Journal of Mobile Multimedia, Vol. 6, No.2 (2010) 128-144

COLLADA-BASED FILE FORMAT FOR VARIOUS ATTRIBUTES OF REALISTIC OBJECTS IN NETWORKED VR APPLICATIONS SUPPORTING VARIOUS PERIPHERALS

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Received July 31, 2009
Revised January 29, 2010

This paper proposes an extended COLLADA-based file format to represent various attributes of realistic objects used in Virtual Reality (VR) applications that support various peripherals. VR applications provide the user with virtual objects represented as 3D CG. To provide realistic virtual objects in VR applications, the developer of the VR application has to define many attributes of the corresponding real objects besides their 3D geometry and material data in his/her program or in instance definition files of the virtual objects. In this paper, the authors propose the use of a COLLADA file format for such instance definition of virtual objects because it is a XML based 3D model data format and can be easily extended to additionally include various attributes of the virtual objects. This paper introduces the proposed COLLADA-based file format that mainly supports four types of attributes. Those are for haptic parameters of soft objects represented by the spring model used for a haptic device like Phantom, sound data for generating a sound when the user touches a 3D object, text data used as annotations for explaining corresponding objects helpful in simulation/training systems and smell information of objects used for smell generator devices to enhance immersive feeling in VR applications. This paper also clarifies the usefulness of the proposed COLLADA-based file format by showing its examples of actual networked VR applications, and the authors also mention its adaptability to mobile 3D graphics applications by showing one mobile 3D graphics application.

Key words: Virtual reality, immersive environments, Phantom, COLLADA, touch interface device

1 Introduction

In this paper, we propose not only virtual reality (VR) applications that provide the user with intuitive operations on 3D objects like cutting and sewing performed using a force feed-back device like Phantom but also new COLLADA-based file format that includes several attributes necessitated to represent realistic objects of VR applications besides their 3D geometry and material data, i.e., haptic parameters of soft objects represented by the spring model, sound data for generating a sound when the user touches a 3D object, text data used as annotations for explaining corresponding objects and smell information of objects used for smell generator devices. Recently, most of mobile devices such as iPhone provide the touch interface so that it is significant to support the touch interface for manipulating 3D objects in mobile 3D graphics applications. Therefore, in this paper, we also indicate the adaptability of our proposed COLLADA-based file format to mobile 3D graphics applications. Using COLLADA-based file format, it is possible to specify how the touch interface works commonly among several mobile devices for manipulating 3D objects in their 3D graphics applications.

Recent advances of computer hardware technologies make it possible to create 3D CG images and 3D CG animations in real time. On the other hand, as results of VR researches, various types of virtual reality peripherals were proposed and most of them are released as commercial products. In this situation, using these technologies and peripherals, we can develop VR applications those provide an immersive virtual environment where the user operates 3D objects intuitively as if he/she existed in the real world. As one of such applications, we have developed a cloth design system with which the user operates a cloth in a virtual 3D space as if he/she operated in the real world. Our cloth design system provides the user with intuitive operations like cutting, sewing a cloth and fitting it on the body of a 3D character performed using Phantom device [10-12]. After that, we have been developing a surgical simulation system by extending our cloth design system. As the cloth design system needs different haptic parameters for different types of cloth models, the surgical simulation system also needs different haptic parameters for different types of 3D models, e.g., skins and internal organs. In this paper, we call such haptic parameters 'haptic materials'. Haptic materials should be written in the same file of a 3D model to treat them uniformly among different types of VR applications supporting a force-feedback device so that we propose the use of a COLLADA-based file format in this paper because COLLADA is data format based on XML database schema developed to transport 3D asset data between several applications, and can be easily extended to additionally include various attributes of 3D virtual objects manipulated in VR applications. We extended COLLADA file format by adding several new XML-tags to treat haptic materials. We also added sound information in COLLADA-based file format for generating a sound when the user touches a 3D object because sound of touching an object is different depending on the object and important to provide more immersive environments in VR applications.

We have been developing our surgical simulation system for surgical trainee. During the surgical training, the user wants to know the detail information of operations, situation and so on. Our system has a functionality to annotate such information to the user. The annotation information is used as warning information or supporting information for helping surgical operators during his/her training. Since the annotation information also should be written in the same file of a 3D model, we added several new XML-tags to a COLLADA file format. In addition to haptic materials and annotation information, we added another XML-tag to a COLLADA file format to treat smell information used by Aromageur device, a smell generator, because smell of objects is one of the important factors to provide an immersive environment in VR applications. Moreover, to indicate the adaptability of our proposed COLLADA file format to mobile 3D graphics applications, we introduce one application example that support the touch interface for moving 3D objects. In this application example, a certain XML-tag is introduced to represent weight values of 3D objects those are used to specify how the touch interface works for moving 3D objects according to their weight values.

The remainder of this paper is organized as follows: First of all, Section 2 describes related work. Section 3 introduces SensAble Technologies Phantom-Omni device used as a 3D input device of our

VR systems. We introduce a typical COLLADA data format for 3D graphics applications in Section 4. Section 5 describes our proposed COLLADA file format supporting mainly four types of attributes of 3D virtual objects, i.e., haptic material, sound information, annotation information and smell information by showing our cloth design system and surgical simulation system. In Section 6, we also mention the adaptability of our proposed COLLADA-based file format to mobile 3D graphics applications by showing an actual application example. Finally we conclude the paper in Section 7.

