A Simple and Effective 3D Navigation System with 2D Map Guidance

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Abstract: *This paper presents a 3D scene modeling method for a Simple and Effective 3D Navigation (SE3DN) system, with 2D map guidance and multimedia information. SE3DN constructs 3D models and 2D maps of the scene from a series of CAD drawing data. First, the outline model of the scene is created with the CAD data. Then, a 3D model of each building is created with its height information using a geometry-based modeling technique. Finally, textures are pasted on the surface of all buildings and objects in the scene to get photo-realistic effects. Advantages of the proposed method are: 1) Ease in accurate alignment of separate modules to specific positions in the scene; 2) Ease in accommodating changes in the scene; 3) Unrestricted selection of views by the user. The details in the development of this kind of systems are reported.*

Keywords: 3D modeling, 3D navigation, 2D vector map, multimedia information, CAD data

1 Introduction

The increasing popularity of computer animation in all forms of broadcast, entertainment, and educational media is making virtual navigation in 3D space a major and indispensable application in computer graphics. It can give virtual viewers the sensation of being personally in a 3D scene and let them explore an unknown world with ease and security Yet, when navigating 3D virtual scenes without guidance, a user may lose orientation. Hanson [1] presented the approach of Constrained 3D Navigation with 2D Controllers, which uses 2D data to guide a user's navigation. Huber and Sieber [2] proposed the concept of '3D thinking', which allows for a smooth shift among 2D and 3D maps for easy 3D navigation with no loss of orientation. St-Jacques [3] presented a Dynamic Navigation into 3D Media Spaces which maps the media files into 3D topological representations. Inspired by these previous works, we think that 2D maps can give users the overview of the scene, while additional multimedia information such as audio, video, picture and text can offer them lifelike explanation of the details of the scene. With advances in computer graphics, GIS and multimedia technologies, the integration of all of these elements into one system to guide the user's navigating has become feasible.

Our research focuses on two aspects in the development of 3D navigation systems. The first is the creation of the 3D model and 2D map of desired scenes, which presents significant technical challenges and often leads to serious loss of realism. We present a method to model 3D scenes based on CAD data in Section 2, which can be applied quickly and accurately. The second is the design of simple and effective navigation of 3D scenes. We describe the development a Simple and Effective 3D Navigation (SE3DN) system which integrates 2D map, 3D navigation and multimedia information for navigating the new campus of Beijing Technology and Business University (BTBU). The technical details are reported in Section 3. The project development is summarized in Section 4. Conclusions and limitations are discussed in Section 5.

2 CAD data-based methodology

3D models and 2D digital maps are the main information contents in a 3D navigation system. Their quick and accurate creation is the key issue in such system development.

2.1 Creating 3D scene models

(1) Review of modeling techniques

To date, there are primarily two kinds of technologies for 3D modeling and rendering [4]. One is Geometry-Based Modeling and Rendering (GBMR). The other is Image-Based Modeling and Rendering (IBMR).

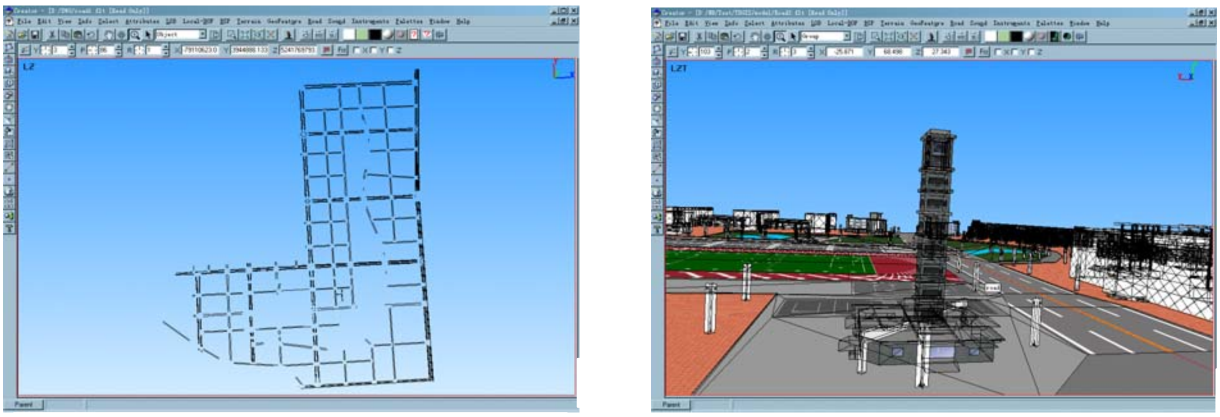
The GBMR approach uses geometric and physical information to synthesize images of the scene. The 3D model is usually represented with polygons, bi-cubic parametric curves, constructive solid geometry or space subdivisions. Then geometric and projective transformations of the 3D model are performed to produce 2D images in the screen [5]. New views are rendered directly from this 3D model and can be manipulated by the viewer without restrictions. This way, the viewer can observe the 3D scene from every perspective. The main problem with this approach is the difficulty in modeling, making it error prone as separate modules must be positioned in the scene accurately. Another problem is the complexity in creating realism.

