3D Interactive Clothing Animation

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***Abstract*—A framework for clothing animation is developed in this paper. It integrates several key techniques involved in clothing animation. Firstly, an improved mechanical model with real material parameters are used to simulate various types of cloth realistically. Secondly, efficient distance constraints are introduced into our cloth model that effectively limits cloth extensible deformation in the plane without breaking bending deformation. Thirdly, an accelerated algorithm on GPU in collision detection process ensures responsible cloth animation. At last, an interactive system is set up on the three-tier architecture that provides users with some basic functionalities including cloth animation, human model editing and clothing simulation. The interactive editor provides a set of intuitive tools for animators to design a rich variety of human shapes and cloth animation. As a prototype system for clothing animation and virtual dressing, it is fast, reliable and expandable.**

Keywords-cloth animation; particle-spring model; virtual dressing ; constraints model; implicit integration

I. Introduction

Cloth simulation and animation has been a challenging problem in computer graphics. A further step in cloth animation is the garment animation which is basically assemblies of different cloth parts. In recent years, with the rapid development of virtual reality technology, there is an increasing demand for cloth simulation both in digital entertainment industries and in apparel industry. In digital entertainment field, the virtual clothing animation enhances the visual realism of the 3D virtual scene and virtual actor in the scene, and brings audience a more detailed, realistic visual experience. In apparel industry, 3D garment design and virtual dressing as new technologies and business model are gradually changing people's traditional way of life. 3D garment design is conducted on the 3D virtual human model corresponding to the individual customer. The dynamic effects of dressing can be displayed for designers and clients before the garments are produced, which facilitate communication between the various participants in the process of garment designing.

In order to meet the daily growing demand for cloth animation, it is necessary to develop a convenient and practical clothing animation system.

Protopsaltou et al. present a system for simulating clothes, in which the user can create the standard virtual bodies and garment around the virtual human body [1]. The system enables the user to animate clothes with physical parameters from real fabric. However, the simulation is not real-time and the simulation result must be prerecorded in order to display the animated garment at an interactive rate.

Cordier et al. present a Web application related to virtual garment manipulation such as sizing and pattern derivation [2]. The customer can fit various garments onto the 3D mannequin that is adjusted according to his/her measurements. The garment simulation keeps the response time interactive.

The Virtual Try-On system [3] leads the progress of virtual fitting that forms the basis of a realistic, three dimensional simulations and visualization of garments on virtual counterparts of real customers. The system is more flexible to enable garments designing, body modeling and clothing animation etc. Users can view the clothing animation on the various angles, and moreover can change actor’s hairstyle, accessories, etc.

Today, VR technologies and efficient hardware open a very attractive perspective for developing interactive systems where virtual actors could manipulate cloth in real time.

In this paper, we present an integrated framework that supports human motion and animation, body modeling and garment animation. Compared with other exiting systems, our system has the following advantages: (1) Improved mechanical model with real material parameters can simulate various types of cloth realistically; (2) Distance constraints enforcement are introduced into our cloth model to effectively simulate inextensible cloth deformation without breaking bending deformation; (3) GPU accelerated collision detection algorithm based on bi-hierarchy candidate sets ensure responsible cloth animation; (4) Render-plugin allows users to export animation data to 3DMAX for rendering. All of the above techniques ensure the effectiveness and efficiency of the clothing animation system.

II. CLOTHING ANIMATION

Cloth animation involves two key technical problems that are cloth modeling and collision handling. Additionally, in order to generate realistic clothing animation, human modeling and human motion synthesis technologies also need to be considered with cloth animation simultaneously.

2.1 Cloth Animation

Physically based methods are often used to simulate cloth animation. It is formulated as a partial time-varying differential equation which needs to be numerically solved as an ordinary differential equation after discretization.

2.1.1 Previous work

Most of research work present physically based models for simulating in a realistic way fabric pieces based on elastic deformation and collision response. Early work by Terzopoulos et al. developed most general elastic models for simulating a wide range of deformable objects, including cloth [4]. This work laid the basis for physical modeling. Later, Breen et al. propose an interacting particle system to reproduce the draping behavior of simple cloth object in equilibrium using experimental fabric deformation data [5]. Provot presents simplified particle system where particles are linked with massless springs [6]. During simulating draping cloth animation, constraints avoiding "super-elastic" are also introduced. Recently, some advanced methods [7][8][9][10] based on particle-spring models are presented for simulating realistic bending deform of a cloth. These models claim to be fast and flexible, as opposed to finite element models[11][12][13], which are very accurate, but slow and complex to use in situations where behavior models are complicated and where collisions create non-linearity and complex boundary conditions, thus not suited for interactive applications.

