Computer Graphics & Scientific Visualization

MPRI 2-39

Character Animation II: Skin, Clothes and hair

Character Animation II

1- Animating character Skin

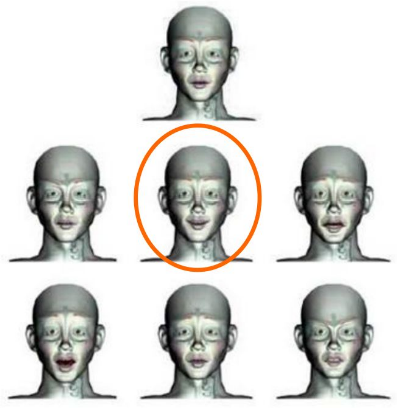
2- Animating character Cloths

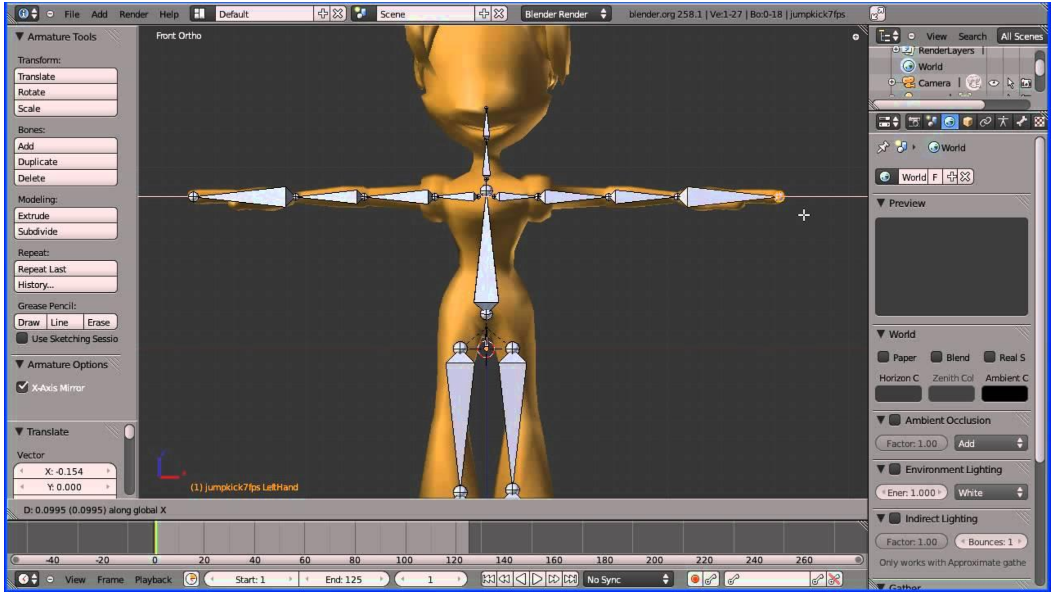
3- Animation character Hairs

Animating sking

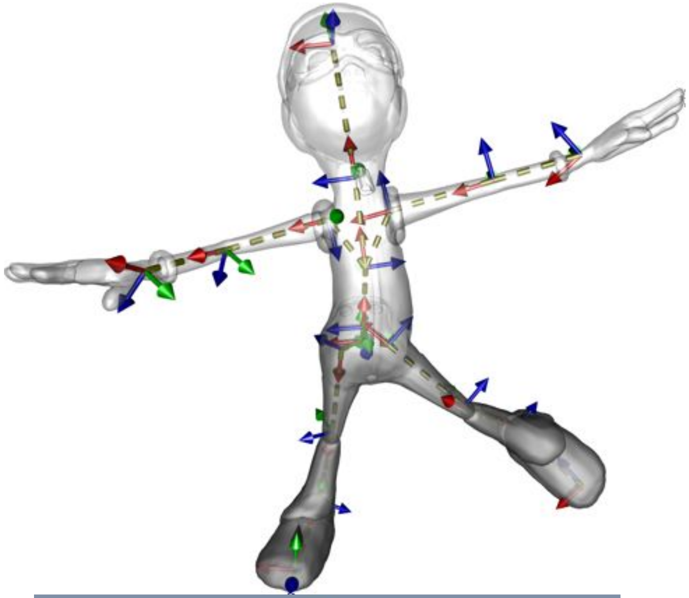
a. Standard approach: Skinning
b. Study cases of skinning improvement

Note:
Valid for articulated **body** skin
For skin **face**: mostly based on **blend shapes**





Animating skin



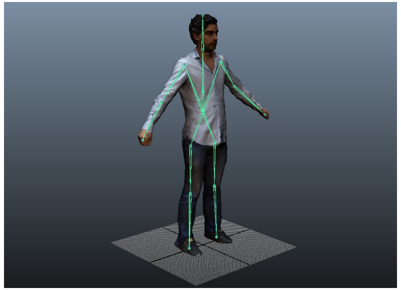
Animated Character = A skeleton + a Mesh

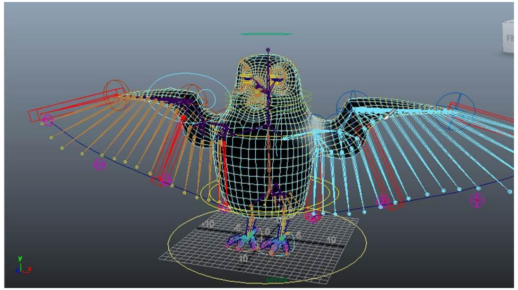
Remind:

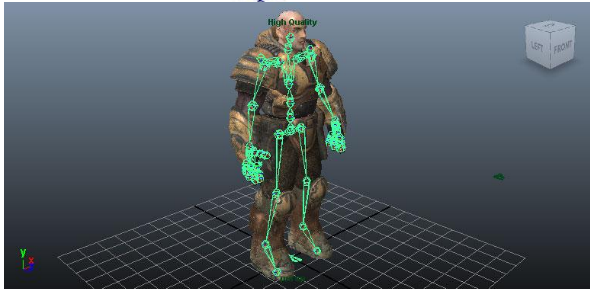
- *Skeleton* = set of hierarchical frames.
- We know how to *pose/animate* a skeleton.

Objective:

