# Movement and deformation of virtual object based on argument passing method

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***Abstract*—Force feedback is a good opportunity for virtual reality technology(VRT) into the field of engineering simulation. haptic device point (HIP) is the common tool used for interacting with the virtual objects, while the mass-spring model consistent with which does not have good scalability, and cannot guarantee the necessary accuracy. By substituting mass-spring model with finite element model (FEM) for contact problems, there will be a solution. This article has set up a system based on argument passing between virtual reality environment and FEM solver, and details the system working process and the challenge.**

***Keywords- Force,Virtual reality,Finite element model,Haptic device,Deformation,Movement,Argument passing***

## I INTRODUCTION

### 1.1 VIRTUAL REALITY TECHNOLOGY APPLYING

Since practical engineering project is making data bigger and bigger, VRT presents an efficient platform to vision the data, which improve intuitively engineers' knowledge of the data. The successful applications can be found in computational fluid dynamics[1],[4], the computer aided engineering2.

More innovational, VRT can broaden human computer interaction (HCI) by using haptic device that is essentially different from the traditional interactive tools, such as keyboard and mouse, from which human obtain 2D visual results on the screen. The new HCI based on haptic device has been used in surgical techniques[6]-[9], imitational training[10]-[13] and the 3D game experience[14].

### 1.2Haptic rendering algorithm

The key for haptic device to work properly is the haptic rendering algorithm, which computes the contact force between virtual objects and avatar representing the haptic device in virtual environment. Basic concepts in haptic rendering can be found in [5], and here is a simple process.See Figure1.

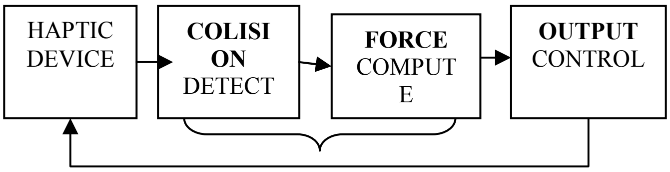


Figure 1 The process of haptic device

Nowadays mostly haptic devices are based on point-based haptic interaction, in which only the end point of the haptic device or haptic interface point (HIP) penetrates into virtual object. Similarly to mass-spring model, the contact force is computed by material empirical stiffness multiplying penetrating depth, which is the distance between the surface node at the entrance and the node neighboring current HIP.

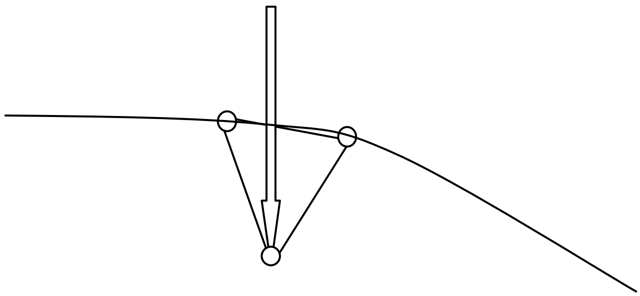

Figure2 Multi haptic interface points

For one thing, this force model limitedly extends to multi haptic interface points. And the material stiffness doesn't have the appropriate physical significance since there should be at least two parameters, Yong's modulus and Poisson' ratio to describe a material. See Figure2.

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By introducing finite element algorithm for contact problems to supplant the force model above, there will be a feasible solution for scalability and material physical significance. First, contact issues in FEM are always related to contact surface, which is divided into multi nodes before numerical calculation; second, finite element algorithm is always due to the physical material properties.

## II SYSTEM ARCHITECTURE

The system architecture composes of three layers as follows: the hardware layer, the virtual reality layer and the FEM solver layer. The hardware layer includes haptic device, computation and communication equipments. The virtual reality layer completes modeling virtual object, synchronizing avatar and haptic device, initializing the system input, and preparing the data for FEM solver. The FEM solver layer realizes contact force calculation and passes the deformation and reacting force data to virtual reality layer. See Figure 3.