2 Related Work

Many researches on the deformable surface simulation have been done. A cloth simulation is well known as a representative example of the deformable surface simulation. We have already developed a cloth design system that simulates a cloth using Mass-Spring model [10-12]. There are many techniques to simulate such realistic cloth [16]. Those cloth simulations are effectively to simulate other deformable surface in real time like a skin and so on. As one of the techniques for the cloth simulation, there is a geometric technique [7]. Recently, physically based cloth simulation is used for realistic graphics and animations [3]. However, these techniques are not suitable for real-time applications due to their heavy calculation costs. For the real-time cloth simulation, a B-spline surface based haptic sculpting system is proposed [4]. By controlling a small number of control points on a surface of a cloth, the system simulates the cloth in real time. As approach similar to this, a particle-based cloth simulation is proposed [14]. By controlling a small number of particles, cloth behavior is simulated at a high speed.

From the viewpoint of the human interface, there are some research systems concerning intuitive operations. For example, Igarashi, et al., proposed a system [21] that provides intuitive operations for fitting and moving a cloth interactively using a 2D input device. Keckeisen, et al. proposed a Virtual Dressmaker [13]. This system allows the user to intuitively select and to drag parts of cloths in a VR environment built by a special hardware set.

There are various kinds of simulation systems that support a haptic device as their input device, e.g., surgical simulators for training of the capsulorhexis procedure during cataract surgery [19]. The tissue of eye is modeled by Mass-Spring model, and the user can perform the operation of tearing the tissue. There is another system that provides functionality to visualize patient specific organs using 3D image datasets scanned by Computed Tomography (CT) or Magnetic Resonance Imaging system (MRI) and that simulates standard endoscopy procedure [17]. Practically 3D model data used in these simulators can be generated from digital images scanned using CT or MRI so that those 3D models are very realistic and the user can perform very realistic surgical operations. There is a surgical simulation system that introduces real dataset into a geometric model in its native format for deploying realistic surgery scenarios [2]. This system navigates a surgery scenario in the 3D virtual environment and also conducts the procedure for user training and study. Although virtual reality technologies occupy the important part of surgical simulators, augmented reality technologies are also important because surgical operations needs a lot of information and augmented reality technologies augment human ability by providing additional information such as the annotation. There is a surgical simulation system [18] that provides a 3D virtual environment using augmented reality technologies. This system aids the surgeon during his/her surgery by playing a role of an orientation guide for planning the surgery or altering existing plans directly. In this way, surgical simulation systems have to treat a lot of information about a surgery so that XML-based data format is useful because it is easy to add new data by employing new XML-tags. Then, in this paper, we propose the use of a COLLADA-based file format to treat various attributes of realistic objects for VR applications.

Recently, sizes of mobile devices become smaller and their performance become higher. Hereby, various mobile systems are researched and developed. For example, a mobile device can be carried anytime, Bohl, et al., developed the system that supports any tasks and works of everyday life by establishing services based on mobile applications [15]. In addition, Gehlee, et al., proposed a Web service employing P2P network architecture using a mobile device [5]. Also, there are researches on tangible interfaces for interactive mobile applications. Kanev developed the multimedia presentation system that the user can perform intuitive operations using a tangible interface [9]. In this way, there are many multimedia systems that can be available on a mobile device. Then, in this paper, we also propose the use of COLLADA-based file format to describe multimedia contents including 3D graphics contents and to specify how intuitive interfaces like the touch interface work commonly used in several mobile 3D graphics applications.

3 3D Input Device: Phantom

As a 3D input device which allows the user to perform some operations intuitively, we use a SensAble Technologies Phantom-Omni device shown in Figure 1. The device mainly consists of a crane-shaped arm with a pen. Two buttons attached to a grip part of the pen play roles like two buttons of a mouse device. Phantom device is connected to a computer via IEEE1394 interface and sends 3D position and orientation data, i.e., 6DOF, of the pen tip to the computer as the input. According to this data, a pointer of Phantom device called Phantom pointer moves in a virtual 3D space. The sampling rate of the device is 1 KHz. Phantom device is not only one of the 3D input devices but also a Haptic device because it generates a feedback force to the user.

Figure 1: Phantom device produced by SensAble Technologies.

4 COLLADA Data Format Based on XML Scheme

The structure of COLLADA document is below. Mainly COLLADA is constructed by three parts such as header, library and scene based on XML scheme.

```
<!-- Definition of header -->
<?xml version="1.0" encoding="UTF-8"?>
<COLLADA>
  <assert>
    <created>…</created>
    <modified>…</modified>
    …
  </assert>
<!-- Definition of library -->
  <library_geometries>
    <geometry id="geometry_id" name="geometry" >
    …
  </library>
<!-- Definition of scene -->
  <scene id="scene_id", name="scene">
    <node id="node_id" name="node">
      <instance_visual_scene url="#sample_scene">
      <translate sid="trans">
        1.0, 1.0, 1.0
      </translate>
      <rotate side="rot">
        1.0, 0.0, 0.0
      </rotate>
      …
    </node>
  </scene>
</COLLADA>
```

