# 3D Multi Resolution Synchronization Scheme Based on Feature Point Selection

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## ABSTRACT

Multimedia protection is one of the main research challenges in computer sciences.[1] We can encrypt the media in order to make the content unreadable without a secret key of decryption, protect the file with Digital Right Management (DRM), or embed an hidden message in the file (watermarking and steganography). We are interested in data hiding applications for 3D mesh. In this domain, there are various problems, of which the synchronization of the message in the support host. The synchronization is the operation that allows to scan a mesh with a unique path and by selecting the same areas (vertices, triangles, quadrangles, for example) before and after the embedding even if the mesh has been noised. In this paper, we propose a new synchronization approach based on feature point selection in a low resolution of the 3D object. The building of the low resolution is made by decimation[2] and the feature point selection is based on the discrete curvature computing. We evaluate the robustness of the synchronization in the low resolution and in the high resolution.

**Keywords:** 3D, watermarking, synchronization, feature point, multi resolutions

## 1. INTRODUCTION

We are daily in touch with 3D data; at the cinema, at television (cartoons, advertising), in video games, in the industry (CAD), etc. Indeed, more and more 3D objects are produced and exchanged. We need to find a protection for these files. As we know, there are different manners to protect files. We can make the content unreadable with cryptographic application, until the customer take the secret key to decrypt the file. It is also possible to limit the using of the file with Digital Right Management (DRM). Another solution consists to hide a message in the file by using steganography or watermarking approaches.

One of the problems main problem of data hiding for 3D content is the synchronization step. Synchronization step allows to select some areas such as a list of vertices or a list of facets and order them in a unique manner to be able to find the same sets after the insertion of various allowed modifications of the mesh.

In the spatial domain, most of the time, we want to make the analogy with 2D images. By creating a band of triangles,[3,4] it is possible for example to scan the mesh as we scan an image rows by rows or columns by columns. With the same idea, inspired by Edgebreaker,[5] a lossless compression algorithm with a high capacity[6] was proposed. Other types of synchronization approaches are also possible but generally they are not robust.

One original approach[7] proposes to do not move any vertices. The synchronization is made by computing a Euclidean Minimum Spanning Tree (EMST). This structure is very interesting because, giving a set of vertices, the EMST is unique. Moreover, with a space orientation and a starting vertex, the scan of the tree is also unique. These uniqueness properties are necessary for synchronization applications.

In this paper, inspired by the work of,[8] we have created a new synchronization scheme that combines the idea of feature point selection and multi resolution aspect with EMST structure.

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## 2. PROPOSED METHOD

Let a set of meshes $\{M_{HR}, M_1, M_2, ..., M_{LR}, ..., M_l\}$ with $M_{HR}$ the original mesh and the other are computed by multi resolution analysis. Multi resolution decomposition can be done by using wavelet decomposition, vertex decimation or other techniques used in Level Of Detail (LOD) applications for example.

Fr the proposed method, we choose a vertex decimation, the Quadric Edge Collapse Decimation[2] which is implemented in MeshLab.[9] From this decomposition, we create a simple parenthood relationship between the vertices in each mesh; such as the vertex $v_i^j \in M_j$ is a father of $v_k^{j-1} \in M_{j-1}$ if and only if $v_k^{j-1}$ is in the Voronoi cell of $v_i^j$ computed with the vertex of $M_j$. In other words, $v_k^{j-1}$ is connected to the nearest vertex of $M_j$.

Then, the selection of feature points is made in one of the mesh from the decomposition. Let $j$ the chosen level and $n_j$ the number of vertices in this resolution. We choose two selection criteria based on the curvature: the Gaussian curvature $k_G$ and another criterion denote by $\tilde{k} = k_{min}^2 + k_{max}^2$. Then, we compare the results between these one. We fixed a selection rate $x \in [0; 1]$ and for each vertex $v_i^j$, we compute $\tilde{k}_i$ and $k_{G,i}$. Then we select the $x \cdot n_k$ vertices with the maximum curvature value, we denote by $V_{j,x}$ the set of the selected vertices.

After this selection, we need to synchronize the vertices. We choose to compute a Euclidean minimum spanning tree (EMST) based on $V_{j,x}$ with the Euclidean distance. The advantage of the EMST is unique for a set of vertices. Moreover, when we let a root vertex, it is possible to define a unique path in the tree. These are interesting properties for the synchronization. The minimum spanning tree (MST) problem is a well-known problem in graph theory. It is a polynomial problem that is solved by two famous algorithm Prim's[10] and Kruskal's.[11] A recent paper proposed a new and fast EMST algorithm[12] in order to accelerate the process.

