A Novel Thinning Algorithm of 3D Image Model Based on Spatial Wavelet Interpolation

Juntao Bi
Qingdao Hotel Management College, Qingdao Shandong 266100, China
E-mail: juntao_bi@163.com

***Abstract*— In dynamic modeling process of 3D image, too much few characteristics extracted in the binocular stereo vision modeling process cause the cloud characteristics of the model node could not be recovered and low fidelity of the model. In order to solve this problem, this paper presents a thinning algorithm of 3D image model based on improved spatial wavelet interpolation. Firstly, several coordinates of dynamic characteristic nodes are collected by the binocular stereo vision method to compose a characteristic' assemblage which is used to build an interpolation region. Then the characteristic nodes of interpolation are built in the region by the dynamic wavelet recovering method, and modified in direction. Whether the characteristic is reasonable is judged by the modified result. Finally the new characteristic is taken as the vertex to construct a new region and complete the iterative interpolation. Simulation results show that the accuracy error of the interpolation is less than 15 pixels when image interpolation is carried out based on a few characteristics which basically meet the requirements of stability, accuracy and anti-interference ability of 3D interpolation.**

***Index Terms*—characteristics extraction, 3D image, wavelet function interpolation**

I. INTRODUCTION

The construction of a 3D image characteristic model is a very crucial issue and also one of the most difficult issues in computer vision and computer graphics field [1]. The object computer 3D image simulation is always an active research area in computer graphics and human-computer interaction [2]. The photorealistic computer 3D image models are widely used in movies, advertisement, computer games, video meeting, human-computer interface, facial surgery, television programs, computer-aid sign language teaching, psychology, cognitive science and so on[3]. With the development of computer image processing techniques in the recent years, researchers can propose some data acquire methods for 3D image modeling [4]. Most of the methods are based on the 2D image characteristics extraction, which have more applications. However, the traditional 3D image modeling methods which are based on 2D image are constrained by the extracted characteristics because the characteristics extracted from 2D image are limited and it's impossible to extract all of the characteristic information. Thus how to recover the 3D information from 2D image as much as possible is still a problem in 3D image modeling [5].

In order to solve the problem, this paper proposes a 3D image thinning algorithm based on spatial wavelet interpolation which can greatly improve the performance of traditional 3D image modeling. The algorithm does the interpolation computation based on limited 2D characteristics in order to calculate more characteristics. It can effectively and accurately recover image 3D characteristic information and enforce the 3D image saturation.

The rest of this paper is organized as follows：

First, describe the point extraction method for image feature based two-dimensional image and establish three-dimensional image model constraints. Then propose three-dimensional characteristics wavelet interpolation algorithm to calculate the coordinates of interpolation points, remove dead pixels and complete three-dimensional image refinement. Finally, related simulation is carried out to verify the performance of the method presented.

II. 2D IMAGE CHARACTERISTICS EXTRACTION ALGORITHM

A. Image Characteristics Extraction based on 2D Image

On the basis of the binocular stereo vision theory [6], the frontal face image and side face image are extracted for the characteristics firstly. According to the advantage of the real application, the position of the two cameras is not limited to the special demands. The 3D characteristics of the P point in different coordinate system were shown in Figure 1.

© 2013 ACADEMY PUBLISHER
doi:10.4304/jcp.8.11.3012-3019

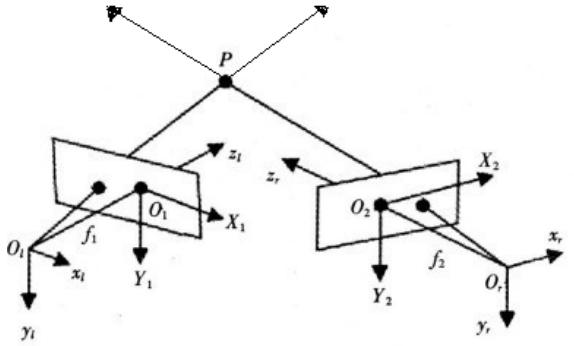


Figure 1. Diagram of extracted 3D characteristics

What is to be mentioned is that the selected characteristics nodes should be representative. It ought to include all the key 3D characteristics [7]. And it need to be unique in the same time, it is shown as the unique symbol for representing an important characteristic of the individual. Assumed that the left camera is $O_l - x_l y_l z_l$, it is located in the origin of the world coordinate system without rotation, the image coordinate system is $O_1 - x_1 y_1 z_1$, the effective focal distance is measured as f_1 with camera calibration. The coordinate system of the right camera is assumed as $O_r - x_r y_r z_r$, the image coordinate system is $O_2 - x_2 y_2 z_2$, and the effective focal distance is f_2.

