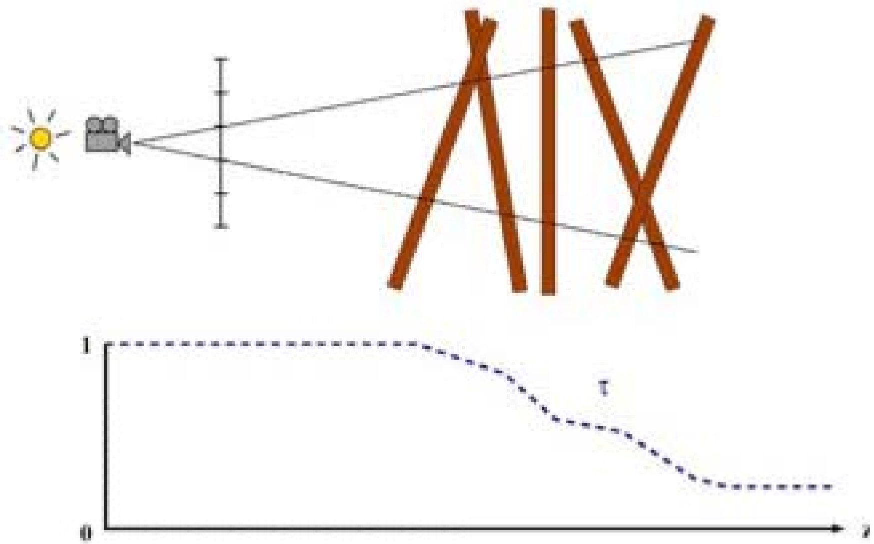

Fig. 24. Top: a beam of light starting at the shadow camera origin (*i.e.*, the light source) and passing through a single pixel of the deep shadow map. Bottom: the corresponding transmittance (or visibility) function τ, stored as a piecewise linear function.

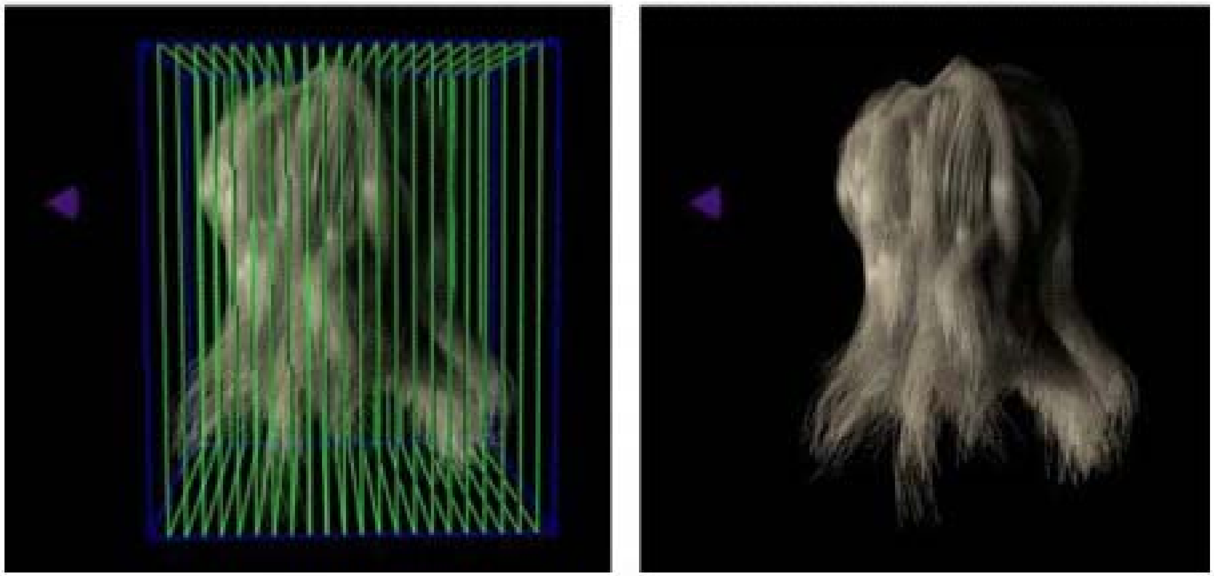

Fig. 25. Opacity Shadow Maps. Hair volume is uniformly sliced perpendicular to the light direction into a set of planar maps storing alpha values (top). The resulting shadowed hair (bottom).

Fig. 26. Interactive hair self-shadowing processed by accumulating transmittance values through a light-oriented voxel grid [80]. (left) Animated hair without self-shadows; (right) Animated hair with self-shadows.

Fig. 27. Real-time rendering of long, moving hair using recent graphics hardware [83]. Image Courtesy of NVIDIA Corporation, 2004