We proved theoretically and by the experience that EMST are fragile.[13] But if we select a set of vertices with a robust criterion, the robustness of the EMST is significantly better.[14] During the synchronization step, we have a set of selected vertices synchronized by an EMST in $M_j$. But the aim is to synchronize the higher resolution of the mesh, so we need to pass the EMST of the selected vertices on $M_{HR}$.

By the parenthood relationship, for each vertex in $M_j$ corresponds to a set of vertices in $M_{j-1}$. We can extend the relationship by transitivity. Indeed, for each vertex in $M_j$, we associate a patch in $M_{HR}$. Since the vertices are ordered, the patches are also ordered. In conclusion of the synchronized method description, this is a technique interesting for 3D insertion technique patch oriented. In the other case, our synchronized scheme can be extended. It is one of the first proposed feature point synchronization method using multi resolutions with,[8],[15][16] and.[17]

## 3. EXPERIMENTAL RESULTS

We focus on the parameters of our method. Our input is this set of meshes $\{M_{HR}, M_1, M_2, ..., M_{LR}, ..., M_l\}$, in other words we assume that the parameters of the multi resolution decomposition are fixed.

First, we can choose the level in which the selection is made. This first parameter is quite interesting to study because we need to find a compromise between the relevance of the curvature measure and the stability of the resolution.

The selection rate $x \in [0; 1]$ is a parameter that we can modify. We want to build a selection that verifies the condition: more $x$ close to 0, more the selection is robust but there is few vertices selected. To be robust to a cropping attack, it is not necessary to have a lot of vertices selected, or a lot of patches. Indeed, they must be spread homogeneously in the mesh. Face to noise addition and filtering attacks for example, the robustness is more important than the quantity or the repartition of the vertices. In these conditions, we need to make another compromise.

Figure 3 and Figure 3 illustrate the areas where the 3D object *Angel* is the most robust. Figure 3.a and 3.a show the areas for the high resolution of the 3D object *Angel* whereas Figure 3.b and 3.b are for a low resolution of the same 3D object.

We compare the influence of the selection rate. We select in the first experiment 10% of the vertices and 5% in the other. The experiment is built as follows:



