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3D SLICING PROCESS-BASED 3D PRINTING MODEL WATERMARKING

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ABSTRACT

This paper presents a novel watermarking algorithm for 3D printing models based on embedding watermark data into the feature points of 3D printing model which are determined and computed by the 3D slicing process. In the proposed algorithm, 3D printing model is cut into slices along the Z axis by the cutting plane in order to compute the feature points of 3D printing model from the intersected points between 3D printing model and the cutting plane. The watermark data is embedded to the feature point of 3D printing model by changing the vector length of feature point in OXY space based on the reference length. And then the x, y coordinates of feature point will be changed according to the changed vector length that has been embedded watermark. In experiments, the distance error between the original 3D printing model and the watermarked 3D printing model is very small, and the accuracy of the proposed algorithm is very high. The proposed algorithm is invisible and robust with geometric attacks as rotation, scaling and translation.

Keywords: *3D printing copyright, 3D model watermarking, 3D printing model, 3D slicing, Additive Layer Manufacturing*

1. INTRODUCTION

Recent years, 3D printing is widely used in many areas of life [1]. Due to the fact that the benefits of 3D printing is enormous in all domain and the price of a 3D printer is not expensive, the individual user can buy a 3D printer and download 3D printing models on Internet to print real objects out. This makes a large effect on manufacturers, and they need a copyright protection solution for 3D printing. So, a watermarking solution for 3D printing is necessary for the ownership identification and copyright protection [2].

For meeting to the issues related to the copyright protection of 3D printing and the weaknesses of previous methods, we proposed a novel watermarking algorithm for 3D printing in this paper. To clarify the proposed algorithm, we organize our paper as follow: in Sec. 2, we show the proposed method in detail. Experimental results and the evaluation of proposed scheme will be shown in Sec. 3. Sec. 4 shows the conclusion

2. THE PROPOSED METHOD

The proposed algorithm is described in Fig. 1. 3D triangle mesh is cut into slices from bottom to top along the Z axis via the 3D slicing process. Slices are then used to extract the intersected points. Besides, a set of facets is extracted from 3D triangle mesh, and facets are then used for the vertices extraction. From a set of vertices and a set of the intersected points, we find the feature points of 3D triangle mesh. The feature points of 3D triangle are the vertices of 3D triangle mesh and are also the intersected points between 3D triangle mesh and the cutting plane. After feature points finding, watermark data will be embedded to each feature point by changing the vector length of each feature point in the OXY space based on the reference length. Next, the x, y coordinates of each

