3D Image Enhancement Model for Large-scale Scene Based on Improved Retinex Algorithm

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Abstract
As the Retinex algorithm still has the deficiency of poor resolution in large-scale 3D generated images, this paper put forward strengthened model of a large-scale image on the basis of optimal Retinex algorithm. First of all, we segregate the image by brightness according to Weber’s law, then we apply enhancement factor of different levels to strengthen the areas after segregation, next we introduce Geometric envelop theorem and multiple-resolution algorithm. Among the input large-scale 3D generated images, we gain estimation of illuminate images so that the reflection coefficient can be acquired. And we apply the principle of image pyramid of multiple-resolution algorithm to conduct overall optimization. The simulated experiment proves that this optimized algorithm, in comparison with traditional algorithm, has strengthened effect on images.

Key words: Large-scale Scene 3D Image; Image Generation; Improved Retinex Algorithm; Brightness Block; Comentropy Optimization; Global Solution Optimization.

1. INTRODUCTION

Image generation in large-scale complex scene is an important research topic of computer graphics and virtual reality, which has a very important application on computer aided design, battlefield visualization, building roaming, driving simulation, virtual simulation, game entertainment and many other fields (Fan and Zhou, 2014). Image enhancement is one of the important ways to solve the contradictions of the scene reality and instantaneity (Chen, 2013). Image enhancement can get the realistic surface detail without increasing the complexity of geometric objects in the scene model, getting more and more extensive research and application (Fan, 2013). Image enhancement not only can decrease the complexity of the objects in the scene model, but also can get real and detailed scenery surface detail, getting satisfactory visual effect (Xie, 2013).

Because of the important theoretical significance and practical value of large-scale complex scene image generation technology, in recent years, many domestic or abroad experts have been organized to do a large amount of research (Zhuang, 2013). D. Nistér proposed the methods of automatic recovery scene information for never calibrated video sequences (Cao, 2013). M. P. Oelofse proposed a method to use the image information from hand-held camera to recovery virtual 3D scene model (Liu, 2014). Levoy has led his team to use the laser scanner based on triangle principle and high-resolution color image acquisition to reconstruct a large complex scenes, and put forward a series of related technologies (Li, 2014). Hkaim and others built its own hardware platform, they fixed the laser scanner and a CCD camera on a car, got a data collection and registration system DCR (Jiang, 2014). Yu made real scene modeling, then extracted some real object in the scene, and provided scene of physical, and provide the function of editing and moving for 3D model of objects (He, 2014).

On the basis of the 3D modeling, domestic and abroad researchers also studied the lighting model. According to the 3D geometric model of depth image restoration scene by Nishino, each side of the model was recorded which was determined by the direction of light source properties and the line of sight of 2D texture space, then according to the properties of linear superposition image grey value, the linear combination of the existing texture feature image was done to get the new point of view, or new scene images under the direction of light (Liu, 2014). Wong presented a controlled illumination rendering method fully based on image, this method sampled through different viewpoints and illumination conditions of scene to get the surface of the pixel element and its bidirectional reflectance distribution function (Fu, 2014). While the suggested environment mapping technology by Blinn got rid of the traditional drawing formula under the illumination model, but relationship between the established deformation of all-optical function need the direct scene geometry information (Zhao, 2014), on the basis of giving a similar scene object model by Dan, in order to meet the target scene of lambert reflection, through the singular value decomposition and fitting lambert objects of base image data matrix under the condition of illumination change to get all the image collection, finally using the base image analytic expression to generate to images under the new light (Zhu, 2014).

Although the big scene 3D image generation effect has had the very big progress, but there are still some problems such as image is not clear, this paper put forward a large-scale scene 3D image enhancement model
based on improved Retinex algorithm, the local details of image enhancement is optimized, so as to improve its clarity in big scene 3D image generation.

2. LARGE-SCALE SCENE 3D IMAGE ENHANCEMENT BASED ON IMPROVED RETINEX ALGORITHM

The 3D image generation in big scene generally uses the Retinex algorithm for image enhancement. In the large-scale scene 3D image enhancement model based on Retinex algorithm, the irradiation light \( L \) directly determines the dynamic range the 3D image pixels can reach in the large-scale scene, while reflection object \( R \) determines the intrinsic properties of the large-scale scene 3D image. The traditional large-scale scene 3D image enhancement based on Retinex algorithm model is the reflection properties \( R \) of the image from the image \( S \).