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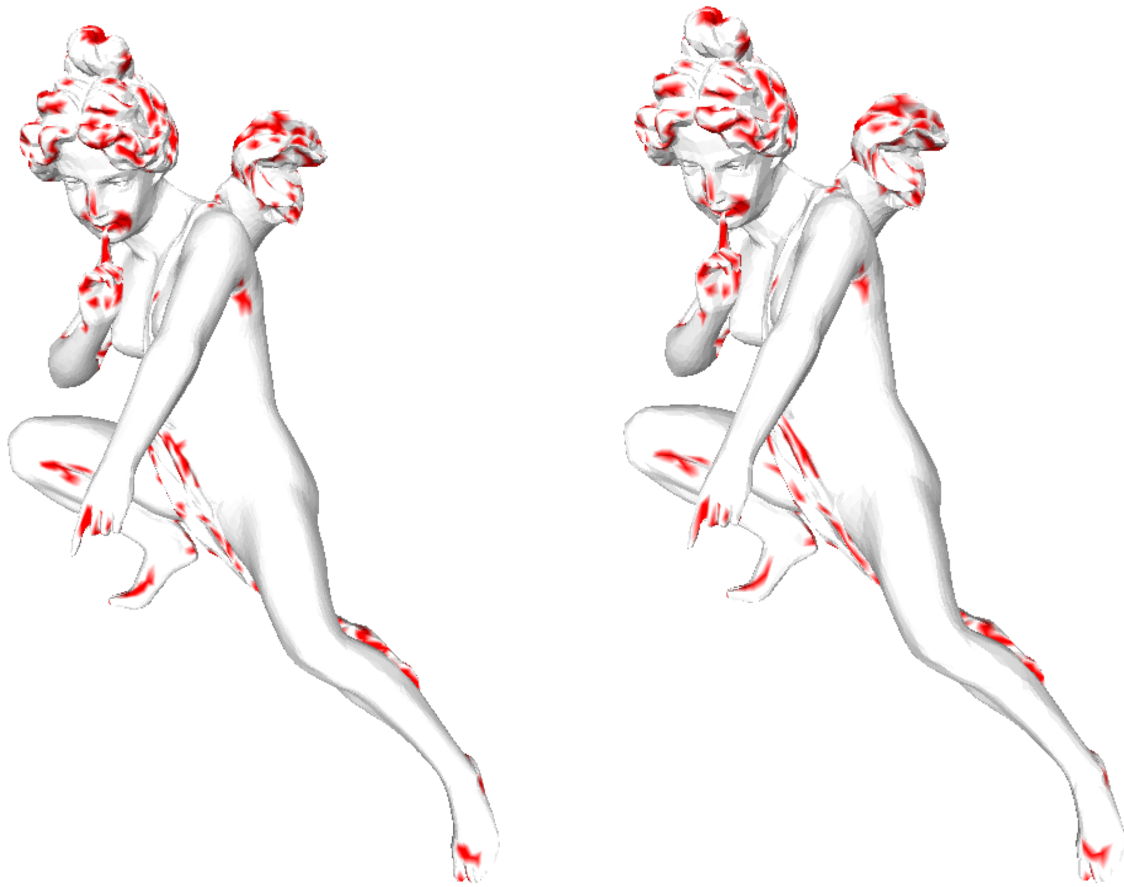
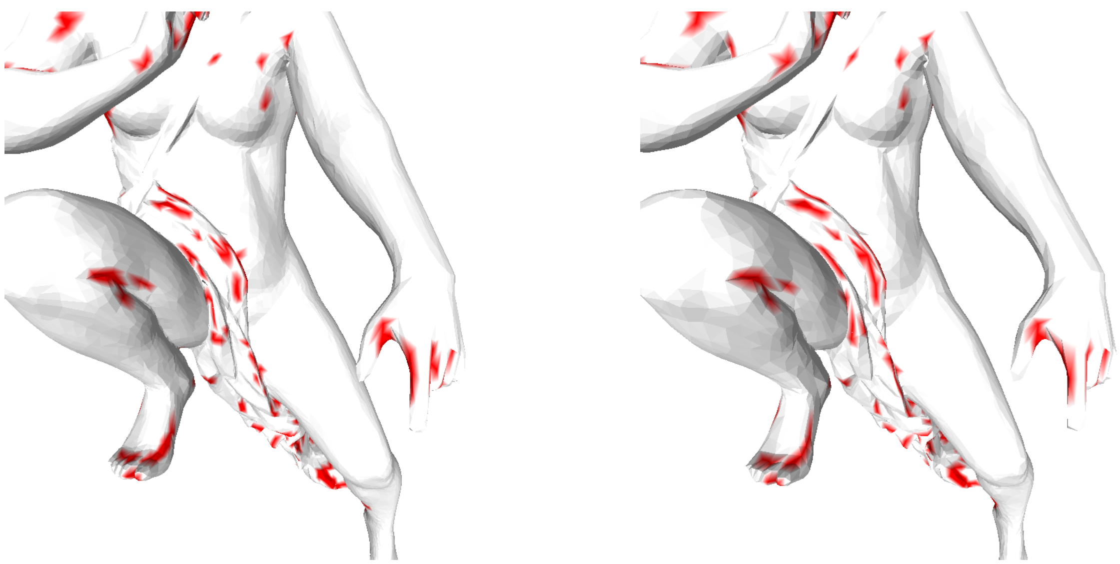


(a) (b)

Figure 1. Representation of the most robust areas of the 3D object *Angel*: a) In the high resolution, b) In the low resolution.



(a) (b)

Figure 2. Zoomed part of the most robust areas of the 3D object *Angel*: a) In the high resolution, b) In the low resolution.



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- Gaussian noise addition $N(\sigma, \mu)$, with $\sigma$ the standard deviation and $\mu$ the mean fixed to 0 to the original mesh $M_{HR}$, and we denote by $M_{HR,\sigma}$ the noised mesh;
- Building the set of multi resolution meshes $\{M_{HR,\sigma}, M_{1,\sigma}, M_{2,\sigma}, ..., M_{LR\sigma}, ..., M_{l,\sigma}\}$ with the same parameter than the original;
- Choosing the same resolution for the curvature computing; Selecting the robust vertices with the selection rate;
- Building the patches in the high resolution by the parenthood relationship;

For these experimentations, we have taken 3D objects with around 10000 vertices, normalized in order to be included in a unitary box. We analyze the evolution Figure 3 and Figure 3 as a function of the standard deviation of the Gaussian noise varying between $[10^{-7}; 10^{-3}]$:

- false positive selection rate (i.e. counting the vertices that are selected in the noise mesh while they are not selected in the original),
- false negative selection rate (i.e. counting the vertices that are not selected in the noise mesh while they are selected in the original),
- and perfect matching.

These measures are made to compare the quality of the vertex selection in the low resolution mesh, and also in the high resolution to measure the quality of the vertex selected in each patch. For this first experimentation, we have chosen the selection ratio equals to 5% and 10%; and the low resolution rate is obtained after one loop of Quadric Edge Collapse Decimation, reducing the number of vertices by 50%.

