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A Prototype Implementation for 3D Animated Anaglyph Rendering of Multi-typed Urban Features using Standard OpenGL API

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Abstract : Animated anaglyph is the most cost-effective method for 3D stereo visualization of virtual or actual 3D geo-based data model. Unlike 3D anaglyph scene generation using paired epipolar images, the main data sets of this study is the multi-typed 3D feature model containing 3D shaped objects, DEM and satellite imagery. For this purpose, a prototype implementation for 3D animated anaglyph using OpenGL API is carried out, and virtual 3D feature modeling is performed to demonstrate the applicability of this anaglyph approach. Although 3D features are not real objects in this stage, these can be substituted with actual 3D feature model with full texture images along all facades. Currently, it is regarded as the special viewing effect within 3D GIS application domains, because just stereo 3D viewing is a part of lots of GIS functionalities or remote sensing image processing modules. Animated anaglyph process can be linked with real-time manipulation process of 3D feature model and its database attributes in real world problem. As well, this approach of feature-based 3D animated anaglyph scheme is a bridging technology to further image-based 3D animated anaglyph rendering system, portable mobile 3D stereo viewing system or auto-stereo viewing system without glasses for multi-viewers.

Key Words : 3D animated anaglyph, OpenGL API, stereo viewing, urban feature.

1. Introduction

The 3D geo-based data processing and visualization has been regarded as one of the important tasks for the linkage and the integration of remote sensing method and GIS technologies in the most geo-based application domains (Zhang, 2002; Lee and Kim, 2006; Paparoditis *et al.*, 2007; Rotge and Farret, 2007). Especially, urban application in the various application domains focuses on 3D modeling and visualization for urban planning and simulation based on 3D GIS (Ranzinger and Gleixner, 1997; Pullar and Tidey, 2001; Sirakov and Muge, 2005).

Laurini (2001) categorized urban 3D rendering into four styles: realistic rendering, urban project rendering, prescriptive rendering, and symbol rendering, and described that some technical barriers in 3D rendering are considered to reach their purposes: rendering speed, visual combination effects, mapping complexity, and vast range of

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display environment possibilities.

Thus, among some basic processing modules in 3D GIS, geo-based data visualization is regarded as the important function, and there are some aspects to be considered from the developers' or users' viewpoint. Firstly, the understanding regarding the processing pipeline of 3D computer graphics, which means common procedure from a model to pixels, are needed to application users to basic level or intermediate level. That is, it is noticed that some limitations with respect to special effects on 3D graphic pipeline exist, according to target application. Second, the used 3D data sets influence system requirements for target system. For instance, stereo system with only stereo satellite image sets does not need 3D processing functions for 3D feature modeling or 3D shape construction with respect to each object. Furthermore, most complex 3D geo-based application systems are dealt with multi-typed or multi sources such as 2D/3D GIS data sets, DEM, satellite images, texture image sets for each feature, and multimedia. Third, in case of the stereo visualization system, display devices are also considered. Till now, the product of 3D stereo viewing system oriented to the field of GIS is rare (Rotge and Farret, 2007), but some devices for VR (Virtual Reality) or 3D imaging application such as scientific visualization, entertainment, games, and art have been released in the commercial basis (Borner, 1999; Peterka *et al.*, 2006): HMD (Head Mounted Device), LCD Shuttered Glasses, holographic system, CAVE system, portable auto-stereo display panel for stereo monitor, and so forth. However, despite these technological advances, Doneus and Hanke (1999) reported that the anaglyph scheme using two colored glass or the lenticular system using barrier strip, although it is somewhat old-fashioned style, is proven to still be the most popular and cheap approach to stereo scene generation to general multi-viewers.

The stereo visualization for 3D geo-based data is known to the useful methodology for the purpose of image recognition, feature extraction, modeling and visualization in remote sensing or photogrammetric applications, but actually there are available few stereo visualization systems using real or semi-real 3D GIS data model. Most commercial remote sensing softwares or image processing softwares provide the anaglyph creating and viewing functions, using red-blue glass, for stereo paired epipolar images to generate a stereo image. However, 3D geo-spatial data modeling function to build 3D animated anaglyph, which means dynamic 3D stereo visualization along arbitrary viewpoint of multi-viewers, is not provided yet.