Setting the light exposure weight in space is smooth, the following formula is:

\[
S(x, y) = R(x, y)L(x, y)
\]

In the formula: \( S(x, y) \) is large-scale scene 3D image; \( R(x, y) \) is reflective image; \( L(x, y) \) is illumination image. In order to isolate reflection and illumination weight easily, usually taking logarithm on both sides of formula (1), as shown in formula (2).

\[
\log[S(x, y)] = \log[R(x, y)] + \log[L(x, y)]
\]

Transform formula (2) into (3),

\[
\log[R(x, y)] = \log\left(\frac{S(x, y)}{L(x, y)}\right)
\]

We can know from the essence of the Retinex that \( R(x, y) \) corresponds to the high frequency part of image, \( L(x, y) \) is corresponds to the low frequency part of image. Application of Gaussian filter \( G(x, y) \) could estimate the light weight \( L(x, y) \) and acquire the reflective weight \( R(x, y) \):

\[
r(x, y) = \log[R(x, y)] = \log[S(x, y)] - \log[S(x, y) \times G(x, y)]
\]

In the formula: \( G(x, y) \) is surround function, usually represented by Gaussian function. A large number of experiments showed that the traditional large-scale scene 3D image enhancement based on Retinex algorithm model, although the image already has a certain effect, but when the difference of brightness in the two parts of the image is big, the halo phenomenon will generate in the big edge of illumination change, if serious, it can cause local contrast details missing in the field where the change of image contrast is big.

3. OPTIMIZATION OF RETINEX ALGORITHM

3.1. The Optimization Of Information Entropy Based On Luminance Block

In order to enhance the Retinex algorithm for supporting details of large-scale scene 3D image enhancement, this paper adopted the theorem of luminance block to be optimized.

(1)Luminance block segmentation

According to the weber's law of psychology \( \Delta B \) is the just noticeable difference of stimulation, \( k \) is constant. Introducing the background intensity to represent the stimulation intensity, the slope in different area are different, it can be divided into three areas: saturation area, middle brightness area and low brightness area. High brightness area is affected by the influence of stimulating saturated which is called the saturation region. Brightness in the regional has uniform brightness change and rich color, the identify areas of human eye is mainly concentrated in the middle brightness area. The human eye can hardly feel the brightness changes in low intensity area.

Brightness can be divided into different areas according to the background intensity of the image and grey value jumping rate of each pixel, and use the background intensity and gradient information of image to give a 2D decomposition, and the image pixel is divided into different areas according to brightness. In which background intensity \( B(x, y) \) is acquired by weighted value of neighbor pixels.
\[ B(x, y) = m \otimes [m \otimes \left( \frac{m}{2} \otimes \sum_{i} P(x, y) \right) \otimes \sum_{i} Q(x, y)] \]

\[ IM = \max(P(x, y)) \cdot \min(P(x, y)) \]

According to luminance threshold \( B_j \) gradient threshold \( T_j \), in which \( j = 1, 2 \). From the image division of brightness area, there are:

\[ B_1 = a \cdot IM \]
\[ B_2 = b \cdot IM \]
\[ T_1 = 0.01 \beta \max \left( \frac{T(x, y)}{B(x, y)} \right) \]
\[ T_2 = \frac{T_1}{B_2} \]

Brightness in middle luminance region should satisfy \( B_i \leq B(x, y) \leq B_j \), moreover \( T(x, y)/B(x, y) \geq T_j \); Brightness in saturation region should satisfy \( B(x, y) \geq B_j \), moreover \( T(x, y)/B(x, y) \geq T_j \); the rest are in low luminance region. The image is divided into several regions in above way, to achieve the goal of image enhancement respectively in different regions. The relative parameters are set as \( a = 0.01 \), \( b = 0.7 \), weighted value \( m = 0.8 \), \( n = 1.6 \).

(2) Luminance block enhancement

This paper divides the brightness into 3 regions which were defined as: low brightness region \( I_1 \), middle brightness region \( I_2 \) and saturation region \( I_3 \). In the calculation process of Retinex algorithm, the linear weighted method was not adopted, but the results of luminance regions were enhanced pointedly with different scales by Retinex algorithm, which can be integrated the merits of different scale Gaussian function.

Because of the best visual effect in middle luminance region, and it is more suitable for the human eye observation of object, for example of the processing in the middle luminance region. Firstly, filtering operation is done with Gaussian function of scale \( \sigma_2 \) to obtain the incoming component in this region, and then wipe off the incoming component to obtain the reflective component, thus to realize the enhancement for middle luminance region, the original image \( S \) here is replaced by luminance \( I \) whose formula as follows:

\[ F_2 = \frac{1}{2\pi\sigma_2} \exp \left\{ -\frac{(x^2 + y^2)}{2\sigma_2^2} \right\} \]
\[ R_2(x, y) = \log I_2(x, y) - \log[I_2(x, y) * F_2(x, y)] \]

In above \( F_2(x, y) \) is the Gaussian function of scale \( \sigma_2 \), \( I_2(x, y) \) is the pixel in divided middle luminance region, * means the Gaussian function \( \sigma_2 \) acting on its corresponding \( I_2(x, y) \) region. This is what has said above in the form of processing in different areas respectively.

