Journal of Engineering Science and Technology Review 6 (2) (2013) 110-114

JOURNAL OF
Engineering Science and Technology Review

www.jestr.org

Research Article

Virtual Texture with Wallis Filter for Terrain Visualization

Li-wen Wang* and An Wang

Civil Aviation University of China, Research Base of Especial Ground Equipment on Aviation, Tianjin, China

Received 15 May 2013; Accepted 25 July 2013

Abstract

As Boeing 737-800 Flight simulator get more and more demanding in terms of rendering time and authenticity. In order to reduce the amount of image data, we use the large region low-resolution remote sensing image mosaic with small region high-resolution remote sensing image. Meanwhile, for the color imbalances between images, we propose the global Wallis transform method based on HSI color space, So that the color is consistent among the images. Finally, we present a novel texture technique to achieve real-time performance. The experiment shows that the method can make sure the texture fit the requirement of Boeing 737-800 Flight Simulator.

Keywords: Virtual Texture, Flight Simulator, Wallis, HSI color space

1. Introduction

Remote sensing image in the construction of 3D real terrain plays a crucial role, especially in building applications in a flight simulator of the three-dimensional real terrain. And the terrain rendering in a flight simulator has its own characteristics. First, the terrain in flight simulator is very large, and some areas need high details. Second, rendering frame speed in the flight simulator is very important[1]. Therefore, if only adopt high resolution of remote sensing image as the terrain texture data sources, the amount of image data that is used by far exceeds available computer memory and video resources. However, if only adopt low resolution remote sensing image as the terrain texture data sources, will cause the authenticity of construct 3D terrain does not meet the requirements of flight simulator. According to the Boeing 737-800 flight simulator's practical training situation, areas of interest require a high-resolution to provide a complete and accurate training environment at very close range. Conversely, the large surrounding areas require lower degrees of resolution. So the approach is that the texture with varying degrees of resolution can reduce the amount of image data.

However, the effect of internal and external factors will lead to the differences of hue, lightness, contrast, etc. between the remote sensing images. The differences are mainly caused by imaging non-uniformity of optical lens, atmospheric attenuation, clouds, smog, different light conditions due to sun/shade conditions, and so on. And that will affect the final constructed 3D terrain's visual effect.

Aiming at above problem, we first proposed the global Wallis transform based on HSI color space for eliminate the color imbalance between images. Then we use the virtual texture technology to increase the rendering frame rate. The final terrain texture can meet the requirements of Boeing 737-800 flight simulator.

2. Relate Work

There are several approaches for color equalization. Some of them[2], [3], [4] are based on Histogram Analysis, these methods are simple and fast. But these methods accuracy of color equalization is not high. Others[5], [6] can provide more accurate correction, however, more computation in the correction process are needed

The histogram equalization[2](HE) is the one of the most popular color equalization method. The mechanism of the HE is to transform the gray-levels of the image to a uniform histogram based on the probability of occurrence of gray levels in an input image, but this method often fail in producing satisfactory results for broad range of low-contrast images.

The principle of the histogram matching method[3] is the shape of the histogram of an image is mapped to one another on the histogram of the image, which makes the two images' histogram are similar, then color equalization completed between two images. However, because it is by directly changing the image histogram shape, which may cause some of the original image's contrast disappeared or increase, resulting in degradation of image resolution. Therefore, only the image is similar between the histogram, the histogram matching method can achieve good results.

Zhang et al.[4] propose to construct a mapping function between the color histograms in the overlapping area of the source images. A color correction is performed using the mapping function for the adjacent image. Since the pixels in the overlapping areas are difficult to correspond to different resolution remote sensing images, therefore, this method is

* E-mail address: wangandqib@163.com
ISSN: 1791-2377

not suitable for different resolution images' color equalization.

Pham et al. [5] use a simple statistical analysis to impose one image's color characteristics on another. The benefit of the method is that no accurate pixel correspondences are required. There are some problems in this approach. The detail components are reduced and the artifacts such as false contours and false color are generated, because this method do not consider the contrast and characteristics

Choi et al.[6] almost the same method as Pham, except that they extracts illumination color features using the color board image captured in each illumination to a target illumination in the preprocessing step.

