

Solver integration developments for CEM

Introduction

The ICE NITe project is exploring the use of the unstructured transmission-line modelling (UTLM) method (Sewell, et al., 2004) to perform electromagnetic simulations of cables and connectors. The Nottingham UTLM software consists of a tetrahedral Delaunay mesh generator, which then passes mesh to the UTLM solver itself, and thus requires geometry, rather than mesh, as its input. This input geometry can come from several sources:

- GK, the Nottingham geometry kernel
- IGES data imported directly by the Nottingham mesher
- Facetted geometry definitions, supplied as a .sgf file, generated by BAE Systems pre-processing tools, based on CADfix (ITI Ltd, 2016)

In this work, we have improved the CADfix tools available to the .sgf generator, and also provided API access to allow the Nottingham UTLM mesher to operate directly on a geometry model held in CADfix. The enhancements have focussed on the use of virtual topology, suppressing unwanted CAD edges, allowing the complexity of the geometry in the .sgf file to be reduced. The virtual topology constructs have also been exposed directly through the CADfix API, allowing solvers to integrate with them directly.

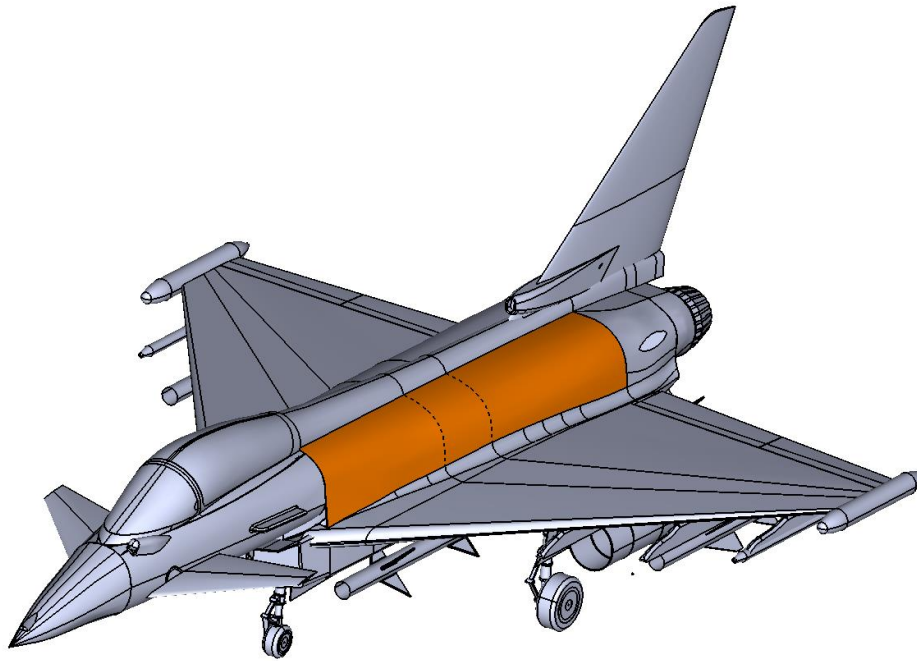
Zoning

A *zone* is a virtual CAD face – a collection of adjacent CAD faces, which is treated as a single face, with the internal divisions between the constituent faces ignored. Zones are typically used to suppress unnecessary detail in a CAD model, such as edges where the adjacent faces are tangential. The suppressed edges are then ignored during meshing, and element edges are free to cross them, reducing constraints on the mesher. Using zones can significantly reduce the element count required to represent a piece of CAD geometry, and can also improve the robustness of tetrahedral meshing, thanks to the improved quality of the resulting surface meshes.

Zones can be constructed using either automatic or manual tools in CADfix. The zone definition consists of two things:

- The list of faces which comprise the zone
- An embedding surface which provides geometry for the zone

