A New Method for Efficient Generation of High Quality Triangular Surface Meshes

Desheng Wang*

School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637616.

Abstract. A novel method for the generation of unstructured triangular surface meshes is presented. The method is based on remeshing techniques including edge splitting/contraction and edge swapping. Normalized edge lengths, based on a metric derived from curvature or from a user–specified spacing, are employed as the remeshing criterion. It is assumed that the geometry is input in the form of composite parametric surfaces, with Ferguson or Nurbs type multiple patch representation. Examples involving typical aircraft geometries and a ship model, are included to demonstrate how high quality meshes can be efficiently generated on surfaces with a high degree of geometric complexity.

Key words: Surface mesh generation; surface remeshing; edge split; edge contraction.

1 Introduction

Surface mesh generation is still a challenging task for numerical simulations involving large scale volumetric mesh generation. Existing approaches can essentially be categorized as being either direct or indirect [1–7]. In the direct approach, the mesh is generated directly on the 3D surface, using an octree based or an advancing front method [8, 9]. The indirect approach relies on generation in the parametric domain, using any 2D mesh generation procedure [4,5,7,10,11]. The mesh is then mapped onto the 3D surface. Direct methods have difficulty in checking the validity of the mesh, while indirect methods have difficulty in controlling the size and shape of the elements generated in the 2D domain. The development of a method for efficiently generating large-scale surface meshes with high quality motivates this work.

---

*Correspondence to: Desheng Wang, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637616. Email: `desheng@ntu.edu.sg`

For engineering simulations, such as computational fluid dynamics, most boundary definitions come directly from CAD systems. The representation of a three dimensional geometry based on CAD patches, such as Ferguson patches or NURBS patches, will consist of both geometrical and topological data. The geometrical data is defined in the physical space and includes the basic parameters defining the shape of the support surfaces and the intersection curves. The topological data defines the generated regions and their support surfaces and bounding curves. In classical surface mesh generation, each region is meshed individually. This means that points must be generated on the bounding curves and these points will be part of the surface mesh for the region. In many cases, the bounding curves are of no physical significance and small thin patches often result in the creation of sliver or distorted triangles [3]. Therefore, the development of an approach that enables the generation of high quality patch independent surface meshes, which conform to the input surface representation, is the second objective of this work.

In this paper, we attempt to meet these objectives by describing a new method for the efficient generation of high quality surface triangular meshes using remeshing techniques [12–14]. The geometry definition formats that are supported by the current implementation of the method include composite parametric surfaces, with discrete composite parametric Ferguson curves and surfaces or NURBS. And the global surface consists of multiple regions. Initially, for each region, a triangulation of the points defining the intersection curves and those of the region's support surface which are lying within the region, is generated. These region-wise triangulations are then assembled into a global surface conforming mesh which can be regarded as an initial surface triangulation or a reference surface mesh to approximate the given surface with an adequate accuracy. Then, remeshing operations, such as edge splitting/contraction coupled with edge swapping, are performed for refinement or coarsening of this initial mesh. Metric controlled edge lengths are computed with respect to surface curvature and coupled with a user specified mesh spacing control function. Mesh points are added by edge splitting, and are located on the surface using the G1 interpolation [12, 14–16]. Finally, the surface mesh is optimized by utilizing nodal smoothing, node connectivity optimization and edge swapping techniques. The remeshing procedure requires only local information and is highly efficient. And the efficiency is demonstrated for various complicated aircraft configurations and a ship model.

The remainder of the article is organized as follows. The geometry modeling and the input data format are discussed in Section 2. An overview of the proposed surface mesh generation method is given in Section 3. Details of the construction of the initial surface triangulation are presented in Section 4, while Section 5 describes the mesh refinement and coarsening techniques that are employed. The optimization of the final grid is also briefly described in Section 5 and a few examples are given in Section 6.