COLLADA was developed by Sony Computer Entertainment America in 2004 for enhancing the portability of 3D model data files among several 3D CG applications. The manual of COLLADA is available by getting from the Internet [8]. A lot of 3D content creation software will support COLLADA file format because major 3D content creation software, e.g., 3ds MAX, Maya, SoftImage XSI have already supported it. Since COLLADA defines 3D assets by XML-based schema, using COLLADA it becomes possible to transport 3D assets between 3D CG applications without any loss of described information as follows: Usually, each 3D CG application only supports its original data file format for its 3D assets including 3D geometric models, their material data, scene data, and so on. So, a 3D assets data file of a certain 3D CG application cannot be accepted by other 3D CG applications. If the user wants to export 3D assets data of a certain 3D CG application to others, he/she has to make exporter functionality as shown in Figure 2. Even if the user could make such exporter functionality, some information included in the original 3D assets data file would be lost because 3D assets data are different among 3D CG applications. To solve this problem, COLLADA was proposed as a prospective standard file format of 3D graphics contents. As shown in Figure 3, COLLADA makes it possible to transport 3D assets between 3D CG applications appropriately using XML-tags for each data such as geometry, material and animation data. For example, there are extra file formats, COLLADA FX and COLLADA PYSICS for extra data sets besides geometry, material and animation data. COLLADA FX enables shaders to be authored and packaged using OpenGL Shading Language while COLLADA PYSICS supports physics simulations.

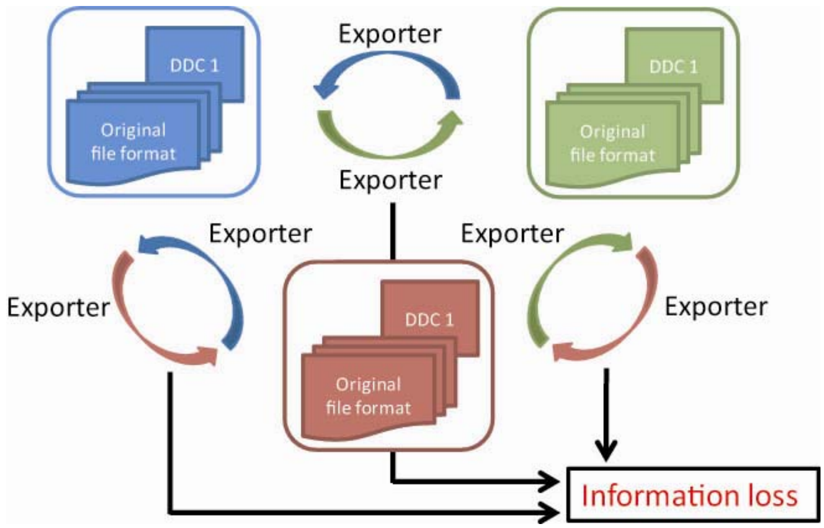

Figure 2: 3D assets data exchange between different 3D CG applications by exporters.

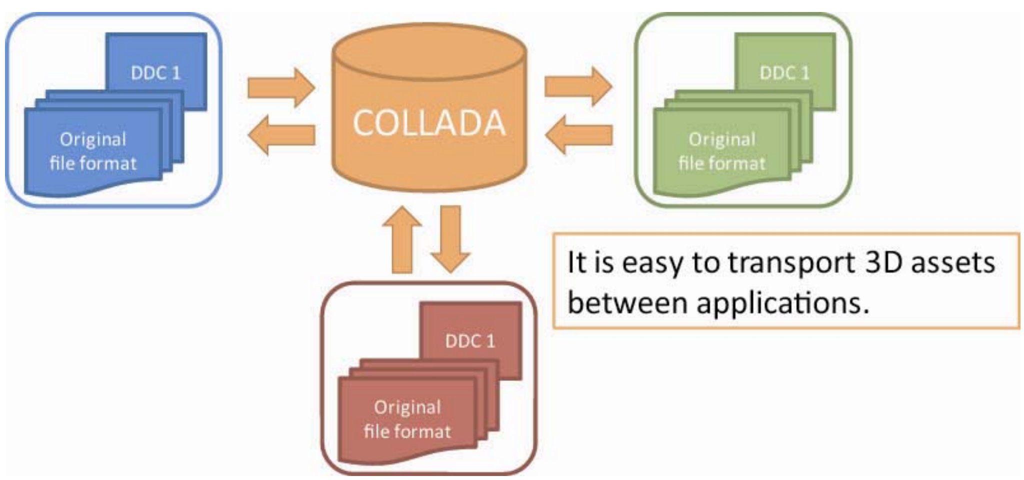

Figure 3: COLLADA enables to transport 3D assets data seamlessly between different 3D CG applications.

5 Networked VR Applications Supporting Various Objects Attributes in Extended COLLADA Data Format

Figure 4 shows an overview of VR applications introduced in this section. COLLADA enables to transport 3D assets data seamlessly between different 3D CG applications because COLLADA is based on XML scheme, so various data can be included easily without any modification of other parts.

In this section, we propose COLLADA-based file format extended for our cloth design system and surgical simulation system. Especially we propose three types of XML-tags for haptic materials data, sound information data and annotation information data. Moreover, we support smell information because smell plays an important role for enhancing the immersion of VR applications although smell is not used in our cloth design or surgical simulation system.