3.Color Equalization

3.1 Color spatial conversion

3.1.1 RGB synthesizing display

Since in the process of constructing 3D terrain, the remote sensing images only been used in making terrain texture. Therefore, in order to reduce the amount of remote sensing image data. We only use three bands in remote sensing image to synthesis of RGB color image. With Landsat TM band synthesis as example. Band1 (wavelength: 0.45 to 0.52μm) corresponds to the B channel, Band2 (wavelength: 0.52 to 0.60μm) corresponds to the G channel, Band3 (wavelength: 0.63 to 0.69μm) corresponds to the R channel. For other sensor band synthetic, can according to the band center wavelength band of Landsat TM.

Despite the color equalization in RGB color space, which sometimes can balance the different images of the color imbalance, but because there will be correlations between the different channels' values, therefore, the image after color equalization in this space, may appear the problem of color distortion. Meanwhile, images are perceived by the human visual system in terms of luminance, hue, and saturation which are all complex functions of the individual color components. This means that to perform any function on the image such as luminance scaling, all three color components must be manipulated simultaneously.

3.1.2. HSI color space

The HSI color space is for the hue, saturation and intensity which reflects the features of human vision, Meanwhile, this color space can be carries from the image color information in the elimination of intensity images. Therefore, the HSI color space is more suitable for color equalization processing and this color space can also reduce the complexity of processing[7], [8].

We can convert the image from RGB color space to HSI color space by the following equations(1-3).

$$I = \frac{R+G+B}{3} \tag{1}$$

$$H = \cos^{-1}\left[\frac{[(R-G)+(R-B)]}{2[(R-G)^2+(R-B)(G-B)]^{\frac{1}{2}}}\right] \tag{2}$$

$$S = 1-3\frac{\min(R,G,B)}{R+G+B} \tag{3}$$

It is notice that when red value is greater than green value, the hue value is 360 minus hue value.

After the color equalization processing, we must transfer the result back to RGB to display it. For convenience, here are the inverse operations. We convert for HSI to RGB using the following equations(4-6).

When $0^\circ < H \leqslant 120^\circ$

$$\begin{cases} B` = I(1-S) \\ R` = I[1+\dfrac{S\cos H}{\cos(60^\circ - H)}] \\ G` = 3I-(R`+B`) \end{cases} \tag{4}$$

When $120^\circ < H \leqslant 240^\circ$

$$\begin{cases} H = H-120^\circ \\ B` = 3I-(R`+G`) \\ G` = I[1+\dfrac{S\cos H}{\cos(60^\circ - H)}] \\ R` = I(1-S) \end{cases} \tag{5}$$

When $240^\circ < H \leq 360^\circ$

$$\begin{cases} H = H-240^\circ \\ G` = I(1-S) \\ B` = I(1+\dfrac{S\cos H}{\cos(60^\circ - H)}) \\ R` = 3I-(G`+B`) \end{cases} \tag{6}$$

3.2 Global Wallis transformation method based on HSI color space

Wallis filter is a kind of local image transform, the principle is make the image of local's mean value and variance value map to the destination image's mean value and variance value, so that the images in different location of the gray mean and gray variance having approximately equal value, then the images can be color equalization[9], [10]. The Wallis filter's expression is as follows:

$$f(x,y) = \frac{[g(x,y)-m_g]cs_f}{cs_g+(1-c)s_f} + bm_f + (1-b)m_g \tag{7}$$

Where $g(x,y)$ is the gray value of the original image, $f(x,y)$ is the gray value of the converted image. m_g is the original image of a neighborhood of a pixel gray mean value of gray, s_g is the original image of a neighborhood of a pixel variance value of gray. m_f is the mean of the destination image. s_f is the variance of the destination image. c is the extension of the image variance constant, the range from 0 to 1, the bigger the value, the larger the range of the processing. b is the image luminance factor, the range from 0 to 1, when $b \rightarrow 1$, the mean of the image is forced to mean m_f, when $b \rightarrow 0$, the mean of the image is forced to m_g.