IBMR combines algorithmic tools in computer vision and computer graphics to create a 3D model directly from images [6]. With this approach the model is relatively easy to build, and the cost of rendering is independent of the complexity of a scene. Realism of the rendered images depends only on the input images, so that photorealistic renderings are readily attainable. The main problem with image-based rendering systems is that they cannot accommodate changes in the scene (e.g. new objects, changes in lightning) and the views are restricted to the prescribed range. Another problem is that they require a lot of memory due to data redundancy.

The goal of our research is to find a method to generate 3D scene models which is accurate, realistic, computationally efficient and not overly complex to implement.

(2) 3D scene modeling method based on CAD data

When CAD data of the scene is available, the process of modeling with GBMR can be simplified. In our method the CAD data file is first converted into 3D format to produce an outline model of the entire scene, as shown in Figure 1 (a). Because the outline model is based on CAD data, its measurements are very accurate. Next, the outline model is used as input to 3D modeling tools. In our project, we use MultiGen Creator, which is a powerful tool for producing realistic three-dimensional models and constructing hierarchical visual databases. These databases conform to the OpenFlight® format for general purpose modeling [7]. Then, a 3D model of each building in the outline model is created according to the descriptions and measurements in the CAD drawing. The result is illustrated in Figure 1 (b). When creating 3D models of the scene, the level of detail adopted should depend on the requirements of navigation. More details enhance realism at the cost of computational efforts for modeling and rendering. Therefore, details that do not represent the characteristics of the building should be omitted as much as possible. To compensate for such omission, texture mapping is used to simulate



(a) Outline model of the campus from CAD data　　(b) 3D model created on the outline model

Figure 1. 3D scene model created on base of CAD data

photorealistic results. Figure 1 shows an aspect of the 3D scene model of the new campus of BTBU created with our modeling method based on CAD data. The application confirms that this modeling approach is fast and accurate. The advantages of the method are: 1) Ease in accurate alignment of separate modules to specific positions in the scene; 2) Ease in accommodating changes in the scene; 3) Unrestricted selection of views by the user. Its limitations are: 1) CAD files of the scene must be available as input data; 2) The photorealistic result is better than GBMR, but not as good as IBMR.

2.2 Creating 2D vector maps

(1) The selection of 2D map format

Digital image formats fall into two main categories: raster and vector. Raster imaging describes the locations and colors of an image with individual pixels. As each pixel must be represented with a few bits information, raster images have large memory requirements. Vector imaging is based on various generic elements, or vector objects that can be lines, curves, circles, rectangles or any other geometric shape connected by paths and points. As each object is defined not by pixels but by mathematical instructions, it is fully scalable and can be transformed, resized or reshaped without loss of quality.

Since a SE3DN system should provide such navigational functions as “zoom in”, “zoom out”, and “position selection” on a 2D map, choice of the vector format for the 2D map is more suitable.