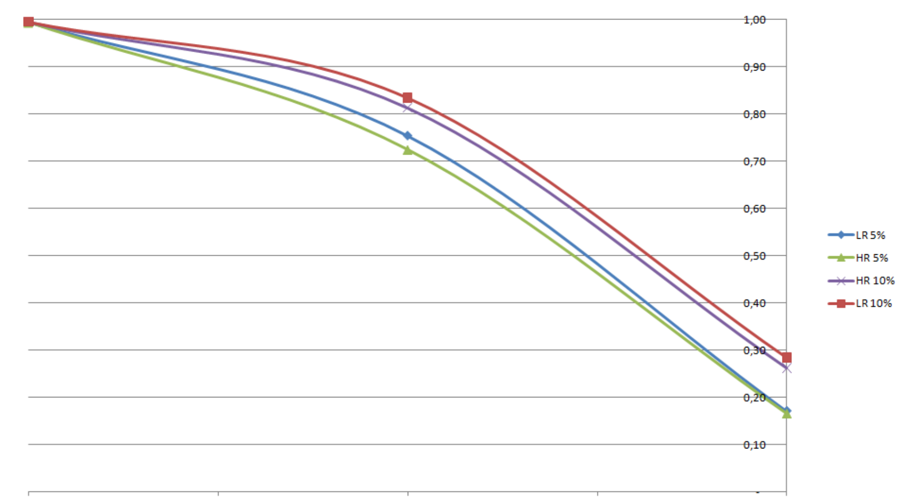


Figure 3. Representation of the selection rate as a function of the standard deviation of the Gaussian noise.

If we are looking to the perfect matching ratio, the results are interesting. For a noise with standard deviation $\sigma = 10^{-7}$, in the same order than the precision of the data, the synchronization is totally preserved (the ratio is very closed to 100%: 99, 7%) in the low resolution mesh for selection rate equals to 5% or 10%.

For a visible noise addition ($\sigma = 10^{-5}$), we preserve only 80% of the vertices in LR and HR for a selection fixed at 10%. Moreover, if the ratio is less important 5%, the result is worse. It is quite surprising, because the selection might be more robust, if and only if the criterion is robust.



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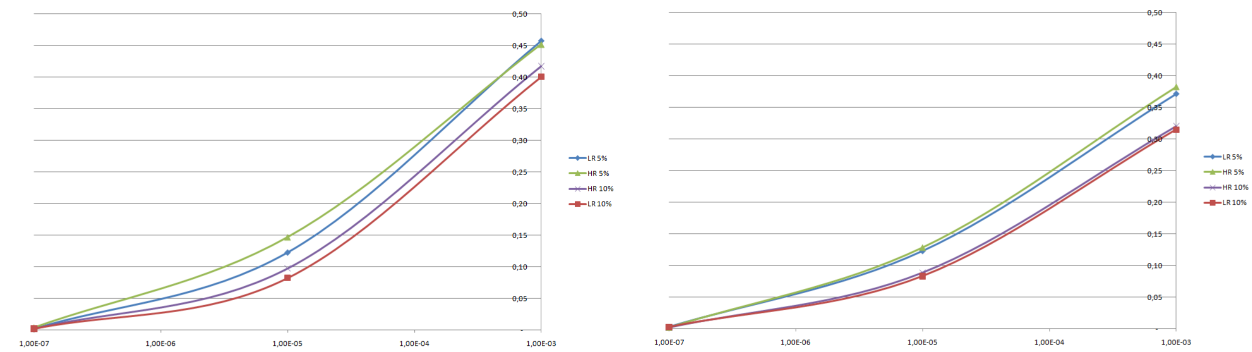


(a) (b)

Figure 4. Representation, as a function of the standard deviation of the Gaussian noise, of the: a) The false positifs, b) The false negatives.

To improve our method, we have changed the level of resolution where the selection of the vertices is made. Moreover, in the selection of the vertices, it will be interesting to choose its neighbors in the LR and then to remove some vertex in the patch (it may be at the frontier) created in HR; because the selected error vertex is in general in the neighborhood of the original one and with this proposed improvement it is possible to limit the errors.

## 4. CONCLUSION

In this paper we have proposed a new 3D synchronization method based on feature point selection and multi resolution. It is one of the first method that combines these two approaches such as[8] and.[16] Feature points are selected in a low resolution of the 3D object we want to watermark. The selection criterion is as function of the curvature of the vertices. The scheme of the method is quite interesting because we need to find a compromise between the choice of the resolution, the criterion of selection and the ratio of the selected vertices.

This proposed approach in this paper presents only the synchronization process that is made to complete for a watermarking scheme. In order to complete the method, the embedding process has to preserve the selection criterion in the low resolution.

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