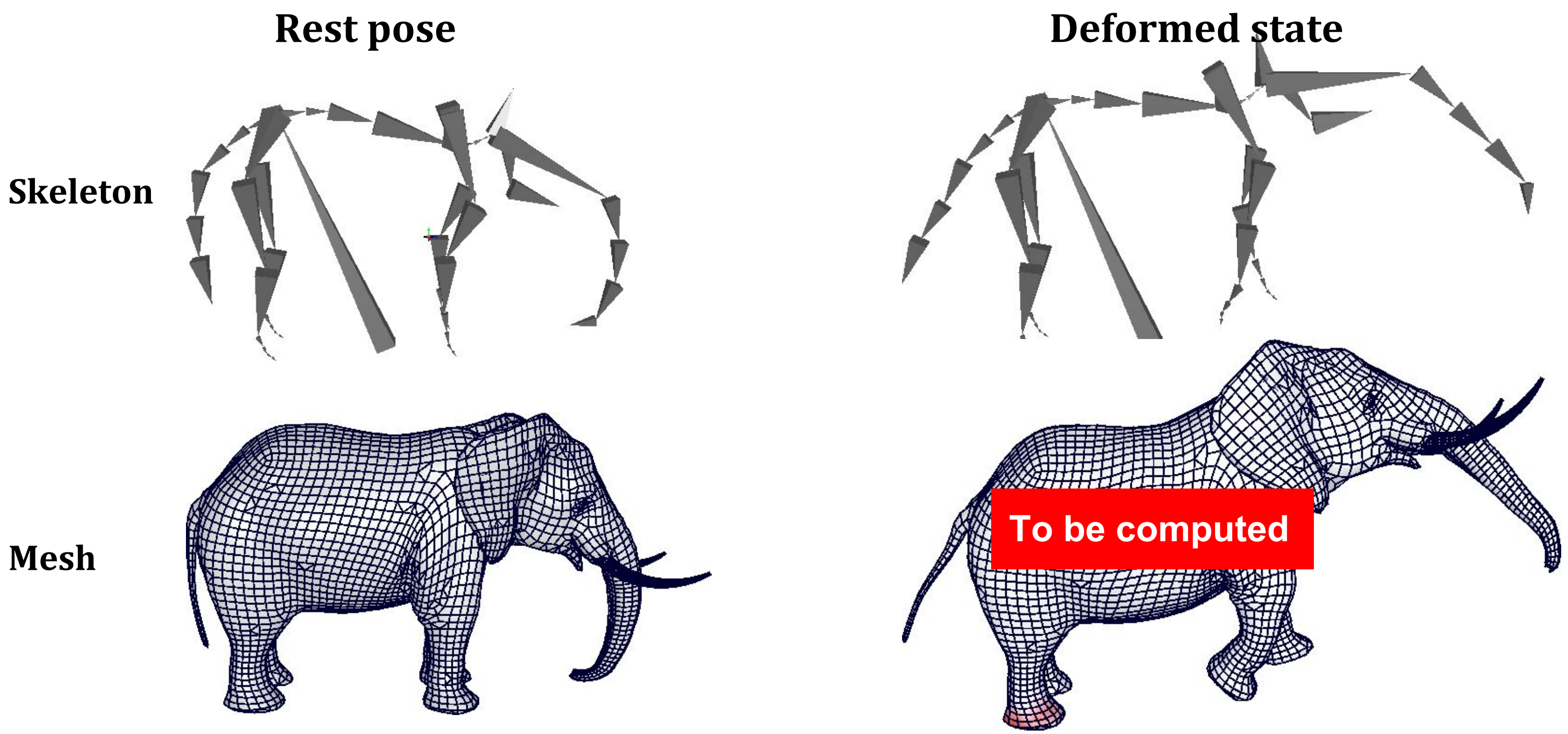
- Deform the mesh, given a skeleton







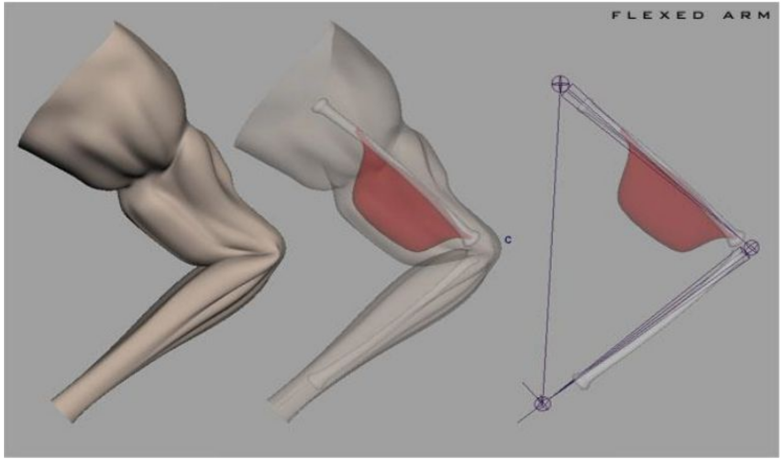
Animating skin: problem set up



“Brute force” physically based approach

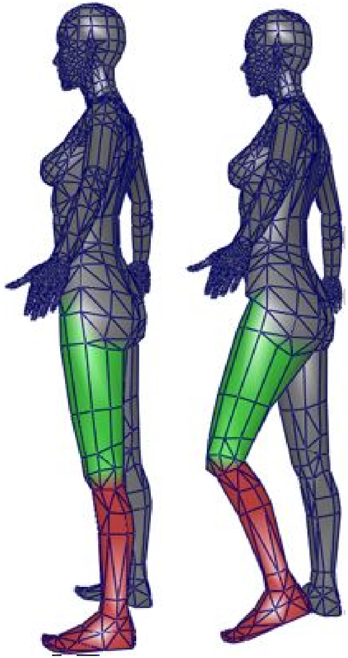
a. Model muscles attach to bones
b. Simulate muscle deformation using FEM
c. Add an elastic skin layer on top of the muscles

+ Can achieve very detailed and dynamic results
- Computational time, very hard setup

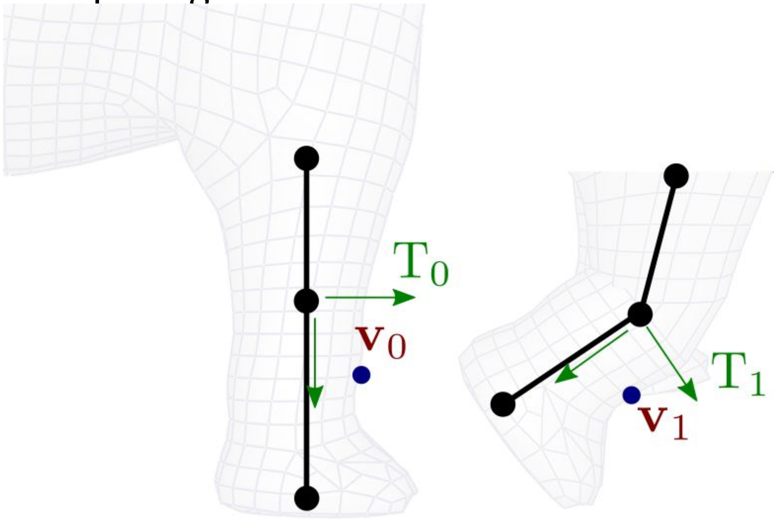


Geometrical approach: Skinning

Rigid skinning: Associate parts of the mesh rigidly to bones

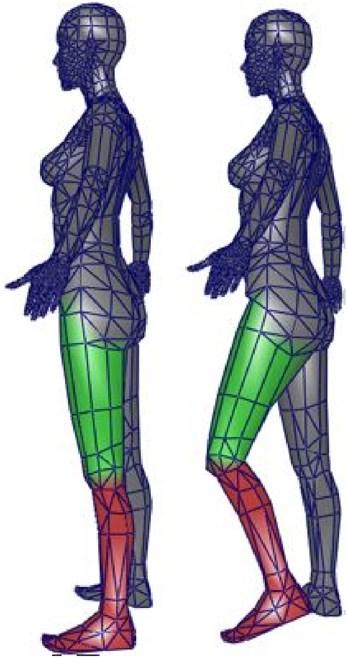


Computing the vertex deformation

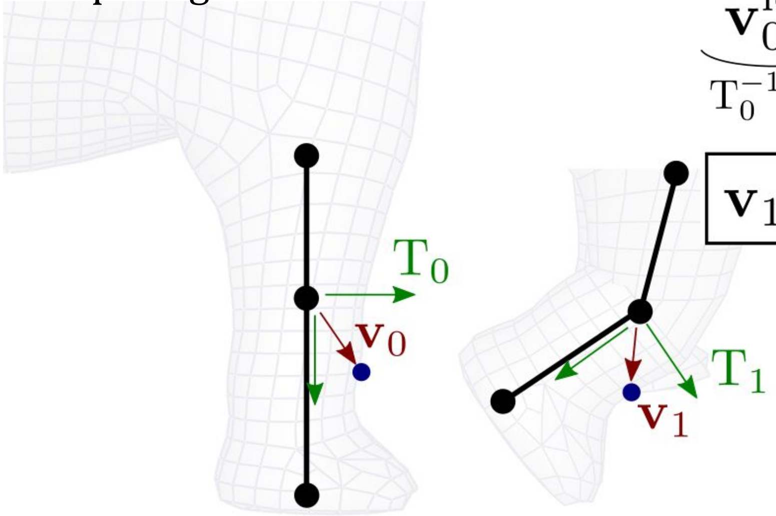


Rigid skinning

Associate parts of the mesh rigidly to bones



Computing the vertex deformation



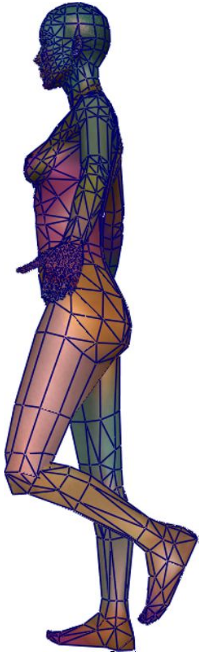
$$\underbrace{\mathbf{v}_0^{\text{local}}}_{T_0^{-1}\mathbf{v}_0} = \underbrace{\mathbf{v}_1^{\text{local}}}_{T_1^{-1}\mathbf{v}_1}$$

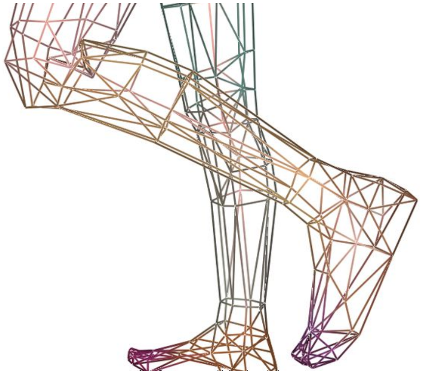
$$\boxed{\mathbf{v}_1 = T_1\, T_0^{-1}\mathbf{v}_0}$$

