Texture mapping approach for transforming arbitrary topology meshes to subdivision connectivity ones

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***Abstract*—this paper presents an original simple and fast approach that uses the technique of texture mapping inspired from computer graphics rendering field, to transform a genus-0 arbitrary topology triangular meshes to its equivalent that have subdivision connectivity, and precisely 1-4 meshes, so-called semi-regular meshes (Fig. 1). The meshes with such topology are useful and necessary for many applications, nevertheless an arbitrary given mesh usually doesn't have such connectivity, therefore a transformation must be applied. Comparing our approach with those given in the literature, the proposed one is the simplest since it avoids the iterative process of parameterization and remeshing between the original mesh and the control one.**

***Keywords*— Texture mapping, subdivision connectivity, arbitrary topology, semi-regular, mesh, texture coordinates.**

I. INTRODUCTION

A large set of algorithms in computer graphics requires 3D meshes with some connectivity features and precisely a subdivision connectivity, these include: remeshing and simplification [1], compression [2], wavelets transform on triangular meshes [3], multiresolution analysis [4], progressive transmission [5], smooth rendering [6], watermarking [7]. Whereas an arbitrary 3D object doesn't usually have such connectivity, thus the transformation of the original topology to another with a subdivision connectivity while maintaining a minimum distortion, must be done.

In the next section, we will mention from the literature some of previous works concerning this field.

II. RELATED WORK

Many transformation algorithms have been given in this context. Unfortunately, the major related approaches need iterative steps of parameterization between the original and the base meshes, which is done by the resolution of point location problem, and this is often complex and expensive in matter of time. Lee and al. have proposed MAPS [8] (Multiresolution Analysis Parameterization of Surfaces), that bases on the DK hierarchical simplification [9], but it extends this latter for a general polyhedrons not only for the convexes polyhedrons. The principle of the method is based on an iterative process that has two stages, the first is the simplification by decimation, and the last is a remeshing followed by a parameterization. Another work have been proposed by Kobbelt and al. intitled "shrink wrapping approach to remeshing polygonal surfaces"[10] that operate by the wrapping of a given arbitrary object by a triangular mesh with some subdivision connectivity, and after that, it tries to close the vertices of this last mesh to subjacent surface of the input objet, and this by applying two kinds of power (attractive and repulsive).

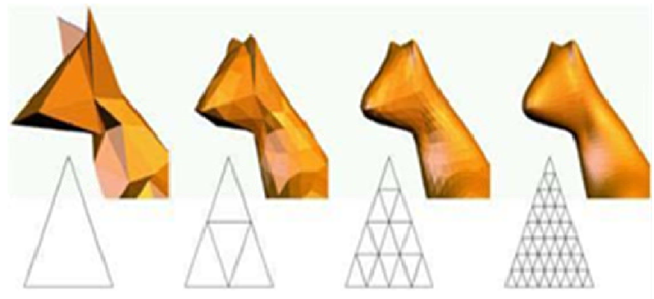

Fig. 1. Example of a semi-regular meshes with different depths.

These powers are a kind of parameterization between two meshes (the original and the base) and this is done firstly by finding the barycentric coordinates in the base mesh, then by finding the corresponding point in the original one. This method are qualified as a general order, in addition, the resulting triangles are not smooth on the limits between the faces that belong to the base mesh. A very recent approach proposed by Guskov is entitled MASR (Manifold-based Approach to Semi-regular Remeshing) [11], this one works in three essential steps: the first is the Voronoï diagram construction, the second is the Delaunay triangulation generation from the last diagram, this triangulation will constitute the control or the base mesh, and the last is the parameterization and remeshing of the model obtained by the previous step (Fig. 2).

III. PROPOSED APPROACH

The proposed approach avoids the classical difficulties usually encountered such as, the searching Voronoï tiles [12], the resolution of point location problem [13], and the iterative parameterization.