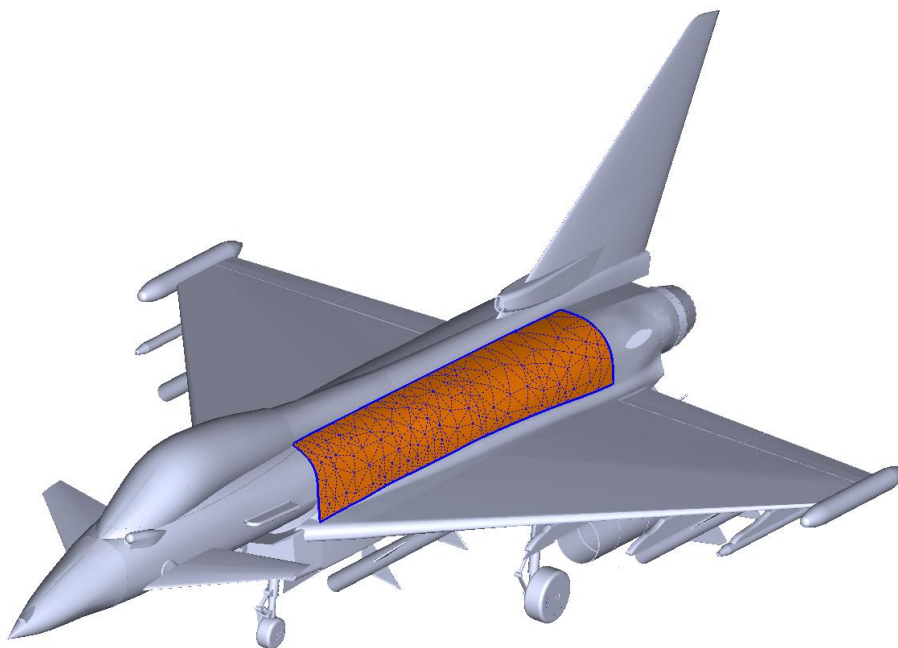
The embedding surface is the extra data that allows geometric enquiries to treat the zone as if it was a single CAD face. Automatic construction of a smooth, parameterised (providing a map from the 2D plane into 3D coordinates on the surface) embedding surface is key to successful construction of the zone.



An example zone on an aircraft fuselage, shown in orange. The suppressed CAD edges are shown as dotted lines.

Faceted surfaces

CAD geometry typically uses NURBS surfaces as the embedding geometry for faces. Whilst NURBS are quite flexible, constructing a single NURBS surface to cover a complex zone is a difficult task. Commonly, multiple faces are present in a region being zoned because the CAD engine required multiple NURBS surfaces to represent the chosen geometry. We therefore use faceted surfaces to represent the geometry in our zones. These can be constructed by calculating triangular facetings for each face of the zone, and joining these facetings together.

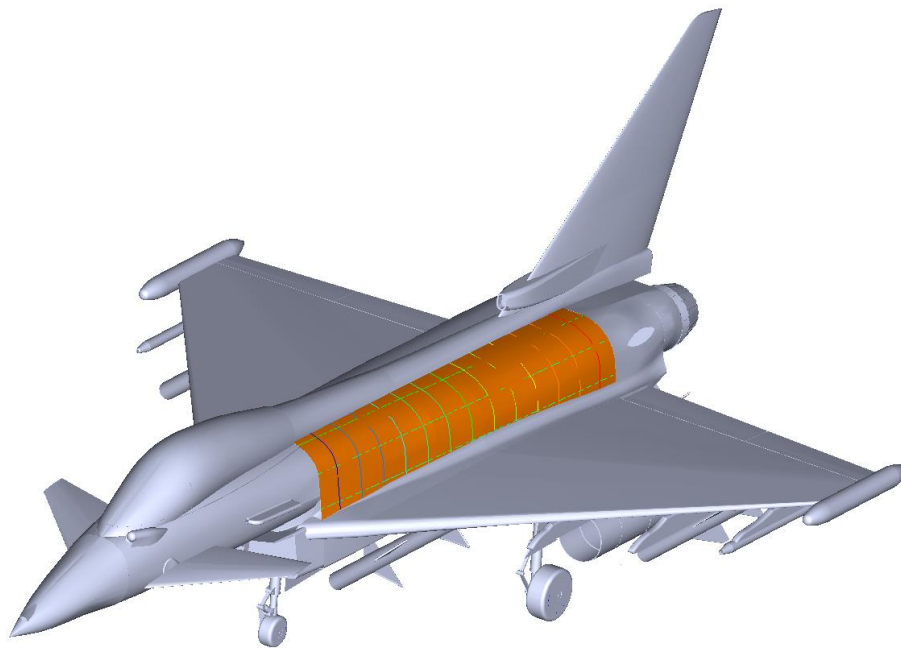


The faceted surface covering the example zone.

Faceted surface parameterisation

For most geometric enquiries, it's necessary for a faceted surface to be parameterised – it must possess a map from positions on the 2D plane to unique 3D coordinates on the surface. Ideally, this parameterisation should be well behaved, with the shape of the zone in the 2D plane being similar to the 3D shape, with as little distortion as possible.

Within ICE NITe, the As Rigid As Possible (ARAP) parameterisation method (Liu, Zhang, Xu, Gotsman, & Gortler, 2008) has been added to CADfix, which hugely improves the robustness and quality of our parameterisations. Unlike previous simple approaches – such as searching for a projective plane – ARAP can be applied to general facetings, without restriction on shape. Unlike previous general approaches, where the boundary of the parameter space was constrained to be a disc – resulting in large parametric distortions – ARAP is a free boundary method, generating a parametric boundary which is similar in shape to the faceted surface. ARAP is now the default method for parameterising faceted surfaces for zones in CADfix.



