Engineering Design Graphics Journal (EDGJ)
Fall 2014, Vol. 78, No. 3
http://www.edgj.org

ISSN: 1949-9167

A Virtual Campus Based on Human Factor Engineering

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Abstract

Three Dimensional or 3D virtual reality has become increasingly popular in many areas, especially in building a digital campus. This paper introduces a virtual campus, which is based on a 3D model of The Tourism and Culture College of Yunnan University (TCYU). Production of the virtual campus was aided by Human Factor and Ergonomics (HF&E), an application which provided a convenient, comfortable, practical and simple environment for users. TCYU, in Lijiang, China, occupies approximately 800 acres. Set in a parkland environment, it is a modern campus with a rich architectural style based on local Naxi houses with gray tiles and white painted walls. Because it is very large for a virtual campus, the scale and complexity of models have been simplified. They have also been reduced for ease of loading the computer program by three means: Object-Oriented Modeling (OOM), textures and portal-connectors, and many easy-to-use tools have been created which support different input hardware and avatars to help the user tour the campus from different perspectives. Testing results show that the virtual system can run smoothly on the general personal computer.

Introduction

With the development of computer software, 3D virtual reality has become increasingly popular in many areas, especially in building a digital campus. Virtual Campus can display the whole campus based on the geographic information system (GIS) of the buildings and using virtual reality technology. Users can retrieve information, tour the virtual campus and design a real campus through the virtual system. Several studies focus on e-learning or using lower cost methods to build their virtual campus (Fominykh et al., 2008 and Lucia et al., 2009). They emphasis more the potential for supporting learning communities (Lucia et al., 2009 and Prasolova-Førland et al., 2010) and co-construct the virtual campus in a simple, low-cost way (e.g. Building Campus on Second Life (Lucia et al., 2009 and Second Life, 2013) or Active Worlds (Active Worlds, 2013)). However, providing better user experience in the virtual scene and simulating the real world is also important in building a virtual campus. Therefore, in building a system based on Human Factor and Ergonomics (HF&E), it is possible to provide a more convenient, comfortable, practical and highly efficient experience for users and make a virtual campus more user friendly.

ISSN: 1949-9167

Review of Literature

The design of educational virtual world often follows Vygotsky's social constructivist approach (Vygotsky, 1978); following this publication, a growing number of universities have introduced virtual representation in the form of virtual campuses to support a wide range of educational activities. The most famous virtual campus is Nanyang Technological University (NTU) in Singapore (Sourin, 2004) and in Norway, The Norwegian University of Science and Technology (NTNU) (Fominykh et al., 2001 and Prasolova-Førland et al., 2010). NTU built a realistic 3D campus based on blaxxum technology. It provides a very realistic, photographic resemblance of the corresponding NTU campus, with offices and students' rooms. There are also different tools available for students to meet new friends, obtain consultation, follow lectures and complete practical exercises especially in computer graphics. NTNU built a similar virtual campus and introduced the concept of cyber-campus which refers to virtual worlds representing real educational institutions such as universities or schools. They consider virtual campus to be a framework around educational and social activities and have produced a set of tools and resources to support such activities as Collaborative Virtual Workshop (CVW) (Fominykh et al., 2008) and virtual museum (Active Worlds, 2013). NTNU is now in the process of building a virtual campus in Second Life Platform (Prasolova-Førland et al., 2010). In addition, other universities including Zhejiang University, Peking University (Chen et al., 2010), HuaZhong University (Wang et al., 2005), BeiHang University (Hao et al., 2000) and the Chinese University of Hong Kong (Gong et al., 2002) are also building their own digital campuses.