According to the theory of camera perspective model, it can get that:

$$\begin{cases} s_t \begin{bmatrix} X_2 \\ Y_2 \\ 1 \end{bmatrix} = \begin{bmatrix} f_2 & & \\ & f_2 & \\ & & 1 \end{bmatrix} \begin{bmatrix} x_r \\ y_r \\ z_r \end{bmatrix} \\ s_1 \begin{bmatrix} X_1 \\ Y_1 \\ 1 \end{bmatrix} = \begin{bmatrix} f_1 & & \\ & f_1 & \\ & & 1 \end{bmatrix} \begin{bmatrix} x_l \\ y_l \\ z_l \end{bmatrix} \end{cases} \tag{1}$$

The mutual position relationship between the coordinate system $O_1 - x_1 y_1 z_1$ and coordinate system $O_r - x_r y_r z_r$ can be shown as follows with space conversion matrix M_{lr}:

$$\begin{cases} \begin{bmatrix} x_r \\ y_r \\ z_r \end{bmatrix} = M_{lr} \begin{bmatrix} x_1 \\ y_1 \\ z_1 \\ 1 \end{bmatrix} = \begin{bmatrix} r_1 & r_2 & r_3 \\ r_4 & r_5 & r_6 \\ r_7 & r_8 & r_9 \end{bmatrix} \\ M_{lr} = \begin{bmatrix} R \middle| T \end{bmatrix} \end{cases} \tag{2}$$

Where the R and T are the translation vectors between the spin matrix and original point for the $O_1 - x_1 y_1 z_1$ and $O_r - x_r y_r z_r$ coordinate system respectively[11]. and:

$$\begin{cases} R = \begin{bmatrix} r_1 & r_2 & r_3 \\ r_4 & r_5 & r_6 \\ r_7 & r_8 & r_9 \end{bmatrix} \\ T = \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix} \end{cases} \tag{3}$$

From above formula, for the spatial points in the $O_1 - x_1 y_1 z_1$ coordinate system, the congruent relationship between the image face nodes of the two cameras is:

$$p \begin{bmatrix} x_r \\ y_r \\ z_r \end{bmatrix} = \begin{bmatrix} f_2 r_1 & f_2 r_2 & f_2 r_3 & f_2 t_x \\ f_2 r_4 & f_2 r_5 & f_2 r_6 & f_2 t_y \\ r_7 & r_8 & r_9 & t_z \end{bmatrix} \begin{bmatrix} zX_1 / f_1 \\ zY_1 / f_1 \\ z \\ 1 \end{bmatrix} \tag{4}$$

Then, the 3-dimensional coordinate of the corresponding 3D points was shown as follows:

$$\begin{cases} x = zX_1 / f_1 \\ y = zY_1 / f_1 \\ z = \dfrac{f_1 (f_2 t_x - X_2 t_z)}{X_2 (r_7 X_1 + r_8 Y_1 + f_1 r_9) - f_2 (r_1 X_1 + r_2 Y_1 + f_1 r_3)} \\ \qquad \dfrac{}{Y_2 (r_7 X_1 + r_8 Y_1 + f_1 r_9) - f_2 (r_4 X_1 + r_5 Y_1 + f_1 r_6)} \end{cases} \tag{5}$$

Assumed that the external parameters of the right and left cameras in the binocular stereo vision system are R_1, T_1 and R_2, T_2. Therefore, for an arbitrary point, assumed the non-homogeneous coordinates of the arbitrary point in the world coordinate system, left camera coordinate system, and right camera coordinate system are x_w, x_1 and x_2 respectively. So

$$\begin{cases} x_1 = R_1 x_w + T_1 \\ x_2 = R_2 x_w + T_2 \end{cases} \tag{6}$$

Hence, the geometrical relationship between the two cameras R and T can be shown as:

$$\begin{cases} R = R_2 R^{-1} \\ T = T_2 - R_2 R^{-1} T_1 \end{cases} \tag{7}$$

According to the formula (7), the R_1, T_1 and R_2,

© 2013 ACADEMY PUBLISHER

T_2 can be calculated effectively, furthermore, the relative geometrical position can be computed, then the 3D coordinates of the corresponding points can be solved in the meanwhile.

B. Added Constraint Condition

Radial alignment constraint of the camera calibration

In the Figure 1, it can be shown that the vector pO_1 and $p'O_1$ is parallel with the vertical direction from P to the Z_c axis. And the radial lens distortion doesn't change the direction of the vector $p'O_1$. So the radial alignment constraint can be shown as pO_1 is parallel with $p'O_1$. In the additional analysis, it can be concluded that change of the focal distance f don't change the constraint condition. So any comparison expressions which concluded from traditional RAC constraint condition are not related to the focal distance f and deformation coefficient k.

