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A High Performance Solver for the Animation of Deformable Objects using Advanced Numerical Methods

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Abstract

Physically based modelling of deformable objects has become the most popular technique to model textiles, skin or human tissue. The crucial problem in the animation of deformable objects is the solution of the resulting differential equations. Recently fast solutions have been presented. In this work we will first give a theoretical analysis and then exploit special properties of the system and advanced numerical techniques to achieve further speed-ups of the simulations. Also, higher accuracy, leading to higher quality animations, will be achieved and an error bound is enforced.

1. Introduction

The animation of deformable objects has established its place in computer graphics. It has become indispensable for generating physically correct animations and increases realism in interactive virtual environments. Currently, the most important applications are simulations of the elastic behaviour of human organs (virtual surgery) and modelling of textiles, in particular realistic modelling of virtual clothes for virtual humans.

In the simulation of deformable models, solving a stiff differential equation is crucial. Therefore some methods have been proposed in computer animation, to build a fast implicit integration method for that task. Although these methods are able to compute models that look like some clothes or some tissue, they cannot guarantee a certain accuracy because not sufficiently suitable methods are used. If some specific material is to be modelled, its material properties may be lost in the simulation. This is not acceptable if the application is to help selecting a certain material, e.g. virtual clothing for e-commerce. In this work methods are presented that ensure a higher quality of the simulations and guarantee a certain error bound. In particular, at each time step of the solver, a nonlinear system of equations has to be solved and neglecting the nonlinearities can lead to very inaccurate results. In this work we completely solve the nonlinear system at high speed. We will also employ more efficient integration methods and improve the performance of the linear solver. The accuracy of the animation also depends on the physical model used. Therefore we will derive the correct forces from the continuous wave equation.

Since the choice of the methods is based on concepts from numerical analysis, we will have to present some of these concepts accompanied by illuminating examples. Equipped with these concepts we will choose the appropriate methods for the problem and the building blocks of a high performance simulator. After exploiting the special properties of the mechanics of deformable objects, these blocks are eventually assembled to obtain a flexible solver for efficient simulations of arbitrary deformable objects. Results on the performance of selected components as well as on the complete algorithm are presented and an example of a cloth modelling animation is given.

1.1. Previous work

In computer animation particle and constraint systems have proven to be an appropriate model for fast physically based simulation of deformable objects[1, 2, 6, 12]. These models require an ordinary differential equation to be solved. Hence more and more techniques from numerical analysis have entered computer animation.

As early as in 1987, Terzopoulos and Fleischer[14] used a semi-implicit numerical method, i.e. explicit in space and implicit in time, later on explicit methods became popular. With the work of Baraff and Witkin[1], implicit time stepping

Figure 7: *A dress of 3120 particles*

stiffness	damping	Newton	*cg*
10^8	160	803	1160
10^8	1600	198	538
10^6	160	377	566
10^4	160	52	52

Table 3: *Performance dependence on material parameters*

9. Conclusions and further work

We have presented a numerical framework that is suitable for the computation of both approximate high speed animations and accurate simulations. High speed computations are required by applications in the animation industry and in virtual environment applications. Other applications, for instance the simulation of clothes for e-commerce applications also depend on a high accuracy, for the virtual dresses have to look like the real materials and clothes the customer is supposed to buy. This framework is the core of the simulator in the *VirtualTryOn* project, a national research project to develop technologies for the whole pipeline to dress up a customer with the clothes of his choice virtually.
Further work will incorporate more recent research results of numerical analysis into this framework. We will especially focus on a closer coupling of Newton and integration methods to improve accuracy and efficiency further.

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