From the perspective of the implementation of algorithm, Wallis transformation is not affected by gray scale statistical distribution characteristics, and therefore will not be like the histogram matching appearing the color aberration, so it is a relatively robust color matching method. Meanwhile, since the calculation of image local gray mean an variance, the method introduce the smoothing operator, so it could indeed suppress noise and increase signal to noise ratio, then improve image quality.

According to the analysis of algorithm, we make the processed image's gray mean and gray variance values as m_g and s_g, and make the destination image's gray mean and gray variance values as m_f and s_f . Then the global Wallis transformation's expression can be show as:

$$f(x,y) = \frac{[g(x,y) - MEAN_{or}]cVAR_{go}}{cVAR_{or} + (1-c)VAR_{go}} + bMEAN_{go} + (1-b)MEAN_{or} \quad (8)$$

Where the $MEAN_{or}$ and VAR_{or} is the processed image's gray mean and gray variance, and the $MEAN_{go}$ and VAR_{go} is the destination image's gray mean and gray variance, these variables are expressed as follows(9 - 10):

$$MEAN_{or} = \sum_{i=0}^{L-1} r_i p(r_i) \quad (9)$$

$$VAR_{or} = \sum_{i=0}^{L-1} (r_i - m)^2 p(r_i) \quad (10)$$

$$MEAN_{go} = \sum_{i=0}^{L-1} r_i p(r_i) \quad (11)$$

$$VAR_{go} = \sum_{i=0}^{L-1} (r_i - m)^2 p(r_i) \quad (12)$$

Where r represents a discrete random variable discrete gray which the range from 0 to L-1. $p(r_i)$ is r_i probabilistic estimated value. Since we need to overall transform of images, therefore, we take b and c is 1.

3.3 Algorithm Verification

Experiment respectively Guiyang Longdongbao airport and Xichang Qingshan airport two regions to validate the algorithm. Guiyang Longdongbao airport's test area we select is 150 square kilometers of 10m resolution remote sensing image, 75 square kilometers of 5m resolution remote sensing image and 25 square kilometers of 0.5m resolution remote sensing images. The original image and the mosaic effect are shown in Fig.1, Fig.3. Xichang Qingshan airport' s test area we select is 3000 square kilometers of 30m resolution remote sensing image, 100 square kilometers of 10m resolution remote sensing image and 25 square kilometers of 1m resolution remote sensing images. The original image and the mosaic effect are shown in Fig.2, Fig.3. The Fig.4. shows the images using the proposed algorithm.