On the basis of the formula (7), it is resulted that:

$$\begin{cases} x' = r_1 X_w + r_2 Y_w + r_3 Z_w + t_x \\ y' = r_4 X_w + r_5 Y_w + r_6 Z_w + t_y \\ z' = r_7 X_w + r_8 Y_w + r_9 Z_w + t_z \end{cases} \tag{8}$$

Combined with the RAC constraint condition, then:

$$\frac{x'}{y'} = \frac{r_1 X_w + r_2 Y_w + r_3 Z_w + t_x}{r_4 X_w + r_5 Y_w + r_6 Z_w + t_y} \tag{9}$$

According to the above two formulas, get that:

$$\begin{bmatrix} X_w y' & Y_w y' & Z_w y' & y' & -X_w x' & -Y_w x' & -Z_w x' \end{bmatrix} \begin{bmatrix} r_1/t_y \\ r_2/t_y \\ r_3/t_y \\ t_x/t_y \\ r_4/t_y \\ r_5/t_y \\ r_6/t_y \end{bmatrix} = x' \tag{10}$$

Where, the row vector $\begin{bmatrix} X_w y' & Y_w y' & Z_w y' & y' & -X_w x' & -Y_w x' & -Z_w x' \end{bmatrix}$ is known, but the column vector $\begin{bmatrix} r_1/t_y & r_2/t_y & r_3/t_y & t_x/t_y & r_4/t_y & r_5/t_y & r_6/t_y \end{bmatrix}^T$ is unknown which should be calculated, if the spatial points from the same dimension are selected as the calibration, and the world coordinate system is made as $Z_w = 0$, then the formula above can be expressed as:

$$\begin{bmatrix} X_w y' & Y_w y' & y' & -X_w x' & -Y_w x' \end{bmatrix} \begin{bmatrix} r_1/t_y \\ r_2/t_y \\ t_x/t_y \\ r_4/t_y \\ r_5/t_y \end{bmatrix} = x' \tag{11}$$

Therefore, it just needs 5 points, and the spin matrix and translation vector can be solved finally.

3D image model constraint

When 2D image characteristics transform the 3D characteristics, a lot of information can be lost in the process, and there are great differences among the images from different viewpoints. The external conditions such as light, geometry of the object, physical characteristics, noise interference and distortion are formed as the gray scale of the sole image. And it results the un-stability of the pixel characteristics. So, the 2D pixel information is taken as the criterion for the modeling, the modeling performance can be uncertain, it is difficult to extract the characteristics for the image precisely and unambiguously. In order to improve the reliability and confidence level of the matching, and eliminate the ambiguity, it is necessary to take the constraint for the limitation based on certain regular.

In the 3D image modeling base on the binocular stereo vision, the similarity constraint is brought for the accuracy of the 3D coordinate system.

(1) Firstly, the triangulation is going to be carried out for the 3D characteristics data points which is included above.

(2) The similarity constraint vector should is established. The angle of the triangulation is taken as the unique similarity constraint vector, the length of a side for the triangle is calculated, and the result is taken as the geometric similarity constraint vector.

(3) The discrimination formula of similarity constraint is constructed as $S=S_1+S_2$. Where the S_1 is shown as the unique function value of similarity constraint, and the S_2 is shown as the function value of geometric similarity constraint. And

$$\begin{cases} S_1=\sqrt{(\theta_1-\theta_1')^2 k_1+(\theta_2-\theta_2')^2 k_2+.....+(\theta_m-\theta_m')^2 k_m} \\ S_2=\sqrt{(d_1-d_1')^2 k_1+(d_2-d_2')^2 k_2+.....+(d_m-d_m')^2 k_m} \end{cases} \tag{12}$$

Where, the θ_i and d_i is the number i characteristic component of the characteristic vector which come from the samples to be detected. θ_i' and d_i' is the number i standard characteristic component of the 3D image model. k_i is the weight of the number i characteristic component. θ_i is shown as the angle information of the 3D model characteristic points, and d is shown as the side length of the triangle in space.

© 2013 ACADEMY PUBLISHER

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \quad (13)$$

By comparing the similarity constraint function S with the threshold value S', the precision of the construction of 3D characteristic points is obtained. If $S < S^{'}$, it can be concluded that the extracted characteristic points is accurate, otherwise, the characteristic points should be extracted again.

C.3D Characteristic Points Interpolation based on Two-dimensional Wavelet

For getting the 3D image of the object model with better sense of reality, triangulation is taken for the known 3D the characteristic points. Considering the complexity of direct triangulation in the 3D space, the 3D characteristic data points need to be mapped in the 2D area one by one firstly, and the mapping points are implemented with triangulation in the 2D projection area, finally, it is returned to the 3D area based on the corresponding relationship. The triangulation of the spatial scattered points is realized to the better.