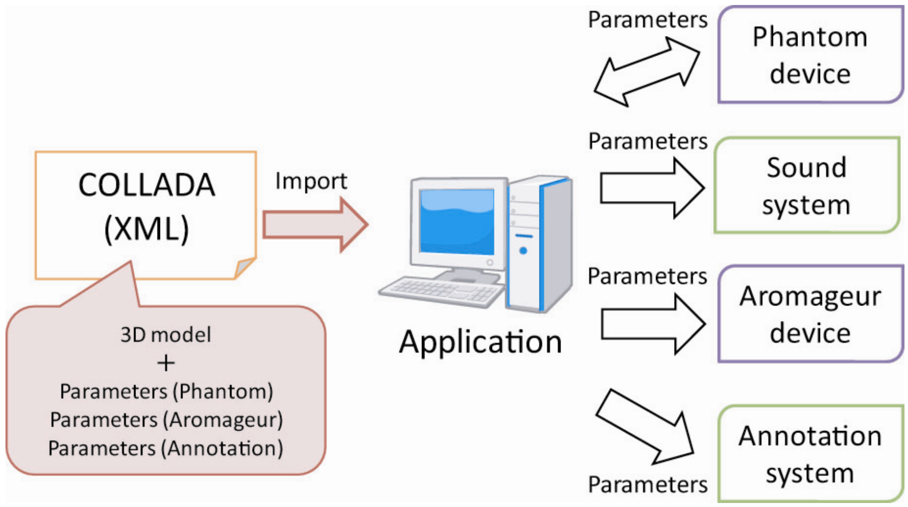

Figure 4: Overview of the introduced VR applications. COLLADA has haptic parameters, annotation information and smell information besides 3D geometric and material data.

5.1 Haptic Materials for Cloth Design System

Figure 5 shows a screen snapshot of our cloth design system when the user pulling up an edge of a cloth. Besides the cloth, there is a 3D character represented as polygonal mesh models. Our system employs the Mass-Spring model for the cloth simulation. Firstly, the user wraps a 3D character in a cloth in the gravity field. This operation requires any collision detection mechanism. We use an OBB-tree [20] for the rapid collision detection. The OBB-tree is a tree hierarchy of oriented bounding boxes (OBBs). After wrapping the 3D character, the user performs any operations on the cloth to design it. We prepare several operations, i.e., pulling, cutting, sewing, and painting/drawing, those can be performed using a force-feedback device, Phantom. The user performs the following operations 1) to 4) , and Figures 6 1) to 4) for creating a cloth of a 3D character.

1. Wrap a 3D character in clothes using a gravity effect.
2. Cut and remove unnecessary parts of the cloths.
3. Sew several edges of the clothes.
4. Paint a picture on a surface of the cloth

Finally the user obtains a designed cloth like shown in Figure 7 by performing the above operations.

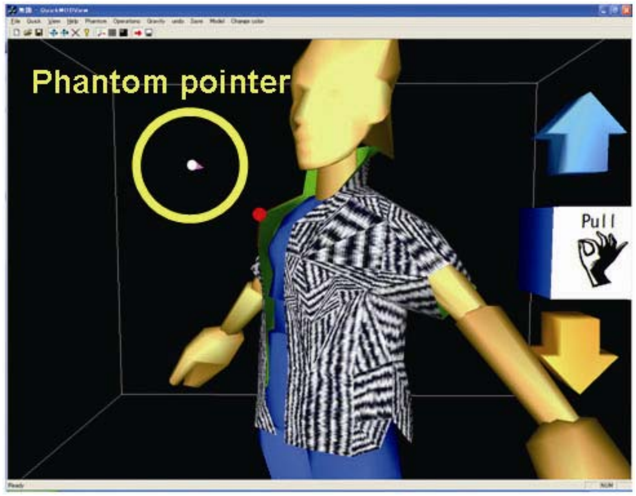

Figure 5: Screen snapshot of manipulating a cloth in the cloth design system.

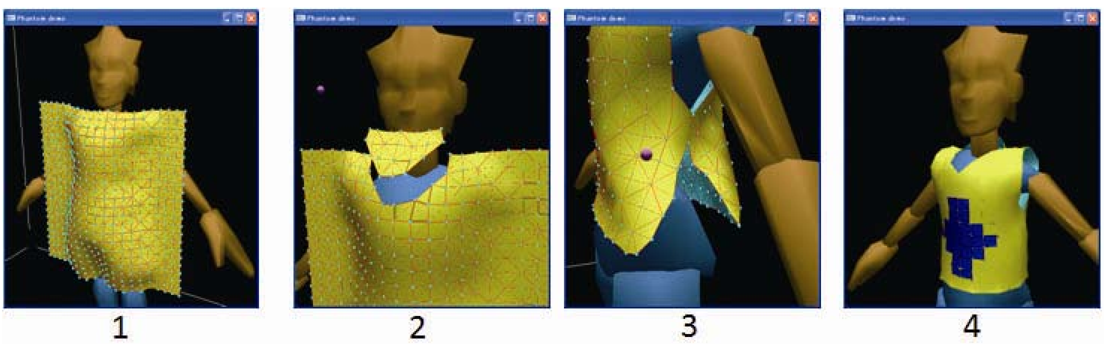

Figure 6: Screen snapshots of cloth design procedures.

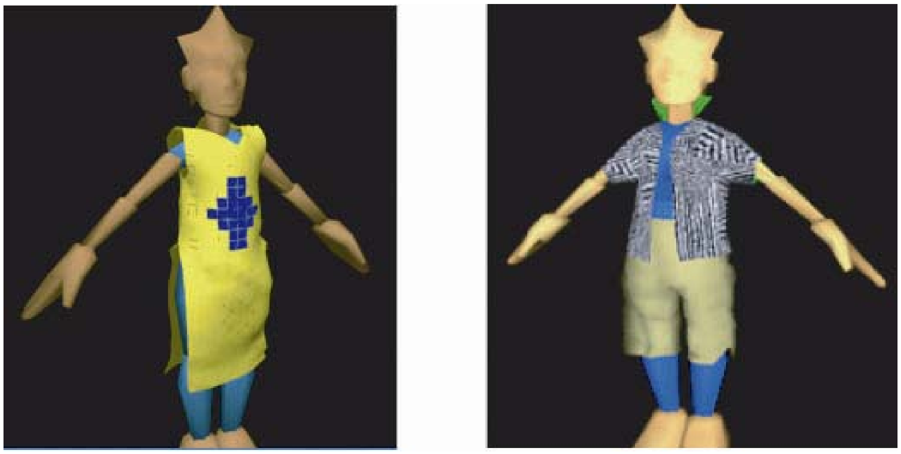

Figure 7: Cloth fitting to a 3D character.

