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Watermarking in 3D Model Using Dihedral Angle

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Abstract

This research is based on a new idea of concealment makes sense depending on the value of the dihedral angle which is the angle between the two planes, concealment began the process of identifying Center of the model and then follow the style of the spider in the process of building his own house in terms of start-point average and then start building the network to walk clockwise and the formation of ring and the transition to the formation of the largest ring, was to follow the same method of concealing data and configure more than one link to the full text is hidden. Method showed very good results in terms of attention to the existence of a change in the picture, because he really has been no change to the original image, the error rate calculation (MSE) and was worth zero results showed good resistance for different types of attack, such as topological, signal attack and geometry so little hidden information destruction did not happen.

Keywords: 3D mesh, digital watermarking, copyright protection, attack, robustness

العلامة المائية في النماذج الثلاثية الابعاد باستخدام الزاوية الثنائية السطح

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الخلاصة

هذا البحث استند على فكرة جديدة هي فكرة الاخفاء المنطقي اعتمادا على قيمة زاوية dihedral وهي الزاوية المحصورة بين مستويين، بدأت عملية الاخفاء بتحديد مركز الموديل ثم اتباع اسلوب العنكبوت في عملية بناء بيته من حيث البدء بنقطة وسطية ثم البدء ببناء الشبكة بالسير باتجاه عقارب الساعة وتكوين حلقة والانتقال الى تكوين حلقة اكبر ، تم اتباع نفس الاسلوب في اخفاء البيانات وتكوين اكثر من حلقة الى يتم اخفاء النص كاملا. اظهرت الطريقة نتائج جيدة جدا من ناحية الانتباه الى الى وجود تغيير في الصورة ، لانه فعلا لم يطرا اي تغيير على الصورة الاصلية، تم حساب معدل الخطأ (MSE) وكانت قيمته صفر.الطريقة اظهرت مقاومة جيدة لانواع الهجوم المختلفة مثل topological, signal attack و geometry بحيث لم يحدث تدمير يذكر للمعلومة المخفية.

1. Introduction

Graphics information area unit more and more applied to a spread of applications, as well as video diversion, engineering style, fine arts walkthrough, e-commerce, computer game and scientific visualisation. Several three-dimensional (3D) objects area unit currently drawn in 3D meshes to really replicate the topological structures of the objects [1]. A three dimensional object are often pictured in many ways in a very graphics application. A surface are often analytically generated victimization its operate involving the coordinates.

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3D representations, such as cloud of points, parametric surface, implicit surface and voxels, 3D mesh has become the de facto standard for numerical representation of 3D objects thanks to its algebraic simplicity and usability. Furthermore, it is quite easy to convert other representations to 3D mesh, which is considered a low-level, but effective model. [2].

The motive for the choice of triangles as primitives is that: (i) polygons will perpetually be divided into triangles, and (ii) vertices within the aspects of discretional polygonal shape might not be coplanar nor convex in in R3 [3]. 3D triangular mesh watermarking is that the operation of inserting information into the mesh model. Among the various kinds of media, 3D modelwatermarking is comparatively troublesome nature [4] In addition the watermark term is employed in ownership protection, content labeling, authentication, and distribution channel tracing.

The largest a part of the studies on 3D model watermarking were mesh based mostly [5] generally; the mesh based techniques insert the mark into the vertex positions. Each non-oblivious and oblivious ways are reportable. However, the most difficulties remain the robustness:

It can be classified powerful ways in spatial methods and spectroscopic methods. Spatial strategies: These methods act either on the pure mathematics (geometry) or the topology of the model. The pure mathematics enclosed the vertices, the facets and also the normals. The topology encompasses connectivity property. The elementary entity carrying the watermark information is referred by the watermark primitive. Several strategies treat the triangular aspect as a watermark primitive. Spectral strategies: essentially, spectral strategies engraft the information in sure coefficients of harmonic or multi-scale transform. These strategies are developed to deal with attacks apart from non-similarity transforms, like simplification, remeshing, etc [6].

In 2013, [Hamghalam] projected a sturdy image watermarking technique supported geometric modelling. during this technique, nine samples of the approximation constant of the image blocks area unit used to construct a plane within the three-dimensional (3D) area. The authors modification the dihedral angle fashioned between the created plane and therefore the x–y plane for knowledge embedding. To preserve the physical property of the watermark, geometrical computations area unit accustomed minimize the embedding distortion. most chance detector is enforced to extract the watermark within the hissing channel at the receiver facet.

2. Diheral Angle

A dihedral angle (also known as the face angle) is that the interior angle at that two adjacent faces meet. Associate angle of zero degrees suggests that the face traditional vectors square measure parallel and also the faces overlap one another (Implying a part of a degenerate polyhedron). Associate angle of a hundred and eighty degrees suggests that the faces square measure parallel (like a tiling). Associate angle bigger than a hundred and eighty exists on concavo-convex parts of a solid [8], as shown in Figure-1.