The main idea of the proposed approach is the exploiting of image warping during the texture mapping process on 3D object, not to fit this image to subjacent surface but to fit a new

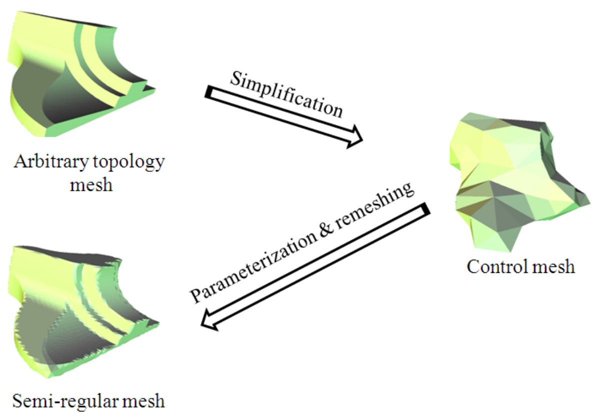

Fig. 2. Global scheme of the previous approaches of transformation an arbitrary topology meshes to its equivalent with subdivision connectivity.

topology (as a new skin) on this surface. Our proposed algorithm works in three stages: topology processing, geometry processing and finally reconstruction.

A. Topology processing stage

In this stage (Fig. 3), we start with a 3D model of sphere that has a subdivision connectivity. Indeed the final equivalent object precision depends to the resolution of this sphere, then in order to have a high precision we have to use a sphere with a high resolution, and vice versa. Since we fix the resolution of the sphere, we extract its connectivity and two kinds of map by applying the reverse spherical mapping on this sphere. The first map is the color map, where we assign to each texture coordinates so-called uv coordinates (that correspond to the nearest-neighbor filtering of the calculated uv coordinates for each vertex, using the mentioned mapping) in the map a green color, and a black color to the rest of the map. The second map is the index map, where we assign at each uv coordinates the index of the corresponding vertex. We note that the dimensions of these two maps must be quite large in behalf of fitting to the resolution of the sphere. In the latter experiments section, we will use three sphere resolutions as illustrated in Table I.

B. Geometry processing stage

In this stage (Fig. 4), we take the target 3D object with arbitrary topology, we sample it to a point cloud (using a sampling algorithm[14]), then we map spherically the previous calculated color map as texture to the point cloud, this simultaneously with the XYZ map filling, *i.e.* when we affect a color to a vertex, we store xyz coordinates of that vertex the to XYZ map at the same position of that color in the color map (the green 3D points are the future vertices of the result mesh).

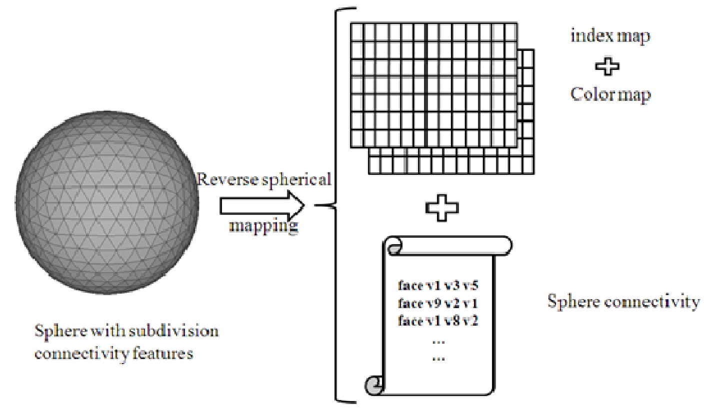

Fig. 3. Topology processing stage.

