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THE PREDICTIVE CODING FOR GEOMETRY IMAGES OF 3D MODELS BASED ON ERROR SENSITIVITY

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ABSTRACT

In this paper we introduce a predictive coding for the geometry image of 3D models. Based on a fact that in a smooth surface the sensitivity of the error in the normal direction of each vertex is higher than the one in its tangent direction, we propose a predictive coding method for the geometry image. We have compared our proposed method with the conventional method and show that our proposed method is able to decrease the error in the same compressibility.

Index Terms— Compression, Geometry Image, 3D Model, Error Sensitivity

1. INTRODUCTION

Recently, three-dimensional models are widely used in various fields such as the CG and medical imaging as the development of the information and communication technology has developed. The amount of data in the three-dimensional model is often so huge that it takes time for transmission through the network, storage and display. Therefore, the progressive expressions and the encoding of the three-dimensional model have been researched a lot today. The geometry image is one way for expressing the three-dimensional model, in which the xyz coordinates of the 3D meshes are mapped on a surface and then it can be represented by a three-dimensional image like RGB image. The expression makes it easy to apply various signal processing techniques for the three-dimensional model. In this paper we introduce a predictive coding for the geometry image. In general the predictive coding causes quantization error in signal, which results in the deterioration of quality. In this research we use a fact that in a smooth surface the sensitivity of the error in the normal direction of each vertex (Figure1 (a)) is higher than the one in its tangent direction (Figure1 (b)), and based on it we propose a method of the predictive coding of geometry image.

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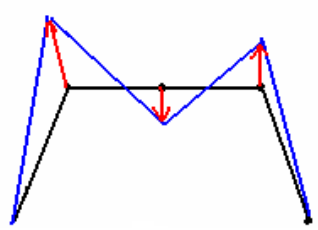
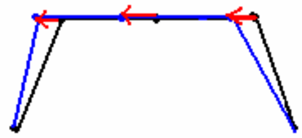


(a) error in normal direction



(b)error in tangent direction

Fig. 1. Error occurred

2. GEOMETRY IMAGE

The geometry image is composed of three channels just like RGB color images. Each channel has one of x, y, z coordinates. Several methods have been proposed for mapping 3D model to the geometry image. Many of the conventional methods find a set of local functions from mesh to plane, which is called parameterization. Among the conventional parameterization methods [1]-[6], we adopt [6], in which the position of every vertex is determined by solving a set of space linear equations.

$$\boldsymbol{U} = \boldsymbol{W}^{-1}\boldsymbol{B}, \tag{1}$$

where $\boldsymbol{U}$ is a matrix composed of s, t coordinates of vertices mapped on a plane, $\boldsymbol{W}$ is specified by the connectivity information of meshes, and $\boldsymbol{B}$ is a matrix derived by the vertices on the boundary of the plane (For details, see [6]). The example of the geometry image derived by [6] is shown in fig.2.

The parameterization assures one to one mapping and the 3D model can be reconstructed from the geometry image. In our method, instead of compressing the 3D model directly, we encode the geometry image. We apply the predictive coding for all the three channels. The predictive coding of geometry image predicts the x,y,z coordinates and then prediction error is quantized in the encoder, then the encoded signal is transmitted to decoder. The transmitted data are de-quantized and the signal is reconstructed by calculating the predicted value that is added to the decoded prediction error. In the encoder of our prediction method it predicts the current pixel value from past pixels stored in memory and only codes the prediction error and transmits them to decoder.

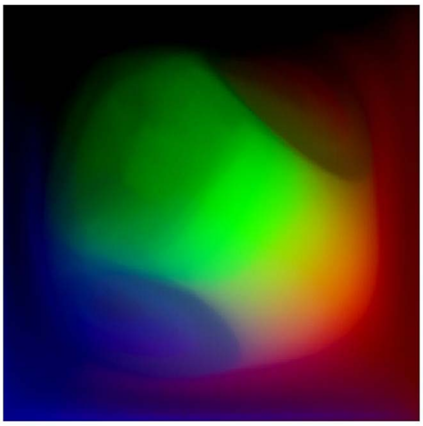


Fig. 2. The geometry image

The following introduces the detailed content of the conventional method. This method is show in fig.3. In this case, when predicting the current pixel, the four neighboring pixels are used for the prediction. The predicted value for the current pixel is the weighted mean of the four pixels (A, B, C, and D). At the encoder we first to process the x coordinate of the current pixel. And the x coordinate of the current pixel is denoted by $x(i,j)$. The process in the encoder includes prediction, quantization, and reconstruction.These are employed as in the following equation.

$$e(i,j) = x(i,j) - \bar{x}(i,j) \tag{2}$$

$$\begin{aligned}\bar{x}(i,j) \quad = \quad & \{\hat{x}(i-1,j-1) + \hat{x}(i,j-1) + \\ & \hat{x}(i+1,j-1) + \hat{x}(i-1,j)\}/4\end{aligned} \tag{3}$$

$$e'(i,j) = \lfloor \frac{e(i,j)}{\delta} \rfloor \tag{4}$$

$$\hat{e}(i,j) = e'(i,j)\delta \tag{5}$$

$$\hat{x}(i,j) = \hat{e}(i,j) + \bar{x}(i,j) \tag{6}$$

where δ is a step size of the quantization. And the y and z coordinates of the vertex also do the same way as the x coordinate at the encoder. Then the transmitted date are de-quantized and reconstructed by the equation (4) and (5). The above procedure is done for x, y and z coordinates of the vertex stored in three channels of a geometry image. Therefore the restored geometry image can be obtained.