Rigid skinning

Skeleton is easy to construct, to animation, intuitive manipulation

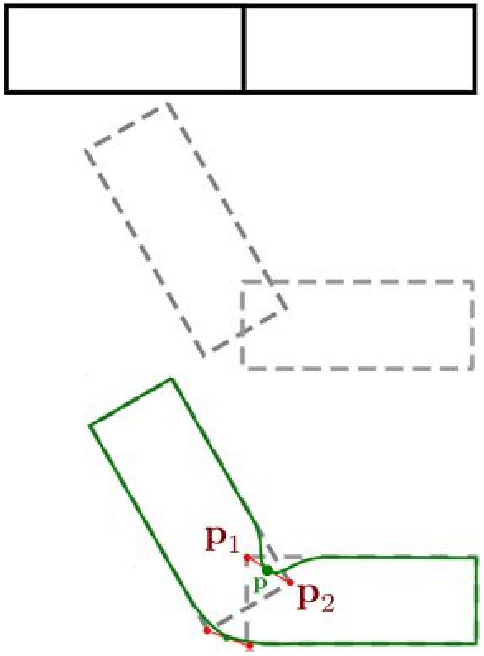
But: rigid skinning is discontinuous





Smooth skinning

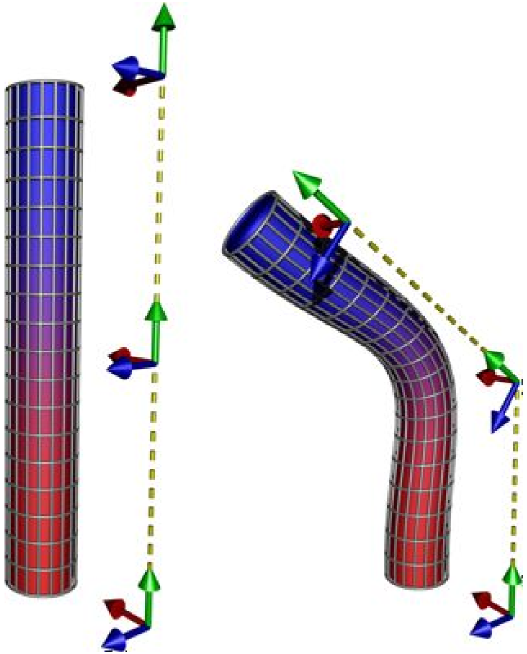
Idea: Interpolate positions between frames



$$\mathbf{p} = 0.5\,\mathbf{p}_1 + 0.5\,\mathbf{p}_2$$

$$\mathbf{p} = 0.5\,\mathrm{T}_1\mathbf{p}_0 + 0.5\,\mathrm{T}_2\mathbf{p}_0$$

$$\mathbf{p} = \underbrace{(0.5\,\mathrm{T}_1 + 0.5\,\mathrm{T}_2)}_{\alpha\mathrm{T}_1 + (1-\alpha)\mathrm{T}_2}\,\mathbf{p}_0$$



$$\mathrm{T} = \alpha\mathrm{T}_1 + (1-\alpha)\mathrm{T}_2$$

Smooth skinning

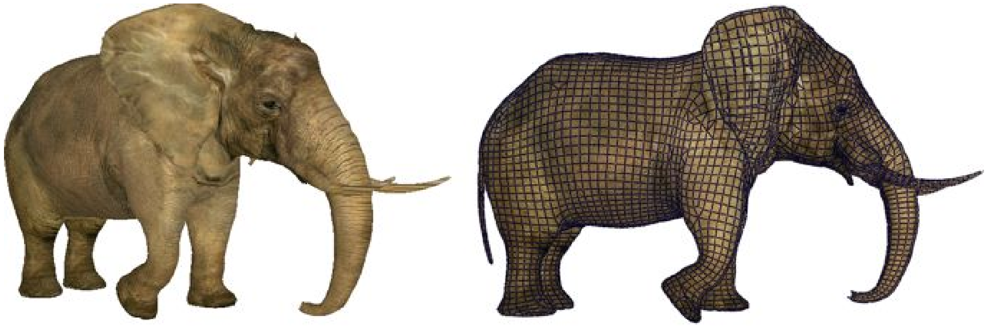
General formula

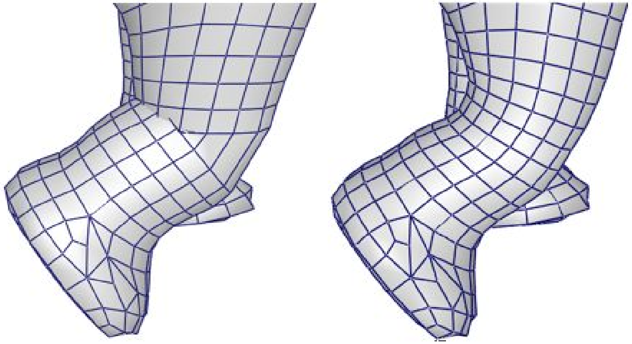
$$\mathbf{p} = \left(\sum_i \omega_i \, \mathrm{M}_i \right) \mathbf{p}_0$$

$$\sum_i \omega_i = 1$$

w: skinning weights

*Also called **LBS** (Linear Blend Skinning)*



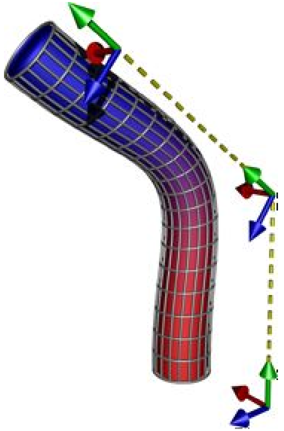


Rigid

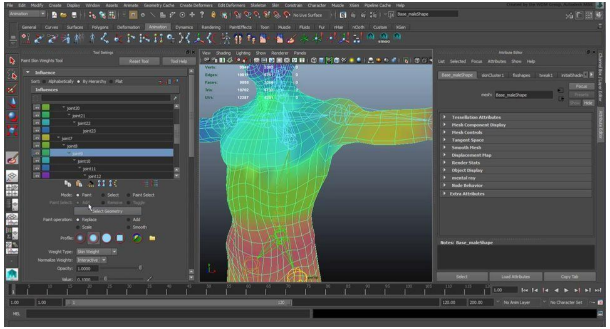
Smooth skinning (LBS)

Skinning weights

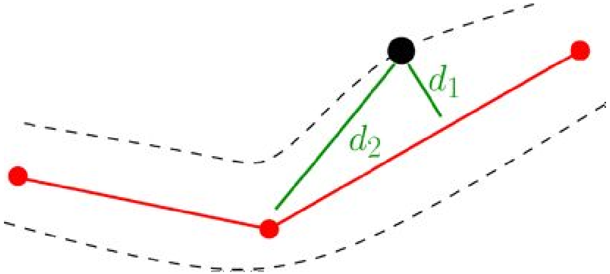
How to compute them



Paint them manually



Automatic computation



Associating bones and skinning weights to mesh is called: **Rigging**
(or any animation proxy)

Linear Blend Skinning

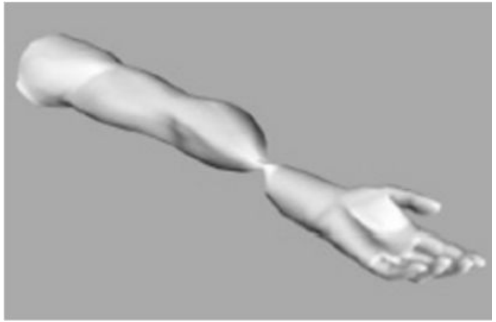
Widely used for character animation (in all modeling software):

- Direct, intuitive control (through skeleton)
- Very efficient (matrix multiplication, GPU)

But has well known defects:

- Artifacts at large angles
- Complex rigging settings

Collapsing elbow

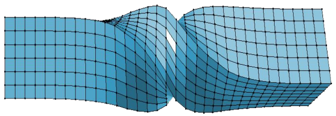


Candy wrapper

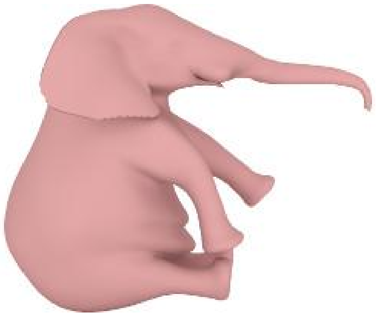
Skinning improvement

Study cases:

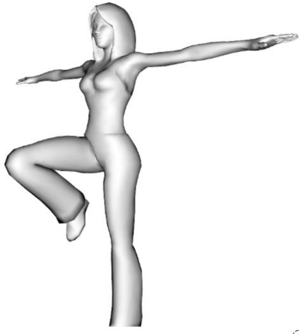
1- Improving the interpolation



2- Preserving a constant volume



3- Improving rigidity and avoiding self collisions



1- Skinning Interpolation

Problem:

Remember that linear interpolation of rigid deformation matrices is not a good idea

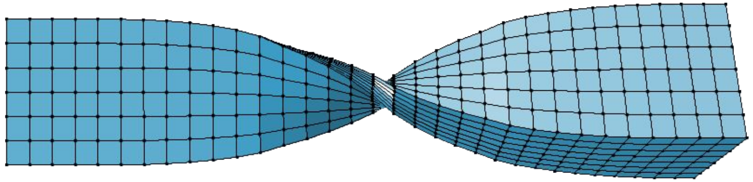
Skinning equation:

$$\mathbf{p} = \left(\sum_i \omega_i \, \mathrm{M}_i \right) \mathbf{p}_0$$

Linear interpolation of rigid frames (translation+rotation)

$$\sum_i \omega_i = 1$$

Does not result in rigid deformation:



Skinning interpolation

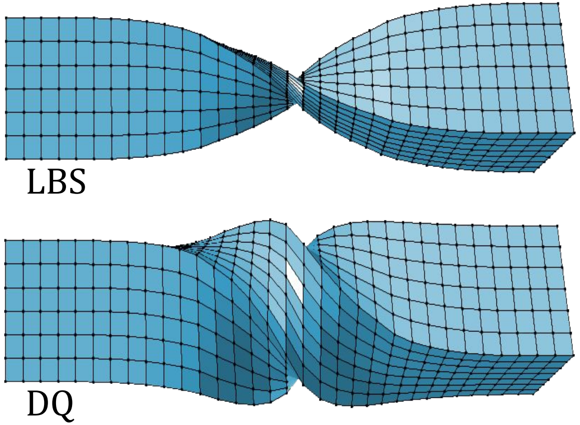
Idea: **Dual Quaternion** $\hat{q} = q_0 + \epsilon q_\epsilon$

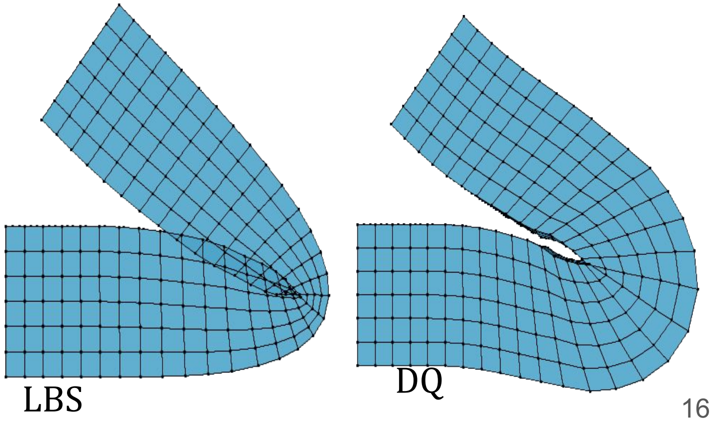
Blending in dual quaternion space $\hat{q} = \sum_i \omega_i \hat{q}_i$

Normalize the dual quaternion $\hat{q}_n = \hat{q} / ||\hat{q}||$

Apply $\hat{q}_n$ to p0

L. Kavan, S. Collins, J. Zara, C. O'Sullivan.
Geometric Skinning with Approximate Dual Quaternion Blending
ACM Trans. on Graphics, 2008





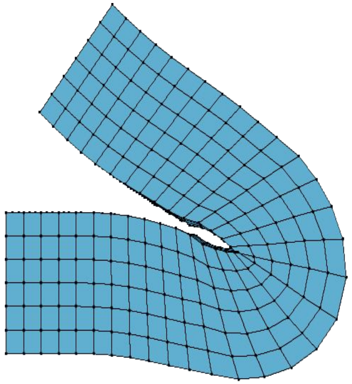
Dual Quaternion VS LBS

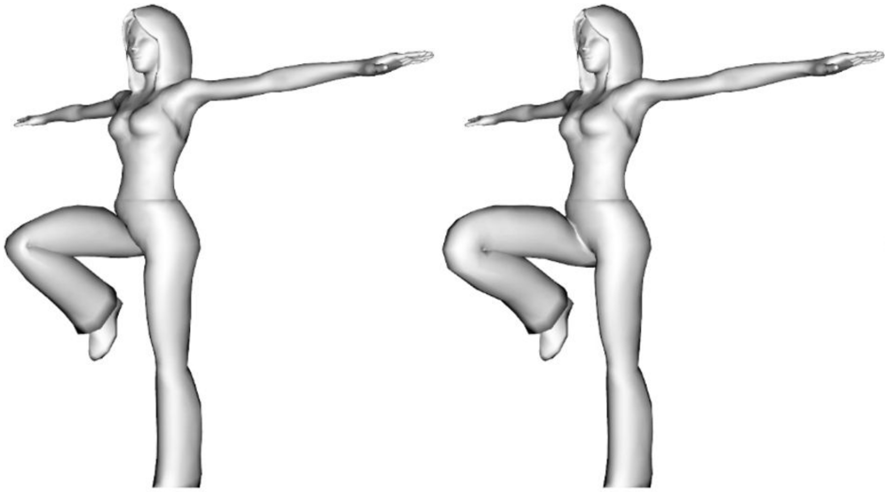
Dual quaternion:

- fully solves 'candy wrapper' artifact
- Almost as efficient as LBS

But: Creates artificial bulge

Not always prefered to LBS



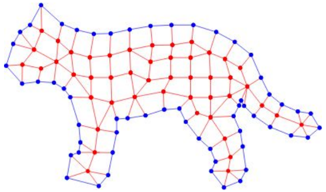


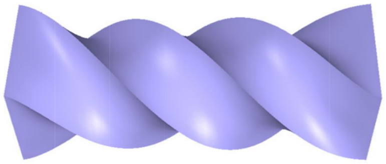
LBS DQ

2- Volume preserving skinning

Possibilities:

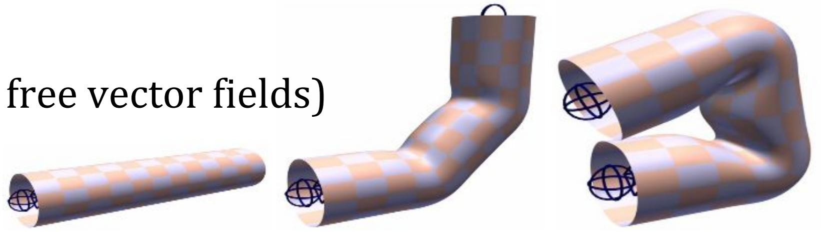
- Physics based models with tetrahedrons





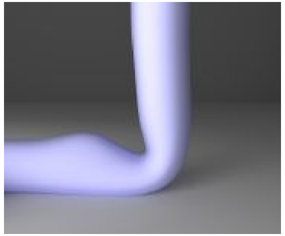
[Zhou et al., SIGGRAPH 05]

- Specific deformers (swirling sweepers, divergent free vector fields)



[Angelidis and Singh, SCA 07]

- Direct surface approach



[Rohmer et al., SCA 09]

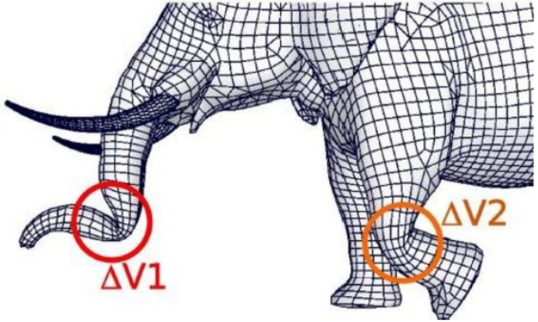
Volume preserving skinning

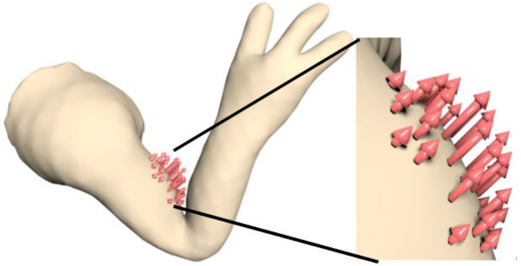
Direct surface approach

2 Steps:

a. Compute the change of volume due to skinning
   - *Sub-problem: how to compute the volume of a mesh*

b. Deform the surface to reach an objective volume

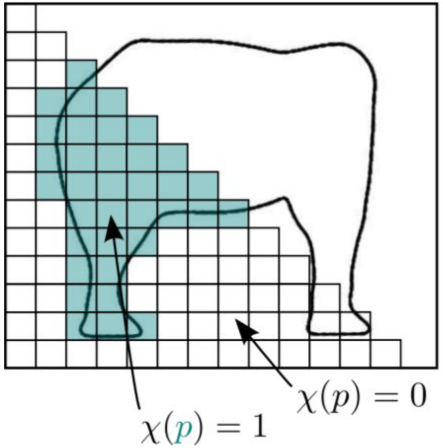


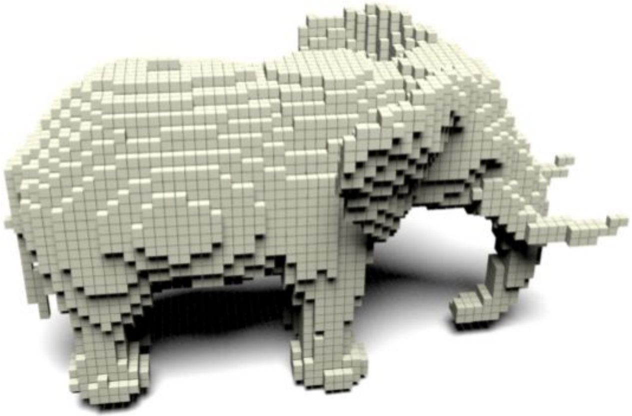


Computing the volume of a mesh

(consider the surface as boundary of a volume)

