

The Construction of Virtual Surgical Clamp Based on the Haptic Feedback System

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Abstract: Haptic feedback technology permits the operators to feel the haptic feedback by features of the virtual model, constraints and interactive states as to guide the operator to conduct the real-time interaction with the virtual environments. Haptic interface is a key interactive device in the study of virtual reality applications. This paper utilized the haptic rendering engine CHAI 3D, SDK of haptic devices Omega.7 together to build the virtual scene. Having established the surgical clamps by using the three-dimensional modeling software SolidWorks and imported it into the virtual scene; The seven DOF matchment with the Omega.7 was finished and the movement, rotation and gripping procedures of the surgical clamps by manipulating the Omega.7 were simulated, making it possible for operators to experience the realistic force telepresence.

Keywords: Haptic Feedback; Virtual Reality; Surgical Clamps; Collision Detection

I. Introduction

Virtual reality technology (referred to as VR) [1-2] is a new research field developed with the in-depth study of computer graphics simulation technology in 80s, people use it to create and experience the virtual world on a computer system[3]. The virtual world is all of the whole virtual environments or a given simulation object. The virtual environment is generated by a computer, which produce an immersive sensory interactive visual simulation through visual, auditory and tactile. Virtual reality is a new discipline involves many practical disciplines, which combines advanced computer technology, sensing and measurement technology, simulation technology and microelectronic technology.

In recent years, the research of virtual reality technology has made a great progress along with the development of computer graphics, image processing and pattern recognition, intelligent interfaces, artificial intelligence and multi-sensor technology. It has been widely applied to various fields, such as the education, entertainment, simulation, virtual training, visual computing and remote operation of robots[4-5].

Tactile feedback is the process that of human-computer interaction, in which the computer responds to input of operator and act on the operator by the haptic feedback device. Virtual reality systems with haptic feedback is composed of the operator, haptic force feedback devices and virtual environments.

The main function of the tactile man-machine interactive device is to measure the movement and position of the users by a sensor and then give the haptic feedback to the user which generated in the virtual environments. The interaction between the operator and the virtual model is achieved via a haptic human-computer interaction device, the deformation of the object that suffered the force can be accurately reflected by the virtual object model. By using the control algorithm to calculate the size of objects, deformation reaction force and then feedback to the users in real-time. In this paper, designed a haptic telepresence system by using the Solidworks, rendering engine CHAI

3D and the tactile force feedback devices Omega.7, imported the surgical clamps into virtual scenes and using the force haptic feedback device Omega.7 to control the surgical clamps, achieved the matchment of seven degrees of freedom between the surgical clamps and Omega.7.

By manipulating the movement, rotation, gripping and other actions of the surgical clamps to sense the tactile feedback. Tactile interaction framework of virtual reality system is shown in Figure.1, the core of haptic rendering system is the deformation of virtual objects with the real situation should be as consistent as possible, fast response and allow the users to produce a immersive feel.

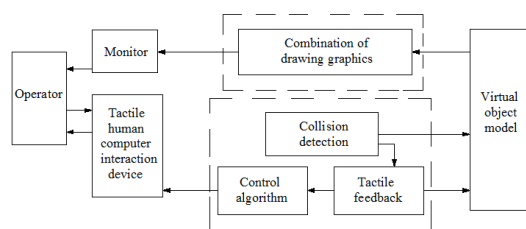


Fig.1 Tactile interaction framework of virtual reality system

II. The Construction of the Force Telepresence Simulation System

2.1 The construction of virtual reality simulation scenarios

Haptic rendering engine CHAI 3D and other components SDK of Omega.7 haptic devices worked together to build the Virtual scene, by using the interaction of Omega.7 and models built in virtual scene to build the tactile sensibility feedback. This system developed the virtual peripherals and Omega.7 tactile device interface program under the visual C++ development environment of visual studio 2010. When create a virtual environment, the background can be generated by using the CWorld, CLight, CCamera and CBitmap that packaged in CHAI 3D. Established some virtual telepresence scene models based on the haptic devices Omega.7 through VC ++ programming.