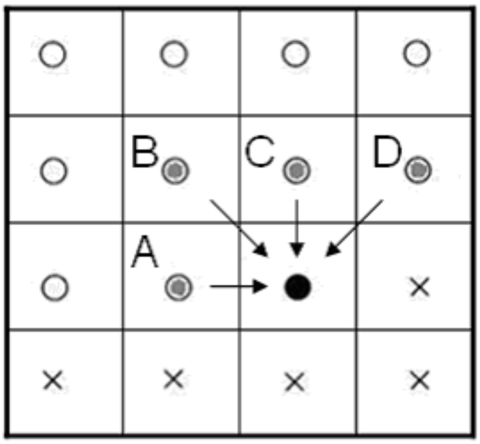


Fig. 3. Four neighbors used for prediction

3. PROPOSED METHOD

The compressibility of the conventional method is fairly good, but the above simple prediction does not take into account the geometry information of the original 3D models, thus its performance can be further enhanced with more sophisticated approach. In our method we propose the predictive coding based on error sensitivity of 3D surfaces.

In our method the procedure before quantization of the original signal is same as conventional method. Our method differs in the quantization step where we employ an adaptive quantization based on the error sensitivity. Before quantizing the prediction error; we predict the normal vector of the 3D surface around the current pixel for deciding the step size of the quantization.

The following explains the prediction of the normal vector. As is shown in fig.4, where the black point is the current pixel, we use the seven neighboring vertices that have already scanned and encoded in the encoding path. Simply connecting the seven vertices, we construct five triangles. And then we calculate the normal vectors for the five triangles by the x, y, z coordinates of the seven pixels. We denote the five normal vectors as $\vec{N}1, \vec{N}2, \cdots, \vec{N}5$. After finding the normal vectors, we take the mean of them, and adopt the mean as the prediction of the normal vector at the current pixel position.

$$\vec{N} = \frac{\vec{N}1 + \vec{N}2 + \vec{N}3 + \vec{N}4 + \vec{N}5}{5} \quad (7)$$

$\vec{N}$ is the normal vector of the current pixel.

In the next step take the absolute values of the x, y, and z coordinate of the normal, and compare them with a threshold. We adopt the mean of the absolute value of the three values as the threshold.

$$th = \frac{|N_x| + |N_y| + |N_z|}{3} \quad (8)$$

If the x element of the normal vector N_x of the current vertex is larger than the threshold, the x channel of this current vertex is quantized in detail by small step size. On the contrary, if the N_x element of the normal vector of the attention vertex is smaller than the threshold, the x element of this attention vertex should roughly quantize by a large step size. Because when we compare the absolute values of N_x, N_y and N_z, N_x larger than the other two implies that the normal vector inclines at x coordinate. In this case the x element is considered important. Therefore, x coordinate of this current vertex is finely quantized by small step size, which results in the reduction of visible noise . Moreover N_y and N_z also are compared with the threshold as well and then are quantized accordingly.

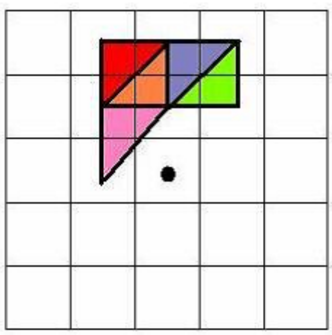


Fig. 4. The geometry image

We send the quantized error to the decoder after quantization. The decode uses the restored signal to predict the normal vector by the same way as encoder, and employ the de-quantization for each and restore the signal.

4. THE ASSESSMENT OF ERROR

To take into consideration the fact that in the smooth area the human visual system is more sensitive to errors in normal direction than in tangential direction, we define a new criteria for the quality of the geometry image.

Let the original geometry image and the reconstructed image be $\mathbf{G}$ and $\mathbf{G1}$, respectively. Then, the difference between the two images are simply calculated by

$$\mathbf{e} = \mathbf{G} - \mathbf{G1}$$

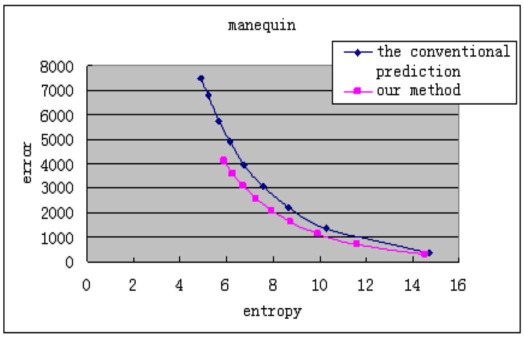
The next step we calculate the normal vector $\mathbf{n}$ of each vertex of the original geometry image. Finally, evaluate the error by

$$Error = \sum_{i,j} \left(0.1 + \frac{|< \mathbf{n}_{i,j} \cdot \mathbf{e}_{i,j} >|}{|\mathbf{n}_{i,j}||\mathbf{e}_{i,j}| + \alpha} \right) |\mathbf{e}_{i,j}| \quad (9)$$