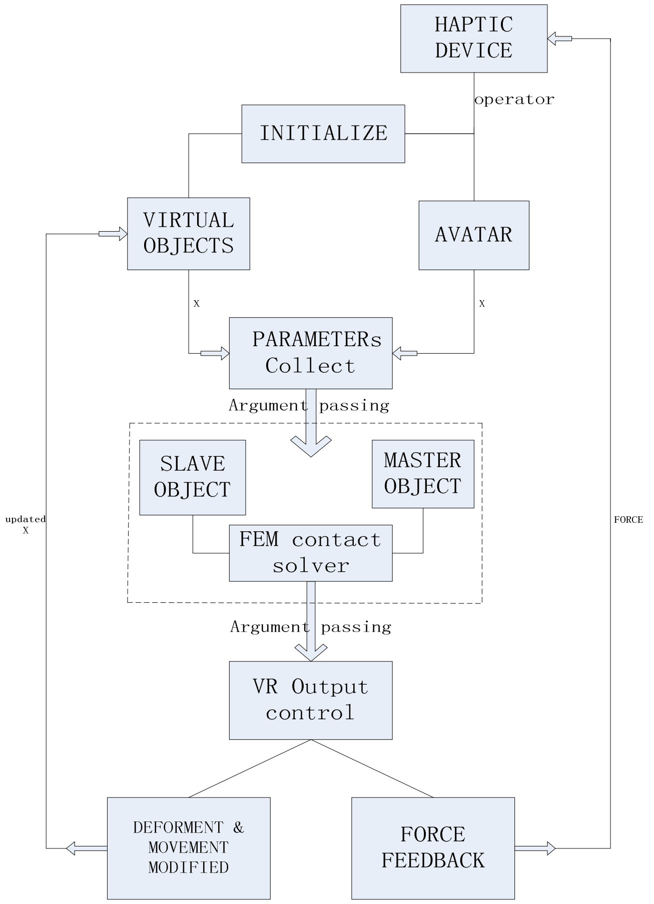


Figure3 The system architecture

The system working process is as follows:

(1)system initialization includes modeling the virtual object, defining the global coordinate system and local coordinate system for avatar and the virtual object.

(2)Arguments preparation, includes collect geometric outline, updated position and material parameters of virtual object and avatar.

(3)Passing arguments into FEM solver, includes the position and deformation data updated from the last time step. As the constant material parameters, it can be saved in a common memory without passing every time step.

(4)In FEM contact calculation module, firstly mesh virtual object and avatar respectively as slave object and master object. In usual, the master object is much more stiffened than slave object, and slave object should be meshed with more elements. Then search the potential collision pairs between the slave surface and the master surface and generate the collision list to compute. and finally passing the result to VR output control.

(5)In every time step, in VR output control module, the penetration depth passed to virtual object as the increment to update position and deformation in next time step, and the contact force passed to haptic device as an pressure increment in force feedback.

Since human only feel force with frequency not less than 1K Hz, at the ideal communication bandwidth condition, FEM solver should be executed in less than 0.001 second. This asks for high performance computation, and actually there are now alternatives, such as Intel's multi integrated cores and NVIDIA's GPGPU products.

## III SYSTEM PARAMETERS

3.1 parameter category

(1)Shape parameter

Shape parameters should be extracted after 3D modeling, and be used to define the deformation of the virtual object.

(2)position parameter

The object geometric properties in space own a certain position. The change of the position represents the object's movement properties. And the position parameter is composed of geometric center..

(3)force parameter

The second derivative changes of object's shape and position represent the force property, the force is three dimensional vector.

(4)material parameter

Material parameters compose of object's density, Yong's modulus, Poisson's ratio et. Al.

(5)Sampling points

Sampling points, that is, vertexes of discrete elements in contact surfaces between virtual object and avatar. Sampling points are reference of discrete object's deformation

3.2 parameter storing and computing

(1)Constant parameters

Constant parameters represent the invariants in problem domain, including object's density, Yong's modulus and others. Constant parameters are stored in common memory as global variables during calculation.

(2)Variable parameters

Variable parameters represent the variants describing object's movement and deformation, such as shape parameters, position parameters and force parameters. Variable parameters are stored in local memory as local variables during calculation.

(3)sampling points

Sampling points is the reference of discrete object's deformation

3.3 argument passing

Realization of system function is derived from argument passing among different modules. transfer of the underlying parameters is done mainly by the parameters of upper layer. argument passing in real time helps to achieve the virtual and the real synchronization.

## IV SYSTEM INITIALIZATION

4.1 virtual object modeling

Virtual object modeling is using open source software, CHAI 3D, as the following reasons are considered:

(1)CHAI 3D presents interfaces for object modeling, which meets the need.

(2) CHAI 3D presents interface for describing reaction force during contact calculation, which satisfies motion and deformation by force.

(3)CHAI 3D is open source software, which is convenient for post development.

4.2 parameter initialization

After modeling, constant parameters should be initialized as the underlying layer's input.

## V CONTACT FORCE CALCULATION

The common model for calculation force is mass-spring model17, represents an object as points of mass joined by springs. For one thing, the mass-spring model does not perform exactly when calculating deformation and reaction force because of the improper material parameters. On the other hand, finite element method is a good choice to calculate deformation and contact force both. Deformation is determined based on surface forces temporarily calculated by penetration depth and physical property parameters, and which can be calculated rapidly in FEM solver layer. See Figure4.