2.2 Establishment of surgical clamp model

Constructed the surgical clamps model as shown in Fig.2 by using the three-dimensional modeling software SolidWorks. The surgical clamp mechanism which mainly consists of a slider-crank mechanism and a parallelogram mechanism, Fig.3 is the schematic diagram of surgical clamps.



Fig.2 The surgical clamps model

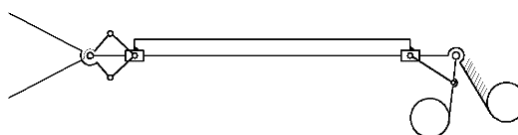


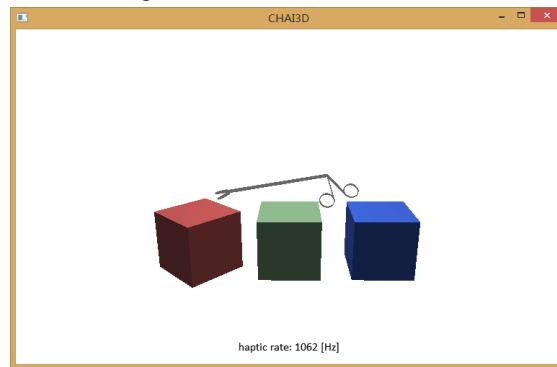
Fig.3 The Schematic diagram of surgical clamps

2.3 The Surgical clamps imported to the virtual scene

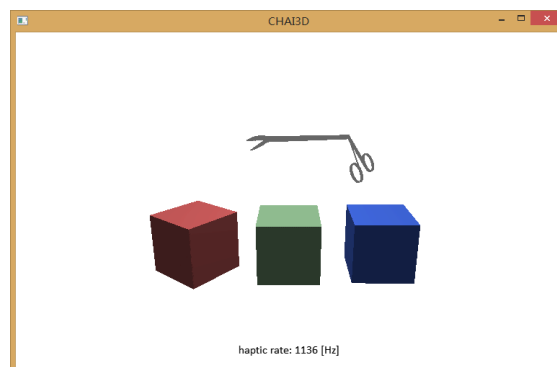
CHAI 3D[6] is a haptic rendering engine with an open source that supports a variety of haptic force feedback devices, CHAI 3D is based on C++, combines with OpenGL graphics library and encapsulates the dynamics engine, can easily touch interactive real-time simulation[7]. As a Windows-based platform, solidworks is a fully parametric feature modeling software, it can very easily achieve the mechanical parts of the three-dimensional solid modeling, assembly and generate drawings. However, the current graphics that drawn out of the three-dimensional modeling software, mostly static, even with three-dimensional modeling software to manufacture animation, that is just keyframe animation and can not achieve real-time interaction. OpenGL, as an outstanding performance 3D graphics standard, has widely application in the field of virtual reality, but in OpenGL, it is relatively difficult to build complex 3D models, more complex three-dimensional models are generally built on professional 3D softwares, such as Auto-CAD, 3Dmax and SolidWorks.

Establish the surgical clamp model in SolidWorks and save it as an STL file, transform the STL file format into CPP and header files utilizes the deep exploration conversion interface software, insert the header files that the Clamp model generated by the #include directive. With regard to STL files for read and display need not consider the internal structure of STL files. The data files that obtained by use of this software have a good package on the properties of the model, such as the model point and area information, material information and