Several studies used various types of platform to create a virtual campus and include VRML, OpenGL, X3D and Second Life. The first three technologies are more complex, but the modeling effect can be controlled and provide more tools for both developers and users. With Second Life (Second Life, 2013) or similar platforms, the development process is relatively simple but the modeling effect cannot be controlled and as such is less extensible and not as ideal as the first three platforms. However, most of these studies focus on learning activities and communication or are interactive with other people in the virtual campus. Here, the discussion is more about e-learning and related tools which can help students to work in the virtual campus. But real virtual modeling and comfortable environment is also very important for users. Therefore, the virtual campus based on HF&E can better reflect the 'human factor' and provide users with a more comfortable experience. Human factors and ergonomics (HF&E) is a multidisciplinary field incorporating contributions from psychology, engineering, biomechanics, industrial design, graphic design, statistics, operations research and anthropology. In essence, it is the study of designing equipment and devices that fit the human and the human body. It can be applied in a variety of ways including the design of safe furniture and easy–to-use interfaces to machines and equipment to provide a comfortable and safe working environment for users (Wiki, 2014 and Zhang et al., 2011).

Through combining virtual reality and HF&E, the virtual campus of TCYU was created based on Crystal Space 3D. The entire system is considered 'user friendly', that is to say the system not only reflects the characteristics of immersion, interaction and imagination of the virtual reality, and is therefore ergonomic with its use of HF&E. Additionally, the functions of people's psychological perception, sense of space, walking, flying and other sensory and behavioral aspects have been considered for human-computer interaction and provide a convenient, comfortable, practical and simple environment for users.

The Design of TCYU

Crystal Space

Crystal Space is used as the basic graphic engine. Crystal Space (Tyberghein, 2013) is an open-source 3D software development kit (3D SDK). It can be used for a variety of 3D visualization tasks including building 3D virtual world and creating 3D applications. It is a portable modular 3D SDK and includes many components for building various applications and games; these are useful for projects that do not involve 3D. Crystal Space also contains many other features; it is not just a game engine and its features are as follows:

- Crystal Space is a package of components and libraries all of which can be useful for creating 2D/3D computer games. The components and libraries are more or less independent of each other in Crystal Space and so can be used independently and create plug-in modules.

- The core of Crystal Space is Shared Class Facility (SCF) and is somewhat similar to Component Object Model (COM), but an easier-to-use and more lightweight mechanism. Thus the whole Crystal Space is a highly modular framework with good extensibility and reusability.

- Crystal Space is written to run under a wide variety of hardware and software platforms, including Window, UNIX and Mac OS.

System Design of TCYU

The virtual campus created is Tourism and Culture College of Yunnan University (TCYU). In order to distinguish from traditional virtual campus and reflect the characteristics of HF&E, this virtual system provides a comfortable, humanized and easy-to-use environment for users and offers a variety of tools to help when entering the system. The different tools offered, allow users to tour the whole campus from different perspectives.

The system consists of two parts: Data and software. The data are responsible for the creation of 3D virtual campus models and actor-models and the Extensible Markup

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ISSN: 1949-9167

Language (XML) files describe the exported models. The software is responsible for the interaction between users and the virtual system, including loading 3D models and giving support for touring the campus. Loading realistic multimedia is the basics for building a realistic environment. Therefore two methods are provided to reduce the complexity and scale of the campus model. Additionally, three types of avatars are offered and support different input hardware which can provide a choice of tools, when touring the whole campus from a variety of perspectives. Figure 1 illustrates the system framework.

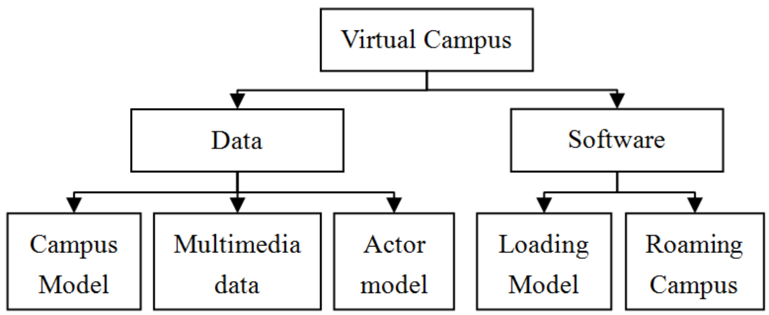

Figure 1. The System Framework.

Creating Models

The realism of the campus model directly affects the quality of the whole virtual campus. The more realistic the 3D model and the greater amount of data included, the slower the system will run but the effect will be better. Furthermore, the model of the whole virtual campus is composed of many buildings and there are many rooms in each; it is large and complex, maybe too heavy for the virtual system, therefore two additional methods are provided to reduce the complexity and scale of the model. One is Object-Oriented Modeling and the other is using texture.

