

SIGGRAPH
2001

Dynamic Real-Time Deformations using Space & Time Adaptive Sampling

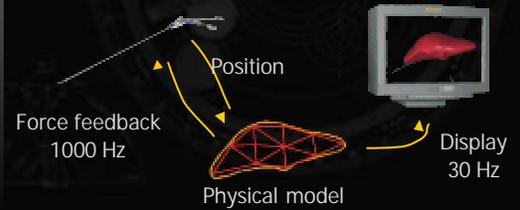
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Goal

Dynamic animation of deformable objects:

- Realistic
- Real-time



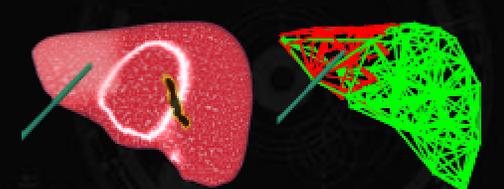
Force feedback 1000 Hz Position Display 30 Hz
Physical model

Difficulties

We must combine:

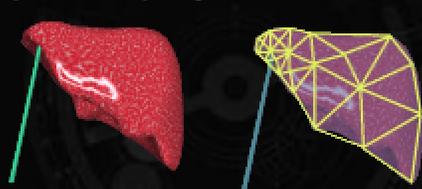
- Visual realism
 - Complex computations
- Haptic feedback, stiff objects
 - Very small time steps (~1000 Hz)
- True real-time simulation
 - 1 second of animation computed in 1 second or less

Surface display vs. internal model



<p>Displayed surface</p> <p>~10,000 triangles</p> <p>30 Hz</p>	<p>Internal physical model</p> <p>~100 points</p> <p>~1000 Hz</p>
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Adaptive sampling



High sampling rate in high deformation zones
Optimal use of the resources
Reach and ensure real-time

Overview

- Multiresolution animation
- Choice of a physical model
- Results

Previous work

Switch techniques according to visual impact

- Dynamic, cinematic...

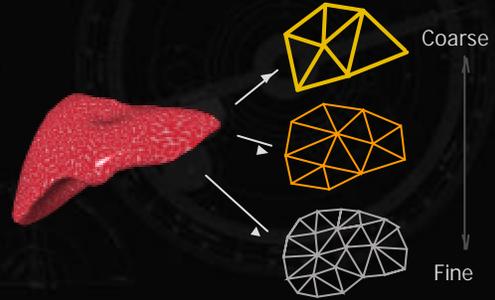
[Berka 97, Cheney & Forsyth 97, Carlson & Hodgins 97]

Adaptive discretization

- Mass-springs [Hutchinson 96, Ganovelli & al 00]
- Finite Elements [O'Brien & Hodgins 99, Zhuang 99]

No simplification

Different discretization rates



Active nodes

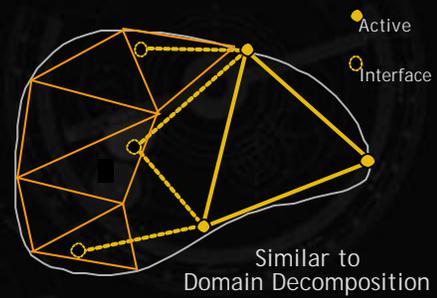
Force computed from neighbors' displacements



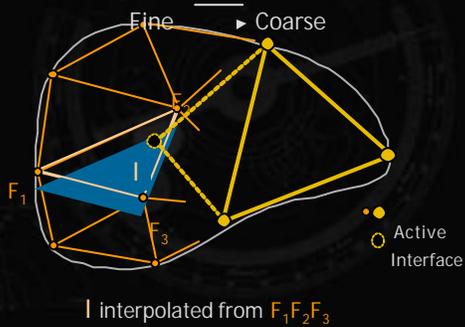
• Active fine nodes

• Active coarse nodes

Interface points



Transmitting deformation information



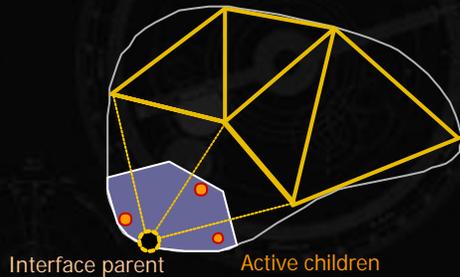
I interpolated from $F_1F_2F_3$

Sampling adaptation

Based on local deformation amplitude
Node replaced by its children in the finer resolution



Children become active



Overview

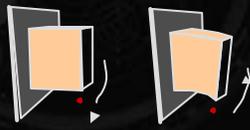
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Goal

Sampling-independent dynamic simulation
Identical vibration modes

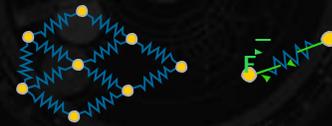
Testbed

No damping
Measure of vertical displacement over time



Particle systems

Mass-springs systems
[Hutch96, BW98, GCS00]



Continuous models

Discretization of a continuous equation
• Stress and strain tensors (Cauchy, Green)

Finite Elements [TW88, GMTT89, BNC96, JP99]

Explicit Finite Elements [Cot97, OH99]

Continuous models

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Continuous models

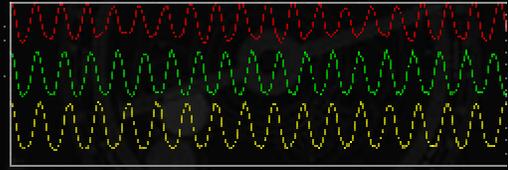
Discretization of a continuous equation

- Stress and strain tensors (Cauchy, Green)

Finite Elements [TW88, GMTT89, BNC96, JP99]

Explicit Finite Elements [Cot97, OH99]

Green tensor [OH99]



Multiresolution !

(Behaves almost independently of the resolution)

Multiresolution in time

Courant criterion (CFL)

- Depending on material's stiffness, sampling

Stability

- When force integration may diverge

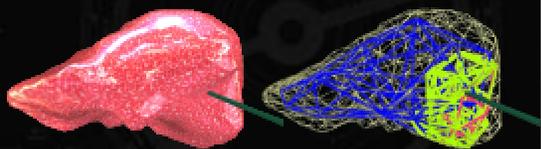
Synchronization with the display

$$dt_i = \frac{dt_{display}}{2^i}$$

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Results



Conclusion

Multiresolution in physically-based animation
Real-time simulation guaranteed

- Force feedback at 1000 Hz
- Display at 30 Hz
- Multiresolution speedup factor : 5 - 20