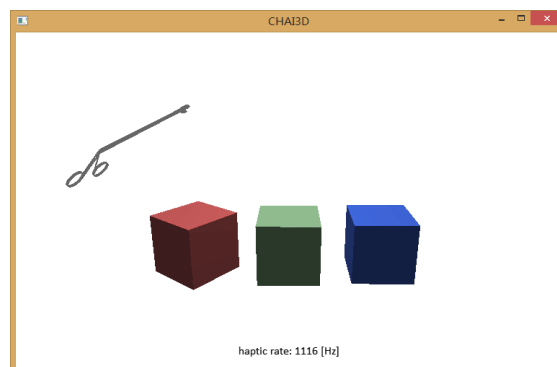
the normal vector information. It has the characteristic of structural clarity and readability. In addition, the resulting document provides a list of OpenGL display tool, the user is added to the file system project after minor modifications to work, calling the list display can be achieved under the system environment models, simple and convenient. The rotation center of the imported clamp model is the center of the minimum bounding box of each part, however, the axis of rotation of the clamp is not at this center, after turning the pan to be transformed so that the axis of rotation center is located in the position of a virtual clamp model. As Omega.7 device has seven degrees of freedom, by writing codes to solve the matching problem of Virtual clamp seven degrees of freedom, virtual clamp imported into the virtual scene and realized the machment with seven degrees of freedom of Omega.7 can be seen in Fig. 4.



(1)



(2)



(3)

Fig.4 The clamp model in virtual scene

2.4 The Collision Detection

Virtual surgery simulation system is an interactive system, in the course of the interaction of visual and tactile combination give people a feeling of being, haptic rendering based on the Haptic force feedback device for drawing in the input and output interface. When the operator manipulates a virtual device by a force feedback device, the virtual device and the Virtual objects occur the collision detection, after the calculation of the deformation and haptic feedback, the result is fed back to the operators, collision detection is a key technology of virtual reality and virtual simulation. Collision detection and the response are very important no

matter it is visual or tactile, collision detection is a prerequisite that the surgical simulation system can obtain a good tactile force feedback effect.

The system utilizes the AABB (Axis -Aligned Bounding Box) collision detection method[8-9], AABB is an external parallel collision detection of three-dimensional geometry of hexahedral and each edge parallel to the axis. The end of the physical device HIP (Haptic Interface Point) should always keep within the virtual object, and the end of the virtual device IHIP (Ideal Haptic Interface Point) is bound to the surface of the virtual object, resulting in visual contact. For deformable elastic membrane organizations, restraint position will change, the end IHIP of virtual devices (Ideal Haptic Interface Point) should vary with the surface deformation. Our task is how to determine the ideal location constraints IHIP quickly and calculate the size of the force feedback.

Assuming the virtual device is a line segment PQ, where one end is the HIP. First, with the object hierarchy AABBs tree quickly determine whether the virtual device and the virtual objects have the collision, if a collision occurs, determine IHIP and define the current element as the active element, here is the algorithm codes.

```

{
  Collision detection status: collision=false
  Simulation status: simulation=true
  while(simulation){
    If(! collision){
      Detection between Virtual Instruments PQ and Intersection detect objects AABBs tree
      If(PQ intersect with a triangle)
      {
        set the triangle as active elements, corresponding to the list to determine the device IHIP
        collision=true
      }
    }
    else
    {
      Set the current active unit=active unit on a moment
      Identifies the active cell types and local models
      Traversal local model from Half of the structure, determine the IHIP, update the active unit
      as IHIP
      Determine whether in continuous contact
      If continuous contact
        collision=true
      else
        collision=false
      Calculate the feedback force
    }
  }
}

```

Since the deformation and force feedback are in different threads and there are very big differences in frame rate, so the deformation calculation associated with force feedback calculate a coordination problem and stability , it is more difficult to solve. For simplicity and stability, we use force feedback calculation method to approximately simulate the feedback force. The calculation formula is:

$$F = -\lambda x - \mu x \dot{x}$$

Wherein λ , μ are elasticity and viscosity coefficient, when touching the membrane tissue penetration, the x , \dot{x} respectively corresponding to the distance and speed, the direction of the force is consistent with normal vector; When the device pulled the membranous tissue, respectively, x , \dot{x} corresponding to the displacement and velocity of pulling point, the direction of the force is in the opposite direction of displacement. Note that this amendment to the penetration of said distance is because the membrane tissue deformation results IHIP equipment varies with the deformation, so the penetration distance also changes.