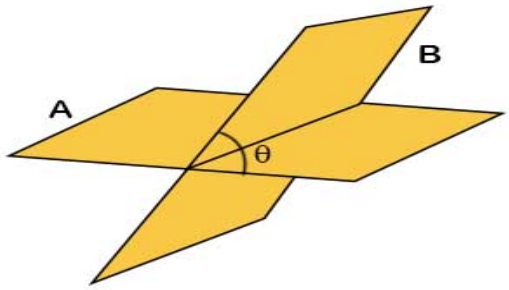


Figure 1- Dihedral angle θ

Dihedral angle is the angle between the traditional vectors of the two planes. Traditional vector is a vector that's perpendicular or normal or perpendicular to the actual plane [7].

The dihedral angle is the angle θbetween two planes.

$$a_1 x + b_1 y + c_1 z + d_1 = 0 \quad (1)$$

$$a_2 x + b_2 y + c_2 z + d_2 = 0 \quad (2)$$

Which have normal vectors $\mathbf{n}_1 = (a_1, b_1, c_1)$and $\mathbf{n}_2 = (a_2, b_2, c_2)$is simply given via the dot product of the normals,

$$\cos\theta = \hat{\mathbf{n}}_1 \cdot \hat{\mathbf{n}}_2 = \frac{a_1 a_2 + b_1 b_2 + c_1 c_2}{\sqrt{a_1^2 + b_1^2 + c_1^2}\ \sqrt{a_2^2 + b_2^2 + c_2^2}}. \quad (3)$$

3. The Proposed Watermarking Algorithm

In this research, a new watermarking method was proposed ,based on the geometric style of hiding data, where they were to follow the same style spider in the construction of his house, the algorithm starts by determine the center of the mesh and then move clockwise rotational such as ring movement ,and after the first ring is complete then going to the biggest ring and start from the same site the beginning of the first ring, and so on until it is complete hide all data as shown in Figure-2.

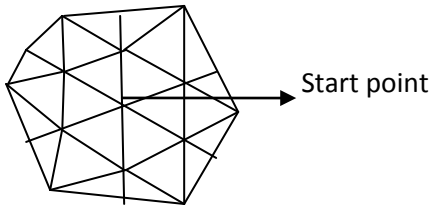


Figure 2- Part of mesh, explain the start point

New in the style of hiding it depends on the values of the ' dihedral angle' where to locate concealment depending on the threshold values of the angle find by the experiment and depending on the input bits involved if it is zero or one, this approach gives the power to the method used since this angle is not affected by most types of attack such as scaling, translation and rotation in addition to the subdivision (smoothing mesh) and mesh compression (mesh reduce).

After calculating the center of the model as a starting point by the equations (4,5,6), Where v (x_{center},y_{center},z_{center}) represents the coordinates of the vertex model center, where m represents the numbers of the vertices in the model.

$$x_{center} = \sum_{i=1}^{m} \frac{xi}{m} \quad (4)$$

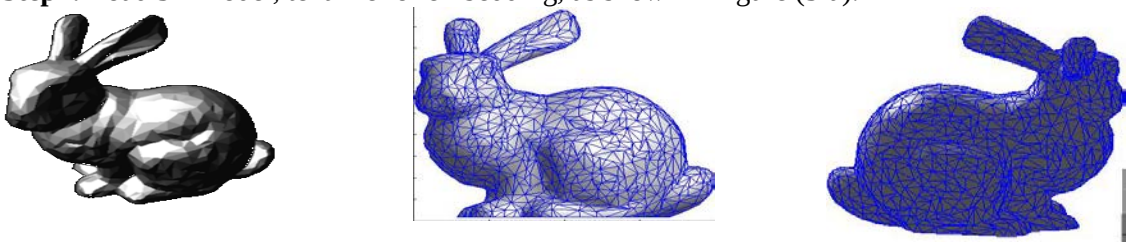
$$y_{center} = \sum_{i=1}^{m} \frac{yi}{m} \quad (5)$$

$$z_{center} = \sum_{i=1}^{m} \frac{zi}{m} \quad (6)$$

After choosing the first face ,start to go and find left and right faces for that face and then calculate the angle between two faces, where they are checking the angle value and decide the entrance and continue to move from the face to another until the completion of the first ring or hide input completion In the case of non-completion of the input bits is going to the larger ring and complete concealment, the problem facing us access to the edge prior to the completion of concealment, when such a situation occurs, leave this level and move on to the next level, the algorithm steps are described later.

The main steps of algorithm for embedding text in triangle mesh using dihedral angle are explained below.

Step1: Load 3D model, text file for embedding, as shown in figure (3-a).



a b c

Figure 3-a) bunny 3d model, b) 3d triangle mesh, c) back view of the bunny

Step2: Convert the text to binary.
Step3: Find the edges and faces, as shown in Figure-3b.
Step4: Check if there is a polygon face then convert to triangle mesh model
Step5: Find the left and right face for every face in the mesh.
Step6: Find the center of the mesh, as start place.
Step7: Compute the dihedral angle between the first two faces left and right, check if the face is visited before, go to the neighbor face,
Step8: Get the first input string bit, if it is equal one, check the dihedral angle if it is between threshold value $\alpha 1$ and $\alpha 2$ then set flag, embedding 1, else move from one face to another in clockwise direction, continue until it find the angle the satisfy the condition, at every step check if it is reach the creaser edge then go to the bigger ring.
Step9: If the input string bit is equal zero, check the angle if it is between $\alpha 3$ and $\alpha 4$ then set flag, embedding 1, else move from one face to another in clockwise direction, continue until it find the angle the satisfy the condition, at every step check if it is reach the creaser edge then go to the bigger ring.
Step10: Continue repeat step from step 7 to 9 until all the input binary is completed
Step11: Save the watermarked object

4. The Experimental Result

Many experiments to test the proposed method according to invisibility and robustness against different types of attack, in Figure-4 shows the models used as examples for the experiment, "bunny", "cat", "flower", and the watermark text is **"Copyright Protection"**.