According to the triangulation of the discrete point set in the 2D space, many triangulation algorithms are existed currently. The Russian mathematician Delaunay proposed the Delaunay triangulation algorithm in 1934. It is considered that there is one but just one triangulation algorithm can make the sum of interior angles for a triangle reach maximum. The Delaunay algorithm avoids the pathological triangles as much as possible based on the maximum average aspect ratio. The algorithm is known as the best triangulation algorithm in the world, the Delaunay triangulation algorithm needs to meet the demands as follows.

(1) The triangle was formed by the three nearest neighbors, and all the line segments should be crossed at a point.

(2) The mapping of the coordinate must be located in the interior of the triangle.

(3) When someone vertex need to be added, deleted and moved, it just can affect the nearest triangle.

According to the demands as above, an improved object 3D model triangulation method is proposed based on the mesh optimization for getting the optimal triangle. Firstly, the scattered points are sequenced, and the minimum point of the X coordinate value is searched which is assumed as v_1, the square of distance between v_1 and the point is calculated, according to the ascending order of calculating result, all the points are sequenced as the series $v_1, v_2, ...v_n$. The first side is formed as the connection of v_1 and v_2. The points which are not on the same line with v_1 and v_2 are searched sequentially in the v_i series, it is symbolized as v_k. Before v_k embedding in v_3, all the other points are turned back sequentially. The initial grid front sides of the first triangle are obtained by combing with v_1, v_2 and v_k three points. Finally, on the basis of the maximization of minimum interior angle criterion, the points are enlarged one by one with the grid advanced technology. The initial face triangular mesh is formed now.

After the 3D triangulation for the object, the coordinates of interpolation points should be determined. According to the future knowledge and facial anatomy principle, some plane coordinates of the special crossover points in the facial triangular patch are adapted to the above demand to the best. It can be used as the coordinate of the points to be embedded. For the realization of judgment of the crossover property, the 2D coordinate (x, y) of the interpolation point should be required firstly. It means that the special crossover points coordinate in the first modeling triangular patch need to be solved on the first step.

The problem of crossover points in triangulation which is formed by several characteristic points is shown in Figure 2.

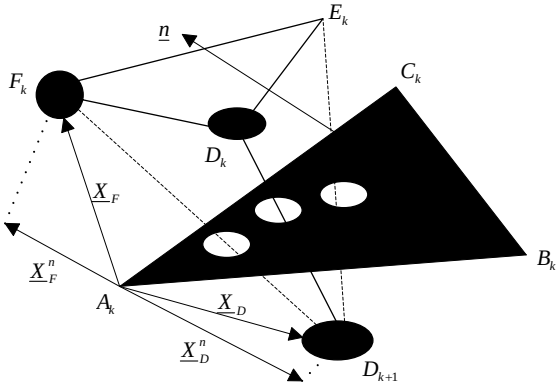


Figure 2. Normal case of triangle intersection

Where $\Delta A_k B_k C_k$ and $\Delta D_{k+1} E_k F_k$ are the relative positions of triangulation which formed by several 3D characteristic points. Assumed point D_k is the crossover point of midlines in $\Delta D_{k+1} E_k F_k$. Crossing over $\Delta A_k B_k C_k$, intersection is reached eventually. Comparing the symbols of $\underline{X}_F \bullet \underline{n}$ and $\underline{X}_D \bullet \underline{n}$, if it is on the opposite direction, the connection between D_k and D_{k+1} can cross over $\Delta A_k B_k C_k$, and the side $D_k F_k$ can cross over $\Delta A_k B_k C_k$ at least. If the intersection for the triangles is referred to the two sides of different triangles which are shown in Figure 3, the intersection is reasonable at yet. Under this condition, the connection of node D_k and D_{k+1} don't cross over $\Delta A_k B_k C_k$. But $D_k F_k$ is also intersecting with $\Delta A_k B_k C_k$, the intersection point is existed. Moreover,

© 2013 ACADEMY PUBLISHER

the intersection point of D_kF_k and triangle is conformed to the optimal triangle norm. Therefore, it can be used as the insertion point of face interpolation for the analysis.

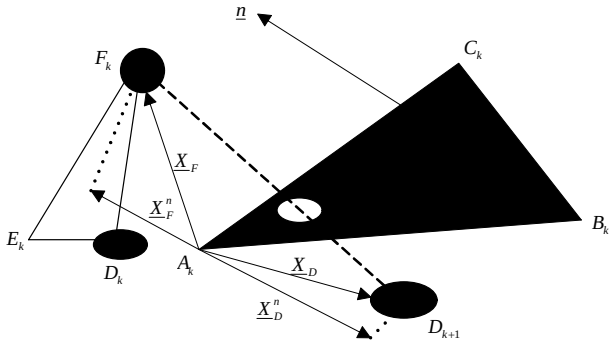


Figure 3 Special case of Intersection detection

D. Computing the Intersection Point Coordinate of the Interpolation Point

After finding the interpolation point, the coordinate of the interpolation point should be computed in the next step, and it means that the 2D coordinate of the intersection point Q need to be calculated which in the plane that determined by the side D_kF_k and $\Delta A_kB_kC_k$, it is shown in Figure 3.