(2) Creating 2D vector maps from CAD data

2D vector maps can be generated from CAD data of the scene using GIS software. We chose ArcGIS, which is desktop GIS software for this purpose. It provides geographic data visualization, mapping, management, and analysis capabilities along with features to create and edit data [8]. First, the CAD data file is used as input to ArcGIS. Second, the CAD data is preprocessed to filter out unnecessary data, such as measurement figures and lines. Last, the CAD data is converted to a 2D vector map. For example, the process of creating the 2D vector map of BTBU’s new campus is illustrated in Figure 2. Figure 2 (a) is the original CAD file of the campus and Figure 2 (b) is the 2D vector map of the campus. The vector map contains 6 graphic layers, namely, building ichnography, lawn, road, man-made lake, pavement, and playground.

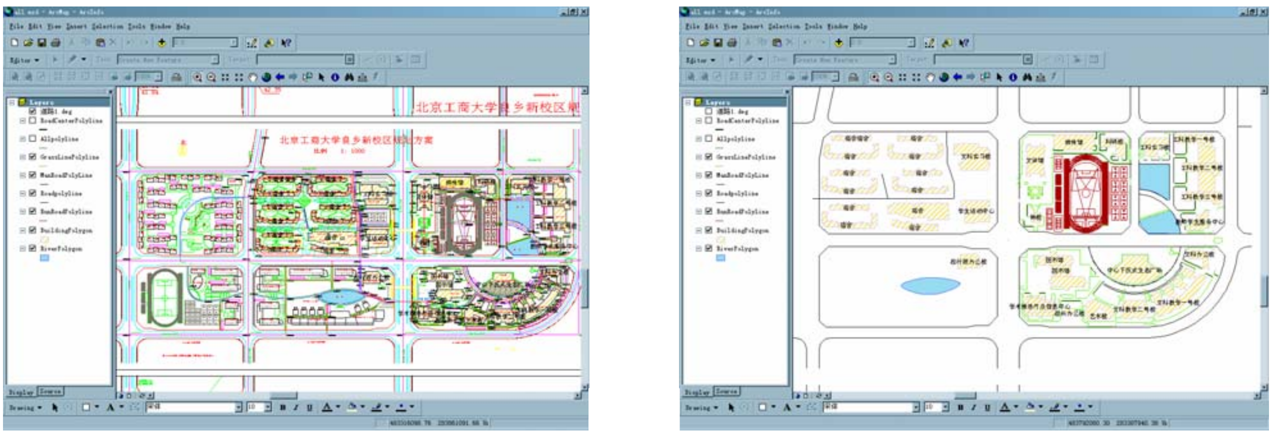
3 SE3DN system

SE3DN (Simple and Effective 3 Dimensional Navigation) is a 3D navigation system integrated with 2D map and multimedia information, which allows for simple and effective 3D navigation with no loss of orientation. As a paradigm of this kind of system, we developed a SE3DN for navigating the new campus of BTBU.

3.1 Functions of SE3DN

SE3DN should provide the following functions.

(1) Display a 2D vector map and 3D images of the scene on the same screen, as shown in Figure 3. Basic control functions are provided on the 2D map, including “zoom in”, “zoom out”, identifying specific positions on the map, etc.



(a) The original CAD file of BTBU’s new campus　　(b) 2D vector map of BTBU’s new campus

Figure 2. The creation of 2D vector Map

(2) Provide the user with two options in navigation. One is called interactive navigation, which allows the user to navigate the 3D scene freely using a mouse. The other is called automatic navigation, which navigates the 3D scene according to a path set up by the user on the 2D map.
(3) Record the navigated path in run time for subsequent playback on request.
(4) Provide the explanation information about buildings in the scene with multimedia information, such as audio, video, picture and text.

Figure 3 shows the screen image, comprising both 2D map and 3D scene, in an instance of application78 of this system.