Similar to the compute mode of middle luminance region, the residual saturation region and low luminance region can also choose their processing method, choose different scale Gaussian filter respectively to calculate and realize enhancement in different luminance region, its formula is:

\[ F_1 = \frac{1}{2\pi\sigma_1} \exp \left\{ -\frac{(x^2 + y^2)}{2\sigma_1^2} \right\} \]
\[ R_1(x, y) = \log I_1(x, y) - \log[I_1(x, y) * F_1(x, y)] \]
In which \( F_k(x, y) \) is the Gaussian function with scale \( \sigma_k \), \( I_k \) is different luminance region, * means that the core of Gaussian template is only used within its corresponding luminance region \( I_k \), \( k = 1, 2, 3 \).

Through above calculation, the different luminance region adopts targeted processing respectively, obtaining the reflection components \( R_1(x, y) \), \( R_2(x, y) \), \( R_3(x, y) \) of their respective regions, since then, the calculation for image enhancement has been finished, the results \( R_1(x, y) \), \( R_2(x, y) \), \( R_3(x, y) \) are combined to obtain the enhanced image which we need.

(3) Fusion of block information

Block information fusion method has some similarities between average filtering methods, both of them are based on a certain pixel as the center, choosing the appropriate window in an area around. But the difference is the adoptive template of median filter belongs to the weighted form. The selection of weight is depending on the template. And the way of block information fusion is proportional to be solved after dividing the pixel edge.

First of all, the processed regional results are defined as \( I_1^r \), \( I_2^r \), \( I_3^r \) according to different scale. Taking pixel point \( O(x, y) \) in the region as center, to get a \( N \times N \) square window near it, the proportion of low-light region, middle-light region and saturation region in the window are presented with \( p_1 \), \( p_2 \), \( p_3 \), respectively, formula in proportion to information fusion is:

\[
I'(x, y) = p_1 I_1^r(x, y) + p_2 I_2^r(x, y) + p_3 I_3^r(x, y)
\]  (15)

In which the value of \( N \) is general 3, 5 and other odd number, like sample of \( 3 \times 3 \) window, the center of matrix represents the luminance of the image point, the luminance near it is depend on specific image and has no unified value.

The calculated quantity will increase with the refining of window selection. Combining the final result and the \( H \), \( S \) component of original image to the enhanced result. Since this algorithm only has carried on the processing to the luminance of the image information, to make the enhanced image in color and saturation distortion smaller than that of the original image which improve the visual feature of image.

3.2. Global Optimization of Solution Based on Geometric Envelope and Multi-Resolution

In view of the traditional large-scale 3D image enhancement based on Retinex algorithm model in solving the global defects, this paper introduced the principle of geometric envelope, a layer in the input image was directly obtained geometric envelope as the estimation of illumination image \( L \), then obtained the scenery reflection coefficient \( R \).

For any pixel point \( s(x_0, y_0) \) in the image, the definition of collection:

\[
n(x_0, y_0) = \{| s(x, y) | \sqrt{(x-x_0)^2 + (y-y_0)^2} < r_0, s(x, y) > s(x_0, y_0) \}\]  (16)

In the formula, \( r_0 \) was distance function. \( n(x_0, y_0) \) represents the collection in which the value of pixel is larger than \( s(x_0, y_0) \) in the neighborhood with the radius of \( r_0 \). The formula of the algorithm in this paper as follows:

\[
l(x, y) = s(x, y) + \sum_{p \in n(x, y)} (p - l(x, y)) \cdot f(r)
\]  (17)

In above formula, \( r \) is the distance from \( p \) to \( l(x, y) \), \( f(r) \) is encircling function, which is:

\[
f(r) = Ke^{-c^2 r^2} \]  (18)

\( K \) is normalization constant, \( c \) is scale parameter.
Figure 1. Cross-sectional view of the illumination image

For each pixel in the image, if grey value of the pixels around is higher, it will produce certain of gain for it to increase its grey value. The greater the difference, namely the position of the oscillation is more intense, the greater the ascension of the grey value. Such effect is, on the one hand, the pixel values of image is higher than that of the input image, on the other hand, the ascension of lower pixel point is more, while the higher pixel point promotes less or even has no ascension, so gradient values of the result image will be smaller. Thus, it will form a higher envelope of grey value than that of the input image. As shown in figure 1, the solid line is the input image section, a dotted line is the calculated intensity of illumination image section in the same position.

The algorithm satisfies the following characteristics:

(1) From the definition of collection \( n \),

\[
\forall p \in n(x, y), \quad p > l(x, y) \quad (19)
\]

\[
\Rightarrow \sum_{p \in n(x, y)} (p - l(x, y)) f(r) \geq 0 
\quad (20)
\]

Which satisfies \( l \geq s \);

(2) From fig.1, The different degree of drive up in low areas of the image, and the peak area is basically the same. This is identical in the formula, for pixel of trough area, its increasing item \( \sum_{p \in n(x, y)} (p - l(x, y)) f(r) \) is larger. Thus, \( l \) is spatial smoothing.