The main theme of this study is to implement a prototype for 3D animated anaglyph or animated anaglyph using complex typed and multi-typed 3D feature model based on standard graphic API (Application Programming Interface) without the help of commercial 3D graphic modeling/rendering tool, CAD tool and GIS tool. The used graphic API in this study is only OPENGL API (URL http://www.opengl.org). Basic rationale and concept on animated anaglyph was described in Doneus and Hanke (1999) and El-Hakim *et al.* (2006). Types of 3D feature model handling in this implementation are 3D building model and other structures, and DEM and satellite imagery are also used. Ervin and Hasbrouck (2001) summarized graphic modeling types of 3D urban feature in the landscape modeling, and some geometric feature generation scheme in those is used in this study. Although real 3D feature model in a certain area is not fully applied in the processed results of a prototype implementation, the applicability of animated anaglyph in further 3D geo-based urban application is demonstrated as example cases.

2. 3D Animated Anaglyph Approach

In basic, stereoscopic displays use a technique to create the illusion of depth in a photograph, movie, or other two-dimensional images, by presenting two slightly different images on epipolar plane (Shapiro and Stockman, 2001). Main idea of anaglyph for stereoscopic display is simple. Paired two data sets, in the form of image or feature, from left viewpoint and right viewpoint are necessary. Any free or paid image processing software can produce anaglyph images easily. Both images have to be loaded into system, converted to grayscale and back to RGB color mode. Then simple operation is carried out to remove the red channel of the right image and replace it by the red channel of the left image by simple cut and past operations. After a slight adjustment of parallax to get the best view of depth, an anaglyph of the original stereo pair is created. In principle colored photos can be converted to anaglyphs this way.

In other plain words, if a left object and a right object are blue and red printed set, respectively, these two data sets are aligned and superimposed into one set. Then red (left lens)-blue (right lens) glass performs as a kind of matching filter. If the viewer then looks at the mixed image through a blue-filter in front of his right and a red-filter in front of his left eye, each complementary colored image is filtered away. This results in a stereoscopic view, where each part of the stereo-pair is viewed only by the corresponding eye. Followed by these processes, human brain fuses them and gives us a stronger depth perception as virtual stereo scene.

On the contrary to 2D image anaglyph, 3D stereo scene generation using actual or virtual 3D features is based on so-called the animated anaglyph. Additional functions for the animated rendering and for post-processing per frame are required to general anaglyph processing. As for depth cues related to depth perception, several aspects should be considered: 3D perspective projection, sizes of objects, detailed level of objects, occlusion, lighting and shadow, and motion effect. These can be the main functionalities in the implementation process for animated anaglyph handling multiple 3D feature models.

As for the anaglyph generation process, there are a couple of methods of setting up a virtual camera or eyes and viewing conditions. The parallel rendering and the toe-in rendering are general cases (Fig. 1(A) and (B)). As for the off-axis scheme (Bourke, 1999) to create stereo pairs shown at Fig. 1(C), it introduces no vertical parallax, and it is known that is creates less discomfort level in the resultant anaglyph scene, compared with other two general anaglyph rendering configurations. The off-axis rendering approach is used in this implementation. In general, the degree of the stereo effect depends on both the distance of eye location to the projection plane and the separation of the left and right eye. It is natural that too large a separation can be hard to resolve. Another constraint in the off-axis rendering is to ensure the negative parallax does not exceed the eye separation.

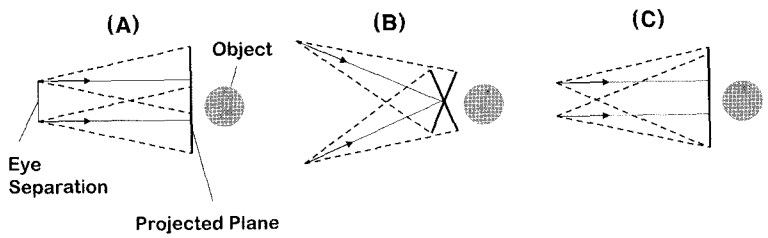

Fig. 1. Types of anaglyph rendering (Bourke, 1999): (A) Parallel, (B) Toe-in, and (C) Off-axis.

Table 1. Comparison with 2D anaglyph, non-anaglyph 3D animated rendering, and 3D animated anaglyph.