We have already proposed and developed a collaborative environment in which two users can operate the 3D object collaboratively through the Internet [12]. In the network architecture, Peer-to-peer architecture is easy to implement rather than Client-server architecture so that many systems those provide a collaborative virtual environment based on Peer-to-peer architecture have been proposed so far [1, 6]. So, we also employed Peer-to-peer architecture for a collaborative environment of our system. As shown in Figure 8, each user can perform his/her desirable operation on a common 3D object. By collaborative environment and annotation information, our system is used as an education system for surgical trainees, and it is so effective when two users are in a different place. Figure 9 shows a screen snapshot of actual collaborative operations by two users, user1 and user2. In the figure, user1 is performing a pulling operation and user2 is performing a cutting operation. In the system, each user can perform his/her desirable operation on a common 3D object simultaneously. Although this paper does not explain the detail performance of the system because of the page limitation, two users can perform any operations in real time, i.e., the rendering speed is more than ten frames per second as described in [12].

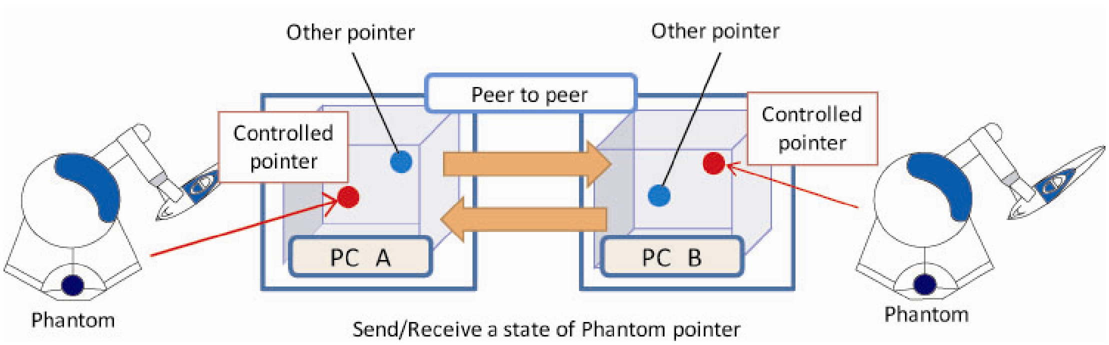

Figure 8: Collaborative environment in which two users perform operation through the Internet.

Figure 9: Operating a cloth by two users collaboratively.

Haptic devices like Phantom need some parameters to generate a feedback force. We call such parameters ‘Haptic materials’. For example, there is a reflection force when the user touches a surface of a 3D object and then, the user can feel a touching force. Each 3D object has specific haptic material and this information is described using certain XML-tags in a COLLADA-based data file. We developed our cloth design system using OpenHaptics API provided by SensAble Technology Inc. Although OpenHaptics accepts many kinds of haptic materials, we decided to employ the following parameters.

1. Stiffness: This parameter controls how hard a surface is. If the user touches the surface of a 3D object, he/she can feel a force feedback from it.
2. Damping: This parameter reduces the springiness of the surface of a 3D object.
3. Static friction: This parameter controls how hard to slide a proxy along on the surface of a 3D object when the proxy starts from its stop state.
4. Dynamic friction: This parameter is opposite to static friction, controls how hard to slide a proxy along on the surface of a 3D object while the proxy is moving.
5. Spring and Damping force of a surface: A 3D object is modelled by Mass-Spring model, so it has coefficient of spring and damping equations.

Each parameter is described in a COLLADA file as follows.

<haptic_material>

1. Tag: <param sid=“stiffness" type="float"> 1.0 </param>
2. Tag: <param sid=“damping" type="float"> 0.5 </param>
3. Tag: <param sid=“static_friction" type="float"> 0.3 </param>
4. Tag: <param sid=“dynamic_friction" type="float"> 0.1 </param>
5. Tag: <param sid=“surface_spring" type="float"> 0.1 </param>

   Tag: <param sid=“surface_damping" type="float"> 0.1 </param>

5.2 Sound Information for Touching Object

In the previous subsection, we added haptic materials into COLLADA format for force feedback functionality. Here, we also add sound information for providing more immersive virtual environments. When the real object is touched, the sound, which is different depending on the type of the object, is generated. For example, aspirate object generates large high-frequency sound. On the other hand, flat surface objects such as metal and paper hardly generate any sound. Sound generated from an object is different depending on the surface of the object. So, sound information is important for identifying its corresponding object.

In this research, sound data are captured from real objects, e.g., cloths for the cloth design system, as shown in Figure 10. However, it is impossible to capture sound data from internal organs required for the surgical simulation system. In this case, we can use real objects those having sound information similar to internal organs. Because sound data of “cutting” and “sewing” operations are very effective for the surgical simulation so that these sound data are also captured through “cutting” and “sewing” operations in the real world. In this way, we can obtain a database of sounds captured from real objects and we can provide more immersive virtual environments in our VR systems.