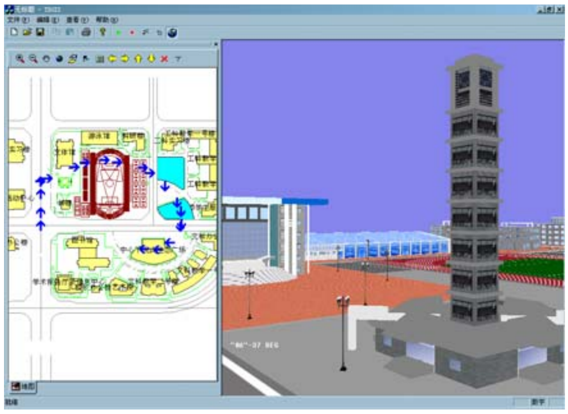


Figure 3. SE3DN for navigating the new campus of BTBU

3.2 Architecture of SE3DN

Figure 4 shows the framework of SE3DN which consists of three major modules and their associated data sets: the 2D Map Management and Rendering (2DMMR) module, the 3D Scene Management and Rendering (3DSMR) module, and the Multimedia Information Management (MIM) module. The functions of these modules are as indicated by their names.

3.3 MFC-based program framework

SE3DN is developed with Visual C++. In order to integrate 2D vector map, 3D scene navigation and multimedia information into one system, we use a multi-thread program framework based on Microsoft Foundation Class (MFC), as shown in Figure 5. Parameters transfer between two threads is enabled by the message-event driven mechanism provided by Win32. The main thread is a Windows Control Program, which is responsible for creating windows, starting sub-threads (thread-1, thread-2 and thread-3), receiving messages from keyboard and mouse, setting up control parameters, etc. Thread-1 is a 2D Map Program which is responsible for displaying and controlling 2D map, performing coordinates conversions, etc. The display and control of 2D map is implemented with MapObject, which is a C++ add-in module that provides a set of programming objects for processing 2D maps through an ActiveX control. Thread-2 is a 3D Navigation Program which is responsible for 3D scene management and rendering, navigation control, and coordinates con- versions. 3D navigation is implemented with an OpenGVS graphics

