An Improved Error Expansion Reversible Watermarking for 3D Mesh Model

Keming Dong*, Hyoung-Joong Kim**
* Center for Information Security Technologies , Korea University
** Center for Information Security Technologies, Korea University

Abstract

In this paper, a new scheme to improve both the capacity and distortion performance for error-prediction method is proposed. For every triangle mesh, two vertices were selected to predict the rest vertex, and the prediction error distances which were vertical and paralleled to the edge between these two vertices would be used to embed two units of secret date amount. We sort the meshes before embedding according to predicted error in order to decrease the distortion. Experiment results show that our approach increase the capacity and decrease the distortion as compared to the original algorithm.

1. Introduction

With the advance of computing power and the increasing of internet transmission bandwidth, 3-D digital contents become more and more popular in many applications such as video game, computer animation, virtual reality and 3D presentation. As a result, the demand for copyright protection and authentication of these contents has aroused more interest than before. Reversible watermarking techniques hide data in a host signal (for example, an image) and allow extraction of the original host signal host signal and also the embedded message [2]. The embedded message called as watermark which can carry information about the data owner or an authorized user/distributor could be used to verify the legality of the current user, and the recovered signal which has no distortion compared to original signal can give the whole information, which will be very essential or preferable for some application such as medical diagnosis, law enforcement, fine art work and so on. As a result, reversible watermarking is a very active research field. Its application to 2D still images has been rather thoroughly studied and lots of papers have been published in this domain.

Tian published his famous difference expansion paper [4] in 2003. In this scheme, the difference between two adjacent pixels will be expanded to embed one bit of secret data, however, the additional location map is generated and also has to be embedded to image to obtain reversible extraction. The following researchers have done a lot of work to decrease the location map size [5] or/and make more precise prediction [6] [2] [3] in order to achieve higher capacity and lower distortion. In addition, the histogram of the pixels in the cover image was utilized to achieve in [7]. The range between the peak and zero point was shifted, then the space of the peak points will be left to embed the date bits. This algorithm has been extended recently during [8]. There are some other approaches based on different techniques such as lossless compression [9].

However, the great difference between the 2D image and the models to represent the 3D objects takes great challenge to develop watermarking method for 3D models. There are some kinds of representation models for 3D object such as mesh modeling, NURBS modeling, splines & patches modeling, primitives modeling and so on. Among them, triangle mesh model is very popular representation model. The watermarking methods on these models modify the texture data (texture-based watermarking) or mesh data (mesh-based watermarking). Most 3D models could be expressed by the triangle mesh, so this paper focus on reversible watermarking based on mesh modification for this model.

Prediction-error expansion method [1] used the adjacent pixels to predict the center pixel, and the prediction error will be expanded to embed secret data. This algorithm shows good performance compared to the previous method, and will be discussed in detail later.

In this paper, a new scheme for prediction-error method is proposed. For every triangle mesh, two vertices were selected to predict the rest vertex, and the prediction error distances which were vertical and paralleled to the edge between these two vertices would be used to embed two units of secret date amount. In order to decrease the distortion, we sort the meshes to find the best mesh to embed the data. Finally, the experiments' result shows that the proposed scheme can improve the performance observably for prediction-error expansion.

2. Proposed Method

In this section, we will apply our scheme to error-prediction method to improve its performance. We will explain the error prediction method shortly at first, and then the modification to error-prediction method will be described.

2.1 New vertex prediction

For one vertex, error-prediction method uses the traversed neighbors to predict the vertex, and the Euler difference will be expended to embed secret date. Assume that the vertex is v and the traversed neighbors are NV_i with k degree. Then the predicted V can be given by:

$$\overline{v} = \frac{\sum_{i=1}^{k} NV_i}{k}$$

Where NV_i is the coordinate (xi,yi,zi) of neighbor i. The predicted difference can be obtained by:

$$d = v - \overline{v}$$

The embedding can be given by:

$$v' = v + Trun_m(d) + w_i * 10^{-m}$$

Where m is embedding place and the truncation function will truncate the value which below then 10^{-m} precision. Since a vertex consists of three coordinates, the amount of embedded bits is three times of the adjusted vertices.

The main idea of our scheme is that for every mesh, we will use two vertices to predict the rest one by assuming it is a regular vertex, and there will be some offset from original vertex to the predicted vertex which we denote as $\overline{d}$, then the vertical and horizontal components of $\overline{d}$ according to the base can be obtained, then we can use this two to embed data. For the traversal order problem, we will sort the mesh to find the best mesh to embed data according to distortion. As a result, we can use same prediction scheme in the modification to error prediction method, and the predicted vertex v_p can be obtained just following equation. Suppose the vertices in one mesh are sorted by their index in the model, and then denoted as V1, V2 and V3. We also denote vector V2V1 as a and V2V3 as b, then the two components can be obtained by

$$aShadowB = a * b' / |b| * b / |b|$$

$$D_h = aShadowB - 1/2 * b$$

$$h' = \frac{\sqrt{3}}{2} * h / |h| * |b|$$

$$D_v = h - h'$$

Where aShadowB is the projection of a vector onto b, and h' is the predicted altitude, namely the altitude of the imaginary regular triangle. Then D_h will be divided by b/2 to form the ratio we denote as R_h, similarly we divide D_v by h' to form R_v .Then we can use error prediction mechanism to embed date.

