몰입감 있는 맞춤형 가상 모델하우스

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Immersive virtual custom-made model house

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ABSTRACT

Putting a high value on individual preferences is a modern trend that more and more companies are considering for their product design and development and the apartment design is not an exception. Most apartments today are built using similar design with no room for customization. People in general want their tastes to be reflected in the design of their apartment. However, delivering what customers like to the construction company may not be an easy task in practice. For this reason, an intuitive and effective medium between the company and consumers for effective communication is needed to ameliorate such a difficulty and in response to this necessity, we propose a platform for the virtual model house with haptic interactions. In our virtual environment, a user can change the interior of an apartment based on their taste and feel through intuitive interactions. Through this virtual experience, the user will find a design that is truly satisfying and affectionate and can realize custom-made apartment design.

Key Words : Virtual model house, Multi-modal interaction, haptic interaction

1. Introduction

These days, people consider many things when they buy an apartment as they pursue a variety of things in their life style. This trend pushes construction companies to construct an apartment that reflects customer's individual favorite design style. For this reason, the apartment market has been transformed to satisfy such a trend and each construction company is trying to provide its unique apartment model. For example, blooming apartment[1] provides a self design project through their web site, where a customer can design a living space and interior as their own tastes. Previously, a customer who wants to buy an apartment goes to an apartment model house and looks around the model of their house directly,

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which is time consuming and not cost-effective. However, through the immersive modeling technique on the internet, such a problem can be relieved. The customer can browse the virtual model house on the website without visiting the real model house for him/herself. On the website, they can select and change the model house corresponding to their own tastes. However, interaction, an important factor for presence, has not yet been addressed by these advances. When viewers have the ability to interact naturally with an environment, or are able to affect and be affected by environmental stimuli, they are likely to become more immersed in that environment. Furthermore, since the human haptic system has the ability both to perceive sensations from the environment and act on the environment, haptic interaction has a potential to create a truly immersive experience. As the interest of immersed multi-modal interaction is increasing, this paper has utilized the state of art interaction technique to modern construction.

In previous works, Buchmann et al.[2] showed one example application in their paper where gesture interaction could be used for urban planning. Also, the fingertip-based haptic devices enable the user to feel a virtual object. McLaughlin, et al.[3] used haptics to allow museum visitors to explore three-dimensional works of art by “touching” them, something that is not possible in ordinary museums due to prevailing “hands-off” policies. Norman, et al.[4] described a virtual environment to support the construction process of buildings from prefabricated components. In that platform, a user can begin constructing a building from the empty environment or a partially constructed building and modify it with a LogiCAD3D Space-Mouse. However, due to the limitation of the mouse, the user can only experience the visual interaction without any haptic feedback. Massimo Bergamasco et al.[5] described the architecture of the “Museum of Pure Form”, a virtual reality system where the user can interact, though the sense of touch and sight, with digital models of 3D art forms and sculptures. This paper considered the technological aspects concerning the implementation of a virtual environment endowed with haptic feedback for cultural heritage applications. Stephen Brewster[6] described the background to haptics, some of the possibilities of haptic technology and how they might be applied to cultural application.

The main purpose of this paper is to develop an immersive virtual custom-made model house platform. Our platform is designed to reflect the customer’s needs in their house design and supports the immersive interaction between the customer and the house when he/she modifies the interior of the model house in real time. For example, in our platform, the user can modify the structure of a model house and interact with the house at the same time using a haptic device so that he/she can feel immersed in the virtual house and design it to his/her own tastes.