In summary, the flow diagram for constructing the force telepresence simulation system is shown in Fig.5

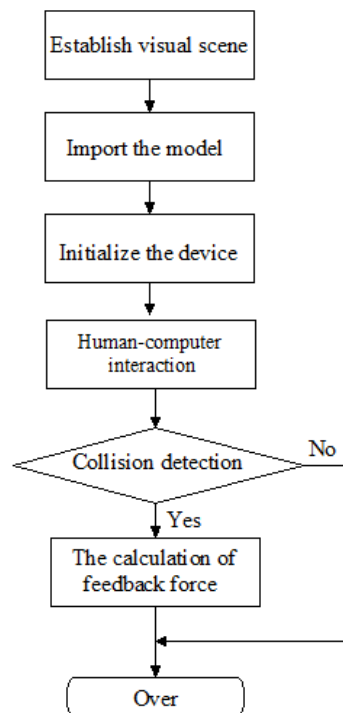


Fig.5 The flow diagram for constructing the force telepresence simulation system

III. The simulation experiment of tactile telepresence system

Based on the above design, built the experimental platform of the system as is shown in Fig.7, take the virtual surgery clamp as an example, since the surgery has a very small puncture area, it is very prone to lead to the operator error. In this system, the operator control the movement, rotation and gripping of the virtual surgical clamp by dominating the Omega.7 to make it contact with virtual objects in the scene, calculating the contact force and then feedback it to the operator, while the real-time location of the surgical clamp will feedback to the operator via the display device. The algorithm listed as follows

The clamp is formed by two rigid body members, and respectively associated with the SDK of Omega.7 by VC ++ programming, achieved the position and posture of the surgical clamp in virtual scene. The brief codes are as follows:

The location and posture of component 1:

The location of component 1:

```
dBodySetPosition(body[0],b0PX,b0PY,b0PZ);
```

The posture of component 1:

```
dBodySetRotation(body[0],b0R);
```

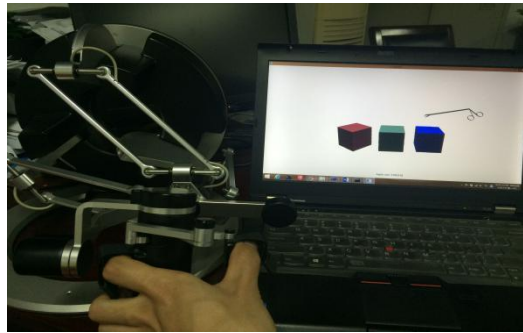
The location and posture of component 2:

The location of component 2:

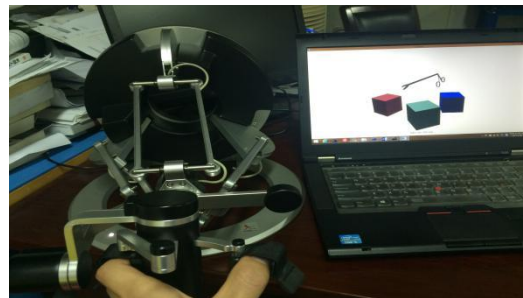
```
dBodySetPosition(body[1],b1PX,b1PY,b1PZ);
```

The posture of component 1:

```
dBodySetRotation (body[1],b1R);
```



(1)



(2)

Fig.6 The interaction between the virtual clamp and object

IV. Conclusion

- (1) The construction of surgical clamps in virtual scene was described.
- (2) The surgical clamps and physical simulation model in virtual scene by collision detection technology was established.
- (3) The force telepresence system was constructed, the virtual surgical clamp was imported into the system and the seven DOF matchment with the Omega.7 was conducted.
- (4) The movement, rotation and gripping procedure of the surgical clamp by manipulating the Omega.7 was simulated.

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