	Conventional 2D Anaglyph	Image-based Animated Rendering, not Anaglyph	Feature-based Aninmated Anaglyph
Basic Concept	Stereo Image Processing	3D Close Range Photogrammetry, Laser Scanning, Semi-automated Feature Extraction and Pattern Recognition	CAD-style Feature Modeling, Virtual Reality and 3D walkthrough, and 3D Game/ Animation
3D Feature Geometry	No	2D/3D Laser Surveying and modeling using 3D GIS Data Sets	2D Surveying or Graphic modeling using GIS Data sets
Texture (Image) Data Acquisition	Paired Photo Images using Digital Camera or Air-borne/ Satellite Image Sets	Field Texture Images using Digital Camera along all Facades	Image Fragments
Texture function	No	Pixel matching for Real Multi-Image Sets and Image Processing	Texture Mapping Processing
DEM Supporting function	No	Partly DEM draping	Full DEM draping
Model Editing/Manipulation	No	Not real-time and Separate Processing	Possibly Real-time Editing
Effects	Image Filtering and Its Effects	Not affordable	3D Landscape Effects based on Computer Graphics
Area Coverage	One Spot	Somewhat Limited	Dependent upon the number of features
Implementation Cost	Free or very low	Relatively High or Very High, Dependent upon Image Accuracy and Acquisition Method	Low or relatively high

In summary, three approaches related to the anaglyph processing are described in Table 1: conventional 2D anaglyph, image-based 3D rendering, and feature-based animated anaglyph. Conventional 2D anaglyph is the most popular scheme to create stereo image using the paired images on one spot location (Fig. 2(A)). Main data types of image-based rendering are on-site level scanning or sensed data sets (Fig. 2(B)), whereas, those for feature-based animated anaglyph are 3D graphic primitives based on general graphic process. Fig. 2 (C) shows one case of image-based rendering using PhotoModeler ^{TM}, one of close-range photogrammetry tools focused on 3D graphics; however, this photo-realistic 3D rendering is not suitable for animated anaglyph in this stage. This nice-looking projected scene is generated by pixel matching and bundle adjustment, and the whole image textures with respect to actual 3D objects are used. But texture images for all sides of actual objects in this scene are difficult to obtain at the given site, although they are in the visible scope. This is normal case in the 3D photo-realistic urban rendering. Thus, some additional image processing processes are needed for texture image preparation.

In feature-based animated anaglyph, image fragments or patterned texture as well as whole image sets are basically utilized. The fragments are transformed into texture image by means of basic image processing such as image mosaicking, merging, resizing and resampling. Of course, image fragments can be applied for the photo-realistic rendering. Furthermore, feature-based approach can provide special functions such as full DEM draping,