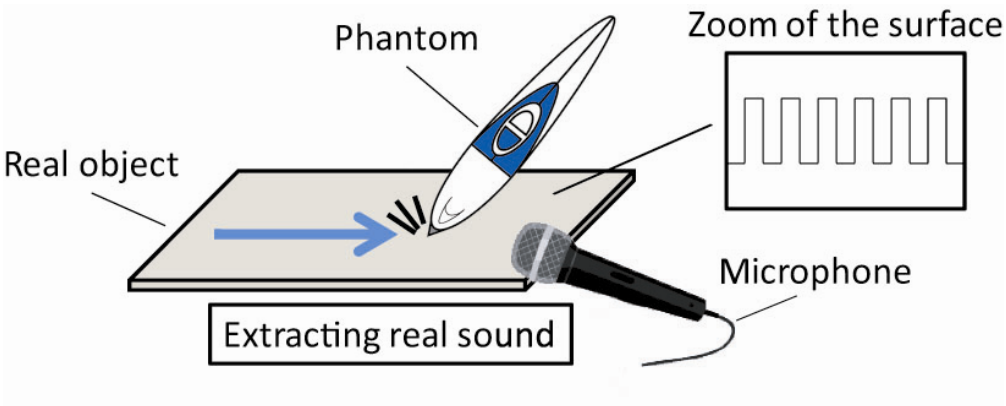

Figure 10: Capturing sound data from real objects.

Here, we explain sound information example defined in a COLLADA file. If the user touches the surface of a 3D object, the system makes the sound defined in the COLLADA file. Tags are described as follows. In the sound information, we define a sound file name with its file path.

<Sound information>

Tag: <param sid=”sound” type=”char”> ./res/sound.wav </param>

5.3 Annotation Information for Surgical Simulation System

We have been developing a surgical simulation system by extending the cloth design system. Figure 11 and Figure 12 show screen snapshots of our surgical simulation system. The surgical simulation system also supports Phantom device. Its haptic materials for skins and internal organs are written in the same file of a 3D model as an extended COLLADA file. In our system, first, the user selects a region of a 3D object as shown in the left part of Figure 11. Next, the selected region is subdivided and starts deformable surface simulation. Our system provides the user with annotation functionality as shown in the right part of the Figure 11.

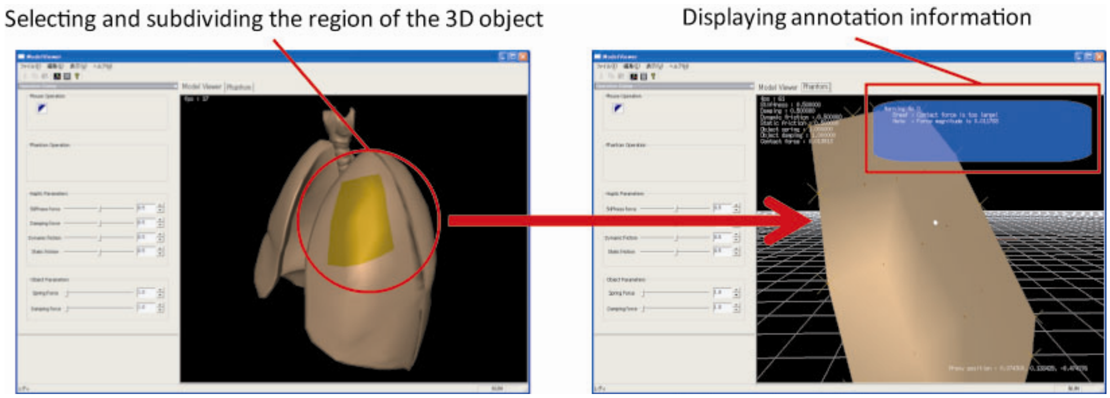

Figure 11: Screen snapshot of cutting operation on an internal organ in the surgical simulation system.

In the surgical simulation system, displaying annotation information about a surgery target on a screen like warning text and detail explanation is very helpful for a surgery trainee during his/her surgery training. This annotation information is unique depending on types of internal organs or skins, and should be described in the same data file as 3D geometry data and haptic materials file. Using specific XML-tags in COLLADA, this becomes possible. In our surgical simulation system, we implemented functionality to manage annotation information described in a COLLADA-based data file. Using such annotation information, when the user performs a wrong operation, the system can warm him/her by a visual annotation as shown in Figure 13.

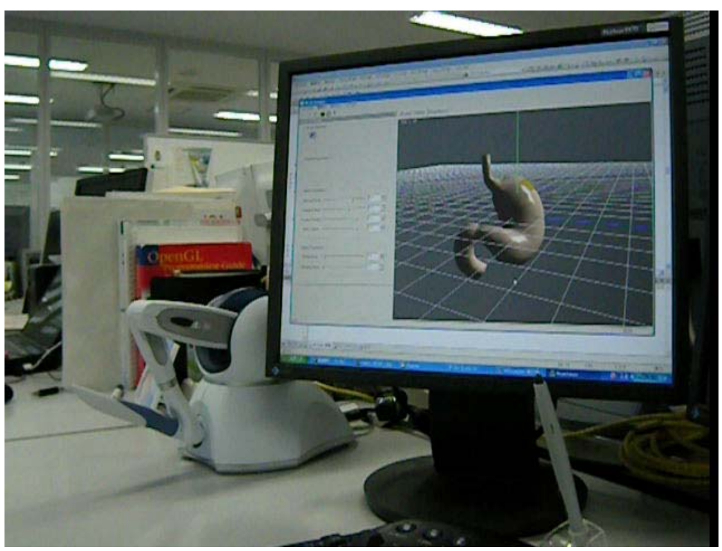

Figure 12: Surgical simulation system using Phantom device.

