MESH OPTIMIZATION WITH VOLUME PRESERVATION USING GPU

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***Abstract*— Surface mesh optimization represents a challenge especially when it corresponds to an evolving geometry used in numerical simulations where the mesh is restricted to an enclosed volume and requires the preservation of certain features. In this context, we propose an efficient and parallelizable method to retrieve the local volume after performing successive operations, such as smoothing and topological changes that optimize the quality of the triangles. Due to the complexity of this algorithm, GPU is used as a calculation unit to reduce processing time.**

Additionally, we present a simple and robust detection of singularities that helps to preserve the appearance of the mesh during the remeshing process. This process is finally validated by the experimental study in simple geometries (such as spheres and regular polyhedra) and then applied to non-regular meshes obtained from segmentations of medical images or from CAD tools.

***Keywords*— Mesh generation, quality metrics, optimization, volume preservation.**

I. INTRODUCTION

Quality surface mesh generation is still a geometric modeling issue in engineering simulations. The meshes used in these calculations require a given size in a space section and a minimum quality per element. In many simulations, such as fluid through a coronary artery, the meshes must also satisfy boundary conditions entered by the user.

There are many methods for obtaining quality triangulations, some are called direct methods, where the mesh is generated directly on the 3D surface using Octrees (Schroeder and Shephard, 1990) or a frontal method (Dari *et al.,* 1997). Other methods, called indirect, are parameterizations of the original mesh and generate a new domain sampling (Baker, 2004; Freitag and Plassman, 2000). Direct methods have difficulty in checking mesh validity, while indirect ones suffer from the complexity of defining the size and shape of the elements generated in another domain.

Another type of widely accepted methods because of their efficiency consist in remeshing arbitrary triangulations generated by CAD tools or by automatic reconstruction methods, which often includes defective elements or with null area. This process, usually iterative, makes changes on the elements, either by adding or removing vertexes, to make the mesh meet the size requirements; and exchanges edges to improve quality. One of the first to use this strategy was Coupez (1994) who proposed restricted changes on the topology of the mesh, then extended by Heckbert and Garland (1999) who define a metric to choose the edges to be removed without affecting the appearance substantially and Suárez *et al.* (2009) who introduced a new method of subdivision to obtain better quality triangles. However, the greatest improvements in quality and efficiency come from relocating the vertexes applying local smoothing filters (Brewer *et al.,* 2003) or softing the entire mesh, as in Sorkine *et al.* (2004).

Another desirable feature of a mesh is the conservation of volume. This feature lets achieve more stable simulations in dynamical systems. It is well known that a simple procedure, such as Laplacian smoothing shrinks significantly the domain volume (Taubin, 1995). Therefore, the preservation of volume has been studied for many jobs in recent years (Zhang *et al.,* 2005; Zhou and Huang, 2005). In this context, several methods where proposed to reduce errors such as volumetric boundaries or vertexes movement constrained to parameterized spaces (Frey and Borouchaki, 1998; Garimella *et al.,* 2002). Even with these restrictions, if smoothing is frequently applied within an adaptive process it tends to accumulate errors.

Our proposal is an iterative remeshing method, similar to Wang (2006) that attempts to achieve reasonable quality elements by reshaping the surface with elements of desired size and maintaining a minimum difference of volume through detection of singularities and projection of the vertexes. The main contribution is an indicator to measure and then reduce the local volumetric error efficiently respect to a reference mesh, after introducing changes in topology or having completed a relocation of vertexes by smoothing.

The next section exploits in detail the steps of the method. The following one describes the data and strategies to improve the quality of the elements. Then it is introduced the proposed volumetric difference estimation and reduction using GPU and the last section shows some evaluation cases.

II. OUR METHOD

The proposed method has the objectives of efficiency, robustness, quality and preservation of the representation. From meshes generated by CADs tools or by automatic systems, it's expected to obtain high quality meshes, performing the following steps:

(1) Defining the initial mesh and the desired element size.

(2) Remeshing the initial surface to meet the requirements of elements size and singularities preservation. The remeshing is conducted through local changes such as edges splitting or collapsing.