2.2 Over base problem

Note that when we make the prediction, we suppose that the vertex after embedding is at the same size with the original vertex according to base of the triangle, however, it will not be always true. If v is lower than v_p, and the vertical difference between v and vp is big, then v' may jump over the base. In this case, we can't extract the date correctly. This is called as over base problem. In order to overcome this problem, for this vertex which exists over base problem, we will not use R_v to embed data.

2.3 Sorting Scheme

In error expansion method, the error will be expended to around to two times in order to embed one bit data, so the less prediction error, the less distortion. As a result, we sort the meshes according to the Euler distance between the original v1 and predicted vertex v1_p to generate the traversal sequence.

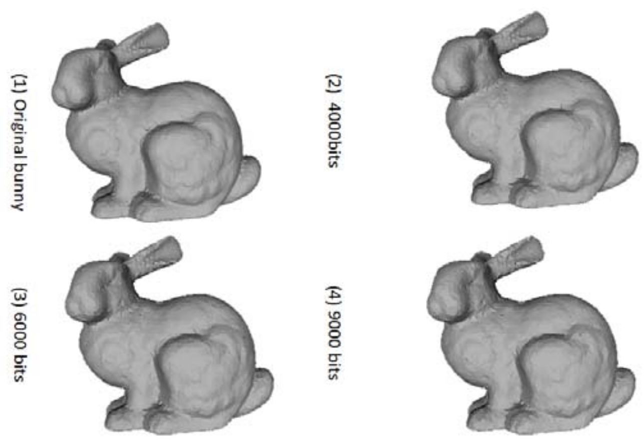
3. Experiments

In this section, we will compare our two improved methods with the original error-prediction method. The popular 3d models Stanford Bunny and Cow are used here. The parameters and the information of all models are given in bellow Table 1.

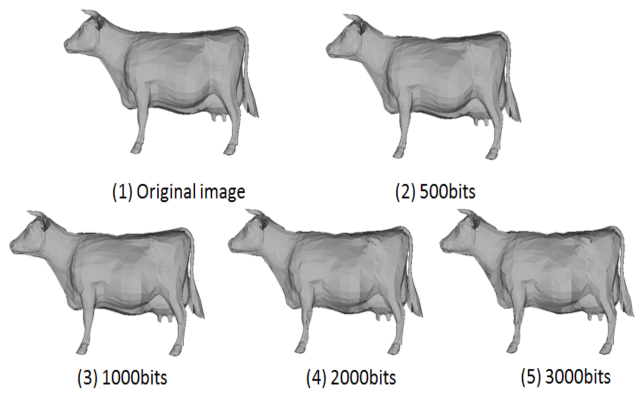
<Table 1> Information of the test models and the used parameter

Models	Vertices	Facets	Parameters	
			m	N
Bunny	35947	69451	5	7
Cow	32328	67240	5	7

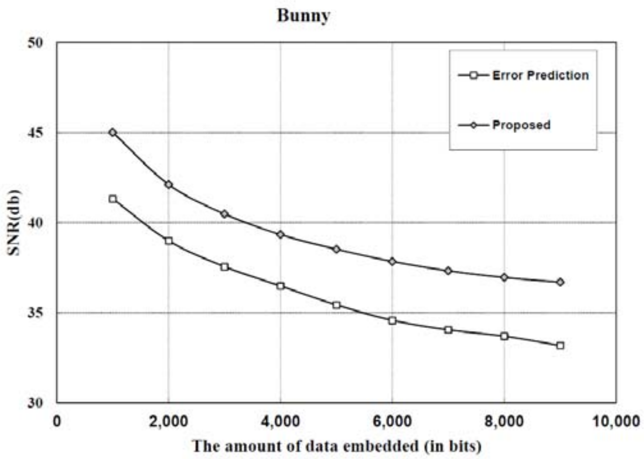
The original models and the stego-models are shown in Fig. 1 and Fig. 2 to show the vision distortion. Future comparison in Fig 3 and Fig 4, shows that our method can decrease the distortion when we embed same length of secret data.



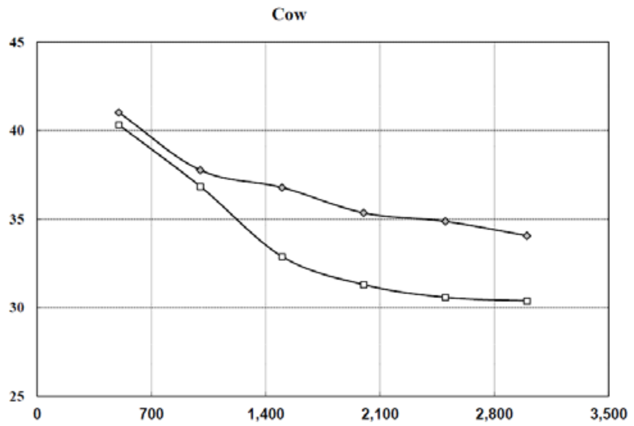
(Figure 1) original Bunny and Stego-Bunny



(Figure 2) original Cow and Stego-Cow



(Figure 3) SNR of Bunny



(Figure 4) SNR of Cow

4. Conclusion

In this paper, we propose a new reversible watermarking method for 3D mesh models based on error expansion. The method used double embedding scheme to increase the capacity and sorting to find the best mesh to embed data which will cause low distortion. Comparisons with the original method show the superiority of the proposed method.

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