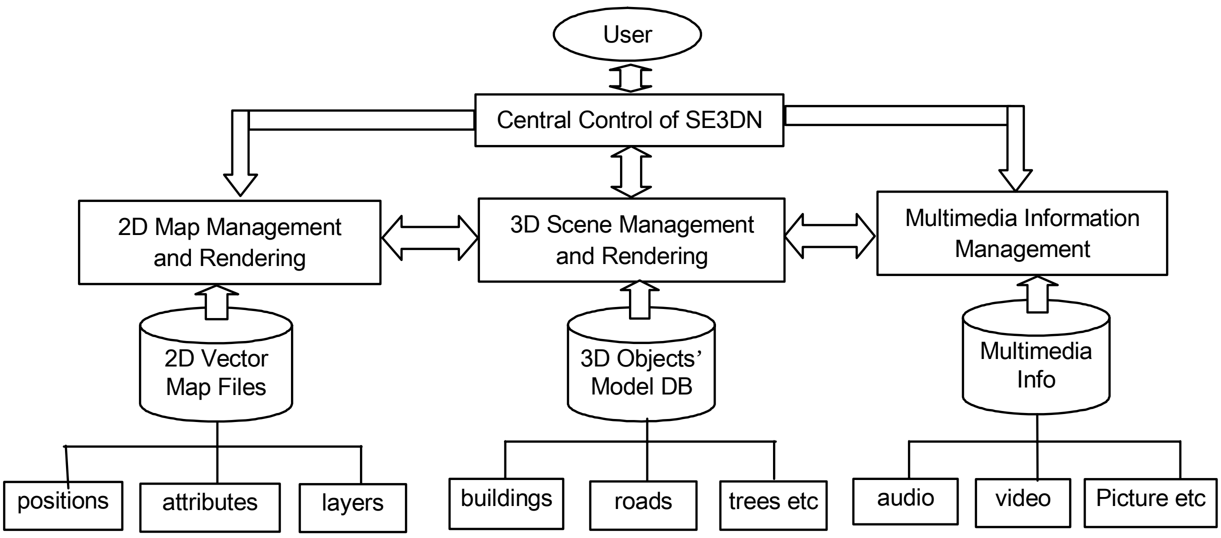


Figure 4. Framework of SE3DN

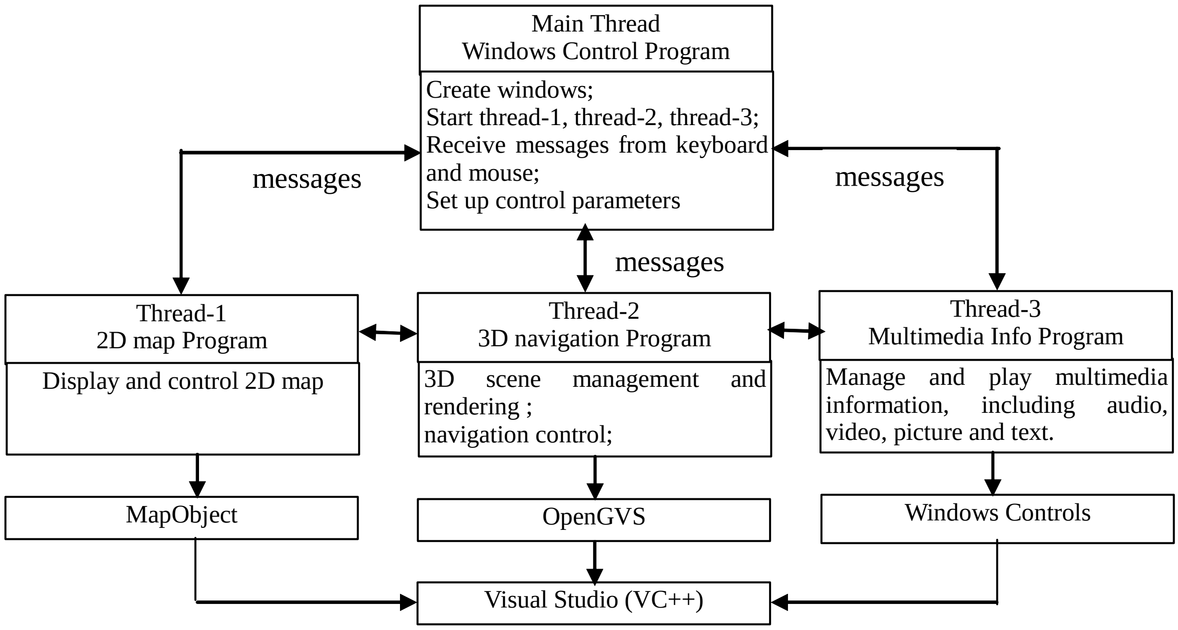


Figure 5. Program framework of SE3DN

engine, which is an API for PCs and graphics workstations that enables 3D database development and the processing of equations of motion. Thread-3 is a Multimedia Information Program which is responsible for managing and displaying multimedia information, including audio, video, picture and text. Multimedia information management and display are implemented through Windows Controls.

4 SE3DN project development

To summarize the research and development project for SE3DN, we demonstrate the Work Breakdown Structure (WBS) listing all the major deliverables in the following. A network diagram indicating the critical path of project tasks is shown in Figure 6.

Work Breakdown Structure for SE3DN Project:

BTBU Campus SE3DN

- *1. Project Approval*
  - *1.1 Wait for approval*
- *2. Requirement Analysis*
  - *2.1 Requirement specification*
  - *2.2 User's requirement*
  - *2.3 Techniques requirement*
  - *2.4 Requirement analysis report*
- *3. Development Preparation*
  - *3.1 Development environment*
    - *3.1.1 hardware environment*
    - *3.1.2 software environment*
  - *3.2 Training*
    - 3.2.1 knowledge of CG
    - 3.2.2 modeling software
    - 3.2.3 image processing software
  - *3.3 Data preparation*
    - *3.3.1 CAD data (files)*
    - *3.3.2 pictures*
    - *3.3.3 audio files*
    - *3.3.4 video files*
    - *3.3.5 text files*
- *4. System Design*
  - *4.1 Program design specification (draft)*
  - *4.2 Integration test plan*
  - *4.3 Data dictionary*
  - *4.4 Program specification*
  - *4.5 Program flow chart*
  - *4.6 Program design specification (final)*
- *5. System Programming*
  - *5.1 Scene modeling*
  - *5.2 2D map creation*
  - *5.3 Program coding*
  - *5.4 Program integration*
  - *5.5 Program debugging*
- *6. System Integration and Testing*
  - *6.1 System integration*
  - *6.2 System testing*
  - *6.3 Testing report*
  - *6.4 User's guide*
- 7. System Submit
  - 7.1 Maintenance plan
  - 7.2 Acceptance test report