To model of a cloth realistically, it is required to apply accurate physical properties of the cloth to the simulated cloth. Some researchers [6][14] used the Kawabata evaluation system (KES) to obtain material parameters. Others [15][16] identify a concise number of steerable control parameters that completely describe the static and dynamic material properties of a cloth. The final feel of simulated cloths is varied by adjusting the stiffness.

Another vital step in the generation of cloth motion is the numerical simulation of the underlying physical model. Baraff and Witkin[17] first proposed the semi-implicit method for large step cloth animation. After that, many research analyzed and improved the method [18][19].

Furthermore, the simulation of dressing is a more complex application. It involves the ability to detect and handle multiple collisions generated between the body and the cloth or self collisions. A large number of work contributed to this topic [20][21][22][23][24][25].

2.1.2 Proposed method

- Mechanical Model

We use a simplified particle-spring model which is the same connectivity structure as the model presented by Choi[8]. Particles are connected with tension spring, shear spring or bending spring. Based on fabric-specific buckling behavior, we formulate two individual interaction models that are tensile-shear spring model and bending spring model. Similar to choi's, our model also uses high stiff linear spring for compression resistance to avoid the shrink of the cloth surface. However, different with choi's nonlinear bending model, since the ultimate goal of our system is to build an interactive clothing animation system, we use an alternative linear bending spring.

The system internal force F_{inter} is represented as follows:

$$F_{inter} = \sum_{(p,q)\in T} F_{spring(p,q)}$$

Where T is a set of springs in the cloth system, and $(p,q) \in T$ says that the particle p and q is connected with a spring.

$F_{spring(p,q)}$ can be given by:

$$F_{spring(p,q)} == \mp(k_s \frac{\overline{x_p x_q} - l_0}{\overline{x_p x_q}} + k_v \frac{\overline{x_p x_q} \cdot \overline{v_p v_q}}{|\overline{x_p x_q}|^2})$$

Where l_0 indicates a default spring length, k_s represents spring elastic coefficient, k_v symbolizes viscosity, x_p, x_q, v_p and v_q are position and velocity of particle p and q respectively.

Note that the above first term is force derived from energy function, and the second term is viscous damping force. Since we want to damp the vertex motion only in the spring direction $(x_p - x_q)$, so the damping force is projected in the plane direction of stretching, that minimize the damping to rotation and decouple the damping to bending and stretching.

The system external force F_{exter} is:

$$F_{exter} = gM - k_{damp}V$$

Where g represents the gravity coefficient, k_{damp} indicates the damping coefficient and V is the particle velocity.

In the cloth animation, parameters of cloth model are key factors to acquire realistic simulation. The parameter database is established base on the method proposed in [16] provides a wealth of fabric material data and damp coefficient which we can use to simulate realistic cloth animation of different fabric.

After obtaining the force, the system can be resolved based on dynamic equations. We achieve numerical integration through the first order Implicit Euler method.

The state equation of motion

$$M\dot{v} = f$$
$$\dot{x} = v$$

is dicretized and rearranged as:

$$\left(M - \Delta t \frac{\partial f}{\partial v} - \Delta t^2 \frac{\partial f}{\partial x}\right) \cdot \Delta v = \Delta t f_0 + \Delta t$$

- Constraints Model

Cloth animation generated based on the above mechanical model cannot avoid elongation in cloth plane that is not consistent with tension deformation of fabric in real world. In order to resolve the problem, we introduce distance constraints to the model. Constraints forces are added to the above dynamic equation. Alternative to directly solve the large system equations, constraints iterative refine method is used to solve constraints force and furthermore solve system state in the paper.

- Collision Handling

Collision handling needs to be performed between garments and the skin layer of the human body in order to obtain realistic simulation results, which consists of two phases: collision detection and collision response. Collision detection is often the bottleneck of deformable surface simulations that handle highly discretized objects, particularly when complete self-collision detection is required, as in wrinkle and crumple situations.