(3) \( l \) has a small amount of increase on the basis of \( s \), which means the value of \( \sum_{p \in n(x, y)} (p - l(x, y)) f(r) \) is very small, and \( l \) is close to \( s \).

(4) Algorithm only completes the solution of the \( m \) through a filtering operation, time efficiency has greatly been improved than iterative solution of traditional algorithm.

It is thus clear that this algorithm is good in accordance with the traditional large-scale 3D image enhancement based on Retinex algorithm model for the illumination of a priori constraints, and there's no need to iteration, which improves the efficiency of the time.

In order to get the overall solution, it needs to set the large distance parameter \( r_0 \). It will increase the time needed for calculation. In order to improve the speed of algorithm, this paper put forward the algorithm of multi-resolution.

The basic idea is to take sample for the original image as image pyramid, and then filter a smaller distance parameter for every layer, and then take a weighted average for the results of each layer. Such high calculated results reflects the detail distribution characteristics of image, while the low calculated results of the layer reeacts the overall features of image. At the same time due to the small coefficient of each layer, the operation time of each layer is very small, and the overall time efficiency greatly improved. The specific calculation formula is as follows:

\[
s_j = \text{PyrDown}(s_{j-1}), s_1 = s 
\]

\[
l_j(x, y) = s_j(x, y) + \sum_{p \in n(x, y)} (p - l(x, y)) f(r) 
\]

\[
l = \sum_w w_j \cdot \text{PyrUp}^{j+1}(l_j) 
\]
Specific steps are as follows:
(1) $s = \log(S)$ is changed to log region;
(2) Make $s_i = s, \ i = 1, \ k$ is times of down sampling;
(3) Calculate $l$ from $s_i$;
(4) If $i = k$, turn to step (7);
(5) $s_{i+1} = PyrDown(s_i)$, $PyrDown$ is for half the proportion of the down sampling function;
(6) $i = i + 1$, turn to step (3);
(7) According to the setting of $w_i(i = 1, 2, ... , k)$, calculate the value of the formula (23).

4. SIMULATION OF ALGORITHM

In order to verify the effectiveness of the proposed improved algorithm in this paper, simulation experiment on the algorithm is carried out, the first experiment is adopted with a picture of a 500 × 500 large-scale 3D image for image enhancement, its definition is carried on the statistics, such as formula (24), the second experiment of a large-scale 3D images with different resolution image are enhanced, the resolution is 100×100, 200×200, 300×300, 400×400, 500×500, 600×600, 700×700, 800×800, 900×900, 1000×1000, the test results is shown in Figure 2.

$$Def = \sum_{a} (df/ dx)^2 / abs(f(b) - f(a))$$

In above formula, $df / dx$ is the change rate of gray at the edge of the normal vector, $f(b) - f(a)$ is the total change of gray in this direction.

Table 1. Contrast resolution 3D image of the same resolution

<table>
<thead>
<tr>
<th>Image No.</th>
<th>Original</th>
<th>Retinex</th>
<th>IM-Retinex</th>
</tr>
</thead>
<tbody>
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<td>100.4</td>
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<tr>
<td>4</td>
<td>19.4</td>
<td>22.8</td>
<td>61.3</td>
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<td>5</td>
<td>59.1</td>
<td>64.6</td>
<td>89.7</td>
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<tr>
<td>10</td>
<td>62.2</td>
<td>70.8</td>
<td>100.6</td>
</tr>
</tbody>
</table>

Figure 2. The same resolution as the image contrast enhancement rate

Figure 3. Image contrast enhancement rate of different resolutions

Then, using the above 10 large-scale scene 3D images of image enhancement with different resolution, the clarity is also tested, the experimental results are shown below.
Table 2. Contrast resolution 3D image of different resolutions

<table>
<thead>
<tr>
<th>Image No.</th>
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<th>IM-Retinex</th>
</tr>
</thead>
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</tbody>
</table>

From the above experimental results, In the 3D image enhancement by Retinex algorithm with the information entropy and the global optimization, the effect is better than traditional Retinex algorithm, and with the increasing of image resolution, the enhancement effect is also enhanced.

5. CONCLUSIONS

In the research of virtual reality system, various large-scale scene image generation technology has always been a very important part, although it has been developing compared with the past, but still can't meet the need of large-scale scene 3D image. This paper put forward the large-scale scene 3D image enhancement model based on improved Retinex algorithm, from the simulation experiment, the effect of image enhancement has been greatly enhanced.

Acknowledgement

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