The plane as $\Delta A_kB_kC_k$ staying is described as:

$$(\underline{P}-\underline{A})\bullet\underline{n}=0 \tag{14}$$

Where P is the vector of an arbitrary point is the plane, and $P=\underline{P}=x\underline{i}+y\underline{j}+z\underline{k}$, and $\underline{A}=x_A\underline{i}+y_A\underline{j}+z_A\underline{k}$ is the vector of the vertex A, $\underline{n}=a\underline{i}+b\underline{j}+c\underline{k}$ is shown as the normal vector of the plane, so the above formula can be shown as:

$$a(x-x_A)+b(y-y_A)+c(z-z_A)=0 \tag{15}$$

The coordinate of vertex F in the k step and the coordinate of vertex D in the k +1 step are taken in advantage, and the parameter equation of the line r which is taken t as the parameter can be shown.

Firstly, from:

$$\begin{cases}\underline{r}=l\underline{i}+m\underline{j}+n\underline{k}\\ l=x_D-x_F, m=y_D-y_F, n=z_D-z_F\end{cases} \tag{16}$$

The parameter equation of the line r can be shown as follows:

$$x=lt+x_F, y=mt+y_F, z=nt+z_F \tag{17}$$

Where, the values range of parameter t is from 0 to 1.

The parameter of intersection point Q is:

$$t_Q=-\frac{p}{s} \tag{18}$$

Where $p=\underline{n}\bullet F-\underline{n}\bullet\underline{A}$ and $s=al+bm+cn$.

Substituted in the above equation, the coordinate of intersection point Q is:

$$x_Q=lt_Q+x_F, y_Q=mt_Q+y_F, z_Q=nt_Q+z_F \tag{19}$$

In the coordinate mapping plane of the triangle, rejection of the Z coordinate, just taken the coordinate of (x,y) in advantage.

The modeling effects can be affected due to the limited amounts of characteristics in 2D data collection procedures. It's a very crucial chain to gain more dense data by some methods for the objects' 3D rebuild process in the data non-dense areas, which can enforce the 3D model saturation and photorealistic. The wavelet functions have their own advantages in incomplete curved faces recovery field. The benefit of using 2D spatial wavelet functions to interpolate is that they don't need define weight or evaluation parameters but ensure the rebuild effect. It can effectively deal with nonsymmetrical sampling 3D sparse data to increase the saturation of the 3D models. Therefore, this paper applies 2D spatial wavelet function to interpolation the characteristics of the initial image model in order to gain more characteristics. The first step of the interpolation is to triangulate the existing characteristics. Using the contiguous three characteristics forms a triangle. The points with the shortest contiguous distance are used as the contiguous points, and then the image forms a triangle structure. It consists of several triangle structure networks and then the 3D data for recovering the image can be attained by interpolation. The detailed steps are as follows. Assuming $P(x,y,z)$ is the points in the triangle which needs interpolation, it should locate in the mapped triangle (actually the map of the point should locate in the mapping area of the triangle in xy plane). Thus the x and y coordinators of the interpolation points in xy plane should be determined first. The determined 2D coordinates should meet the following three requirements: 1) it should form a triangle with adjacent three points and the lines between each of the two points intersect at one point. 2) The mapping of the coordinates should in the interior of the triangle. 3) Adding removing and moving one point will merely affect the adjacent triangle. The points which meet all the above requirements will be more likely to form optimized triangle. This paper chooses the coordinates need the triangle gravity center as the xy coordinates of the interpolation points. After determining the xy coordinates, the key is to determine its z value, which is the depth of interpolation. It's also the key step of the interpolation computation. The z can be determined by 2D spatial wavelet function when the depth coordinates can compute the new interpolation in the triangle. The method is following.