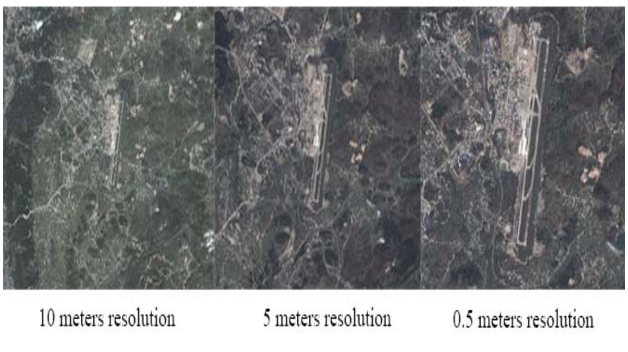

Fig. 1. Guiyang Longdongbao airport original image

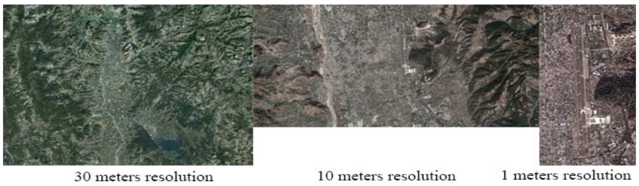

Fig. 2. Qingshan airport original image

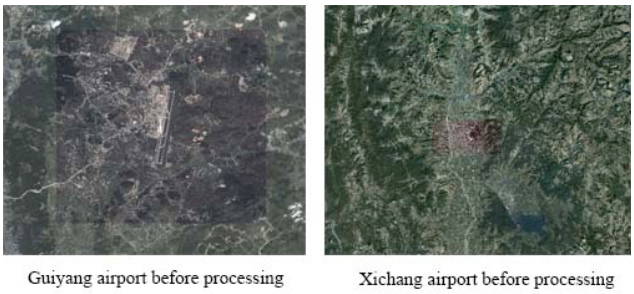

Fig. 3. Mosaic renderings before treatment

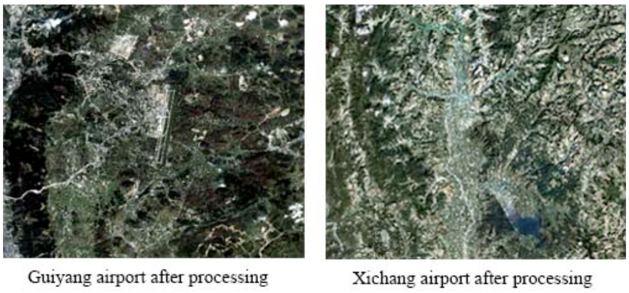

Fig. 4. Mosaic renderings after treatment

As we can see from the Fig.3 and Fig.4, the color is apparent in Fig.3 imbalances in Fig.4 are well balanced.

4. Virtual Texture

Despite treatment with the above method, the amount of the remote sensing image data has been greatly reduced, but the rendering frame rate still can't meet the requirement of real-time application. We found that in the process of 3D terrain roaming, the field of view is usually only a small part of the entire terrain database, and the resolution of the human eye decreases with the increasing distance, according to these characteristic, by the processing of the remote sensing image using virtual texture technology, the final terrain texture can be meet the requirement of the flight simulator.

4.1 Virtual Texture Techniques

Mipmap[11],[12] technology and Clipmap[13],[14],[15] technology were the most important references in the field of real-time terrain texturing. However, the biggest drawback of these techniques is strong coupling between terrain geometry and texture regarding database structure and run-time LOD selection. Geometry must be tessellated and tile boundaries must exactly match those of the tiles of the texture mosaic.

Virtual texture combine the Mipmap and Clipmap's advantage, and use layer and tile structure as its data organization. First, by the idea of Mipmap technique, we resample the original image into a series of different resolution textures, and we call them the texture layer. Because the Mipmap request the choice to down sample each level by a factor of 2[16], therefore, we make a texture layer resolution is the next level texture resolution level 2 times. In order to ensure a smooth transition between the layers, according to the transmission speed of the RAM, the texture's size must be limited, if the texture size is larger than the limit value, the texture must be cut until the every piece of texture's size smaller than the limit value, and we named the block texture as the tile.

The virtual texture's data organization as shown in Fig.5:

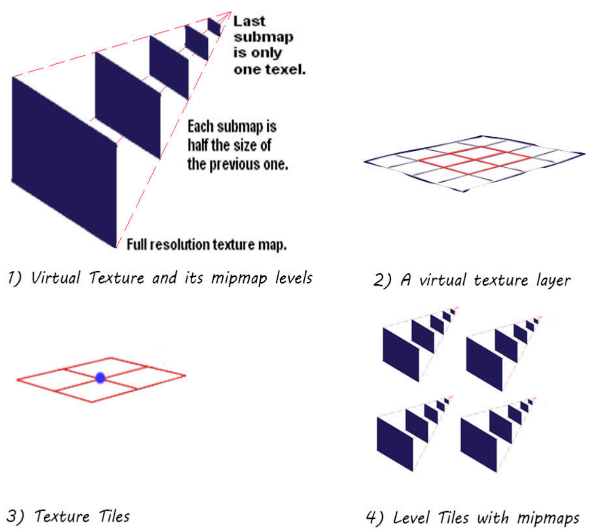

Fig. 5. Virtual Texture's Structure

The graph in the Fig.5 1) shows the virtual texture multi-level texture organizational structure, each blue face represents one level of the texture layer. The graph in the Fig.5 2) shows the one of the higher-resolution texture layer structure. The Fig.5 3) represents the average of the layer is divided into four texture tiles, and the Fig.5 4) shows the each of texture tiles' multi-level organization structure.