Our paper is structured as follows: in Section 2, we introduce the basis of our system: hardware and software, and present how a user can manipulate the virtual environment. In Section 3, we discuss event handling for the immersive experience. Section 4 describes haptic effects which include dynamic models to represent various feelings such as reaction force, stiffness and friction. Sections 5 explain a navigation mode which allows the user to experience a virtual house and a virtual TV to enhance realism in our system. Section 6, we compared our system with existing cyber model house. Finally, in Section 7, we conclude this paper by identifying the benefits of our system and suggesting the future work

2. Basis of our system

In our system, a user enters a virtual apartment model house and designs it for him/herself by interactively changing parts in it. For giving the user a realistic feeling when the user modifies the model house, a haptic device such as Omni™ [7] is used. Our system is based on the open source CHAI3D API for haptic interactions[8]. CHAI3D is a minimal API which is notable mainly for incorporating a tight coupling between its graphical and haptic representations. We consider that the whole house model is constructed using parts individually defined in a hierarchical data structure, which allows the user to manipulate each part such as changing the position of furniture, the color of the wall, etc. and to manage easily graphic and haptic interactions. Each part of the model house is represented in triangular mesh and the model house is composed of totally 34 parts consisting of about 30,000 polygon meshes. These parts are used as the components of the XML file format to define the model house using the hierarchical data structure. Fig.1 shows the XML file format being used for graphic and haptic rendering.

```
<scene> [collection]: An entire scene composed of models.
    <model> [collection]: 3 model types composed of mesh below.
        <static_object> [collection]: Describes static mesh.
            <filename> [string]: The filename form which to load the mesh
            <stiffness> [int]: The stiffness of the object
            <staticfriction> [double]: The object's static friction
            <dynamicfriction> [double]: The object's dynamic friction
            <unique_id> [int]: An identifier for the object
            <parent_id> [int]: A reference to the unique_id of the parent
            <trans> [float][float][float]: Local translation of the object
            <rot> [float][float][float]: Local rotation of the object
        <button_object> [collection]: Describes button mesh.
            ==== same with static object ====
            <k1> [float]: First spring constant
            <k2> [float]: Second spring constant
            <l1> [float]: First spring displacement
            <l2> [float]: Second spring displacement
            <cutoff> [float]: Max displacement for cutoff
        <push_object> [collection]: Describes slider mesh.
            ==== same with static object ====
            <k> [float]: Spring constant
```

Fig. 1. XML file format for graphic and haptic rendering

In the file, there are several syntaxes which denote scene, model, object type and object properties. “Scene” describes an entire scene composed of one or more models. The current implementation of the scene automatically displays only the first model in a scene description. “Model” describes a cad model composed of a number of meshes. According to the function of parts, the model can be divided into three types. Those are the static object, button object and push object. Each object denotes non-movable parts, button parts, moving parts respectively. It includes several properties such as filename, stiffness, friction, part identifier, translation vector, rotation vector, etc. Detail explanation of object will be explained in Chap.4. Moreover, texture mapping is used in order to increase the visual quality.

Fig. 2 shows an event map of our system. Our software is composed of two parts: navigation and haptic interaction modes. In navigation mode, a user can enter the model house and look around the interior of the house by changing the camera position. The user can change wall papers and floors to his/her own taste. In addition, there is a television which can display a movie when clicking a button for TV view. In haptic interaction mode, the user can feel the interaction such as reaction force, stiffness and friction through the haptic device when he/she modifies the layout of the model house.