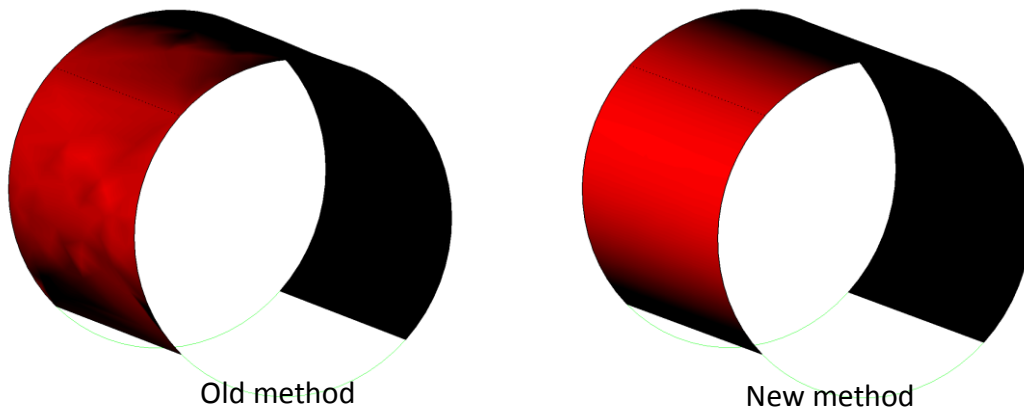
The iso-parameter lines of the parameterisation over this zone. Note they are equally spaced, cross at right angles, and are well aligned with the boundaries of the zone – all hallmarks of a good parameterisation.

Curved facets

Traditionally, faceted surfaces have been constructed from flat (C0) triangles. Large numbers of triangles are required, to accurately represent curved CAD surfaces. However, it is also possible to use higher-order facetings – based around quadratic or cubic triangles, for example, which allow curved shapes to be represented accurately with far fewer triangles.

CADfix has two constructions for curved triangles: point-normal (PN) and C1. The PN construction uses normal data at each vertex of the faceting to construct cubic triangles. Whilst the triangles are curved, they are not tangent continuous between each triangle and its neighbour. The C1 construction uses parametric derivatives at each vertex of the faceting, and is tangent continuous between each triangle and its neighbour.

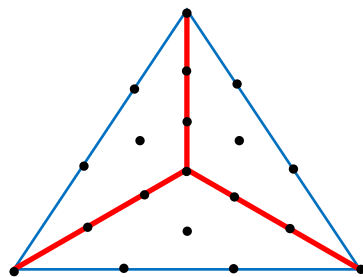
Calculating a C1 faceting from a single face is straightforward, as parametric derivatives can be taken from the underlying face. Unfortunately, when constructing a faceting over a zone, the facets must be re-parameterised to provide a unified parameter space over the whole faceting, which loses the parametric derivatives at the vertices, and degrades the faceting from C1 to C0. Derivatives can be recalculated by finite difference, but the resulting C1 shape is poor quality. To avoid this, within ICE NITe, a technique has been developed which allows new parametric derivatives to be calculated, using a least squares fit, to keep the joined faceting as C1, and correctly preserve the shape of the constituent C1 facetings.



A comparison of C1 joining methods: the old method, using finite difference derivatives, and the new method, using a least-squares fit.

Access via CADfix API

All of the pieces described here have been made available via the CADfix API (CFI). Access to zone definitions, FROG definitions, and properties on FROGs, such as their parameterisations and normal, were already available via CFI. In addition, access to C1 FROG control points, defining the cubic triangles which make up a C1 faceting, has been added, to allow the solver to read C1 FROGs directly.



Layout of Bezier control points for a single C1 facet. C1 facets are divided into three sub-facets (in red).

Conclusion

Significant improvements have been made to zoning technology within the ICE NITe project, with improved FROG parameterisations, joining of curved C1 facetings, and API access to the curved C1 FROGs. These improvements provide new tools which are available for suppressing unwanted CAD edges, and also give access to additional geometry data which can be read by external mesh generators and solvers.

References

- ITI Ltd. (2016). *CADfix: CAD translation, repair and simplification*. Retrieved from <http://www.cadfix.com/>
- Liu, L., Zhang, L., Xu, Y., Gotsman, C., & Gortler, S. J. (2008). A local/global approach to mesh parameterization. *Proceedings of the Symposium on Geometry Processing*, (pp. 1495-1504).
- Sewell, P., Wykes, J. G., Benson, T. M., Christopoulos, C., Thomas, D. W., & Vukovic, A. (2004). Transmission-line modeling using unstructured triangular meshes.