11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Aligned Metric-Based Anisotropic Solution Adaptive Mesh Generation

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Key Words: *unstructured mesh generation, anisotropic mesh, solution adaptive mesh.*

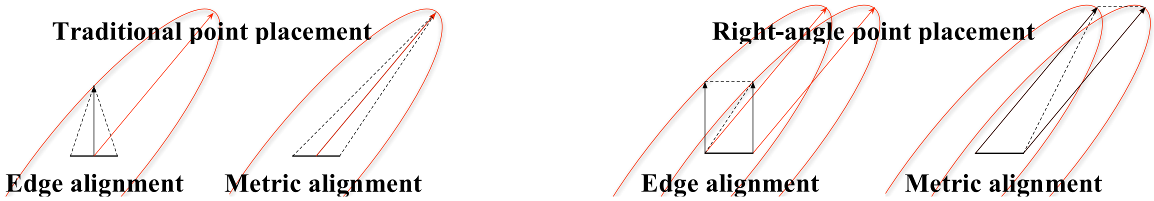
The benefits of metric-based mesh adaptation for dealing with anisotropic physical phenomena are well established. The fundamental metric-based concepts are well established [1] and several successful examples [2-5] with real-life problems have already proven its ability to efficiently improve the ratio between solution accuracy and the number of degrees of freedom. This success has been based on the following key points:

- Efficient adaptive anisotropic mesh generator that can handle extreme anisotropy
- Accurate metric-based anisotropic error estimates: feature-based or adjoint-based
- Appropriate operator on metrics: interpolation, intersection and gradation
- Accurate solution transfer for transient problems

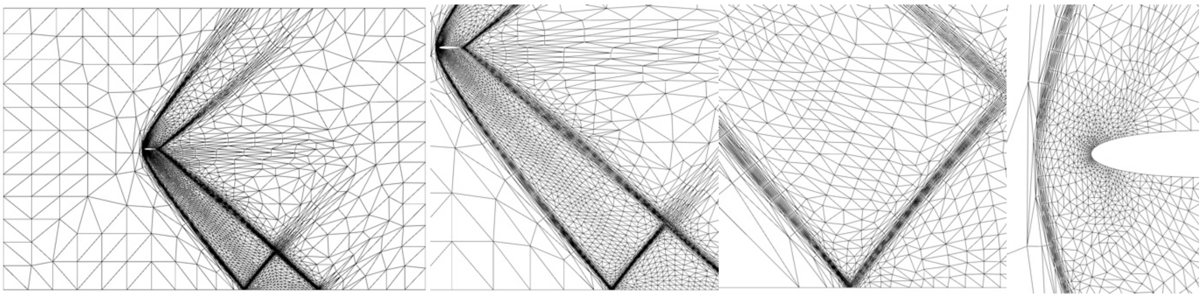
There are several solver and meshing tools that utilize a solution adaptive metric-based concept. Some examples in 3D include Epic, Feflo.a, Forge3d, Fun3d, Gamanic3d, MAdLib, MeshAdap, Mmg3d, Mom3d, Tango and AdapLibrary. It is worth mentioning that these codes include adaptive remeshers based on local mesh modifications and others are mesh generation codes using Delaunay kernels or related approaches. Existing approaches assume that mesh quality and edge length sufficiency are fully satisfied if true in metric space. However, element shape and alignment with the metric field also impacts accuracy and efficiency of the solution process. There is a need to investigate approaches that can provide improvement in this aspect and the present work seeks to do that.

The approach used in this work is based on an existing advancing-front method with local-reconnection/face-swapping for mesh connectivity optimization [6-8], which is known to generate very-high quality unstructured grids as compared to Delaunay type approaches. We will present a new extension of this methodology to metric-based anisotropic mesh generation wherein the advancing-front type point placement is modified to satisfy a metric space definition. All geometric operations are performed in metric space with a consistent operational framework as defined in [1-5].