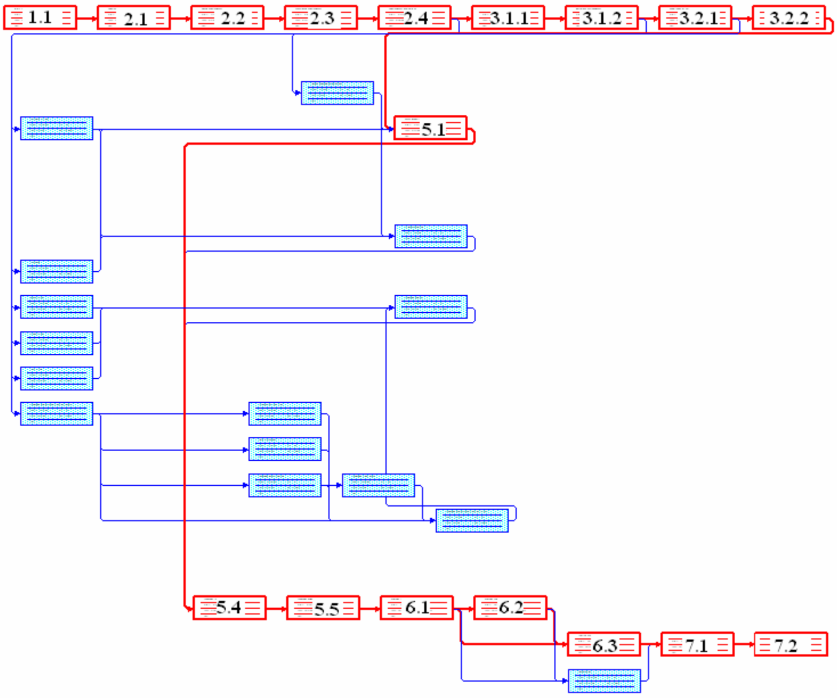


Figure 6. Network diagram and critical path for SE3DN project

5 Conclusions

The paper presents a Simple and Effective 3D Navigation (SE3DN) system and a 3D scene modeling method based on CAD data. The SE3DN system was developed for navigating the new campus of BTBU. It uses multi-thread program framework based MFC and integrates 2D map, 3D navigation and multimedia information into one system to give users an easy and effective navigation. Advantages of the proposed method are: 1) Ease in accurate alignment of separate modules to specific positions in the scene; 2) Ease in accommodating changes in the scene; 3) Unrestricted selection of views by the user. Its limitations are: 1) CAD files of the scene must be available as input data; 2) The photorealistic result is better than GBMR, but not as good as IBMR.

6 References

[1] A. J. Hanson and E. A. Wernert. Constrained 3D navigation with 2D controllers. *Proceedings of the 8th IEEE Visualization Conference*, 1997. pp. 175-182.

[2] S. Huber and R. Sieber. From Flatland to Spaceland: Concepts for interactive 3D navigation in high standard atlases. *Proceedings of 20th International Cartographic Conference*, 2001.

[3] C. St-Jacques, L. Paquin and M. Lavallee. Dynamic navigation into 3D media spaces. *Proceedings of the Second IEEE International Conference on Intelligent Systems*, June 2004, pp 468-473.

[4] D. Burschka, D. Cobzas, Z. Dodds et al. Recent methods for image-based modeling and rendering. *IEEE Virtual Reality 2003 tutorial 1*, 2003, p 299.

[5] J. D. Foley, A. van Dam, S. K. Feiner, and J. F. Hughes. *Computer Graphics: Principles and Practice.* New York: Addison-Wesley, 1997.

[6] V. Sequeira and J. Gonçalves. 3D Reality modeling: photo-realistic 3D models of real world scenes. *Proceedings of the First International Symposium on 3D Data Processing Visualization and Transmission.* 2002, pp 76 – 783.

[7] Creator User's Guide v3.0. www2.ondemandmanuals.com/multigen-paradigm

[8] ArcGIS Desktop. http://www.esri.com/software/arcgis/about/desktop.html