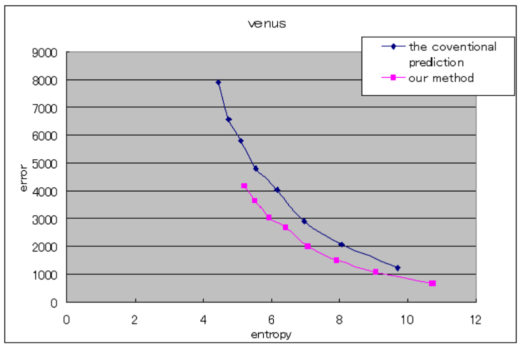
where $< \mathbf{n} \cdot \mathbf{e} >$ is the inner product between the error and the normal vector of each vertex, α is a small value. When the direction of the error has some correlation with the normal vector, the inner product becomes high and vice versa.

5. RESULT

We have applied our algorithm to some 3D models. We use the parameterization method [1] to map the 3D model to the geometry image. In Fig.5, we show entropy v.s. error curve for our method and the conventional prediction. It can be seen from the figure that the error of our method is smaller.



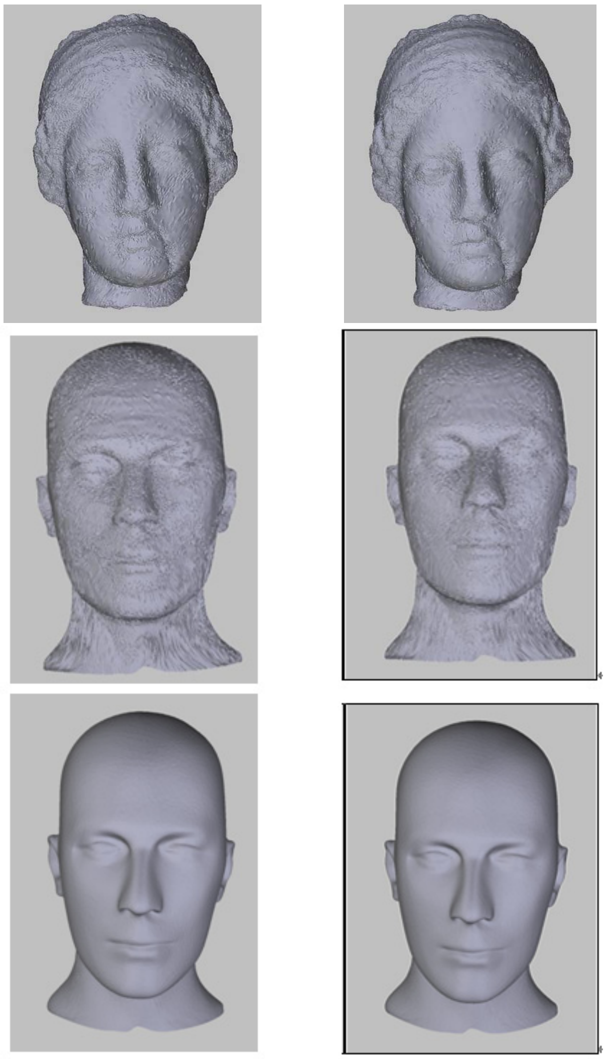
(a)manequin



(b)venus

Fig. 5. Entropy v.s. error plot

In Fig.6 the 3D models compressed by the conventional prediction (left) and our method (right) are shown, where we can see some improvements (for example in his forehead).



(a)The conventional prediction (b) our method

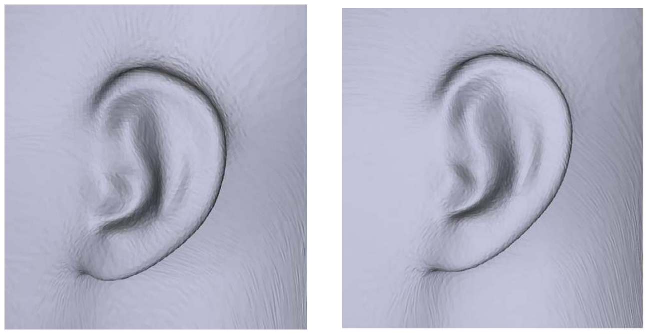
Fig. 6. Compressed 3D Models

At last to become plain we enlarged the 3D model of the two lower images in Fig.6.That is shown in Fig.7.From Fig.7 we can know that the 3D image from our method is more similar with the original image.

6. CONCLUSION

In this paper we use the fact that in a smooth surface the sensitivity of the error in the normal direction of each vertex is higher than the one in its tangent direction ,and based on it a new predictive coding has been proposed.We have shown that our method provides better results than the conventional prediction.That is our method was able to decrease the error in the same compressibility.And we can restore the 3D model neatly.

(a) original image



(b)The conventional prediction (c) our method

Fig. 7. enlarged image

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