Naive approach: Discrete approximation





- \+ Simple
- \- Slow & memory intensive: not the best approach

Computing the volume of a mesh

Analytical expression

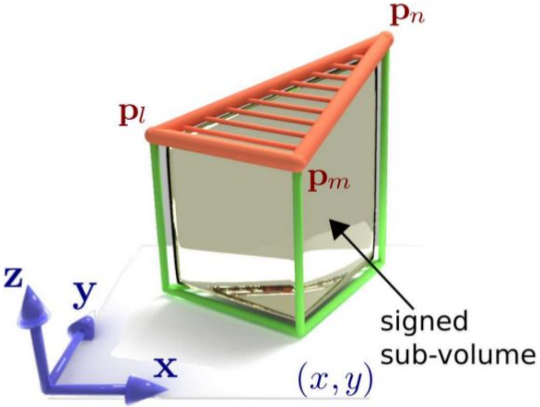
$$V = \int_\Omega \mathrm{d}\Omega = \int_{\partial\Omega} z\, n_z \,\mathrm{d}S$$ *divergence theorem*

Express it on a triangulated mesh. On each triangle: z is linear, normal is constant

$$V = \sum_{\mathrm{face}(l,m,n)\in S} \frac{z_l + z_m + z_n}{6} \begin{vmatrix} (x_m - x_l) & (y_m - y_l) \\ (x_n - x_l) & (y_n - y_l) \end{vmatrix}$$

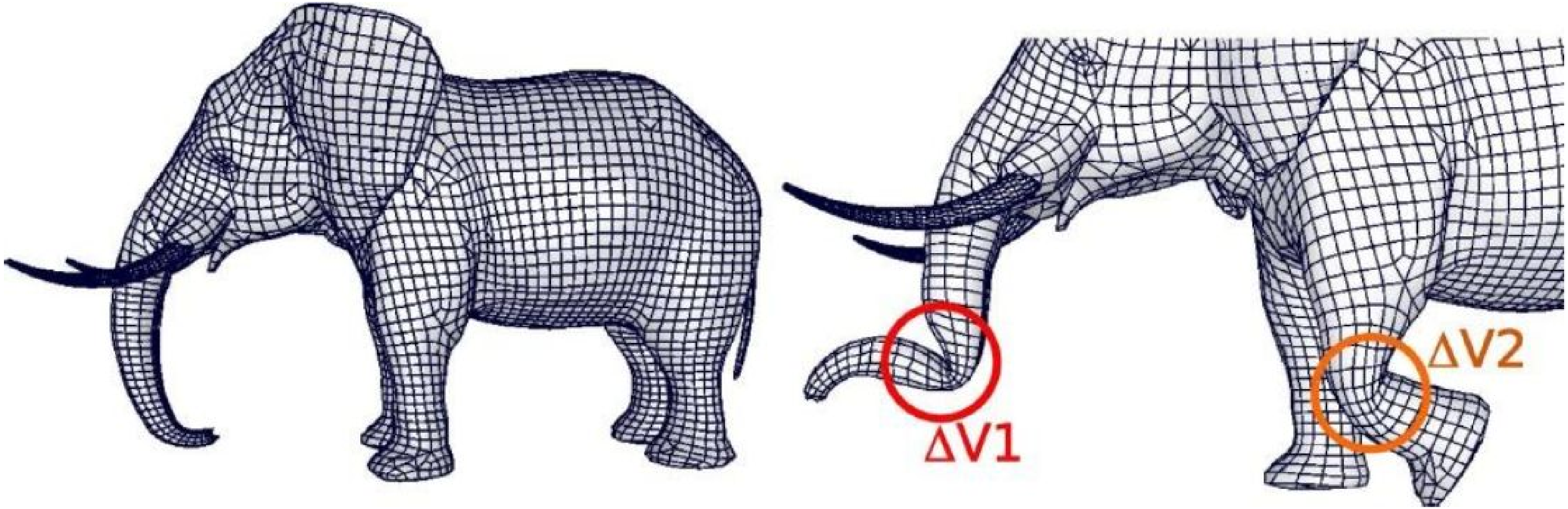
avg height

triangle
area



a- Compute the change of volume

Compute the change of volume for each articulation



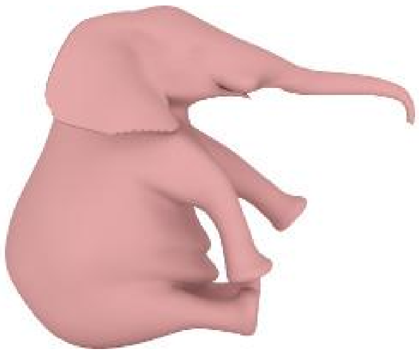
b- Deform the surface to reach an objective volume

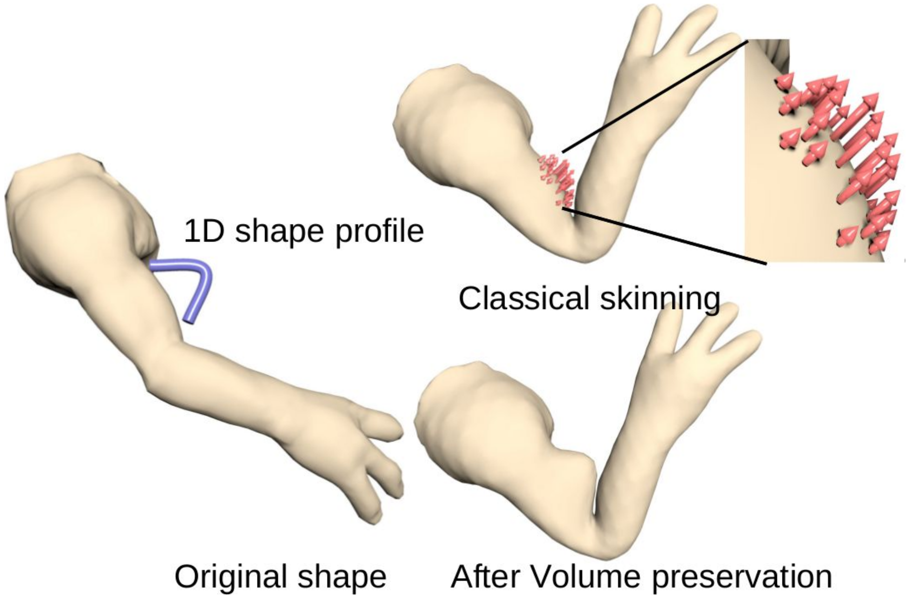
$$\begin{cases} \min \sum_{k=0}^{N-1} \frac{\|\mathbf{u}_k\|^2}{\gamma_k} \\ \text{subject to } V(\mathbf{p}_k + \mathbf{u}_k) = V(\overline{\mathbf{p}}_{\mathbf{k}}) \end{cases}$$

Vector of deformation

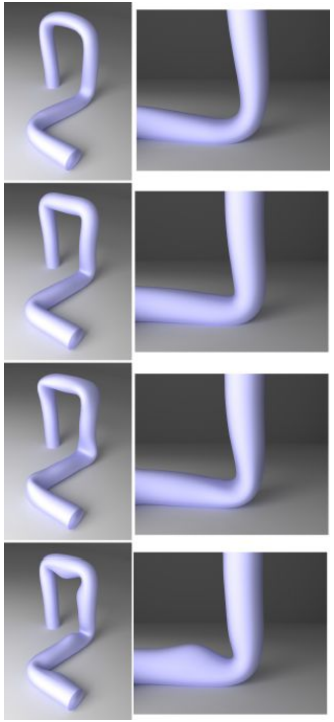
weights

Objective volume

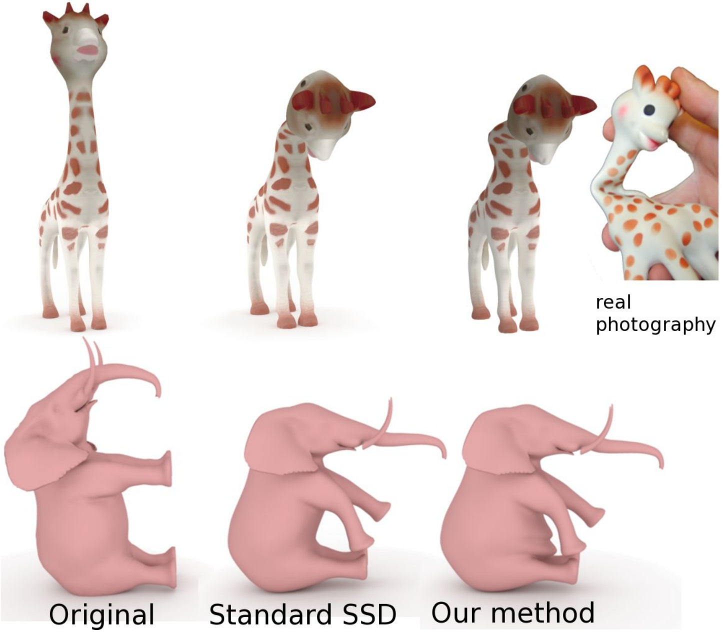




Constant volume skinning



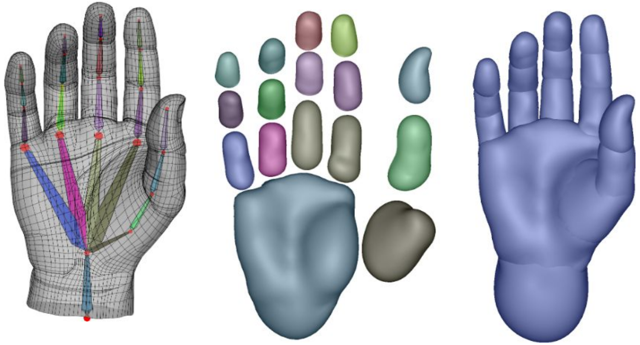
Choice of profile curve



Exact volume preserving skinning with shape control.
D. Rohmer, S. Hahmann, M.-P. Cani.
Symposium on Computer Animation, 2009

