A Simplified Approach for Animation of Deformable Objects

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Abstract

We present a simplified approach for animation of geometrically complex deformable objects represented as tetrahedral meshes. Our prototype system detects and responds to collisions of objects subject to elastic deformations of variable stiffness. The proposed approach combines several techniques, namely, collision detection using a spatial hashed grid [6], consistent penetration depth using propagation [1], contact surface computed according to [5] and projection [2], the animation is based in a modal analysis scheme using an explicit-implicit integrator as in [3]. Preliminary results show that collisions between objects containing several thousand tetrahedra can be animated in real-time.

1. Introduction

There is a vast demand for interactive deformable modeling in computer animation and entertainment, especially in games and movie special effects. These applications do not necessarily require physically correct deformation, provided that the animation can be conducted efficiently and with plausible physical behavior.

This paper describes a method suited for animating deformable objects represented by tetrahedral meshes. We use some existing deformable modeling techniques and combine them to achieve plausible animation for scenes with many complex deformable bodies. Currently we use the collision detection scheme described in [6]. Collision response is handled through contact surfaces computed with a combination of Spillman's [5] and Jakobsen's [2] approaches. Finally, the animation is given by Müller's [3] approach.

The rest of this paper is organized as follows: Section 2 describes the collision detection, collision response and animation schemes. Section 3 reports some preliminary results and gives directions for future work.

2. Collision detection and response

2.1. Collision detection

The spatial hashing approach of Teschner *et al.* [6] is used to detect vertices that penetrate tetrahedra. In a nutshell, the idea is to classify vertices and tetrahedra which are within or intersect grid voxels and hash them.

The collisions are encountered checking all hashed voxels and testing vertices inside tetrahedra. Furthermore, this method also handles self collision cases.

2.2. Collision response

In a first step, we compute the penetration depth and penetration direction for all colliding vertices as in [1]. The method returns a consistent penetration depth and a contact face (triangle) for each colliding vertex. Since these faces are being penetrated, they must be moved in the opposite direction. Normally, all its vertices are colliding and therefore have their penetration depth computed. But, even in the case where one or two of its vertices are non colliding, they should be moved too. Unlike the Spillman's [5] approach, we use the Jakobsen's [2] projection scheme to solve those situations.

In a second step, we use a method similar to that described in [5], which overcomes problems inherent to penalty-based approaches. This method tries to determine a so-called *deformation region*, which is obtained by moving vertices along their displacement vectors. The displacement algorithm is similar to a binary search in the sense that each vertex is moved approximately half the length of its displacement vector.

2.3. Shape restitution and Animation

After the collision response, the shapes of the colliding bodies have suffered deformations. In order to bring the object to its original shape, we use the shape matching approach of [3] *et al.*, and the animation is made in much the same way described by Müller.

3. Conclusions and Future Work

We have implemented a prototype for the collision detection and response scheme described herein. It has been programmed in C++ with rendering performed using OpenGL. An important observation is that the Vertex Buffer Object (VBO) OpenGL extension was crucial for achieving good rendering rates of deformable objects. All experiments have been performed on a PC Intel Core 2 Duo running at 2.4Ghz. The figures (2, 3 and 4) below shown some results employing our prototype.

Real time frame rates are achieved when objects are composed of up to ten thousand tetrahedra. The major bottleneck of our implementation is due to the fact that at each time-step the grid data structure must be updated with the moved vertices and tetrahedra. Our experiments indicate that this operation takes approximately 50% of the overall time (see figure 1).

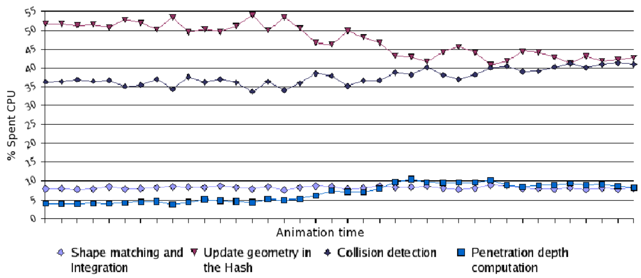

Figure 1. This image depicts the percentage spent by each sub process with respect to the overall CPU time.

We are currently investigating an alternative hashing approach for handling updates in a more graceful way. Also, we intend to study other non-volumetric approaches (i.e., models represented only by their surfaces), in particular the one proposed by Pauly [4].

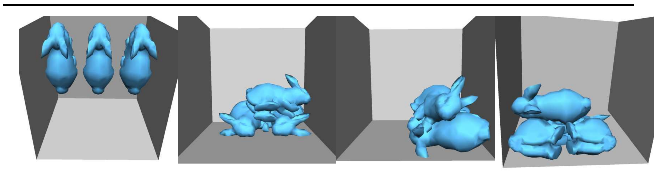

Figure 2. Three bunnies in contact. This scene contains 10623 tetrahedra and 3225 vertices animated at 15fps.

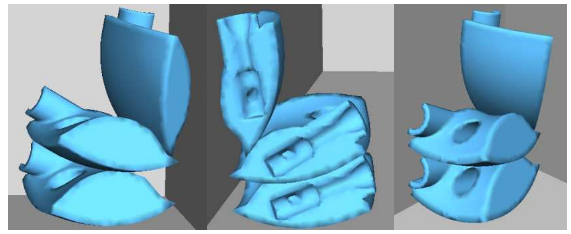

Figure 3. Three tetrahedral spx in contact. The scene contains 19428 tetrahedra and 8691 vertices animated between 8-12fps.

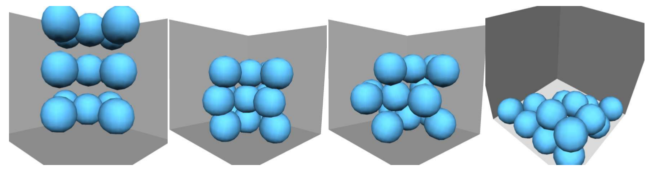

Figure 4. Fifteen spheres in contact. The scene contains 1600 tetrahedra and 1470 vertices animating about 60fps.

References

[1] B. Heidelberger, M. Teschner, R. Keiser, and M. Muller. Consistent penetration depth estimation for deformable collision response. In *Proceedings of Vision, Modeling, Visualization VMV'04*, pages 157–164, Stanford, USA, 2004.

[2] T. Jakobsen. Advanced character physics. In *Proceedings, Game Developer's Conference 2001*, SJ, USA, 2001. GDC Press.

[3] M. Müller, B. Heidelberger, M. Teschner, and M. Gross. Meshless deformations based on shape matching. In *SIGGRAPH '05: ACM SIGGRAPH 2005 Papers*, pages 471–478, New York, NY, USA, 2005. ACM Press.

[4] M. Pauly, D. K. Pai, and L. J. Guibas. Quasi-rigid objects in contact. In *SCA '04: Proceedings of the 2004 ACM SIGGRAPH/Eurographics symposium on Computer animation*, pages 109–119, Aire-la-Ville, Switzerland, Switzerland, 2004. Eurographics Association.

[5] J. Spillmann and M. Teschner. Contact surface computation for coarsely sampled deformable objects. In *Proceedings of Vision, Modeling, Visualization VMV'05*, pages 16–18, Stanford, USA, 2005.

[6] M. Teschner, B. Heidelberger, M. Muller, and D. Pomeranets. Optimized spatial hashing for collision detection of deformable objects. In *Proceedings of Vision, Modeling, Visualization VMV'03Proceedings of SPM 2005*, pages 47–54, 2003.