4.2 Result an discussion

The current implementation of the described technique has been tested on a personal computer powered by Pentium G620@ 2.6GHz with 2GB DDR3 RAM, an Nvidia Geforce 9600GT chip with 256MB video memory and a SATA disk 7200 rpm.

Experiment compare the loading and unloading terrain texture of system's drawing time for get the texture's drawing time.

Rendering result is illustrated in Fig.6, the red line represents the scene drawing time. In the case shown in Fig. 6(1) , the unloading texture's drawing time is about 14ms, while in Fig. 6 (2), the loading texture's drawing time is about 16ms. The difference is only about 2ms, meet the real-time requirements. In Fig. 6(2), the red overlay areas represents the highest resolution texture layer, the yellow overlay areas' texture resolution is lower than the red overlay areas' texture resolution. The textures' resolution were decreased with the color change, the blue overlay areas indicates the lowest resolution of the terrain texture. Fig. 7 is the flow chart of building terrain texture.

Fig. 8 shows the examples of using virtual texture technique.

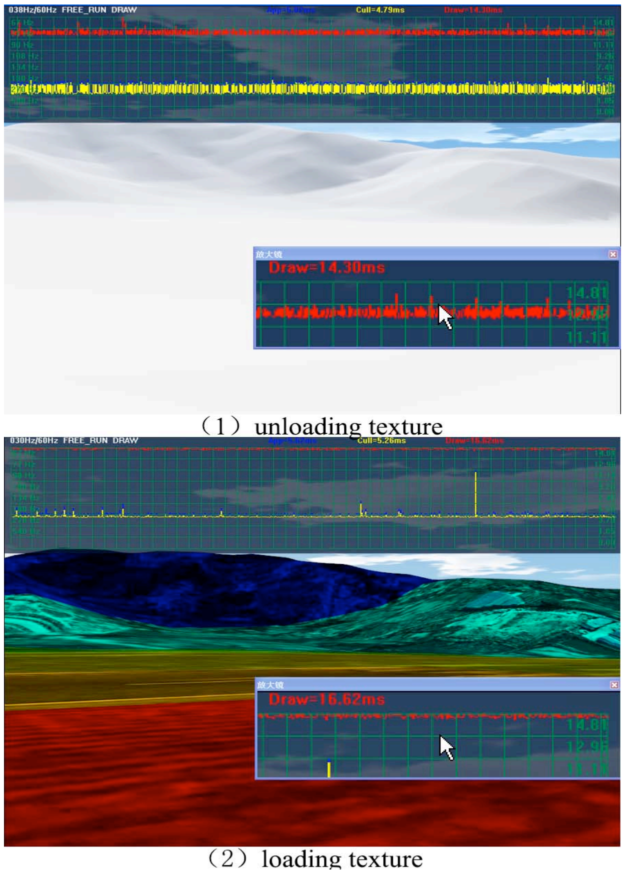

Fig. 6 Test results

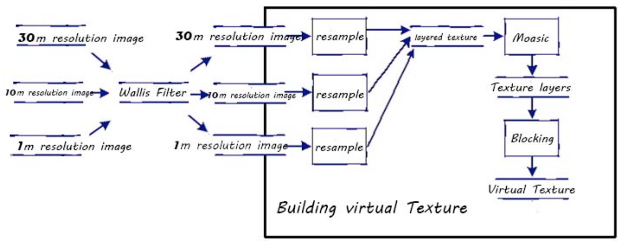

Fig. 7 Overall generate 3D terrain texture architecture

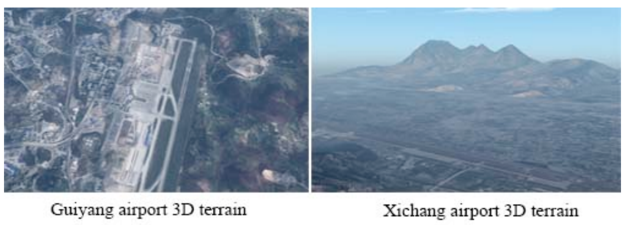

Fig. 8 3D terrain models

Fig.9 Boeing 737-800 Flight Slimulator Experimental Platform

5. Conclusion

In this paper, we use the Boeing 737-800 flight simulator in 3D terrain building as research background, in the light of different resolution sensing remote image's color imbalance, we propose the global Wallis transformation method based on HSI color space to make the color equalization, and the benefit of virtual texture technique is that it allows for efficient visualization with imagery at real-time frame rates on a commodity PC platform. The experimental result proves that the texture building by the above method, not only can satisfy the requirements of the flight simulator in visualization, but also can meet flight simulator for real-time requirements.