© 2013 ACADEMY PUBLISHER

2D spatial wavelet function is as follows.

$$\psi(x) = e^{-(\frac{x-a}{m})^2/2} e^{-(\frac{y-b}{m})^2/2} \quad (20)$$

When it is transformed to image interpolation, the equation is as follows.

$$z = f(x,y) = ke^{-(\frac{x-a}{m})^2/2} e^{-(\frac{y-b}{m})^2/2} \quad (21)$$

In the equation, k is the wavelet coefficient; a,b represent the deviation in xy axis; m represents the dilation factor, indicating the distribution dense level of the characteristics. In this paper, it's a variable. When pick the three vertexes of the triangle and presents as $p_i(x_i, y_i, z_i), i = 1,2,3$. The results when the logarithmic values are got on both sides are as follows.

$$(a-x)^2 + (b-y)^2 = 2(\ln k - \ln z)m^2 \quad (22)$$

The results are as follows when the three vertex values are taken into the above expression.

$$\begin{aligned}(a-x_1)^2 + (b-y_1)^2 &= 2(\ln k - \ln z_1)m^2 \\ (a-x_2)^2 + (b-y_2)^2 &= 2(\ln k - \ln z_2)m^2 \\ (a-x_3)^2 + (b-y_3)^2 &= 2(\ln k - \ln z_3)m^2\end{aligned} \quad (23)$$

The results are below when the two equations are abstracted.

$$\begin{aligned}&2(x_1 - x_2)a + 2(y_1 - y_2)b \\ &= x_1^2 - x_2^2 + y_1^2 - y_2^2 + 2(\ln z_1 - \ln z_2)m^2 \\ &2(x_2 - x_3)a + 2(y_2 - y_3)b \\ &= x_2^2 - x_3^2 + y_2^2 - y_3^2 + 2(\ln z_2 - \ln z_3)m^2\end{aligned} \quad (24)$$

For the above 2 equations the results can be derived as follows.

$$\begin{aligned}a = {} & (y_2 - y_3)[x_1^2 - x_2^2 + y_1^2 - y_2^2 + 2(\ln z_1 - \ln z_2)m^2] \\ & -(y_1 - y_2)[x_2^2 - x_3^2 + y_2^2 - y_3^2 + 2(\ln z_2 - \ln z_3)m^2] \\ & / 2[(x_1 - x_2)(y_2 - y_3) - (x_2 - x_3)(y_1 - y_2)] \\ b = {} & (x_2 - x_3)[x_1^2 - x_2^2 + y_1^2 - y_2^2 + 2(\ln z_1 - \ln z_2)m^2] \\ & -(x_1 - x_2)[x_2^2 - x_3^2 + y_2^2 - y_3^2 + 2(\ln z_2 - \ln z_3)m^2] \\ & / \quad -2[(x_1 - x_2)(y_2 - y_3) - (x_2 - x_3)(y_1 - y_2)]\end{aligned} \quad (25)$$

Where, a, b is solved and put into $z_1 = ke^{-(\frac{x_1-a}{m})^2/2} e^{-(\frac{y_1-b}{m})^2/2}$,

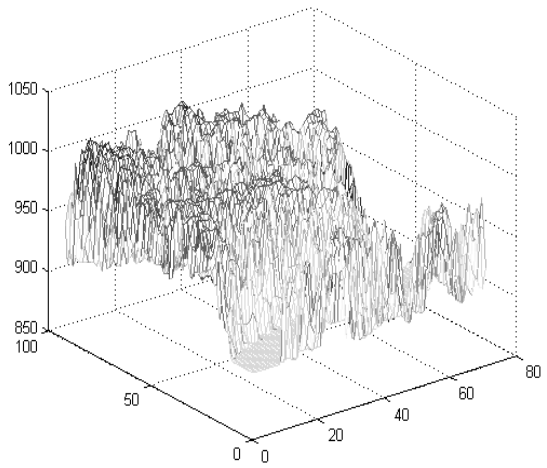
The value of k can be gained. Finally the value of x, y are taken in $z = f(x,y) = ke^{-(\frac{x-a}{m})^2/2} e^{-(\frac{y-b}{m})^2/2}$ and we can get the coordinate of Z. The value of m is adjusted according to the coordinates of the three vertexes of each triangle in order to make sure Z can attain good effect. The 3D coordinates can be finally determined. The software OpenGL is used to build the models and attain the interpolated image model.

E. Remove the Bad Points

During the interpolation computation, due to the constrains of some objective factors, even the dense level of the interpolation value can adjust m to make Z more perfect, some values excess Z will be attained，which are called bad points. Such points must be removed to prevent it affecting the model performance. The bad points' identification method is below. The range of m can be determined according to the three vertexes of the triangle. The $Z\min$（Minimization of Z）and $Z\max$（Maximum of Z） can be computed to ensure $Z\min \le Z \le Z\max$. If the values in the range of m exceed the range of Z, the interpolation value should be removed and the parameters should be adjusted to get new value. Then OpenGL is used to model the 3D image.

III. Experimental Results and Analysis

In order to compare the results of the two different thinning algorithms, a dataset of the 3D characteristic pixels are picked, the original sampling interval is 80m. The matrix of the altitude value is 93×71, as shown in figure4. The square thinning algorithm and the proposed algorithm are respectively used to do the interpolation computation and the intervals respectively increase to 40m, 20m, 10m and 5m. The results are shown in Figure 5 and figure 6.