Since the cloth and human models are represented by a great number of geometry primitives, it's hard to achieve real-time cloth-body collision detection through checking for intersections between all cloth-body primitives. In this paper, we use the method similar to that proposed by Mao[25], that reduces the collision detection between human skin surface and cloth model to a simple distance measurement from particles on cloth model to human skeleton through reconstructing 3D human body model. When a collision is detected, the particle's next displacement along the normal direction of the colliding surface is determined. For the tangential direction, a frictional force is added that is proportional to the velocity between the solid surface and the particle in contact.

In addition, we use bi-hierarchy candidate sets to eliminate non-collide primitives and the intersection test methods based on GPU [26] in collision detection phase to accelerate collision detection.

2.2 3D parametric human modeling

Virtual dressing requires a tool that is able to quickly create 3D human body model based on individual features. In the paper, we create a new model based on template and feature parameters. The process of generating new model is as follows.

Firstly, in measuring parameter space, weight of each merged sample is calculated using radial basis function network according to the input anthropometric parameters of the body model and sample models. Secondly, bone scaling of sample models is merged. Thirdly, based on skin deformation algorithm, bones of the template model are zoomed in and out according to bones scaling and points impacted by the bones are deformed to obtain the new template model. Finally, skin migration information of all sample models are merged, mesh information after merging are calculated:

2.3 Clothing Animation Synthesis

Through combining human body and motion, garment animation and fabric model parameter, a realistic virtual human clothing movement can be achieved. The framework of the synthesis is shown in Figure 1. The fabric model parameters are obtained from the fabric database we established, which provides the variety of material model parameters.

III. SYSTEM ARCHITECTURE

Based on the simulation techniques presented in the above, we develop a clothing animation system. Our system is divided into three levels: the underlying support layer, the middle control layer and the user interface layer. The bottom, including human body modeling and human motion control modules, provides support for clothing animation and control. The middle, clothing animation control module, is mainly responsible for generation and control of cloth animation, is the core part of the system. The top, user interface, provides users with some interactive functionality including creating personalized 3D human body model, generating cloth animation and human dressed animation, recording animation and playback, etc. For the whole software, modularity and abstraction has been an important

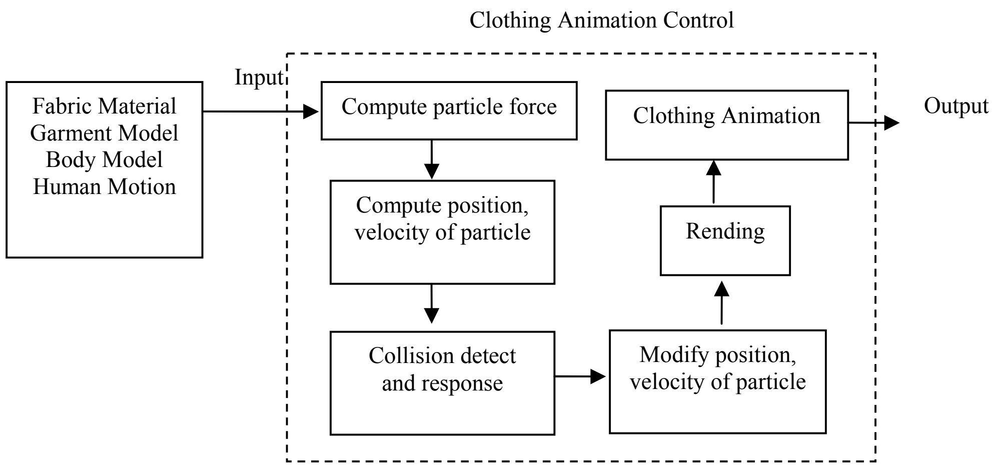

Figure 1 Synthesis of clothing animation driven by virtual human motion

development idea. For example, the system only requires user input a small number of high-level parameters to generate a new 3D model. The system architecture is given in Figure 2.