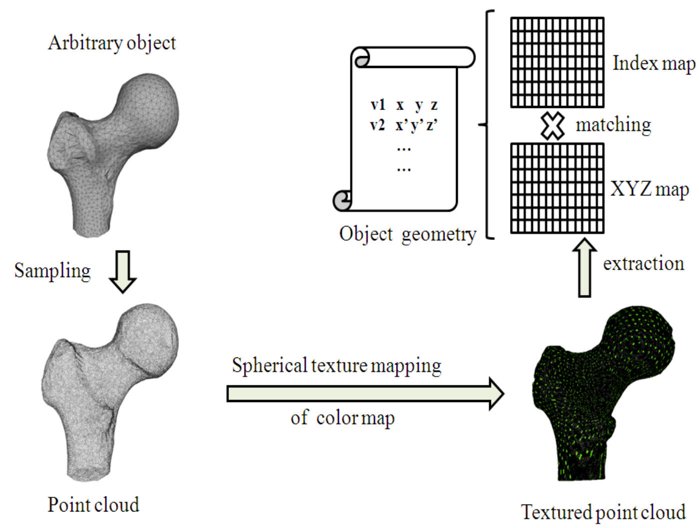

Fig. 4. Geometry processing stage.

Now we can match the index and the XYZ maps to know which vertex index have which xyz coordinates. The matching between the two maps is not direct, and a successive look up for a not null xyz coordinates must be done, and that by visiting the first rings neighborhood of the same coordinates in the XYZ map, until we find a not null xyz coordinates, as illustrated in Fig. 5.This matching will be followed by a sorting to result finally the object geometric part.

C. Reconstruction stage

Using the sphere connectivity and the object geometry produced by the precedents stages, we will reconstruct a whole object with subdivision connectivity in this stage by a simple merging of the two parts as illustrated in Fig. 6.

The figure illustrated in Fig. 7 shows the original arbitrary topology object and its equivalent with subdivision connectivity.

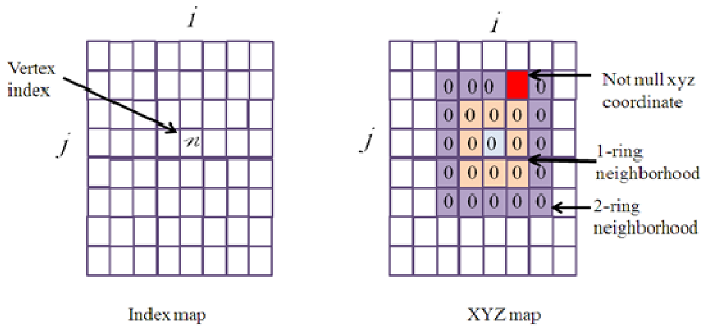

Fig. 5. Matching between index and XYZ maps by looking up the nearest not null xyz coordinates in the neighborhood of a given vertex index.

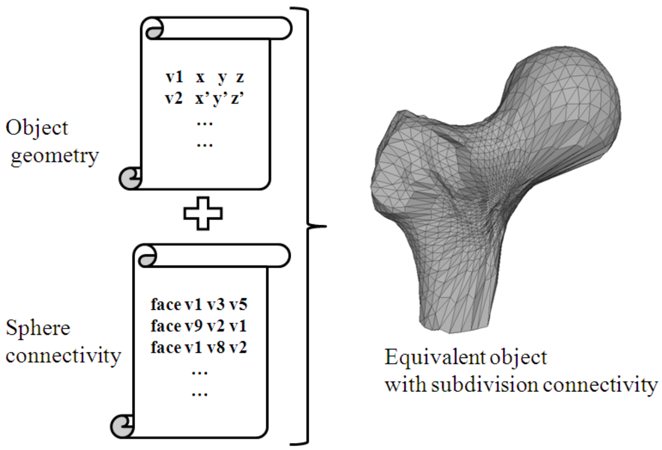

Fig. 6. Reconstruction stage.

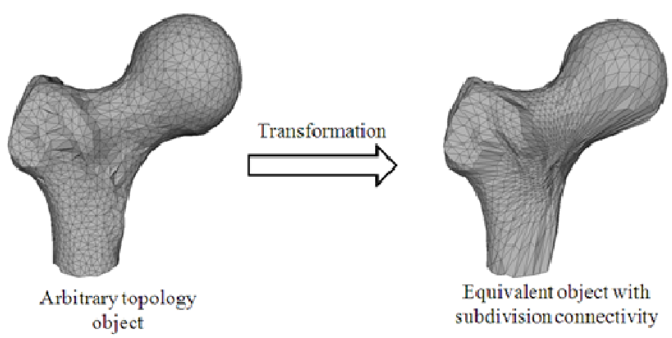

Fig. 7. Comparing the original arbitrary topology object with its equivalent with subdivision connectivity.