3- Improving rigidity and avoiding self collision

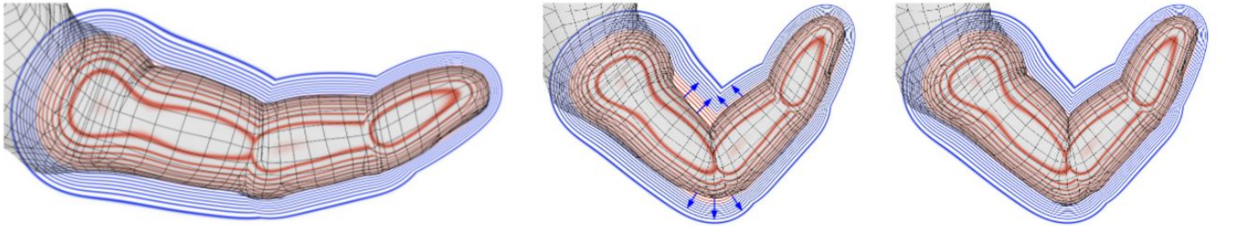
Idea: Extend implicit surface modeling to skinning deformation



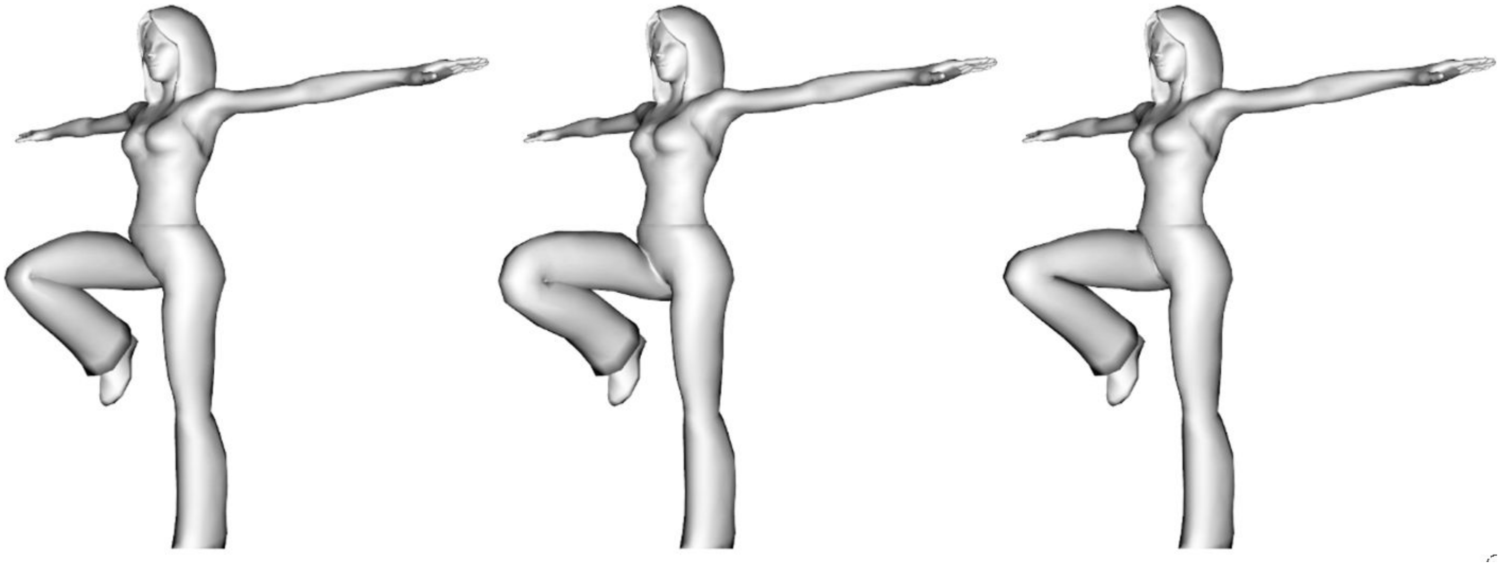
1- Approximate the mesh using implicit surface
(store the exact isovalue for each vertex)

2- Deform the mesh using LBS/DQ
Articulate rigidly each implicit surface

3- Project vertices back onto their original isovalue
(stop when intersection)



3- Improving rigidity and avoid self collision



LBS DQ Implicit Skinning

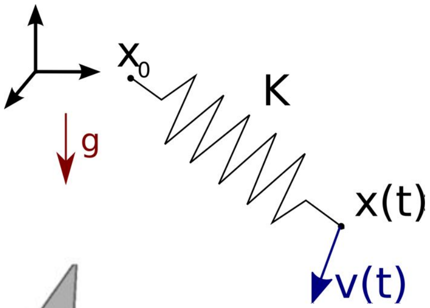
Implicit Skinning: Real-Time Skin Deformation with Contact Modeling.
R. Vaillant, et al. ACM SIGGRAPH 2013

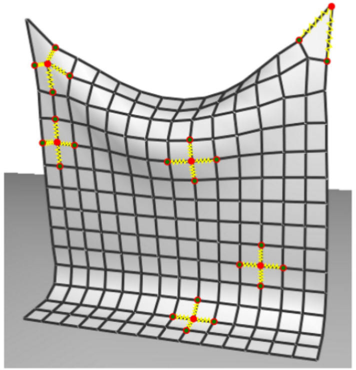
Animating cloth

1- Standard approach: spring mass

2- Improved model

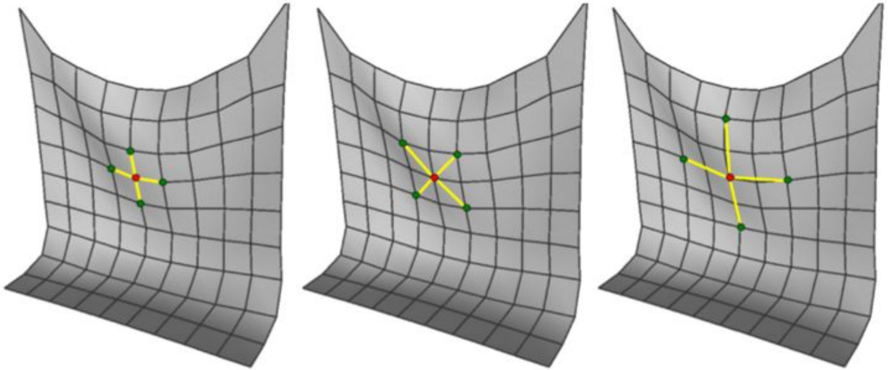
Cloth simulation: spring-mass systems





Type of springs
(on quad meshes)

Structural Shearing Bending



$$F(x_i, t) = \sum_{j \in \mathcal{V}_i} K^{ij} \left(L_0^{ij} - \|x_i - x_j\| \right) \frac{x_i - x_j}{\|x_i - x_j\|} + g$$

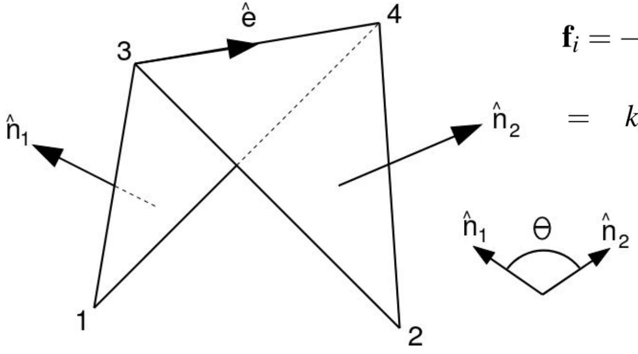
$$\forall i \,, \quad \begin{cases} x_i'(t) = v_i(t) \\ v_i'(t) = \frac{1}{m_i} \sum_j K^{ij} \left(L_0^{ij} - \|x_i - x_j\| \right) \frac{x_i - x_j}{\|x_i - x_j\|} + g \end{cases}$$