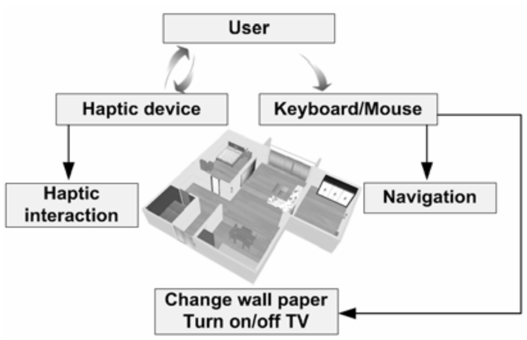

Fig. 2. Event map of our software

3. Event handling for graphic and haptic interaction

In this chapter, we introduce the method of event handling when modifying the model house by a haptic device. Due to different functions of each part such as translation, rotation, overlap, there could be a lot of events during modification process. It makes the event handling complex. Fig.3 shows event handling algorithm that was used to execute appropriate events such as translation, rotation, stop, etc. While a user moves the haptic probe, whether the collision between a probe and a part is detected or not is inspected. If collision is detected, by several operations such as pushing the wall, doorbell, opening/closing the door and windows and changing the position of furniture, etc., specific messages are generated with a corresponding part identifier. By using these messages, the selected part can be moved or rotated in proper directions according to movement vectors from the haptic device. At the same time, the user can feel feedback force as well as movements visually. Furthermore, since each part has more than one movement direction for various moving actions, we use a keyboard to distinguish whether the selected part is supposed to move linearly or rotate when the haptic probe collides with the part of a model. For example, a door attached to the moving wall can be rotated itself and it can also be translated when the wall is moving. Sometimes, more than two parts can be overlapped while some part is moved. In such case, we calculate the bounding box of each part and check whether the moving part is contacting with adjacent parts or not. If there is a contact, then, the contacting parts are translated with the moving part together for translation case, but those would be stopped for rotation case to prevent bad modification results.

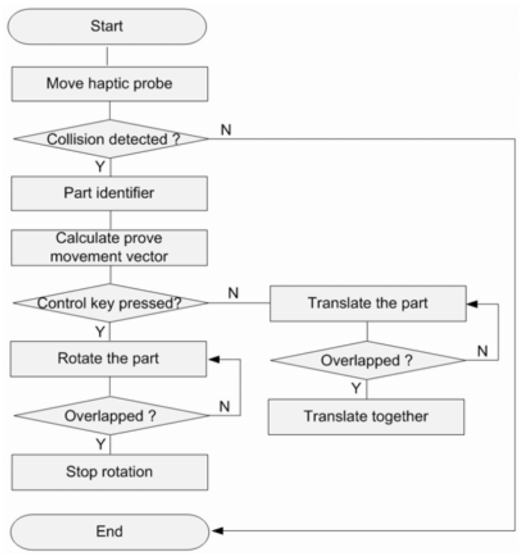

Fig. 3. Event handling algorithm

Fig.4 shows the image of modifying the structure of house using the haptic device. In this figure, we changed the position and orientation of bed, desk and furniture by linear translation or rotation. Also, we could change the wall paper by loading corresponding image with mouse. The modification process is pretty easy and intuitive, a user can feel immersive during the modification.

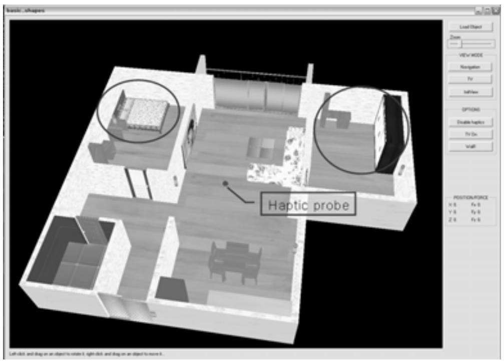

Fig. 4. Modification of the structure of the model house by haptic device (Circles denote modified parts.)

4. Haptic effects

Haptic technology leads impressiveness and presence so that users have better performance as well as better interaction. Many researchers brought the haptics into medical, education, entertainment, military area for many purposes[9-12]. In this paper a haptic device, Omni^{TM}, was used in order to provide the presence and immersion to users when they touch the wall and furniture by generating feedback force. Fig.5 shows the Omni^{TM} device which is well known for a commercial product from Sensable Technology company.

Fig. 5. Omni^{TM} haptic device manufactured by Sensable Technology

4.1 Static object

Static object defines as an object which does not move by users interactions. As an example, users can touch and feel the static wall but it stays in the same location. Simply, collision detection between the haptic probe and virtual objects enables users feel the virtual objects haptically. Haptic rendering of geometry is done using the proxy method. Fig. 6 illustrates schematic view of haptic feedback by proxy rendering. When haptic probe is moving by user manipulation, the probe can contact at a point. This point is usually called as the proxy that closely follows the position of the haptic probe. The haptic rendering engine continually updates the position of the proxy, attempting to move it to match the haptic probe position, but not allowing it to move inside any shapes. When in contact with a shape the haptic device will penetrate the surface of the shape and the proxy will remain on the outside of the surface. The force sent to the haptic device is calculated by stretching a virtual spring between the haptic probe position and the proxy position. This idea is also applied to dynamic object as well as static object.