Sampling interval 80m

Figure4. Original DEM data

© 2013 ACADEMY PUBLISHER

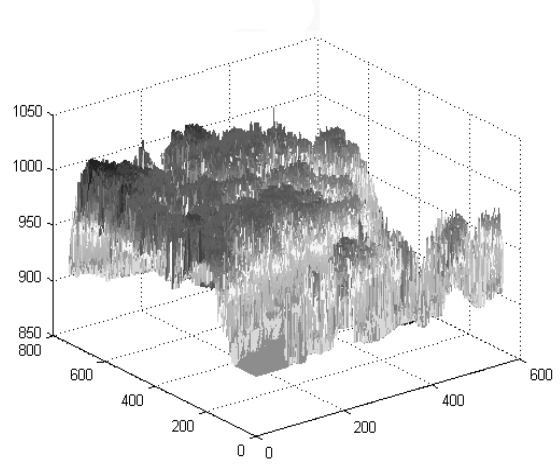


Figure5. The traditional algorithm

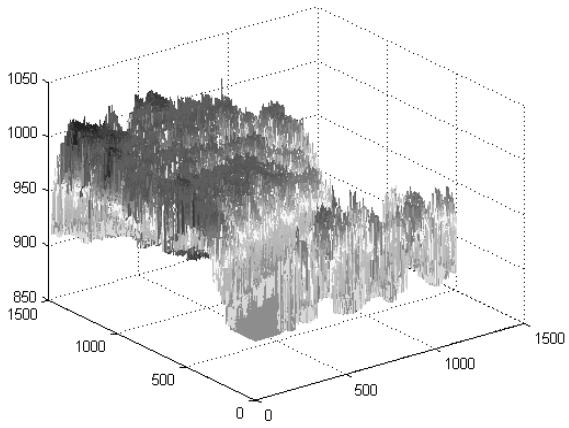
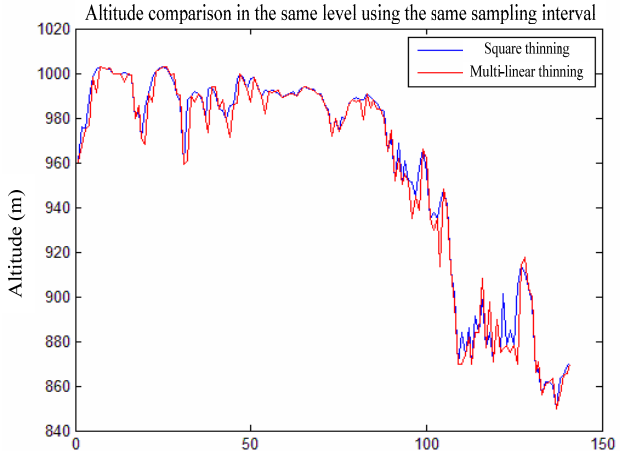
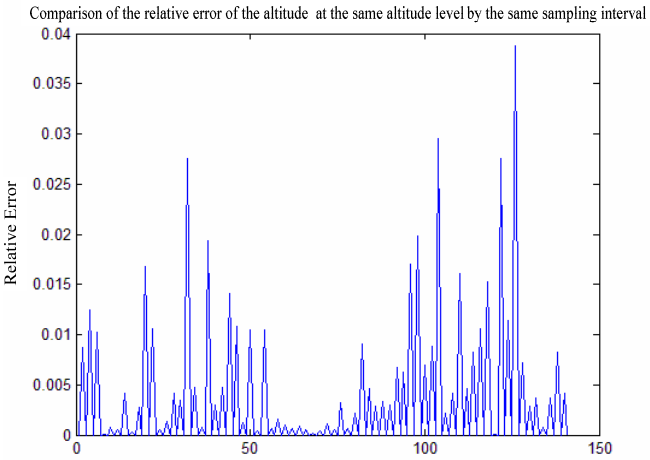