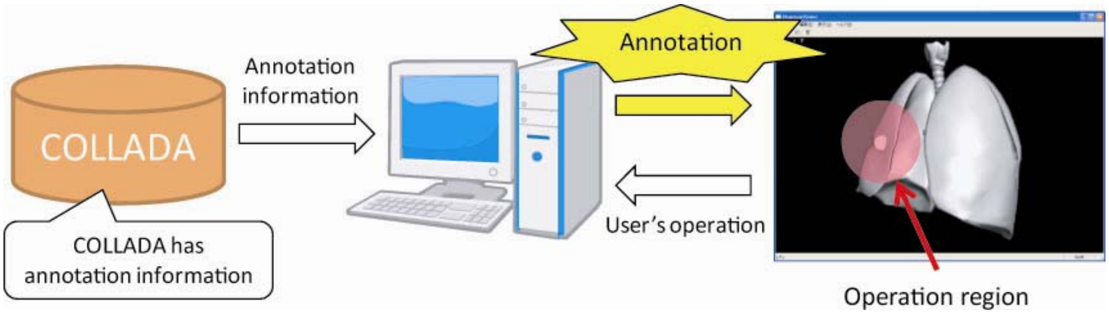

Figure 13: Warning functionality of the system using annotation information described in a COLLADA-based data file.

Here, we explain annotation example. If the touch force is over a threshold of maximum force when the user touches the surface of a 3D object, then, the system displays annotation information on a screen using warning text with sound effect. In this case, tags are described as follows.

<Annotation information>

Tag: <param sid=”touch_max_force” type=”float”> 0.2 </param>

Tag: <param sid=”warning_comment” type=”string”> Touch force is too large </param>

Usually most interactive applications require the programmer to modify their program when help messages or annotation contents of the program have to be changed. Modifying the program by changing its source programs and by rebuilding its execution file is a time-consuming task. However, our surgical simulation system does not need to be modified even when its help messages or annotation contents have to be changed because such information is included in the COLLADA file of a target 3D object.

5.4 Smell Information for Other VR Applications

In addition to haptic materials and annotation information, we added several new XML-tags to a COLLADA file format to treat smell information used by Aromageur device, a smell generator, because smell of objects is one of the important factors to provide an immersive environment in VR applications. For example, in the case that the user wants to grasp an object having smell such as foods or fruits and to sniff the smell in a virtual 3D space, Aromaguer device is very useful and smell information is very significant.

As shown in Figure 14, Aromageur device has six output ports of six kinds of aromas. By controlling each of the six ports, the device generates a smell as mixture of the six aromas. In an extended COLLADA file format, we can describe each tag to specify output percentage of its corresponding port of the six output ports as follows.

<Smell information>

Tag: <param sid=“Port1" type=“int">10</param>

Tag: <param sid="Port2" type="int">30</param>

…Each tag defines output percentage of a port.

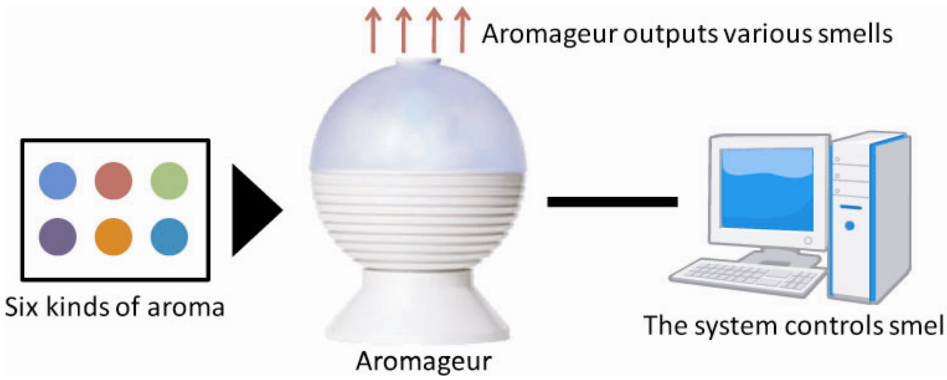

Figure 14: Aromageur device generates a smell by controlling six output ports of six different aromas.

6 Adaptability of COLLADA File to Mobile 3D Graphics Applications

We expect that COLLADA file format will be used more widely and become more popular as an intermediate file format of 3D models for transporting them among 3D graphics applications in the near future. Currently, Google Earth has adopted COLLADA file format as its native file format for describing 3D objects located on the earth, and many 3D content creation software such as Maya, 3ds Max and SoftImage have already started to support COLLADA files.

As shown in Figure 15, in some mobile devices such as iPhone, COLLADA files can be used for displaying 3D objects on its display. For example, NaviCAD is an application of iPhone/iPod touch that can display 3D models described in COLLADA format files downloaded from the Google 3D Warehouse. In this way, by supporting COLLADA file format, it will be possible to more easily develop 3D graphics applications for mobile devices besides standard PCs due to reducing the implementation time of importer functionality of 3D graphics contents.