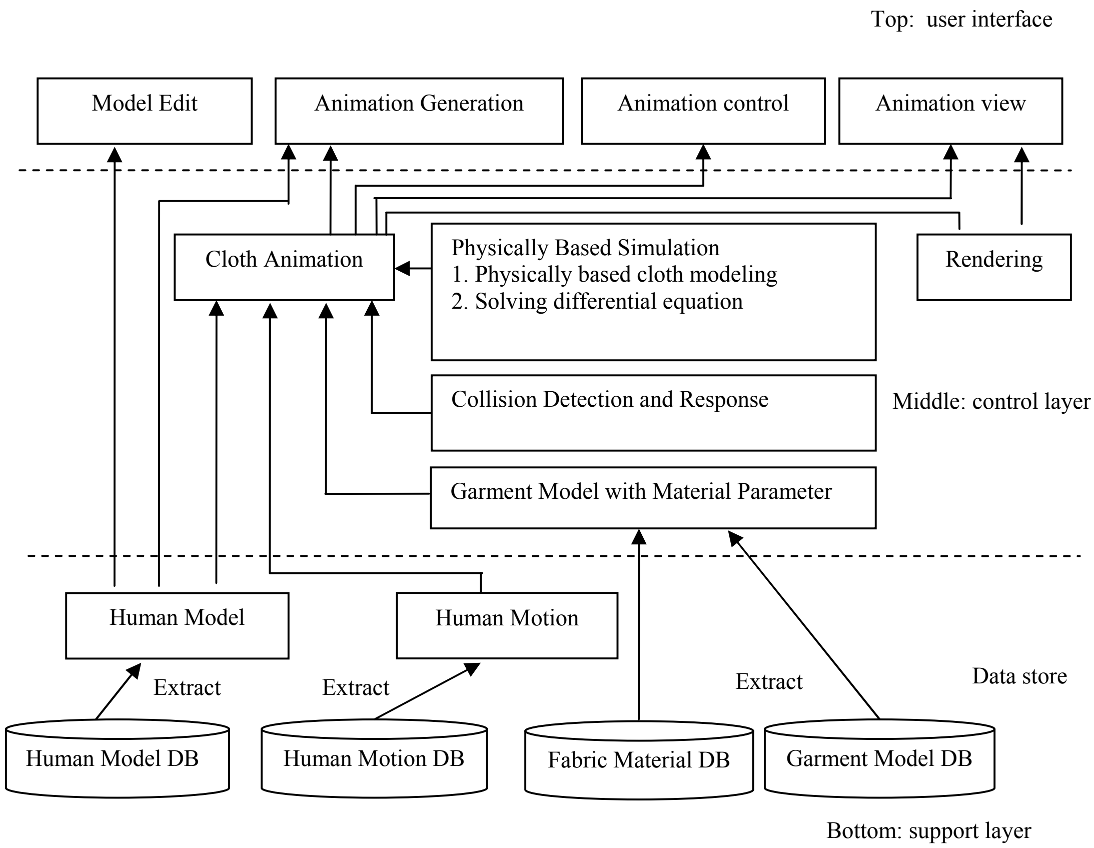

Figure 2 System Architecture

3.2 Bottom Support Layer

The support layer is on the most lower in the architecture, which includes database and core algorithms, provides support for cloth animation and garment animation. The human animation and human modeling components are included in the layer.

3.3Middle Control Layer

The middle control layer is above the support layer. The most important part in the layer is cloth animation module, which includes physically based cloth simulation and collision detection and response engine. The physically based simulation engine animates cloth object according to different mechanical models for cloth. The collision detection engine computes the collisions between the body and cloth or self collisions.

The simulation module allows for human motion, cloth deformation and collision handling to be considered simultaneously.

In addition, a plug-in for rendering is provided in this level, which allows users to export animation data to 3DMAX for rendering.

3.4 User Interface Layer

The user Interface layer is on the most top, which provides users with the functionalities including human models and human animation input, animation manipulating and model editing, and rendering, etc.

IV. IMPLEMENT

Our system is developed based on the proposed three-tier architecture, which integrates some key techniques involved in clothing animation and human modeling. It is an effective tool for creating human clothing animation, which provides users with some basic functionalities including cloth animation, human model editing and clothing simulation.

Through the following examples, we illustrate the advances brought by our system and the new potentialities concerning interactive cloth applications. The simulations were implemented on an Intel Dual Core 2.4G CPU SGI with 1G memory and NVIDIA GeForce 8800GTS GPU.