Cloth simulation: Energy based

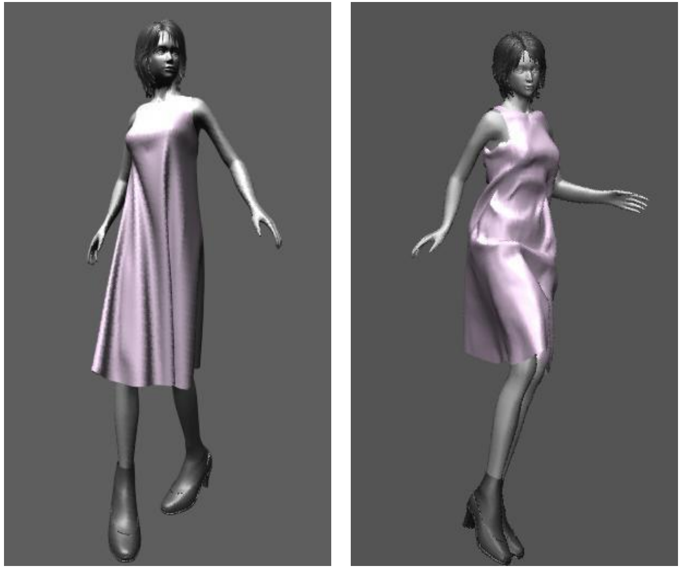
For more general triangulated mesh, based on energy minimisation

[Choi, Ko, Stable but responsive cloth. ACM SIGGRAPH 2002]

[Simulation of Clothing with Folds and Wrinkles, SCA 2003]

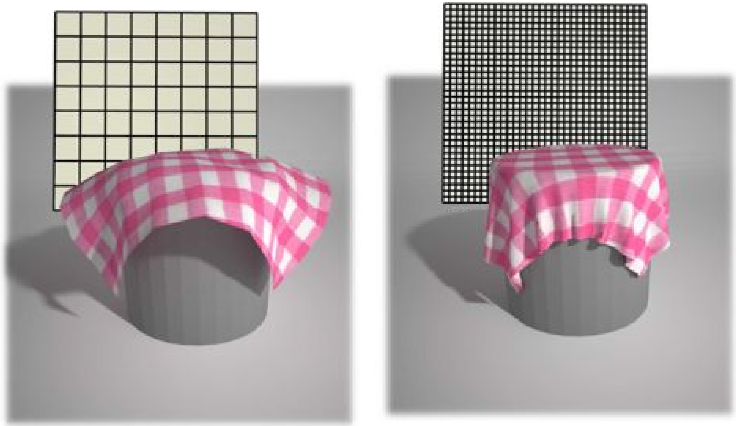


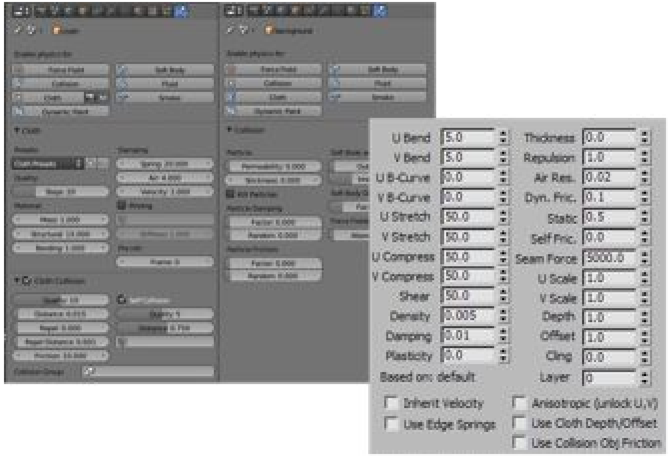
$$
\begin{aligned}
\mathbf{f}_i &= -\frac{\partial E}{\partial \mathbf{x}_i} \\
&= k_b \kappa^2 \left(\cos\frac{\kappa L}{2} - \mathrm{sinc}\left(\frac{\kappa L}{2}\right)\right)^{-1} \frac{\mathbf{x}_{ij}}{|\mathbf{x}_{ij}|}
\end{aligned}
$$



Limitation to physically based approach

Computational time + complex parameters



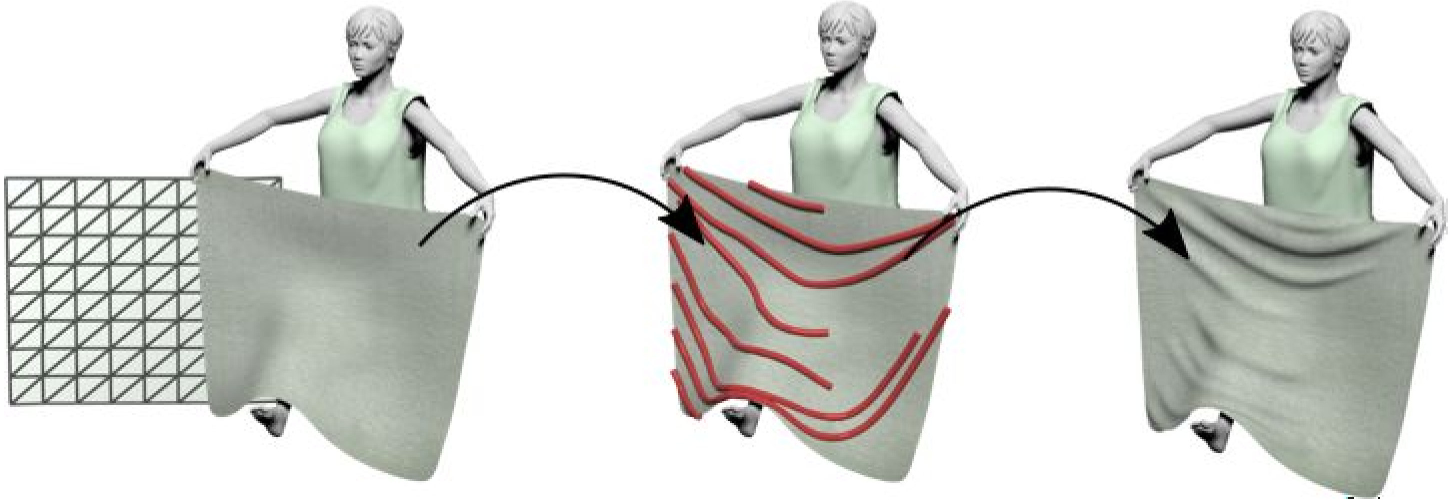


Hard to obtain: expected result + wrinkle details
In practice: Loops of trials and errors

Direct cloth animation

Idea: **Two layered model**

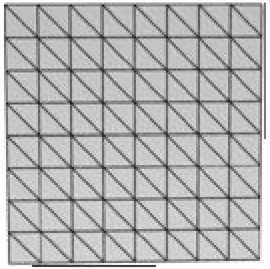
- A **low resolution simulation** (general dynamic, collision handling)
- A **geometrical wrinkle synthesis** (details)

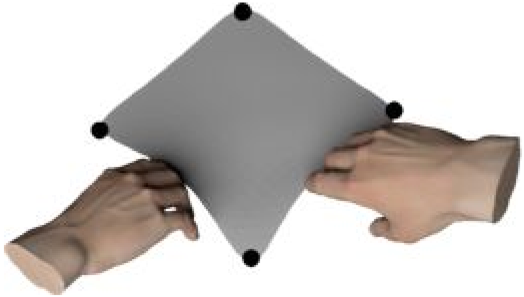


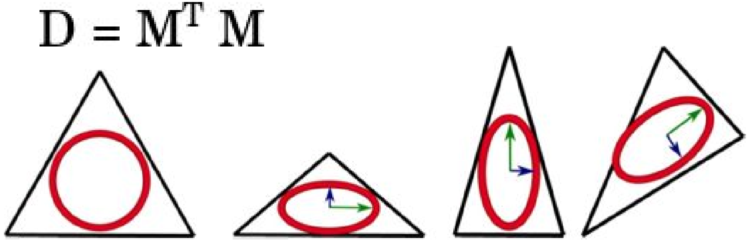
Fast low res simulation

Surface analysis + wrinkle synthesis

Tracing cloth wrinkles

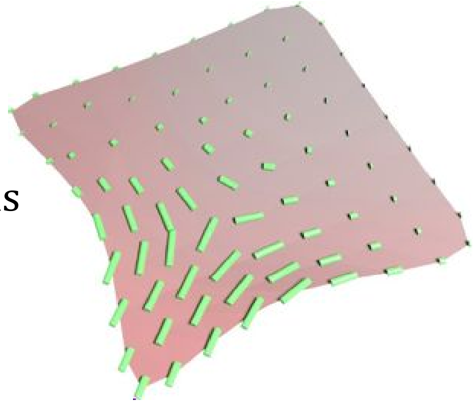


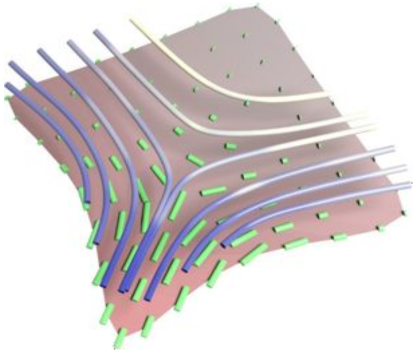




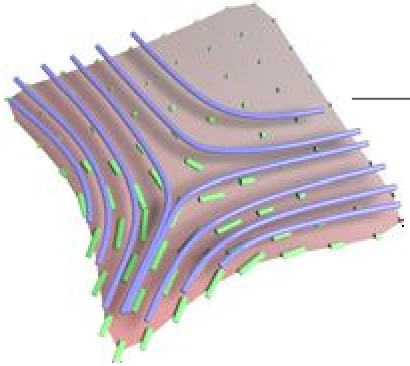
Analyse the main compression => extract vector field