Basic Data Collection

The actual TCYU is a modern campus occupying approximately 800 acres set in a parkland environment. There are about 117 campus buildings of which a great number have a rich architectural style based on the local Naxi houses with gray tiles and white walls. Representing Naxi architectural features is very important because it is one of the major characteristics of the campus. In order to build a realistic virtual campus, first, the position of the buildings was confirmed using a satellite map. Secondly, the 3D models of the architecture were created based on the pictures of Computer Assistant Design (CAD) which are at a 1:1 scale. Thirdly, every kind of texture and material was collected from the real campus and used on the model's surface to make the building look realistic and maintain an authentic style. Finally, the inner structure of the buildings was constructed and decorated. Figure 2 illustrates the satellite map of the main buildings. Figure 3 illustrates the CAD elevation of Wen-Zhi building and Figure 4 is an actual photograph of the Wen-Zhi building.

ISSN: 1949-9167

Figure 2. Satellite Map of the Main TCYU.

Figure 3. Part of CAD Elevation Picture of Wen-Zhi.

Figure 4. The Actual Photograph of Wen-Zhi Building(1:150).

ISSN: 1949-9167

Object-Oriented Modeling (OOM)

Object-Oriented Modelling (OOM) is provided as a method to reduce the scale and complexity of virtual campus. In order to distinguish between the original Object-oriented, the following definitions are provided:

- Model Class: Model Class is a “factory” object, which represents model’s structural information and material (for example a tree class).

- Model Instance: Model Instance is the copy of model class. It represents the reference to the factory object and their position and rotation. All the model instances will be identical to their class, but they can use different types of materials which distinguishes them from their class (for example a real tree).

In OOM, model class describes the common characteristics of geometries (for example tree class) and model instance only describes the specific characteristics of a single geometry (for example a single tree). That is, the same structural information needs only to be stored once in model class, and model instance only represents the different parts from their own class. Furthermore, in the rendering phase, the model class is invisible and the model instances use the information of their own class to implement the rendering of the virtual objects. For example, if a tree class is created and copied many times, we get a wood. In the wood, the geometrics which compose the tree, actually just need to be stored once as ‘tree class’ and the other trees are the description of the reference to the same ‘tree class’. Thus the scale of the ‘wood’ is a little larger than that of a single ‘tree’. It is very similar to the Object-Oriented therefore it is referred to as Object-Oriented Modelling and the method can help reduce the complexity and scale of virtual campus.

Using Texture

The building includes many windows on the outside walls; this increases the complexity of the model. The reduced visual quality of the model often goes unnoticed by users because it is far away and the details cannot be seen. Based on this premise, texture has been used instead of the original model to reduce the total number of polygons of the building. When comparing the rendering difference between the original model and optimized model of Wen-Zhi building, it can be seen there are only slight differences on the rendering result. Figure 5 illustrates the detailed model of Wen-Zhi building and Figure 6 illustrates the optimized result of the right side wall by using texture. The rendering result is shown in figure 7.

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Figure 5. The Detail Model.

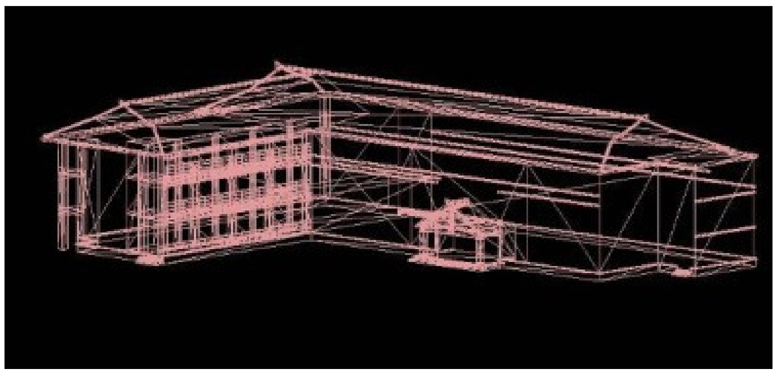

Figure 6. Optimize the Right Side of the Wall.