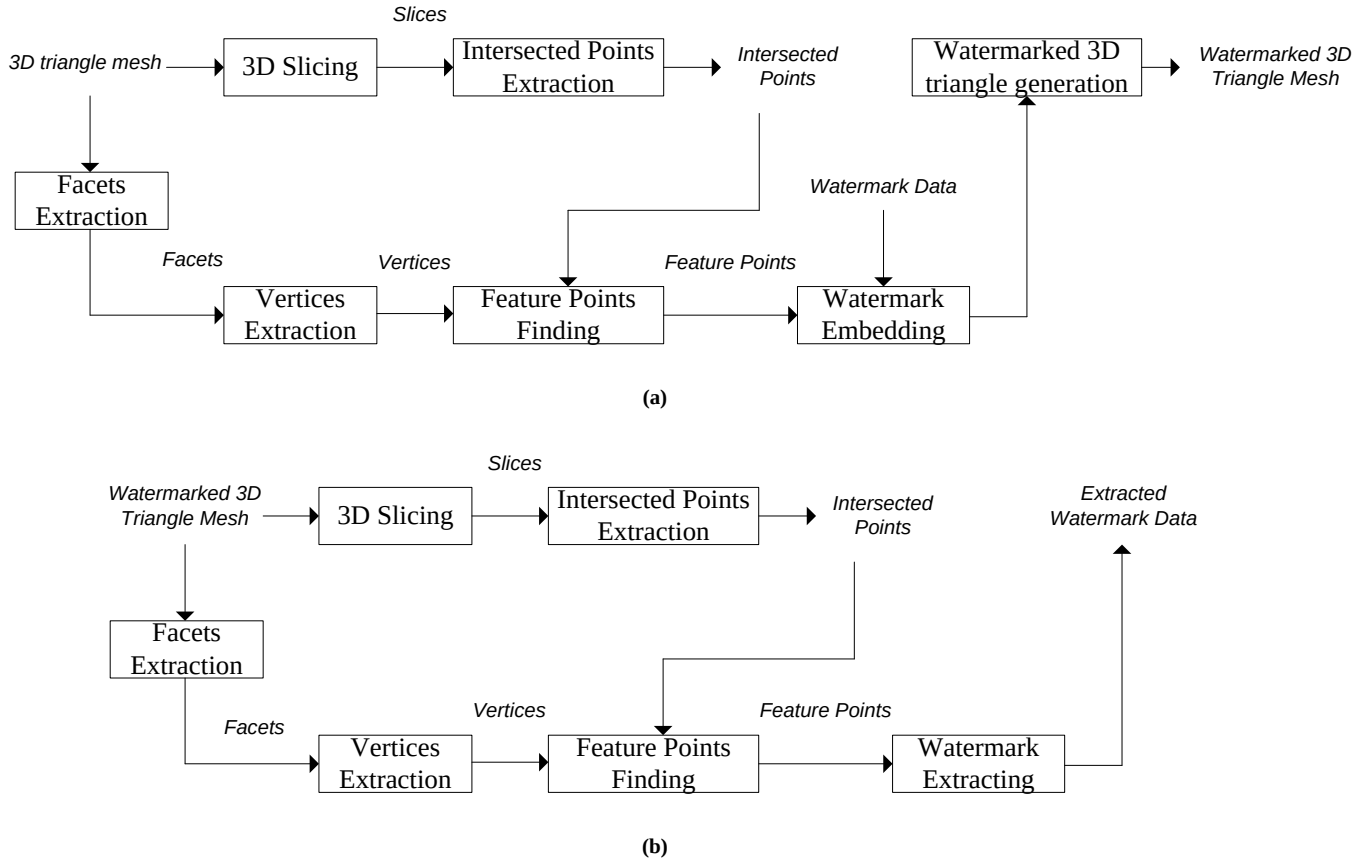

Figure 1. The proposed method, (a) watermark embedding and (b) watermark extraction.

-feature point will be changed according to the changed vector length that has been embedded watermark. The purpose of no changing the z coordinate of feature point is to find feature points again from the watermarked 3D triangle mesh in the watermark extraction process. After embedding watermark data to feature points, the watermarked 3D triangle mesh will be generated. The watermark extraction process is shown in Fig. 1b.

3. EXPERIMENTAL RESULTS

We experimented the proposed algorithm with test models, which the format of models is STL file [3]. The detailed information of models is shown in Tab.1. Test models are sliced in to slices along the Z axis [4] of 3D triangle mesh for finding feature points. The number of slices is dependent on both the Z-axis height of that model and the thickness of slice. In experiments, we defined the thickness of slice is 1 mm. After computing feature points, we embed watermark data into the feature points of 3D triangle mesh. The number of feature points of each 3D triangle mesh is shown in Tab.1. To evaluate the proposed algorithm, we evaluate the invisibility, and robustness. Tab. 1 shows the mean distance error between the watermarked 3D triangle mesh and the original 3D triangle mesh corresponding to test models. This mean proof that the invisibility of the proposed algorithm is very high. From Tab. 2 we can see that with no noise the accuracy is 100%, with noises 1%, 5% and 10% respectively the average accuracy is decreased from 78.05% to 57.24%f.

Table1. Distance Error

Name	# vertices	# feature point	Distance error
Rabbit	10530	11	2.6611E-06
Batman	6785	12	0.1079E-06
Lizard	34625	19	3.4201E-06
Bear	20248	34	0.1099E-06
Yoda	24910	34	7.0214E-06

Lion	39583	35	3.7276E-06
Tower	1311	48	1.6932E-04
Pollo	8526	263	1.5386E-04
Stitch	384034	737	0.1020E-04
Airplane	2796	1072	0.7655E-04
Chicken Trump	49424	1194	1.2391E-04
Swan	70682	1587	0.1013E-04

Table 2. Robustness Evaluation

Name	**Accuracy** (%)			
	No Noise	Noise 1%	Noise 5 %	Noise 10 %
Rabbit	100	100	100	54.54
Batman	100	83.33	58.33	58.33
Lizard People	100	94.74	52.63	57.89
Bear	100	94.12	32.35	52.94
Yoda	100	100	76.47	76.47
Lion	100	45.71	45.71	51.43
Tower	100	50.00	58.33	58.33
Pollo	100	80.61	62.74	51.33
Stitch	100	75.71	51.29	52.78
Airplane	100	99.22	83.12	68.67
Chicken Trump	100	58.46	51.67	53.01
Swan	100	54.66	48.51	51.21
Average	**100**	**78.05**	**60.10**	**57.24**

4. CONCLUSION

In this paper, we proposed a novel watermarking method for 3D printing models with the 3D triangle mesh is the input of 3D printing. The proposed method is invisible and robust with geometric attacks as rotation, translation and scaling. Comparing with conventional works and previous methods, the proposed algorithm is better with high accuracy and robustness. Next time, we will improve the proposed algorithm and applied to the copyright protection system.

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