Deformable objects in real-time with haptic feedback
Work in progress

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1 Introduction

For realism in computer graphics today rigid body physics is no longer sufficient. Models that take into account soft objects and deformations give *better visual results*, and allows for *interaction* with *accurately modelled objects.*

Due to increased computer power, haptic feedback from soft bodies is emerging as an possible method of augmentation for information presentation.

We are currently developing a framework for simulating and visualizing deformable body physics using the finite element method (FEM), where the simulations include haptic feedback. This framework will be able to handle a large class of fixed topology objects described by elasticity theory.

2 Exposition

We have implemented a solver for simulating and interacting with deformable objects based upon FEM [Zienkiewicz and Taylor 2000]. The solver currently handles objects that are linear in material but nonlinear in geometry. The system exploits the sparsity of the FEM mesh and is coupled with highly optimized linear algebra subroutines for optimal performance. The solver uses the well-documented and widely used Newmark scheme. As of today we handle meshes of the order of thousands of degrees of freedom on a standard desktop computer and still achieve interactive refresh rates.

2.1 The numerical model

The system solves for accelerations of the displacements $\mathbf{u} = \{u, v, w\}^T$ in the linear matrix differential equation

$$\mathbf{M}\ddot{\mathbf{u}} + \mathbf{C}\dot{\mathbf{u}} + \mathbf{K}\mathbf{u} + \mathbf{f} = 0 \quad (1)$$

at each time step. We then track the surface nodal forces which are coupled back to the ReachIn desktop to give haptic feedback (see Figure 1).

The large uncompressed size of the matrices in equation 1 makes interactive solving impossible. However, with clever use of the sparsity structure real-time can be achieved. Especially when the solver is of the *direct* type, meaning that an inversion of one of the sparse matrices needs to be done. The sparsity structure of the inversion can be minimized, but this problem is NP-hard. We apply a Cuthill-McKee reordering scheme that approximates the optimal reordering. This transforms the size of the problem from $O(n^2)$ to $O(n^c)$ where c is close to 1.

We present the latest benchmarkings of our solver and discuss its components in terms of speed and accuracy, as well as physical realism. We will also present up-to-date results from the connection to the haptic system.

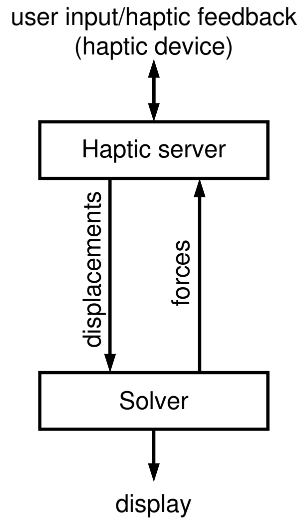

Figure 1: Connection of forces and displacements in the solver framework.

3 Results

We are currently connecting this solver to our haptics stations, ReachIn desktops with PHANToM haptics device. The haptic feedback is of today not fully implemented and under evaluation.

On an Athlon, 1.3 GHz, we solve a system with 1000 degrees of freedom at a refresh rate well above 100 Hz, and for 5000 degrees of freedom we get 20 Hz.

References

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