4.1 Cloth Animation

Here, we illustrate basic manipulations that are performed on a cloth element discretized to about 300 triangles. Figure 3 shows the result of the hanging animation of the cloth fixed on one corner. Figure 5 shows the animation of the cloth blocked on one edge.

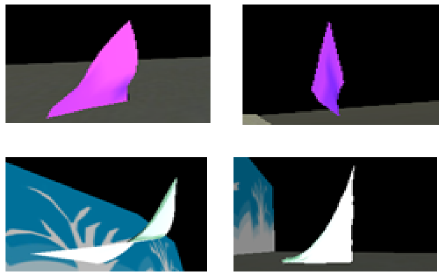

Figure 3 Hanging cloth fixed on one corner

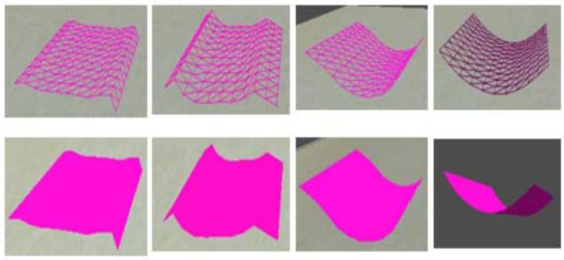

Figure 5 Cloth blocked on one edge

4.2 Clothing Animation

The system allows users to quickly create new three-dimensional human body models through modifying existing template. The interactive editor and proportion box provide a set of intuitive tools for animators to design a rich variety of human shapes.

Human motion data is loaded to generate a sequence of motion in real time.

Garment model are loaded from a file containing the description of the 3D meshes. The meshes are discretized into triangle meshes and then automatically placed in an initial position around actor body. Then, selecting mechanical simulation method and collision handling method, clothing animation will take place using mechanical simulation, and then continuing the simulation on the animated scene and characters. The human body in the virtual scene may that will interact with the garments through collision.

The animated garments can be recorded frame by frame as animations, which can be reused as input data for subsequent computations.

Figure 4 shows a dressed actor in a real environment.

Figure 4 dressed actor animation

V. CONCLUSION

In this paper, we present a clothing animation system which enables efficient cloth animation, human parametric modeling and virtual dressing animation. Compared with other exiting system, our system has some advantages as follows:

(1) An improved mechanical model with real material parameters is used which ensure that our system can quickly generate cloth animation with different fabric material parameters;

(2) Distance constraints enforcement is introduced into our cloth model that can effectively limit cloth elongation in plane without breaking bending deformation, and so our system can generate more realistic cloth animation.

(3) In collision handling process, bi-hierarchy candidate sets technique and GPU accelerated algorithm are used that ensure that the system generate animation in responsible time;

(4) The modular creating 3D parametric model based on radius base function is embedding in the system, that allows users to generate human models with different sizes and proportions through interactively adjusting;

(5)A render-plugins is developed that allows users to export animation data to 3DMAX for more realistic rendering.

All of the above techniques ensure the effectiveness and efficiency of the system. As a prototype system for clothing animation and virtual dressing, it is fast, reliable and expandable.

In order to expand the application range of our system, some aspects still need to be improved in the future, including improving the interactive control of cloth animation, enhancing cloth model library, and so on.

REFERENCE

[1] D. Protopsaltou, C. Luible, M. Arevalo, and N.Magnenat-Thalmann. A body and garment creation method for an Internet based virtual fitting room. In Proceedings of Computer Graphics International (CGI'02), pages 105-122,2002.

[2] F. Cordier, H. Seo, and N. Magnenat-Thalmann. Made-to-measure technologies for an online clothing store.IEEE Computer Graphics and Applications,23(1):38-48,2003.

[3] C. Gross, A. Fuhrmann, V. Luckas, and J. Encarnacao. Virtual try-on:Topics in realistic, individualized dressing in virtual reality. In Proceedings of the Virtual and Augmented Reality Status Conference, 2004.

[4] Terzopoulos D, Fleischer K. Modeling inelastic deformation: viscoelasticity, plasticity, fracture[A]. Computer Graphics(Proceedings of ACM SIGGRAPH 87)[C]. ACM Press, 1987:205-214.

[5] X. Provot. Deformation constraints in a mass-spring model to describe rigid cloth behavior. In Graphics Interface, pages 147–154, May 1995.