IV. EXPERIMENTAL RESULTS

Our scheme has been implemented totally under Microsoft Visual Studio 2005 with c++ programming language & OpenGL library with the help of MeshLab (during the sampling step and also the visualization) .

We have used an arbitrary topology 3D model of a ball joint, and we applied our scheme on this object with three different sphere resolutions (see Table I). We also calculated the mean hausdorff [15] distance as measure of distortion between the original arbitrary model and its equivalent with subdivision connectivity. The result is illustrated in Table II.

We have also applied the proposed approach to a set of basic 3D objects (sphere, cube and cylinder), and that so with the three resolutions of the sphere, as illustrated in Table III.

Comparing the results obtained by our scheme with those of Lee et al., obviously in terms of quality, we can notice that the distribution of triangles on the surface, in our scheme depends on curves of the underlying surface, so we have more triangles in regions wit high curvature and less triangles in regions with low curvatures and this is due to stretching presented in the texture-mapped and consequently this increases the distortion. However the distribution of triangles in the method of Lee et al. depends on the underlying surface normal making it qualitatively less distorted.

But from point of view complexity and speed, our approach is probably less complex and faster.

V. CONCLUSION & FUTURE WORK

We have presented a new approach to transform an arbitrary topology meshes to its equivalent that have subdivision connectivity, and particularly 1-4 meshes, so-called semi-regular meshes, and that by the exploiting of image warping during the texturing mapping process in behalf of fitting subdivision connectivity topology of a sphere to the target object, all that without the need of control mesh creation, nor any iterative parameterization process. However the distortion due to the stretching presented in the warped texture during the texture mapping, need to be decreased, in the future, and this by applying a specific spherical texture mapping [16] instead of the simple one.

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TABLE I.
SUMMARY OF THREE SPHERES WITH PROGRESSIVE RESOLUTIONS AND THEIR COLOR MAPS

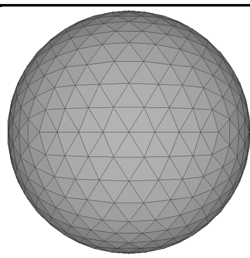
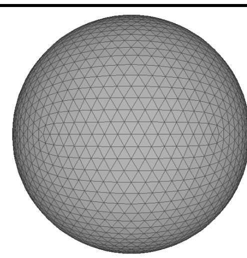
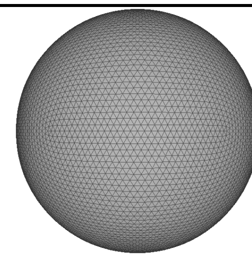
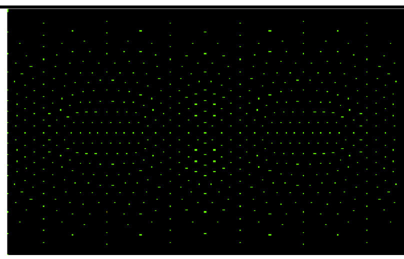
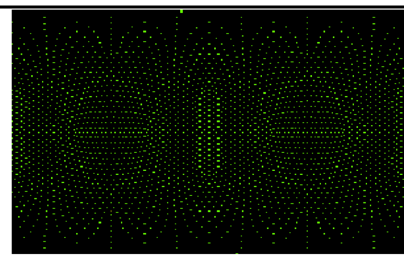
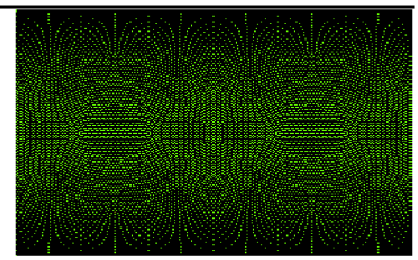
Sphere			
Color map			
Resolution	642 vertices 1280 faces	2562 vertices 5120 faces	10242 vertices 20480 faces

