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The generation of axially aligned seams on triangulated pipe faces

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Abstract

This paper presents a method for creating seams on pipe faces which are effective for reducing the distortion of the face flattening and thus promote the generation of high quality meshes on the faces. The method is applicable to groups of connected B-rep triangulated faces whose underlying surfaces resemble Generalised Cylinders. Isoparametric curves of Generalised Cylinder parametrisations are approximated by establishing singularity-free cross-fields starting with estimated principal curvature directions from which the seams are derived.

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1. Introduction

Piping networks and assemblies comprising many cylindrical surfaces can be found in a huge variety of mechanical devices including automotive and aero-engines, fans, turbines, heating systems etc. In industry an emergent requirement in the modelling and analysis of these geometries is the ability to generate more structured meshes to facilitate structural, CFD and acoustic simulations. For example, accurate contact analysis on cylindrical components is dependent upon well-aligned structured meshes, both axially and circumferentially, on opposite mating surfaces to promote the creation of MPCs and compatible boundary conditions.

1.1. Flattening or parametrisation of triangulated faces

Many face meshing algorithms essentially work in 2-D and for them to be used on a 3-D curved face a flattened representation along with a mapping must be found. This is equivalent to finding a continuous *u*-*v* parametrisation over the face. If the face is an analytic or NURBS geometry face then this is already available but if the face is a triangulation it must be computed. If the mesh is generated on the flattened representation with the objective of high quality elements, large distortion in the mapping will adversely affect the qualities of the resulting elements in 3-D. Thus, flattening algorithms are generally designed with the aim of minimising a combination of length, area and

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angular distortion in the mapping. Other applications include texture mapping, morphing and remeshing. See [1] for a comprehensive survey.

1.2. Flattening of pipe faces

A pipe face is understood here to be a region of a Generalised Cylinder (*c.f.* Sec. 2). For pipe faces a flattening mapping with significantly reduced distortion is often possible by redefining its B-rep to turn its two boundary edge loops into to a single boundary edge loop by introducing a *seam* cut. This is an edge on the face that spans between the two boundary edge loops of the original B-rep and it is included twice with opposite senses in the boundary edge loop of the modified B-rep. This is shown in Fig. 1 and the benefit on mesh quality is clearly demonstrated.

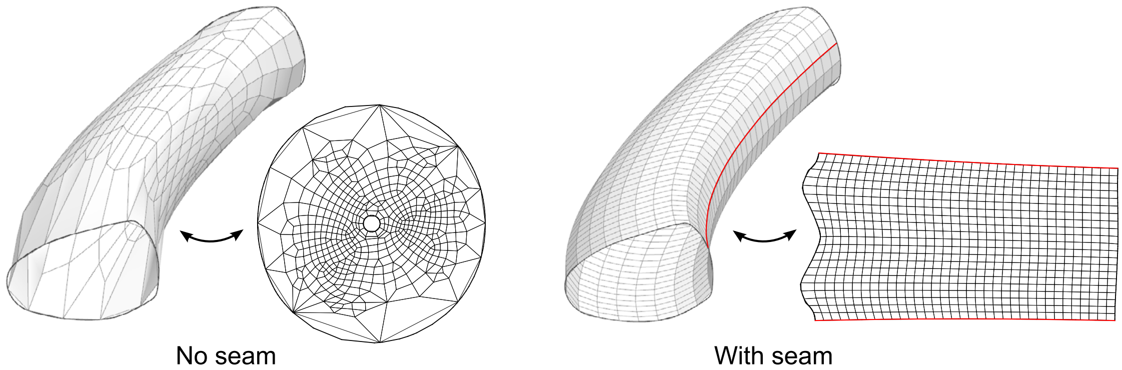

Fig. 1: A 3-D pipe face and its flattened 2-D representations with and without a seam cut, and corresponding sample meshes. These were generated in Simcenter 12 using the flattening method of [2].

1.3. Related work

Various methods have been developed to generate constructive seams on triangulations for parametrisation. Grundig *et al.* [3] proposed a geodesic based algorithm for the particular case of generating optimum seam cuts on architectural textile structures. Guskov *et al.* [4] proposed a method for segmenting a detailed curved triangulation with a net of curves by a process involving mesh simplification and iterative adjustment. Sander *et al.* [5] apply a progressive merging procedure to produce a collection of topological disc charts. Vallet and Levy [6] use a spectral segmentation method to solve for a set of seams which can be manually edited in the event of over segmentation. Campen *et al.* [7] deal with the general problem of generating quantised global parametrisations. Their methods by-pass the need for seams altogether although the techniques involved are complex and require the solution of mixed integer programming problems via clever heuristics to give good performance.

1.4. Contribution

An algorithm is presented that is designed for the particular case of generating effective seams on pipe faces for quad meshing. The approach of establishing a singularity free cross-field starting from approximated principal curvature directions is novel and the value of the approach is supported by theory and by the quality of the resultant quad meshes on the faces.

2. Generalised cylinders

A Generalised Cylinder (GC) is a surface loosely characterised by having a curve in 3-D called an *axis* along which a closed *cross-section* curve is swept to construct the surface. The shape of the cross-section curve may be constant or, more generally, be controlled by a sweeping rule. They cover a wide range of different shapes and their form lends