[6] Breen, D. E., House D. H., and Wozny, M. J. 1994. Predicting the drape of woven cloth using interacting particles. In Proceedings of SIGGRAPH 94, ACM Press / ACM SIGGRAPH, Computer Graphics Proceedings, Annual Conference Series, ACM, 365–372.

[7] Bridson, R., Marino, S., and Fedkiw, R. 2003. Simulation of clothing with folds and wrinkles. In Symposium on Computer animation, 28–36.

[8] Choi K J, Ko H S. Stable but responsive cloth[J]. ACM Transactions on Graphics(ACM SIGGRAPH 2002), 2002, 21(3): 604-611.

[9] Plausible Cloth Animation using Dynamic Bending Model[J]. Process in Natural Science, 2008,18(7):879-885.

[10] Shear Buckling and Dynamic Bending in Cloth Simulation[J]. Computer Animation and Virtual Worlds(CASA 2008), 2008,19(3-4):493-503.

[11] J.R. Collier et al, "Drape Prediction by Means, of Finite-Element Analysis", Journal of the Textile Institute, 82 (1), pp 96-107, 1991.

[12] T.J. Kang, W.R. Yu, "Drape Simulation of Wowen Fabric Using the Finite-Element Method", Journal of the Textile Institute, 86 (4), pp 635-648, 1995.

[13] J.W. Eischen, S. Deng, T.G. Clapp, "Finite-Element Modeling and Control of Flexible Fabric Parts", Computer Graphics in Textiles and Apparel (IEEE Computer Graphics and Applications), pp 71-80, Sept. 1996.

[14] Bernhard Eberhardt, Andreas Weber, Wolfgang Strasser. A fast, flexible, particle-system model for cloth draping. IEEE Computer Graph Appl 1996, 16(5), PP 9-52.

[15] Bhat K S, Twigg C D, Hodgins J K, et al. Estimating cloth simulation parameters from video[A]. Proceedings of ACM SIGGRAPH/Eurographics Symposium on Computer Animation (SCA 2003)[C].ACM Press,2003:37-51.

[16] Tianlu Mao, Shihong Xia, Zhaoqi Wang. Evaluating simplified air force models for cloth simulation. IEEE International Conference on CAD/Graphics 2009, 81-86.

[17] D. Barraff and A. P. Witkin. Large steps in cloth simulation. In Proceedings of SIGGRAPH 98, Computer Graphics Proceedings, Annual Conference Series, Pages 43-54, July 1998.

[18] M. Desbrun, W. Schroeder, and A. Barr. Interactive animation of structured deformable objects. In Proceedings of Graphics Interface (GI'99), pages 1-8,1999.

[19] Kang Y M. Real-time cloth animation with physical plausibility and numerical stability. Pusan, South Korean: Pusan National University, 2003.

[20] Provot X. Collision and Self-Collision Handling in Cloth Model Dedicated to Design Garments. In Graphics Interface’97, Canadian Information Processing Society, Canadian Human-Computer Communications Society, 1997, pp. 177-189

[21] Volino P., Magnenat Thalmann N. Collision and Self-Collision Detection: Efficient and Robust Solutions for Highly Deformable Surfaces. In Comp. Animation and Simulation(1995), Springer Verlag, 1995, pp. 55-65.

[22] J Mezger, S Kimmerle, O Etzmuf3. Improved Collision Detection and Response Techniques for Cloth Animation. University of Tiibingen, Tech Rep, 2002.

[23] J Mezger, S Kimmerle, O Etzmu. Hierarchical Techniques in Collision Detection for Cloth Animation. Journal of WSCG, 2003,11(1): 322-329.

[24] Zhu Xiaolong, Xia Shihong, Yu Yong and Mao Tianlu. A novel method for cloth-body collision detection, In Proceeding of the 12th International Conference on Human-Computer Interaction, 2007. Beijing, China.

[25] Mao Tianlu, Wang Zhaoqi, Xia Shihong, An Aigorithm for Collision Detection and Response Between Human Body Modeland Cloth in 3D Gament Simulation, Journal of Computer Research and Development, 43(2): 356-361, 2006.

[26] Zhu Xiaolong, A Efficient Cloth-Body Collision Detection Method Based on Bi-Hierarchy Candidate Sets, Journal of Computer-Aided Design & Computer Graphics, Vol.20, No 7, July,2008.