TABLE II.
RESULT OF APPLYING THE PROPOSED APPROACH ON BALL JOINT MODEL WITH THREE SPHERE RESOLUTIONS

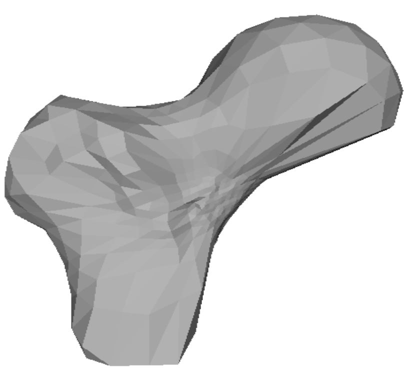
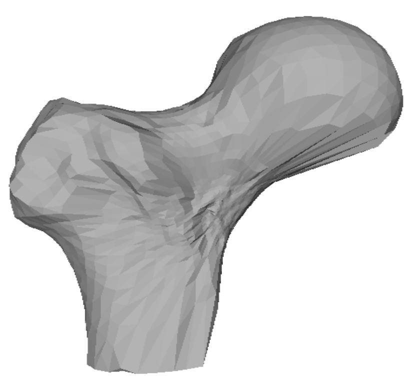
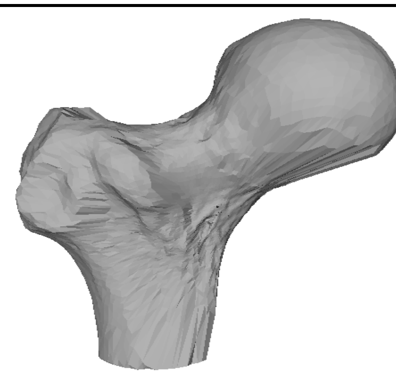
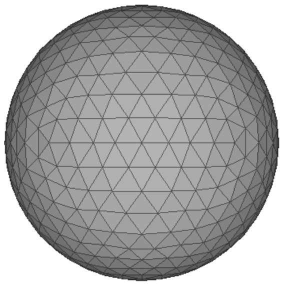
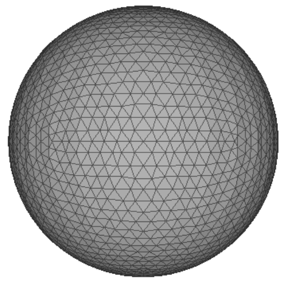
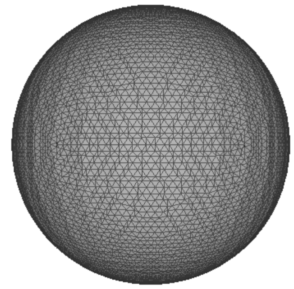
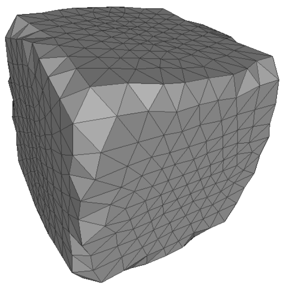
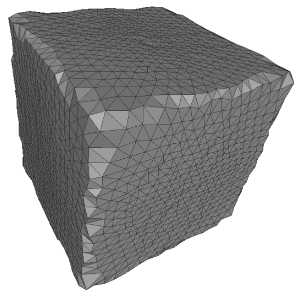
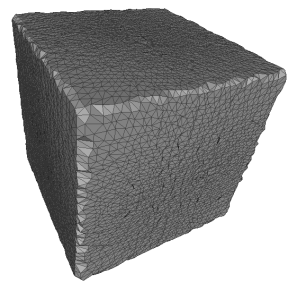
Model			
Sphere resolution	1280 faces	5120 faces	20480 faces
Distortion	0.002753	0.001965	0.001703

TABLE III.
THE RESULT OF APPLYING THE PROPOSED APPROACH ON DIFFERENT BASIC MODELS

Resolution / Model	1280 faces	5120 faces	20480 faces
Sphere			
Cube			
Cylinder