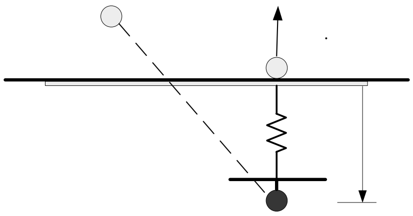

Fig. 6. Haptic feedback by proxy rendering

4.2 Dynamic object

There are a set of dynamic classes which represent haptically rendered objects which respond to pressure against them by adjusting their positions and generating windows events after particular conditions are met. In our project, two types of dynamic meshes are added in order to interact with virtual model house. The first part is ButtonMesh which is used for pressing doorbell, lamps. For producing the button clicking feeling, we used the force-profile described in Fig.7(a)[13].

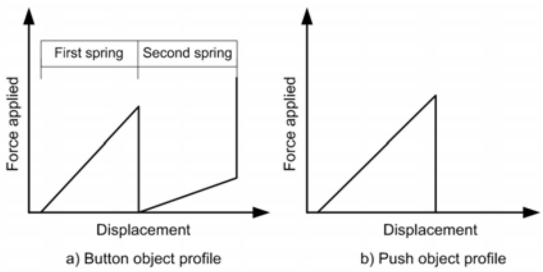

Fig. 7. Force profile

By modifying the XML file format, we can easily set the coefficient of spring, length of button travel and translation/rotation vector. The second part is PushMesh which is the most popular dynamic model in this work since the main role of haptic sensory channel is that our system lets users push the wall in order to change the size of a room and place furniture with haptic feedback. In the case of push object, the force is increasing until the object reaches to the constrained distance illustrated in Fig. 7(b). Therefore, users are allowed to push the wall and move the furniture such as TV, table, chair, couch, and counter based on this dynamic model. Fig.8 shows that a user interacts with virtual model house by using the haptic device

Fig. 8. Haptic interaction with virtual model house

4.3 Surface operation (friction, stiffness)

Feeling the surface of objects also can help users interact with it better. In our system we can set the haptic material properties of the object to be adjusted by using XML file format. There are two different surface operations such as friction and stiffness at the current state. There are two types of friction we can set. Those are static friction (in place when the cursor is still on the surface of an object) and dynamic friction (active when the cursor is moving). Therefore, by tuning the each of models, users are allowed to feel different haptic material property between TV and couch.

5. Navigation and other effects

5.1 Collision detection method

In navigation mode, we can look around the model house. Such navigation is essential in our system since it provides the user to experience the virtual house by walking around inside it for him/herself. This can be achieved by controlling the camera setting, which consists of two parts: the first part is the camera position and the second part is the camera gazed point which is the target point that the camera is looking at. We implement this navigation capability by using keyboards. Whenever a user pushes down a key, a message event is triggered and a set of corresponding functions for setting the camera position and the camera gazed point are called with appropriate parameters to generate desired navigation effects.
Fig. 9 illustrates representative scenes when a user experiences navigation mode.

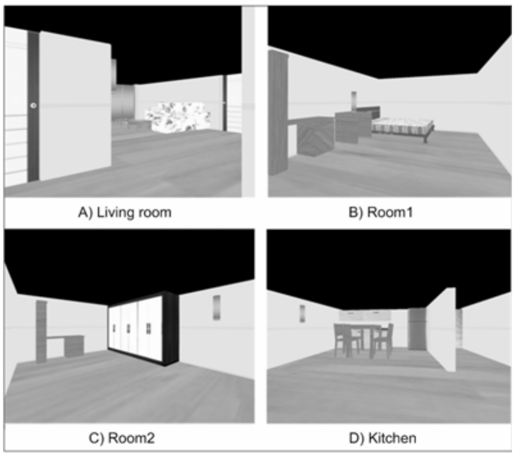

Fig. 9. Scenes of model house in Navigation mode

For navigation mode, there must be a collision detection algorithm, because the camera can not go through wall and other objects. The collision detection algorithm calculates a distance between the position of camera and other objects with position matrix in real-time. If the camera position closes to some objects, the camera keeps their distance with other objects to avoid collision.