Figure 7. Rendering after Optimized.

The Implementation of TCYU

Export and Load Models

Extensible Markup Language (XML) has been used to represent the exported 3D models. XML is a mark-up language that defines a set of rules for encoding documents in a format that both the user finds easy to use and also is machine readable. It is a textual data format and is widely used for the representation of arbitrary data structures. Through using XML, structural and organizational forms of 3D models can better be described. It also makes reading and analyzing model data easier, clearer and faster, bringing convenience for loading models into a virtual system. A simple example of 3D world represented by XML is as follows:

```
<world>        <!--building virtual world-->
<textures>
   <texture name="oldmetal">
      <file>/lib/stdtex/oldmetal.jpg</file>
   </texture>
</textures>
<!-- the detail of building -->
<meshfact name="walls">
   <plugin>thingFact</plugin>
   <zfill />
<params>
      <v x="-10" y="-1" z="10"/>
…………
      <material>old_metal</material>
      <p name="up">  <v>6</v> <v>7</v> </p>
   </params>
</meshfact>
</world>
```

In addition, in order to reflect the 'human factor' and provide users with a more comfortable experience in the virtual campus, an avatar start position in front of the gate of the campus is set to help the user understand where they are more easily. Figure 8 illustrates the start position of avatar. Also added is collision detection for the avatar to simulate the real world. Figure 9 illustrates the effect of collision detection for avatar. In addition, the virtual system supports a variety of hardware to control the activities of avatar which includes mouse, keyboard and joy stick. Users can choose a variety of ways to tour the virtual campus.

Portal-Connectors

Virtual campus models are large and complex. During the virtual campus modeling phase, two methods, OOM and textures, are provided to optimize the model. Portal-connectors can also be used to further optimize the virtual campus model and reduce the total geometries at run time.

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Figure 8. The Start Position of Avatar.

Figure 9. Collision Detection of Avatar.

Interactive System

Portals are specific kind of polygons used extensively for accelerating visible determination in complex architectural scenes. They are used to partition a scene into cells such that another cell is only visible if a portal that bounds that cell is visible (Lowe et al., 2005). We created special portals, which have the characteristics of normal portals and can be used as connectors to link different cells called portal-connectors. The characteristics of portal-connectors are as follows:

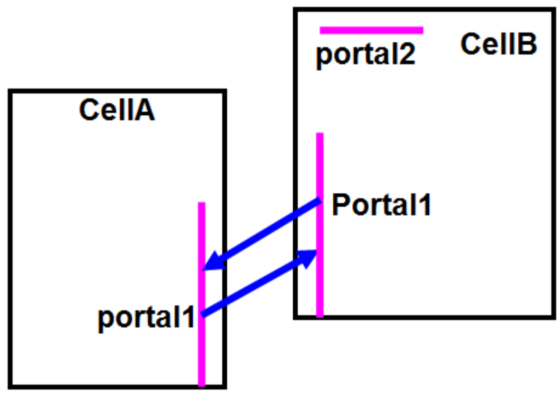
- Warping transformation is included, so that it may be used in space to connect different cells which are not adjacent to each other; doors and windows are generally defined as portal-connectors.

- Portal-connectors are unidirectional. In order to link cell A and cell B, both cells should define a portal-connector. One is used to identify cell B from A and the other

ISSN: 1949-9167

is used to identify cell A from B; therefore it is possible to see (or go through) each of the cells. The feature provides the basis to further optimize the model. Figure 10 illustrates the characteristics of portal-connectors.

- All cells which are connected by portal-connectors have the same world space coordinate. By getting a current cell reference together with a world space coordinate, we can get our actual position.



Portal-Connector	Source Cell	Destination Cell
CellA.portal1	CellA	CellB
CellB.portal1	CellB	CellA

Figure 10. The Characteristic of Portal Connector.