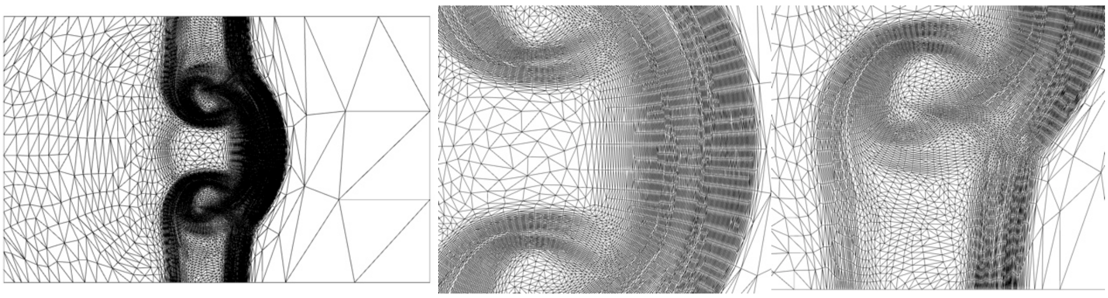
In addition a new and unique point placement algorithm has been developed to align the mesh elements with the solution based metric field. When new points are created using the advancing-front point placement they are by default aligned with the edge (or face in 3D) that locally represents the front. In metric space the ideal point placement is created to form equilateral triangular or tetrahedral elements in metric space. In our approach the alignment is performed with the local metric field. Further improvements can be obtained if we consider local topology. Using right-angle type advancing-front point placement, pseudo-structured type element topology is produced locally that can be aligned with the solution gradients by the metric field. With right-angle type placement two-points are created from the edge (or three-points from the face in 3D) that locally represents the front. In the following figures, traditional and right angle point placement are shown with both edge- and metric-alignment.



Alignment with the metric produces elements that are naturally ideal with respect to the metric field and also pseudo-structured in the case of right-angle point placement. Results with our initial work in 2D will be presented for actual cases along with a discussion on the natural extension to 3D. An example case of a solution adapted mesh for a supersonic flow-field about a simple NACA airfoil is shown below. As shown below excellent alignment is achieved without any constraint other than satisfying the metric field.



Similar alignment is generated automatically in less organized flow features as shown below.



REFERENCES

[1] F. Alauzet, "A Paper defining basic Metric Based adaptation," *International Journal for Numerical Methods in Engineering*, 60, (2004), p138.

[2] F. Alauzet, "A Paper on Metric Based adaptation with Mesh Movement," *International Journal for Numerical Methods in Engineering*, 60, (2004), p138.

[3] F. Alauzet, P.J. Frey, P.L. George, and B. Mohammadi. 3D transient fixed point mesh adaptation for time-dependent problems: Application to CFD simulations. J. Comp. Phys., 222:592–623, 2007.

[4] F. Alauzet and A. Loseille. High order sonic boom modeling by adaptive methods. J. Comp. Phys., 229:561–593, 2010.

[5] F. Alauzet and G. Olivier. Extension of metric-based anisotropic mesh adaptation to time-dependent problems involving moving geometries. In 49th AIAA Aerospace Sciences Meeting, AIAA Paper 2011-0896, Orlando, FL, USA, Jan 2011.

[6] D.L. Marcum, "Unstructured Grid Generation Using Automatic Point Insertion and Local Reconnection," *The Handbook of Grid Generation,* edited by J.F. Thompson, B. Soni, and N.P. Weatherill, CRC Press, (1998), p18-1.

[7] D.L. Marcum, and N.P. Weatherill, "Unstructured Grid Generation Using Iterative Point Insertion and Local Reconnection," *AIAA Journal,* 33, 9, (1995), p1619.

[8] Marcum, D. and Alauzet, F., "Unstructured Mesh Generation Using Metric-Based Transition for Viscous Flowfields," AIAA 21st Computational Fluid Dynamics Conference, San Diego, CA, June 2013.