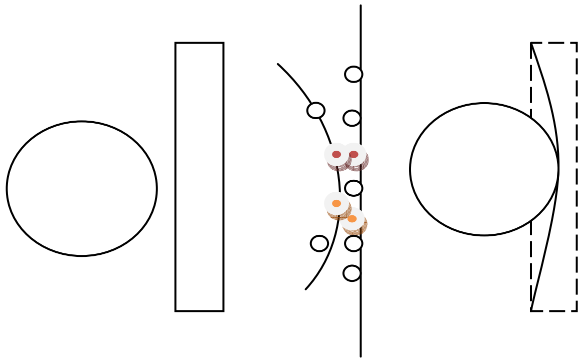

Figure4 The Deformation

As finite element method for contact problems18, there are three steps.

Step one: detecting collision

The point Q on slave surface is found the nearest point P on master surface, since Q is only possible collision with nearby points on master surface, the searching process is regional and efficient. As for the other points on slave surface go on the similar searching process, from which the contact list is set up, and by interpolating all these sampling pairs, the surface contact information is obtained.

Step two: iterative computations

Since FEM contact problems are nonlinear, every time step still need to be subdivided into several more sub steps for numerical convergence.

Step three: results passing

After calculation, points' positions which correspond to deformation and point's reaction forces which are used to form surface pressure should be pass to VR output control.

## VI CONCLUSION

This paper presents a system based on argument passing method between FEM solver and virtual reality environment. Different from past architectures, the interaction force between virtual object and avatar is calculated by finite element method, which, in one way, prevents the empirical stiffness settings, and also more suitable for surface-surface interaction, which is more common compared to single point interaction in practice..

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## REFERENCES

[1] Ali M. Malkawi, Ravi S. Srinivasan "a new paradigm for human-building interaction: the use of CFD and augmented reality" Automation in Construction 14(2005) 71-84

[2] Inho Song, Jeongsam Yang "a scene graph based visualization method for representing continuous simulation data" Computers in Industry 62(2011) 301-310

[3] Yuichi Tamura, Akira Kageyama, Tetsuya Sato, et. Al "virtual reality system to visualize and auralize numerical simulation data" Computer Physics Communications 142(2001) 227-230

[4] Tamer M. Wasfy, Ahmed K. Noor "visualization of CFD results in immersive virtual environments" Advances in Engineering Software 32(2001) 717-730

[5] Kenneth Salisbury, Francois Conti, Federico Barbagli "haptic rendering introductory concepts"

[6] Kup-Sze Choi, Hanqiu Sun, Pheng-Ann Heng "an efficient and scalable deformable model for virtual reality based medical application" Artificial Intelligence in Medicine Vol.32, September 2004, 51-69

[7] Yeong Hwa Chang, Yung Te Chen, Chia Wen Chang and Chih Lung Lin "development scheme of haptic-based system for interactive deformable simulation" Computer Aided Design 42(2010) 414-424

[8] P. Wang, A. A. Becker, I. A. Jones, et al "a virtual reality surgery simulation of cutting and retraction in neurosurgery with force-feedback" Computer methods and programs in biomedicine 82(2006) 11-18

[9] Yoshihiro Kuroda, Megumi Nakao et al "interaction model between elastic objects for haptic feedback considering collisions of soft tissue" computer methods and programs in biomedicine (2005) 80, 216-224

[10] Moohyun Cha, Soonhung Han, et al "a virtual reality based fire training simulate integrated with fire dynamics data" Fire Safety Journal 50(2012) 12-24

[11] Jeffrey Osterlund, Brad Lawrence "virtual reality: avatars in human spaceflight training" Acta Astronautica 71(2012) 139-150

[12] J. S Tsang, P. A. Naughton et al " virtual reality in endovascular surgical training" Surgeon, 2008 August, 214-220

[13] Jeenal Vora, Santosh Nair, et al "using virtual reality technology for aircraft visual inspection training: presence and comparison studies" Applied Ergonomics 33(2002) 559-570

[14] Shira Yalon- Chamovitz, Patric L. Weiss "virtual reality as a leisure activity for young adults with physical and intellectual disabilities" Research in Development Disablities 29(2008) 273-287

[15] Mandayam A. Srinivasan, Cagatay Basdogan "haptic in virtual environments taxonomy research status and challenges" Compute & Graphics, Vol.21, No.4, pp 393-404, 1997

[16] U. Meier, O. Lopez, C. Monserrat et al "real time deformable models for surgery simulation: a survey" Computer Methods and Programs in Biomedicine (2205) 77, 183-197

[17] Shiya Miyazaki, Takami Yasuda, Shigeki Yokoi et al "modeling and implementation of elastic object manipulation in virtual space" Electronics and communications in Japan Part3: Fundamental Electronic Science(1998) , 1919-1926.