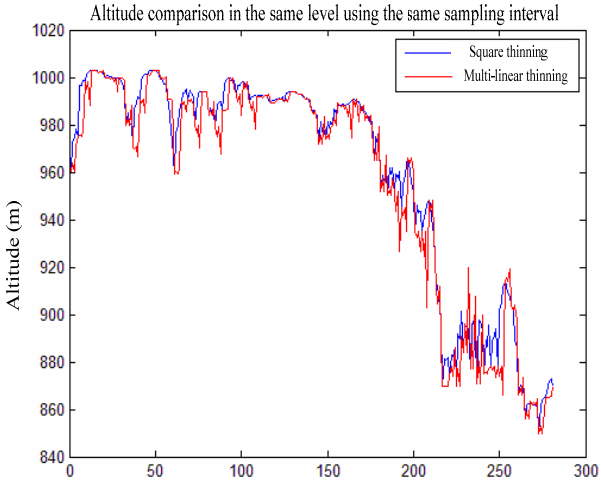
Figure6. The proposed algorithm

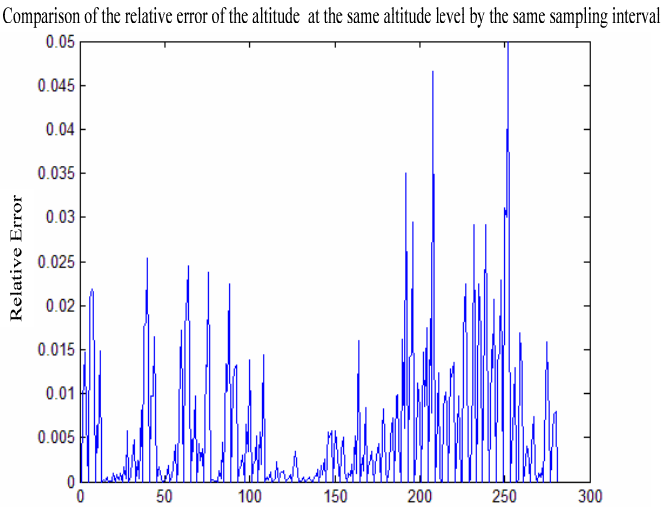
At the same time we compare the altitude curves and relative errors curves using the same line interpolation results under the same interpolation situation. The relative errors = |square thinning interpolation altitude — multi-linear thinning interpolation altitude| / square thinning interpolation altitude, the results are as shown in figure 7. The altitude relative error is less than 0.02 in the results which can illustrate the results of the two interpolation method are very close and prove the accessibility and accuracy of the two methods.





(a) Interval is 40m





(b) Interval is 20m

Figure7. The comparison of the altitude curves in same level and relative errors curves of the two algorithms when they use the same interval to do the interpolation computation

© 2013 ACADEMY PUBLISHER

In addition, we compare the programming time of the two algorithms. The computer model in the experiment is HP w5367cl, the operation system is 32 bits Windows XP, the CPU is Intel Pentium 4 and the processing frequency is 3.06GHz, the memory is 2G (after extension) and the programs are compiled in the environment Matlab. From the cost time, the proposed algorithm is much better than the traditional square thinning algorithm. When the accuracy requirements of the DEM data is restrict and there are many times of interpolation, the proposed algorithm need less thinning time.

TABLE 1

COMPARISON OF THE COST TIME BETWEEN THE TWO THINNING METHODS

	40 m	20 m	10 m	5 m
Square thinning algorithm	3.19 s	13.29 s	54.93s	233.48 s
The proposed algorithm in the paper	2.66 s	10.83 s	45.71 s	203.57 s

IV. CONCLUSIONS

The paper proposes a kind of 3D image thinning algorithm based on spatial wavelet interpolation. The algorithm applies orthogonal measurement to transfer 2D image coordinates to 3D image coordinates and uses spatial self-study wavelet function to do the spatial image interpolation to recover the 3D image structure information as much as possible. The experiments illustrate that the method can finally enforce the saturation of the 3D image characteristic model to achieve satisfactory performance.

REFERENCES

[1] N. Paragios, Y. Chen, O. D. Faugeras, "Handbook of mathematical models in computer vision", *Springer Publishing Company, Incorporated*, 2010.

[2] G. Blais, M. D. Levine, "Registering multiview range data to create 3D computer objects", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 17, NO. 8, 1995, pp. 820-824.

[3] I. Stamos, P. K. Allen, "Integration of range and image sensing for photo-realistic 3D modeling", *IEEE International Conference on Robotics and Automation*, vol. 2, 2000, pp. 1435-1440.

[4] F. Bernardini, H. Rushmeier, "The 3D model acquisition pipeline", *Computer Graphics Forum. Blackwell Publishers Ltd*, vol. 21, NO. 2, 2002, pp. 149-172.

[5] D. Jakóbczak, "2D and 3D image modeling using Hurwitz-Radon matrices", *Polish Journal of Environmental Studies A*, vol. 4, 2007, pp. 104-107.

[6] D. Geiger, B. Ladendorf, A. Yuille, "Occlusions and binocular stereo". *International Journal of Computer Vision*, vol. 14, NO. 3, 1995, pp. 211-226.

[7] Y. Lee, H. Song, U. Yang, H. Shin, K. Sohn, "Local feature based 3D face recognition", *Audio-and Video-Based Biometric Person Authentication. Springer Berlin Heidelberg*, 2005, pp. 909-918.

© 2013 ACADEMY PUBLISHER