Streamline integration => locus of wrinkles

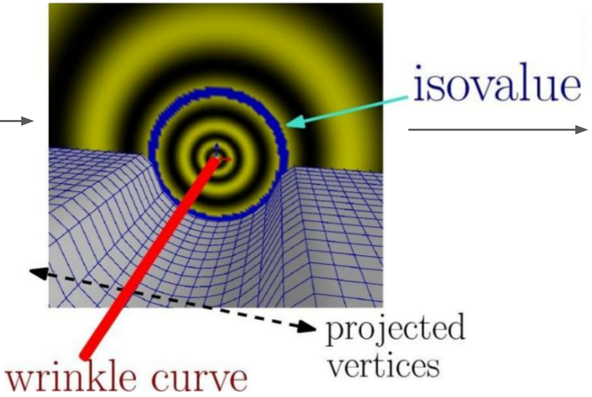




Geometrical wrinkle synthesis



Wrinkle curves

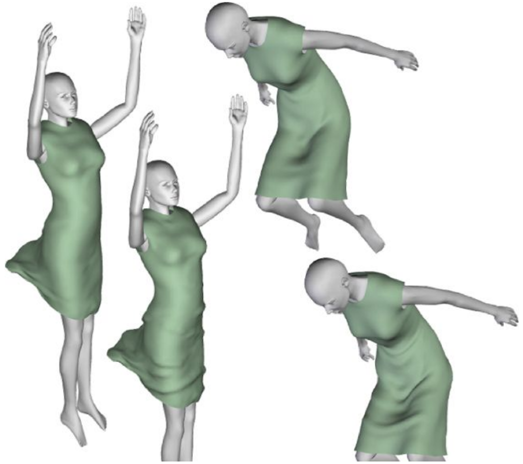


Implicit field deformer

Geometrical deformation

Implicit field:
Allows seamless wrinkle
blending

Animating geometrical wrinkles



Animation Wrinkling: Augmenting Coarse Cloth Simulations with Realistic-Looking Wrinkles.
D. Rohmer, T. Popa, M.-P. Cani, S. Hahmann, A. Sheffer.
ACM SIGGRAPH Asia 2011

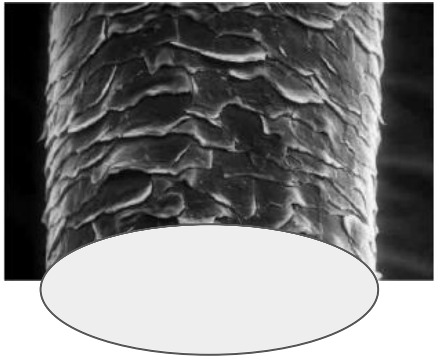
Virtual hair animation

Hairs animation

Characteristics:

- Thin elastic fiber with bending & twist
- Various elliptical radius
    - circular: straight hairs
    - elliptical: curly hair, non zero rest curvature
- About 10^5 hairs on a head

Problem: How to efficiently model hairs and their interactions.



bending twisting

Individual hair model

Standard model:

- Springs
- Rigid sticks

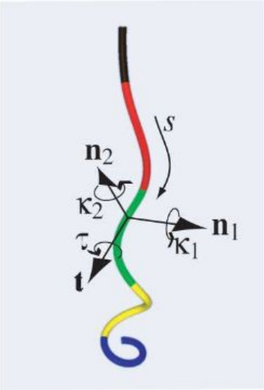
~ 50 nodes per hair
Requires careful numerical integration (stiff equations)

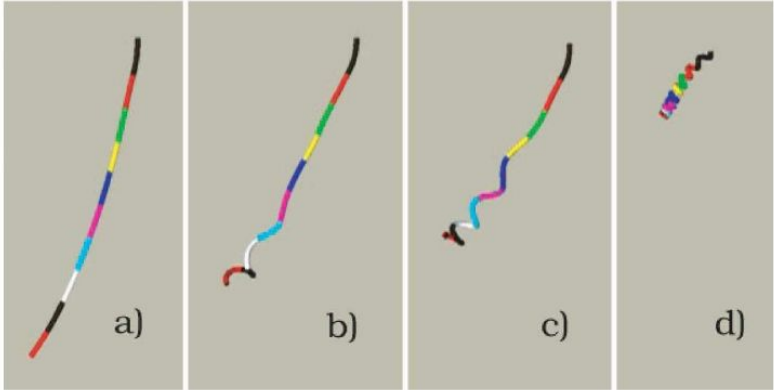
Super helices model

- Piecewise constant curvature helix
- Constant length

Non stiff equations

~5-10 elements / hair





Populating

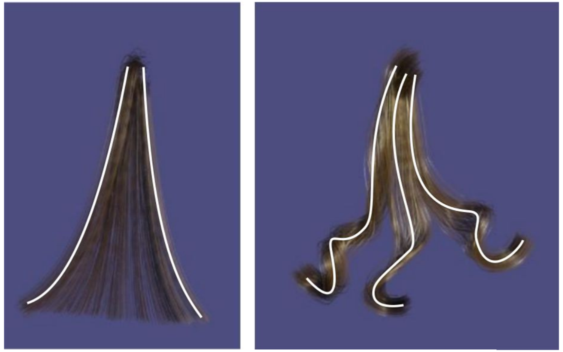
Simulating each hair individually is too costly

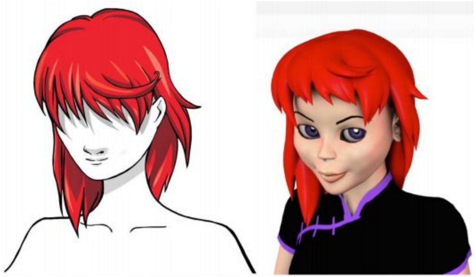
Layered model:

Use hair guide

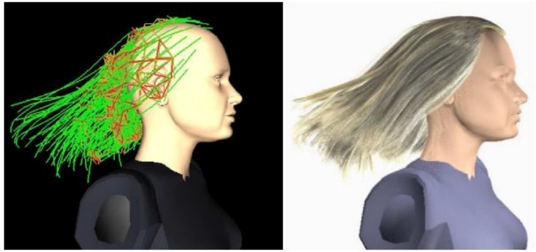
- Model individual strand (can be implicit surface)
- Interpolate between guide

[Yang et al, 01]





[Zanni et al, 15]

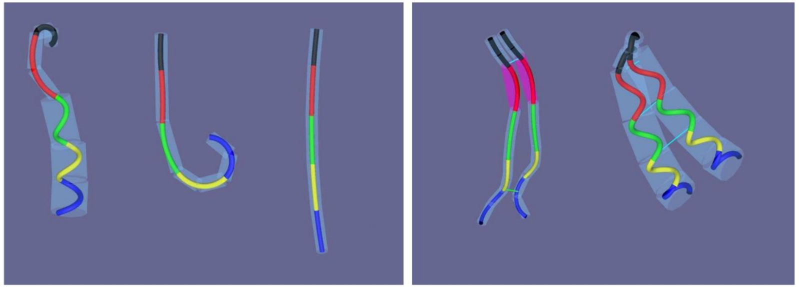


[Chang et al, 02]

Animation and interaction

Use approximating collision volumes

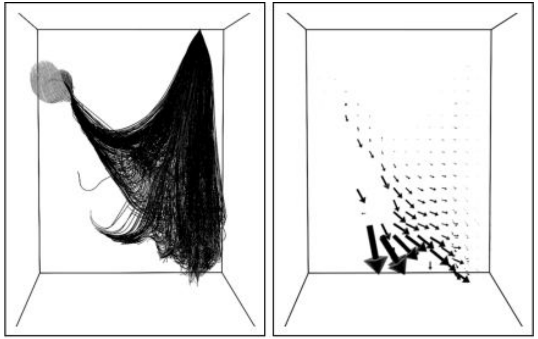
- Bounding cylinders
- Band layers *(keep the volume)*



[Bertails et al, 06]

Use fluids equation

- Project particles on a grid, define density of hairs



[McAdams et al., SIGGRAPH 09]