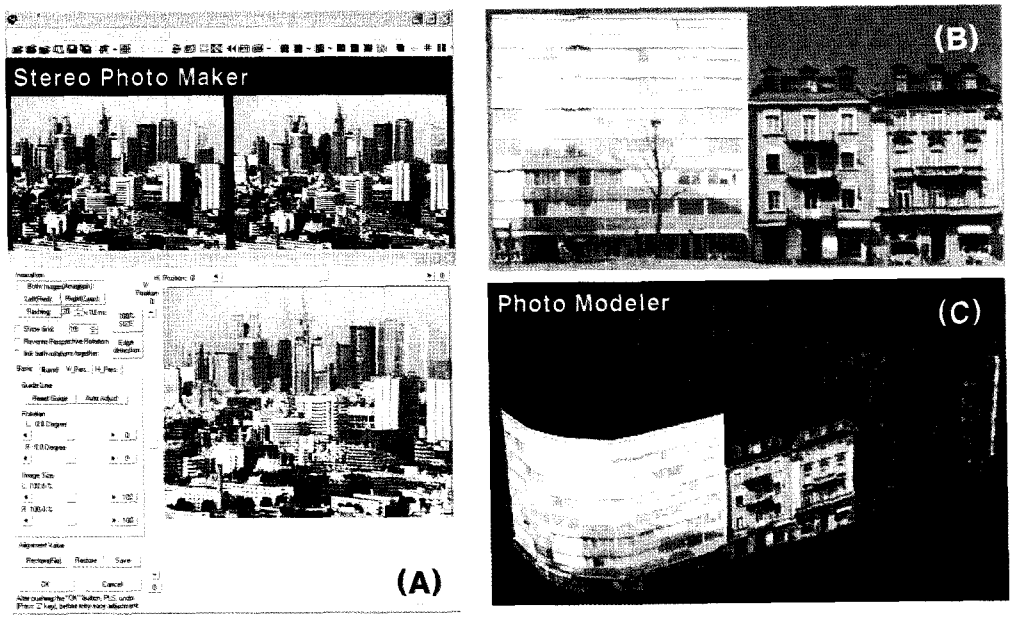

Fig. 2. (A): Conventional 2D anaglyph using StereoPhoto Maker tool (freeware by Suto (2006); (B) and (C): Image-based 3D rendering, non-anaglyph, using PhotoModeler™ tool. These figures are not original ones, cited from each vender site, and not processed in this study. These are presented for the purpose to compare with feature-based 3D animated anaglyph, as the main subject of this study.

real-time editing, and 3D landscape effects. Area coverage is also the important factor in the 3D animated anaglyph implementation. Feature-based approach depends upon the number of features and size of DEM resolution and draping image; whereas, 3D image-based rendering by close range photogrammetry may cover somewhat limited area due to large number of photo images for real-time texturing. In general, implementation cost for 3D image-based approach is much higher then feature-based approach. While, other passive 3D stereo viewing systems using two projectors can be used (Fig. 3), but 3D animated anaglyph thorough 3D graphic processing on single projector is more cost-effective.

Fig. 3. 3D stereo viewing for multi-viewers: Passive 3D display system with 2 projectors and polarized glasses (US-based BARCO case at SIGGRAPH 2006).

3. Implementation and Example Cases

For the implementation of 3D animated anaglyph using 3D feature models, the several processing step is necessary, shown in Fig. 4. Among these, the ortho-rectified image draping is for the matching process of DEM and space-borne imagery, and the result is used to the geo-referencing base for 3D feature modeling. It is a kind of general 3D terrain visualization process. Geo-referencing process is

needed for the horizontal coordinate of texture mapped 3D feature model. Image fragment sets, in the form of patterned image sub sets, are used for texture mapping, in the step for the pre-processing for animated anaglyph. While, synthetic 3D modeling and stereo scene generation is to prepare initial anaglyph scene as a reference frame to adjust animated scene generation according to viewing parameters. In adjusting anaglyph frame, two projection frustums according to off-axis rendering scheme are built. Viewing condition setting and viewing parameter changing is crucial to make depth cues for 3D animated anaglyph. Viewing condition means initial location and eye focusing of virtual viewer. According to general multi-viewers' purpose of uses, viewing parameters can be changed for navigation effect or fly-by effect.

In this implementation, OpenGL, which is an international standard 2D/3D graphic API that can control graphic hardware, is used. OpenGL has a low-level rendering function that offers geometry primitive of point, line, and polygon. As well, OpenGL can embody special effects functions such as a RGBA color type and lighting, shading, blending, fog, texture mapping, color filtering, accumulation buffer function to help the realistic rendering processing and the base environment for stereoscopic processing. Therefore, most processing steps in Fig. 4 are coded in VC++ integrated developing environment with OpenGL dll (Dynamic Linked Library) components. Especially, there are several extensions based on OpenGL (Lengyel, 2003), but only standard API which is released by OpenGL ARB (Architecture Review Board) is used in this implementation without any other extensions.

As the prototype results of animated anaglyph towards synthetic 3D urban modeling and visualization, two example cases are presented in Figs. 5 and 6. In both cases, regarding data preparation in these examples, DEM data and space-borne imagery are used in the form of draped satellite imagery with DEM. Satellite imagery is a subset of actual VHR (Very High Resolution) imagery. In this stage, the covered area is virtual area for demonstration of an