In virtual campus, many scenes like classroom, study room or student bedroom are the same as each other and these mostly comprise the interior of the building. One classroom only is created and portal connector is used to link the door and classroom. Thus different doors can point to the same classroom and classroom also can point to different doors with multiple portal-connectors. As the appearances of the classrooms are the same as each other, a single classroom only is created, and users consider that they have seen many different classrooms. Even if users believe that different doors correspond to different classrooms, (assuming that a classroom has only one door), the difference will never be seen during walkthrough in virtual campus. That is, there is no impact on the users' experience. Using this method, the same classroom, study room or bedroom can be used repeatedly and a lot of time and resources can be saved during interaction.

Interactive System

Reflecting 'human factor' is the core of this system and many easy-to-use tools are provided compared to other systems. Through choosing a variety of tools, users can obtain different operating and touring experiences. Users can travel the campus in many different ways for instance by car, by plane or on foot. Users can also choose to

Engineering Design Graphics Journal (EDGJ)
Fall 2014, Vol. 78, No. 3
http://www.edgj.org

ISSN: 1949-9167

walk or fly with first-person perspective for example like playing games and can set their own speed or flight altitude by themselves. Figures 11 and 12 illustrate different ways to travel the virtual campus using first-person. Figures 13, 14 and 15 illustrate different tools to make traveling more comfortable. In addition, a music system has been created, providing background music to assist users learning the basic information of virtual campus and actual campus.

Figure 11. The First-Person Walking.

Figure 12. The First-Person Flying.

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ISSN: 1949-9167

Figure 13. Walking Mode.

Figure 14. Driving Mode.

Figure 15. Flying Mode.

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Conclusion

The real TCYU campus has a diverse landscape and a great number of buildings with rich architectural style based on the local Naxi houses. TCYU aims to integrate the actual TCYU campus into 3D virtual world and provide users with a real experience on virtual campus. Many methods have been used to reduce the scale and complexity of the campus models and to create the virtual campus based on HF&E. The virtual system supports many easy-to-use tools which provide a simpler, convenient, comfortable, practical and highly efficient experience for the user, therefore making the virtual campus more 'user friendly'. Users can immerse themselves in TCYU through 3D modeling form of avatar and experience virtual campus with different input hardware. Moreover, users can run virtual campus on a normal personal computer that runs MS Windows. During the test, the measured maximum was 265 frames per second; the minimum rate was 221 frames per second and with an average of 240.67 frames per second. Figure 11 illustrates the test frame rate of the system. Further work will focus on supporting multiplayer in the virtual campus for education and communication and even sharing resources, information and knowledge.

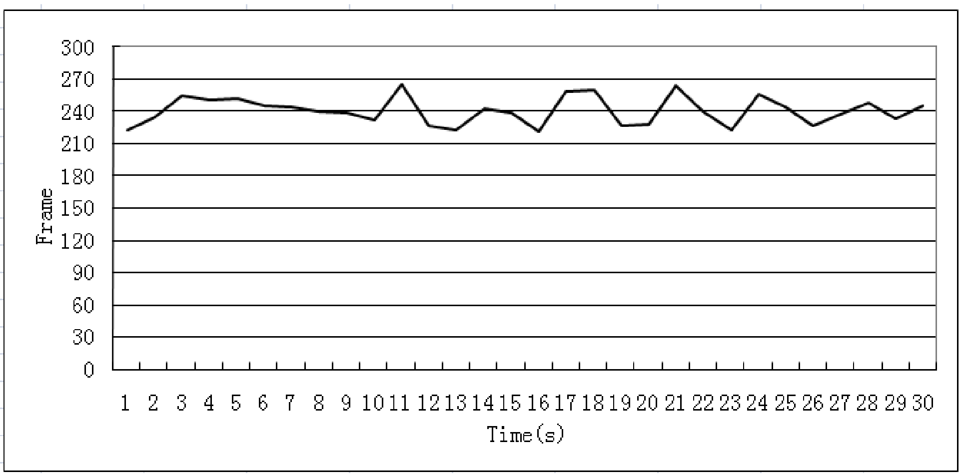

Figure 11. Frame Rate.

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Acknowledgements

The authors would like to thank the people who have helped and generously provided materials for this work. This research was partially supported by the Scientific Research Fund of Yunnan Education Department (2012Y430).

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