5.2 Other effects (Sound effects and TV display)

A virtual TV with sound and display is added to enhance realism to the virtual model house. We load an avi video clip data file, grab consecutive images by changing the video clip frame and map the images to the virtual TV screen as a texture. Also we use windows wave sound play API for sound effects. Since the texture generated from each image and sound are handled asynchronously with each other, we need to synchronize them to yield the consistent image and sound. In order to solve this problem, all avi frames corresponding to appropriate sound frames are stored in advance. And then, we check the state of sound frame and execute the proper avi frame.

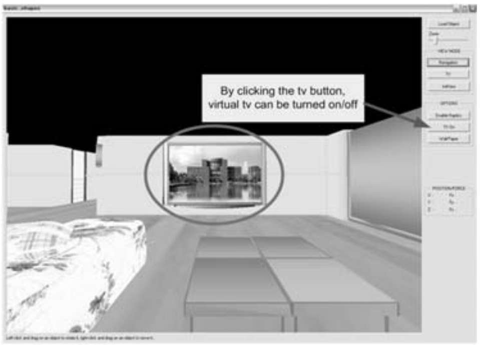

Fig. 10. Sound effects and TV display using texture mapping

6. Discussions

6.1 Comparison with existing techniques

There have been many attempts to provide cyber virtual model house in domestic construction market. Among them, we investigated two relatively well established virtual model house for figuring out the supporting technical level of variety. Blooming is the first apartment which introduced self design concept. Kovi[14] is well known for providing cyber model house through the website. Each website helps the users to make up their mind in selecting the apartment that they are going to live by showing the realistic information such as images of overall interiors, rooms and detail features. However, existing cyber model house services have limitation to give impression when a user experiences it. Table 1 shows the comparison of our system with other web services.

		Bloom-ing	Kovi	Ours
Navigation		x	0	0
Collision detection		x	x	0
Haptic interaction	Space modification	x	x	0
	Furniture arrangement	x	x	0
	Feeling surface texture	x	x	0
Changing wall-paper, tile		0	0	0
Experiencing the virtual TV		x	x	0
Internet service		0	0	x

Table 1. Cyber model house service comparison

Most of websites have an advantage of providing information to customer through internet service. However they just offer images of the interiors but not giving a user realistic feeling like as walking inside of the apartment. Even though there is a function of navigation to look around the inside of apartment, it penetrates walls, furniture without physical collision. And there is no user interaction with things in the interior such as living space modification, furniture arrangement and feeling surface texture etc. After comparison, we assume our system can provide versatile services. However, for more objective evaluation, user evaluation is required to reach reliable results.

7. Conclusions and future works

In today's extremely competitive construction industry, it is logical for industry professionals to identify ways to combine tasks and save time and money. Although there has been a remarkable increase in utilization of 3D modeling in the construction area, it is not being adopted to their full potential in practice. In this paper, we present multi-modal interactions with a virtual model house. O'Mally *et al*.[15] made an online haptic interaction platform where three dimensional content created with a simple modeling is displayed haptically by the internet browser. Through the combination of online services, we can give the convenience, satisfaction and realistic feelings to buyers. Namely, people who want to buy an apartment living in distance can visit a model house and experience it by using a haptic device through the internet, anytime, anywhere. For design and construction companies, they can save money and advertise effectively. In our future work, we will enhance our system with more complex event scenarios to give more realistic feelings to buyers and expand it to operate online using ActiveX. Also part selection from the prefabricated model library and constraint based assembly of the parts will be integrated into the system.

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