Object Animation using deformable reference frames

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May 26, 2008

Plan

1. Related work
   - Mechanics of continuous material
   - FEM, meshless deformations and mass-spring method
   - Adaptive remeshing
   - Skinning method
2. Contribution
   - The deformable frames
   - Attaching a surface
   - Mass
   - Elasticity response
   - Deformations in higher dimensions
   - Local deformations
3. Future work

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Overview

Goal: find a model which interrelate the forces applied on a model and the resulting deformations.

Main idea:

- Sample the continuous middle.
- Define a displacement field.
- Integrate over space the equations of continuous material

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Overview:

- Sample the continuous middle:

Finite elements: with a 2D or 3D mesh.
Meshless deformations: with a point cloud.

- Define a displacement field.

Finite elements: interpolated in each cell.
Meshless deformations: weighted sum of a radial basis function.

- Integrate over space the equations of continuous material

For all methods, derive the physical equations from:

- partial derivatives of the displacements field
-

Physical simulation:

	Pros	**Cons**
Finite elements	precision	mesh resolution
Meshless deformations	no topology => cutting, adaptivity	precision implementation
mass-spring method	implementation	precision edge mesh

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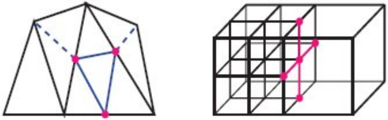
[*Charms*, *Grinspunetal*.2002] has dynamically added DOFs during the computation to obtain better results.



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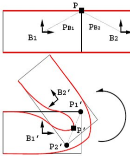
Principle:
The position of the skin (surface) is a linear combinaison of the bones (DOFs).



Weighting:
Problem on large bend and twist deformations.
Solution: other weights.
Ex: arclength, 1/d, 1/d2, or as in $[VGL, KunZhouetal.2005]$

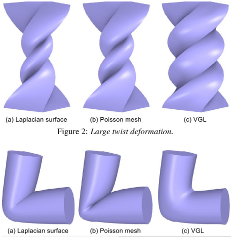


Figure 2: *Large twist deformation.*

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Kinematic primitive

New 12D DOF:

$$x = \left(\vec{t}, q, \vec{sh}, \vec{st}\right)^T$$

$$v = \left(\dot{\vec{t}}, \Omega, \dot{\vec{sh}}, \dot{\vec{st}}\right)^T$$

$$f = \left(\vec{f}_t, \vec{f}_r, \vec{f}_{sh}, \vec{f}_{st}\right)^T$$

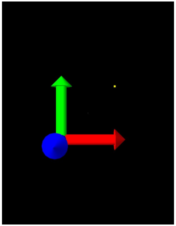

Figure: movie of shear effect

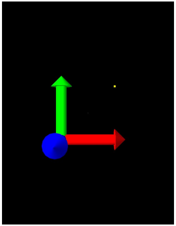

Figure: movie of stretch effect

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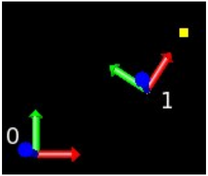
Displacement field:

$$\vec{p_0} = \vec{t_0} + B_{1/0} * \vec{p_1}$$

with $B_{1/0} = RE$.



R is a rotation matrix
and E contains the shear and stretch components.

$$E = \begin{pmatrix} 1 + e_{xx} & e_{xy} & e_{zx} \\ e_{xy} & 1 + e_{yy} & e_{yz} \\ e_{zx} & e_{yz} & 1 + e_{zz} \end{pmatrix}$$

Velocity of a point

Coord: $\vec{p_0} = \vec{t_0} + B_{1/0} * \vec{p_1}$

Vel : $\dot{\vec{p_0}} = \dot{\vec{t_0}} + \dot{B}_{1/0} * \vec{p_1}$

(with $\dot{B}_{1/0} = \dot{R}E + R\dot{E}$)

Displacement interpolation matrix: $J = \frac{du}{dx}$

So,

$$\dot{\vec{p_0}} = J(p)\ v_{DOF}$$

$$f_{DOF} = \sum J(p)^T \vec{f_p}$$

(according to virtual powers)

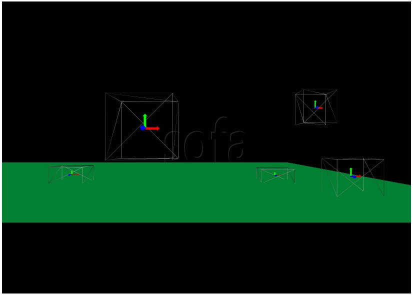


Figure: demo of surface collision

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The mass matrix is used to compute accelerations.
According to Newton: $f_{[12x1]} = m_{[12x12]} \; a_{[12x1]}$
And according to the mecanic of continuous middle: $M = \int \rho \; J \; J^T \; dv$

	tr_{1x3}	rot_{1x3}	sh_{1x3}	st_{1x3}
tr_{3x1}				
rot_{3x1}				
sh_{3x1}		M_{12x12}		
st_{3x1}				

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We need a shear and stretch constraint to simulate the elasticity response on our deformable frames.

$$\dot{\vec{shear}} += -k_{shear} * \vec{shear}$$

$$\dot{\vec{stretch}} += -k_{stretch} * \vec{stretch}$$

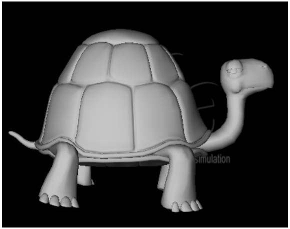

Figure: linear deformation demo

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We have linear deformations, but we want more !
So, we create a spring to begin skinning with the DOFs.

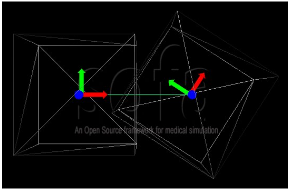

Figure: video of spring without damping

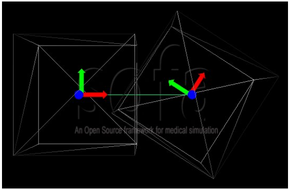

Figure: video of spring with damping

Now, we are able to do a linear combinaison between the DOFs.

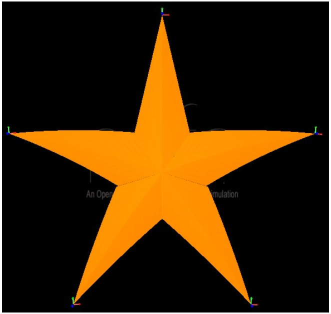

Figure: demo using skinning

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unrealistic deformation => We need local deformations.
So, we create a contact manager.

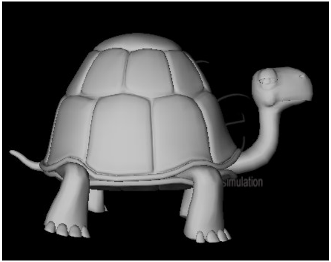

Figure: video of local deformations

- Finish the contact manager
- Animation applications
- Results physically exact
- Other functionalities

Automatically remove DOF
Different influence radius

- Finish the contact manager
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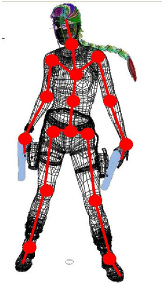
Video games with skinning
Ragdoll effect



- Finish the contact manager
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- Results physically exact
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For medical simulation.
Compute the M, J and K matrices based on the mesh geometry or volumetric images.
According to the mecanic of continuous middle:

$$M = \int \rho \; J \; J^T \; dv$$

$$K = \int B^T \; C \; B \; dv$$

- Finish the contact manager
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Cutting
Tearing