The techniques use in our Boeing 737-800 Flight Simulator Experimental Platform is shown in Fig. 9

The future work for us will improve the performance of the algorithm by using of compressing the terrain datasets.

References

1. Zhang Y, Cong D, Han J. Real-time Rendering of Large-scale Terrain in the Flight Simulator. Integration Technology, 2007. ICIT'07. IEEE International Conference on. IEEE, 2007. pp.426-431.
2. Rafael C.Gonzalez, Richard E.Wook. Digital Image Processing. 2nd ed. New York : Prentice Hall, 2007.pp. 74-81
3. Shi Y, Wang H, Li Y, et al. Practical Color Matching Approach for Color Computer-Generated Holography. Display Technology, 2013, Volume:PP , Issue: 99, pp. 1-6
4. M.Zhang, J.Xie, Y.Li, and D.Wu.Color histogram correction for panoramic images. In Virtual Systems' and Multimedia, 2001. Proceedings. Seventh International Conference on, ,2001pp. 328-331.
5. Pham B, Pringle G. Color correction for an image sequence. Computer Graphics and Applications, IEEE, 15(3), 1995, pp.38-42.
6. Choi Y J, Lee Y B, Cho W D. Color correction for object identification from images with different color illumination. INC, IMS and IDC, 2009. NCM'09. Fifth International Joint Conference on. IEEE, 2009, pp.1598-1603.
7. G.Y.Tian, D.Gledhill, D.Taylor, and D.Clark. Colour correction for panoramic imaging.In Information Visualisation Proceedings. Sixth International Conference on, 2002, pp. 483-448.
8. Song Y, Shan J. Color correction of texture images for true photorealistic visualization. ISPRS Journal of Photogrammetry and Remote Sensing, 65(3),2010, pp.308-315.
9. Zhang Li, Zhang Zuxun, Zhang Jianqing.The image Matching Based on Wallis Filtering. Journal of Wuhan Technical University of Surveying and Mapping,1999,pp. 01:24-27 35.
10. Wang Zhijun, Li Deren, Li Qingquan. Application of Wallis Transform in Wavelet Based Image Fusion. Journal of Wuhan Technical University of Surveying and Mapping,2000,pp. 04:338-342.
11. J.P.Ewins, M.D.Warcus, M. White,P.F.Lister. Mip-map Level Selection For Texture Mapping. IEEE Trans, Visual Compat, vol 4,no.4,pp.317-329,1998
12. Manson, Josiah ; Schaefer, Scott. Parameterization-Aware MIP-Mapping. COMPUTER GRAPHICS FORUM, JUN 2012, Volume: 31 Issue: 4 pp. 1455-1463
13. Seoane A, Taibo J, Hernández L, et al. Hardware-independent clipmapping.WSCG2007, International Conference in Central Europe on Computer Graphics, Czech Republic. 2007.pp.177-183
14. Böttger J, Preiser M, Balzer M, et al. Detail - In - Context Visualization for Satellite Imagery. Computer Graphics Forum. Blackwell Publishing Ltd, 27(2), 2008. pp. 587-596.
15. Amara Y, Marsault X. A GPU Tile-Load-Map architecture for terrain rendering: theory and applications. The Visual Computer, 25(8), 2009. pp.805-824.
16. Woo M, Neider J, Davis T. OpenGL Programming Guide. 6th ed. Addison-Wesley, 2008.pp.247-254
17. Lerbour R., Marvie J.-E., Gautron P.: Adaptive real-time rendering of planetary terrains. In Full Paper Proc. Int. Conf. Computer Graphics, Visualization and Computer Vision (WSCG) (Feb. 2010). 2, 3, 5