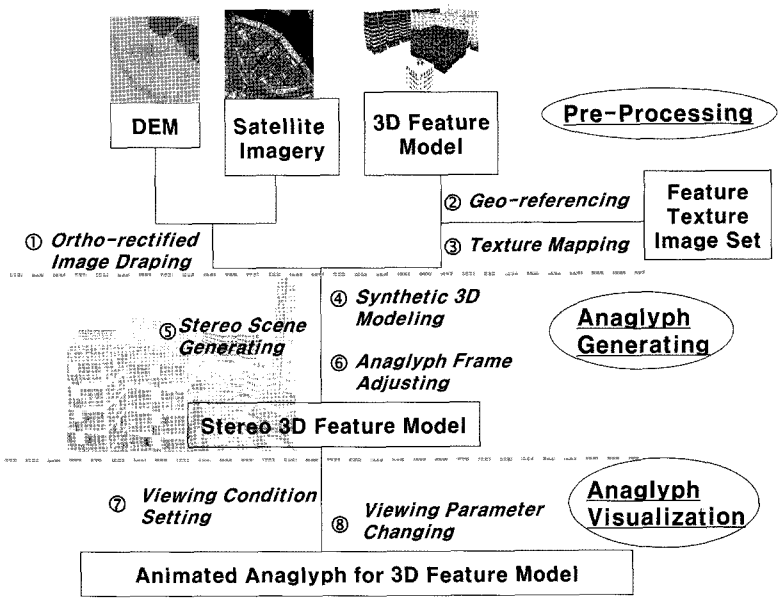

Fig. 4. Processes for 3D animated anaglyph applied in this study.

Fig. 5. Demonstration of animated anaglyph with multiple urban components: An example case 1. [Note] Stereo effect may be dimmed in this printed figure due to color calibration.

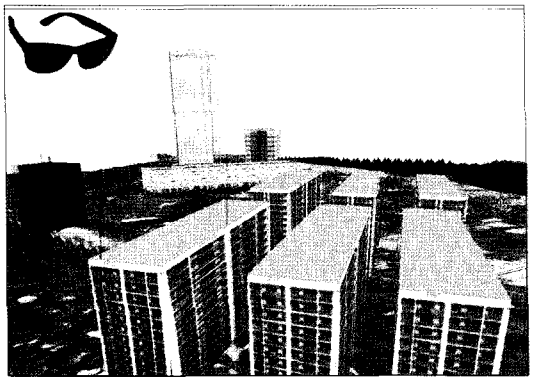

Fig. 6. Demonstration of animated anaglyph with multiple urban components: An example case 2. [Note] Stereo effect may be dimmed in this printed figure due to color calibration.

implemented prototype. As for the shape construction for 3D feature models, points and nodes about over millions are applied, and the nested triangulation around one million is generated. The 3D features composed of several kinds of buildings are texture mapped ones. Some pattern images are used for texture primitives, although they are not real urban objects in a certain region in this demonstration. However, the substitution with actual 3D model data and other geo-spatial data sets is possible.

4. Concluding Remarks

Animated anaglyph is the most cost-effective method for stereo visualization with depth perception. For this purpose, implementation using OpenGL API is carried out, and virtual 3D feature modeling is performed. The motivation of this study is to demonstrate applicability of stereo visualization of synthetic 3D urban model, followed by OpenGL-based prototype implementation for 3D animated anaglyph using the off-axis rendering scheme.

Besides animated anaglyph scheme, there are other 3D stereo viewing systems such as auto 3D without glasses or HMD devices. Their uses are increasing in the 3D imaging industries. But multi-viewers' stereo system using stereo viewing devices is an initial stage in the 3D GIS application domains. Currently, just stereo 3D viewing function using paired epipolar images is regarded as a part of the GIS functionalities.

Although these virtual 3D models are not dealt with real objects composing urban environment in a certain area, these can be substituted with actual 3D feature model. Animated anaglyph is relatively easy approach. But it is possible to link with manipulation of 3D feature model and its database attributes, on the contrary to the 3D imaging system oriented to 3D stereo viewing purpose. Furthermore, image-based 3D rendering system by photo-realistic 3D rendering and laser scanning data acquisition is an important improvement in 3D GIS, but it is not reached to 3D stereo viewing stage for general multi-viewers yet. Therefore, this approach of feature-based animated anaglyph scheme is a bridging technology to further image-based 3D animated anaglyph rendering system by photo-realistic 3D scene generation using laser scanning data in real-time and on-site level and fully functioned 3D stereo GIS application. Further researches and development regarding new stereo viewing system dealing with actual 3D geo-based data sets are progressing: portable mobile 3D stereo viewing system or auto-stereo viewing system without glasses for multi-viewers. It is thought that

these technologies contribute to expand general uses of 3D urban applications.

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