

Soft Body and Deformable Object

In Computer Graphics

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There are different uses of soft body in computer graphics and digital entertainment. They are involved in many effects such as fracturing, tearing, cutting. Those objects can have a rest position (in case of blobby effect, cloth) or without rest position (in case of plasticity). The main difference between rigid and soft bodies is the fact soft bodies can change their shapes during the simulation and by squeezing or tearing they lose energy. By consequence the collision response are affected.

It exists plenty of different techniques to simulate soft body. We can split those algorithms into two main categories : mesh based methods (FEM / Spring mass) and mesh free methods (Implicit surfaces / Point based / Meshless / SPH).

- References

In 2005, at Eurographics, Matthias Müller and other contributors released a "survey" about physical based deformation. This paper covers the most popular techniques used for deformable objects.

- Nealen, A., Müller, M., Keiser, R., Boxerman and Carlson M., 2005. *Physically based deformable models in computer graphics*, EUROGRAPHICS 2005

. Finite element method (FEM)

Finite element method is a physically and accurate approach. It uses a 3D elastic continuum and the property of the material.

Terzopoulos is the pioneer in physically based simulation and in 1987 at SIGGRAPH 87, he published a technique to compute the deformation of an object by using the potential energy into a deformable body.

- Terzopoulos, D., Platt, J., Barr, A., Fleischer, K., 1987, *Elastically deformable models. In SIGGRAPH 87*, pp.205-214.

In 2008 and 2009, Kaufmann introduces a new way to simulate elastical by using finite element method. - Kaufmann, P. , Martin, S., Botsch, M., Gross, M. , 2008. *Flexible Simulation of Deformable Models Using Discontinuous Galerkin FEM*, ACM SIGGRAPH / Eurographics Symp. on Computer Animation 2008, pp. 105-115.

- Kaufmann, P. , Martin, S., Botsch, M., Gross, M. , 2009. *Flexible Simulation of Deformable Models Using Discontinuous Galerkin FEM*, Graphical Models 71(4), pp. 153-167.

. Spring Mass

The spring-mass technique links the vertices together with springs. When the spring stretches it tends to shrink, and when it shrinks it tends to stretch. After a while the spring reaches its rest length and the system is stable.

This spring-mass technique is very popular with cloth simulation. In 1994, Breen published a paper to model the motion of a cloth by using particles and springs.

- Breen, D., House, D., Wozny, D., 1994. *Predicting the drape of woven cloth using interacting particles*. In SIGGRAPH 94, pp. 365-372.

This technique is also used to convert any geometry into a soft body by using angular and linear spring. In 1995, Ammar Joukhadar and Christian Laugier demonstrates a framework to create soft body from any geometry using damping-mass-spring. By using a large stiffness it's possible to simulate rigid body dynamics.

- Joukhadar, A. and Laugier, C., 1995. *Fast dynamic Simulation of Rigid and Deformable Objects*, Proceedings of the International Conference on Intelligent Robots and Systems.

. Implicit Surfaces

Implicit surfaces are useful to simulate soft substances such as water and modeling clay. Every particles emit a field of force decreasing with the distance which interact with their neighbours. Those particle (or mass points) can also be subjected to external forces.

In 1986, Geoff Wyvill, Craig McPheeters and Brian Wyvill implemented this technique explained above. This system can use the iso-surface for the collision (such as metaballs).

- Wyvill, B., McPheeters, C., Wyvill, G., 1986. *Data Structure for soft objects*, The Visual Computer, 2, 4 (1986), 227 –234.

- Wyvill, B., McPheeters, C., Wyvill, G., 1986. *Animating soft objects*, The Visual Computer, 2, 4 (1986), 235–242.

In 2010, Valery Adzhiev and his colleagues developed a technique to create interaction between a soft substance using implicit surfaces and a polygonal geometry. This technique can be used to simulate soft substance or liquid interacting with an animated object

- Kravtsov, D., Fryazinov, O., Adzhiev, V., Pasko, A., Comninos, P., 2010. *Embedded implicit stand-Ins for animated meshes: a case of hybrid modelling*, Computer Graphics Forum, 29, 1, 128-140.

. Point-based

The volume of the object is filled with particles. The cloud of points are connected together to maintain the shape and the volume of the object.

At SIGGRAPH 2004, Matthias Müller and colleagues developed a point based system representing the volume of the object. This technique keeps the volume of the deformable objects and can have a large deformations.

- Müller, M., Keiser, R., Nealen, A., Pauly, M., Gross, M., Alexa, M., 2004. *Point based animation of elastic, plastic and melting objects*. In Proceedings of the 2004 ACM SIGGRAPH/Eurographics symposium on Computer animation, pp. 141-151

In 2006, Matthias Müller and colleagues developed a position based dynamics where every points are linked by a constraint.

- Müller, M., Heidelberger, B., Hennix, M., Ratcliff, J., 2006. *Position based dynamics*, 3rd Workshop in Virtual Reality Interactions and Physical Simulation "VRIPHYS".

. Meshless method

Meshless is a fast and popular technique to create soft body. It doesn't require lots of computation; It can be used in real-time vizualisation and games. It's one of the most stable algorithm for soft body and prevents the object to have strange behaviors during the simulation. The implementation is simple and intuitive.

In 2005, Muller introduces a meshless deformation using shape matching which consists in animating particles without connectivities (no constraint between particles) and next extracting the most appropriate transformation to match with the cloud of particles.

- Muller, M., Heidelberger B., Teschner, M., and Gross M., "*Meshless deformations based on shape matching*," ACM Trans. Graph., vol. 24, no. 3, pp. 471–478, 2005.

Meshless algorithms are not only used to simulate jelly and rubber effects, at SIGGRAPH 2005, M. Pauly and colleagues developed a system to fracture plastic and elastic objects. There is no pre-fracturing and the cracking or fracturing are re-sampled through the crack propagation.

- Pauly, M., Keiser, R., Adams, B., Dutre, P., Gross, M., Guibas, Leonidas J. Meshless Animation of Fracturing Solids, 2005, ACM SIGGRAPH Symposium 2005, ACM Transactions on Graphics (TOG), Volume 24, Issue 3, pp. 957-964.

In 2007, Alec R. Rivers and Doug L. James speeded up the meshless technique for deformable objects developed by Muller in 2005 by doing the calculation on a lattice instead of the object itself. This new approach increases the speed and give a larger range of deformation.

- Rivers, Alec R., James, Doug L., 2007. *FastLSM: fast lattice shape matching for robust real-time*

- Resources

BOB in Monster vs aliens is a good representation of soft body and uses implicit surfaces to create the surface of the monster.

- Roberson,, B. 2009, Monsters of the deep: *DreamWorks authors a CG-animated creature feature in stereo 3D*, Computer graphics World

- *Monster vs aliens*, 2009, Film Directed by Rob Letterman and Conrad Vernon. USA Dreamworks.

In 2010, NVIDIA developed a system called APEX Clothing which lets artists quickly generating characters with dynamic clothing.

- NVIDIA, Apex clothing 2010.

For Ratatouille, Pixar used a range of different soft body techniques to simulate the digital effects for cooking.

- Ratatouille, 2007, Film Directed by Brad Bird and Jan Pinkava. USA Pixar.

The OpenGL framework, I have developed for the course animation software development has been reused for implement the meshless technique.

- Bonnet., V., 2010, Realtime hair simulation, Animation Software Development.