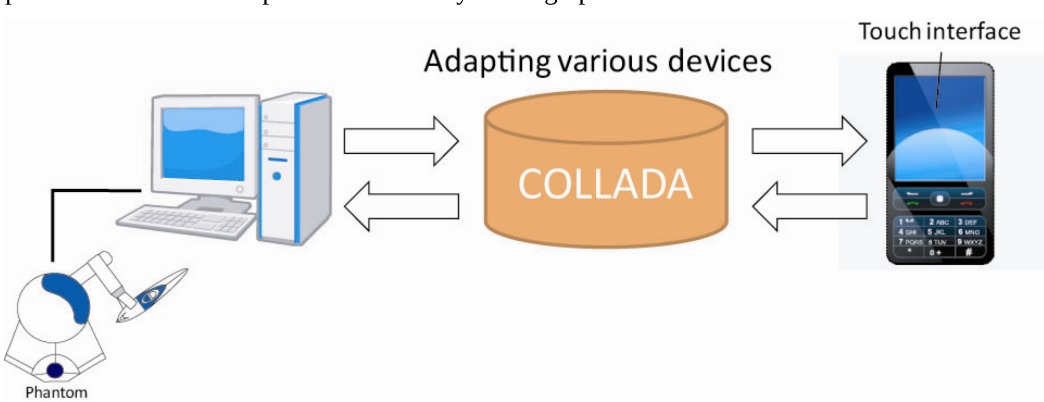

Figure 15: Adapting various devices to our system using Collada file format.

As an example of mobile 3D graphics applications, we introduce a 3D object viewer that supports the touch interface. In this system, we employ the weight of an object as one of its important material information for the touch interface and add such information as a certain XML-tag to COLLADA file format. Figure 16 shows an actual system implemented in iPhone device. When the user moves 3D objects using the touch interface, if the weight of an object is heavy, the movement of the 3D object becomes slow. On the other hand, if the weight of an object is light, the movement of the 3D object becomes fast. In this way, the user can feel the weight of a 3D object intuitively. For constructing immersive virtual environments even on mobile devices, to employ various material parameters of real objects applied to 3D CG virtual objects is very significant and the use of COLLADA-based files is suitable for it.

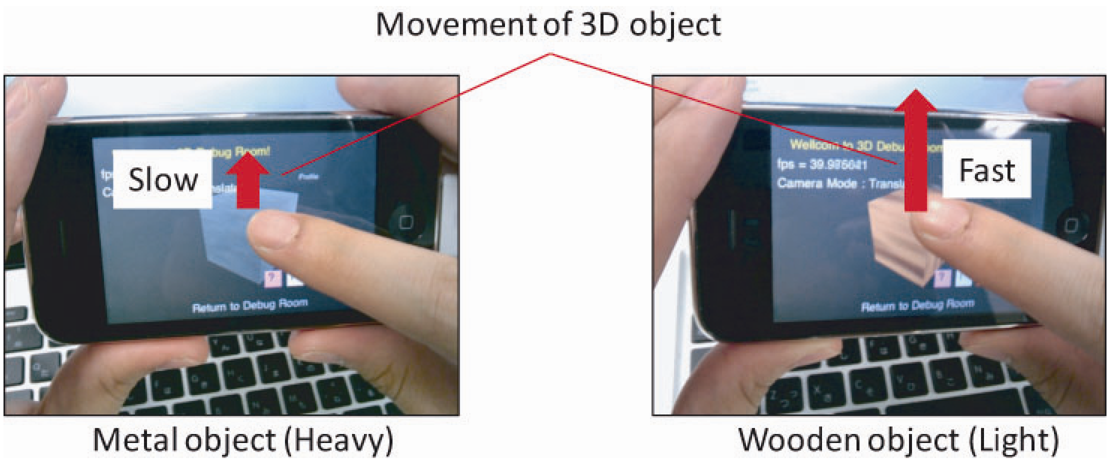

Figure 16: Left figure is a screen snapshot of a metal 3D object and its movement is slow. Right figure is a screen snapshot of a wooden 3D object and its movement is fast.

7 Conclusions

We have already proposed a cloth design system that provides intuitive operations, pulling, cutting, sewing and painting/drawing performed using a haptic device like Phantom. Based on this development experience, currently we have been developing a surgical simulation system that provides intuitive operations performed using Phantom device. In this paper, we proposed these prototype systems. Our prototype systems not only provide intuitive operations but also supports COLLADA-based file format. In this paper, we also proposed the use of an extended COLLADA-based file format to treat various attributes of realistic objects for networked VR applications besides their standard 3D geometry and material data. This paper introduced the proposed COLLADA-based file format that mainly supports four types of attributes. Those are haptic parameters of soft objects represented by the spring model used for haptic device like Phantom, sound data for generating a sound when the user touches a 3D object, text data used as annotations for explaining corresponding objects helpful in simulation/training systems and smell information of objects used for smell generator devices to enhance immersive feeling in VR applications. Moreover, we also mentioned the adaptability of COLLADA format files to mobile 3D graphics applications.

We employed a Mass-Spring model for the deformation simulation of the introduced systems. It needs much computational cost so that it is impossible for real-time operations to increase the number of vertices of deformable target mesh. We have to employ more efficient deformation model to reduce the computational cost for real-time operations. We have to prepare efficient menus and dialogs for our surgical simulation system to make it practically useful for various users. We will try to introduce other attributes of realistic objects for various VR applications and to define XML-tags for them described in an extended COLLADA file. These are our future works.

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