Model Name	**No of vertices**	**Faces**
Bunny 	1355	2641
cat 	7850	1215
Planter flower 	594	571

Figure 4- The test 3D object examples

To measure the imperceptibility of the watermarked model, Mean Square Error (MSE) matrices used explained in equation (7), Figure-5 shows the model before and after embedding and also the result of matrices, it can be noticed that there is no obvious difference to the human eyes, there is no visual effect on the object because there is no real embedding operation on the original model but its logical embedding .

$$MSE = m\sum_{i=0}^{m}\frac{v_i^2}{(v_i - v_i')^2} \quad (7)$$

Where v_i represents the vertex of the original model, while v_i' represents the vertex of the watermarked model, m represent the number of the vertices in the model.

Object before embedding	Object after embedding	MSE
		0
		0
		0

Figure 5- The 3D objects before embedding and also after embedding the watermark

From the above Figure-5, it can be observed that the error ratio in the proposed method read value zero because the guiding here is depending on a real computed value and did not depend on a predicated value. Dihedral angle computations are a real values, these values come from vertices by which the surface is generated, no predicated values, no fractals, there is no change on the original vertices because it is logical embedding.

5. Evalution of the Proposed Method

To check the robustness of the proposed algorithm many types of 3d model attacks are used,

1. "Geometrical attack", including rotation, scaling, translation.
2. "Signal processing attack", including noise addition, and smoothing.
3. "Topological attack", including mesh simplifies,

Table-1 and Table-2 below show the effect of these different types of attack on the watermarked model and we see the distortion on the watermark by the **R**atio of the **D**etected correct **B**its after attack (RDB).

RDB= Numbers of correct bits / Total numbers of bits (8)

Table 1- The geometrical attack on the watermarked object

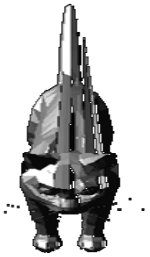
Original object	Scaling	Rotation	Translation	RDB
				1
				1
				1

Table-2 shows the effect of different types of attack, the smoothing on the original objects by subdividing the mesh specified by (Vertices, Faces) such that each face F is divided into N^2 smaller faces, the noise is inserted in the normal direction for every element of the vertices, and the more complex attack is the mesh simplification by reduce the number of faces in mesh but keep the same shape.

Table2- Different types of attack

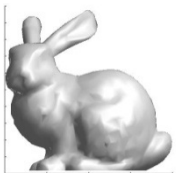
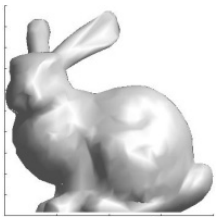
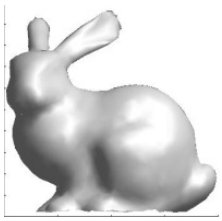
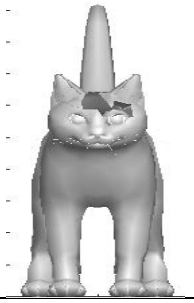
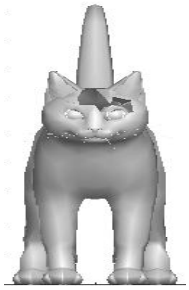
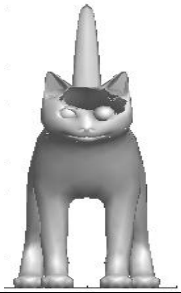
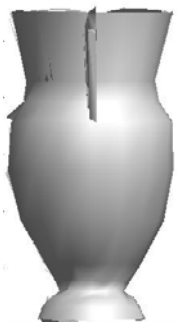
Watermarked model	Mesh simplify	Mesh smooth	Add noise
			
			
			

Table-3 explains the values of the Ratio of the Corrected Bit (RDB) for the extracted data after the different types of attack explained in Table-2.

Table 3-The Values of RDB

Model name	Mesh reduce	Noise	Mesh smooth
bunny	0.97	1	1
cat	0.89	0.96	1
flower	0.87	0.80	1

6. Conclusion

Proposed method is efficient in terms of non-observation, capacity and power, style of concealment is a new style because it depends on the angle measurement dihedral, was chosen this method because this angle represents the angle between the two levels or both sides so that is not affected by different types of attack such as rotation, scaling, translation and the more complex attack, smoothing influence and pressure reducing any number of faces in the three-dimensional shape, adding noise**.**

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