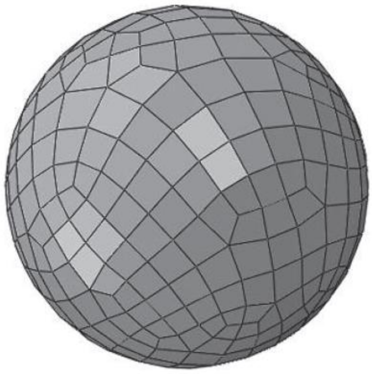
Surface Gradient Algorithms for Unstructured Grid Panel Methods

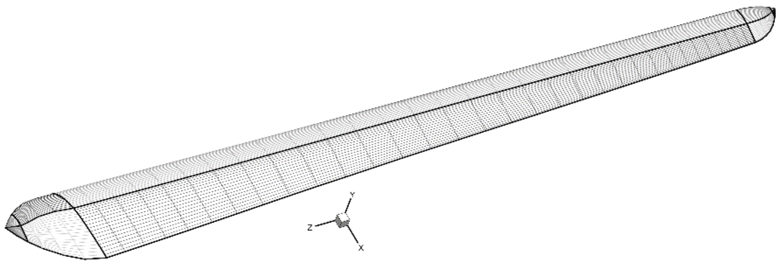
MSc Project Proposal

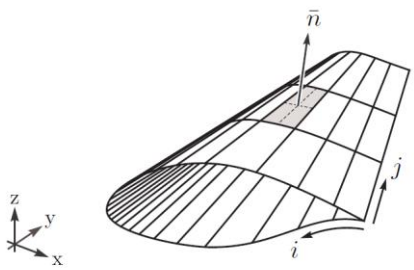
1. Introduction



In advanced low-order panel methods that are based on the internal Dirichlet boundary condition, the flow velocity tangential to the surface is constructed using the surface gradient of the dipole distribution. These dipole strengths are determined in the panel midpoints, while the tangential velocities are to be determined in the panel corner points (nodes). The aim is to develop a hybrid grid panel method that can handle both structured and unstructured grids. The benefit of the unstructured grid feature lies in the opportunity to use automatic grid generators and in extensions such as adaptive grid technology.

While relatively simple to implement in a structured grid panel method, the determination of the surface gradient in an unstructured grid panel method introduces some problems concerning accuracy and practical implementation.





2. Problem Description

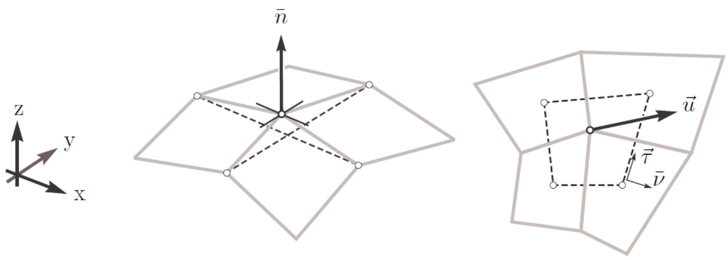
In this master thesis project, you design, program, and investigate the accuracy of numerical approaches to determine the surface gradient of a dipole distribution in the panel corner points that are internal to a surface patch or located along its edge. The panels that make up a surface patch are arranged as an unstructured hybrid grid of triangles and/or quadrilateral panels. Design (and implementation) of an efficient data structure in Fortran is an important part of this project.

One possible approach to determine the surface gradient of the dipole (scalar) distribution in a node is based on the Gradient Theorem and involves a contour integral around that node:

$$\overline{\nabla_S \mu} = \frac{1}{S} \int_{\partial S} \mu \, \bar{\nu} \, dl$$

where

$$\bar{\nu} = \frac{\vec{\tau} \times \bar{n}}{|\vec{\tau} \times \bar{n}|}$$

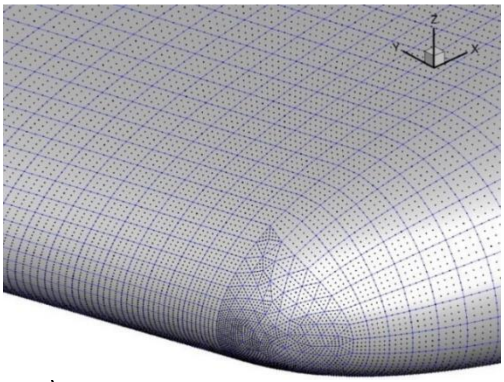


This approach needs to be extended when the gradient at free nodes at the edge of a surface patch is needed, for example at the trailing edge of a rotor blade. Other approaches are also possible, for example by approximating the surface dipole distribution with (harmonic) polynomial functions and determine the surface gradient through differentiation, or by a least-squares approximation using gradient approximations of dipole strengths in the near field.

The major steps of the study will consist of the following:

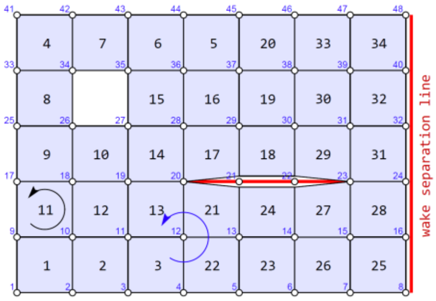
- Literature study into theory and numerical approaches
- Analysis of the proposed numerical solutions

- Design of an unstructured panel method data structure
- Implementation in Fortran
- Demonstration on manufactured test problems
- Analysis of the numerical results
- Report



3. Your Profile

- Basic knowledge of fluid dynamics
- Knowledge of numerical analysis and algorithm development
- Knowledge of a high-level programming language (preferably Fortran)



4. Project details

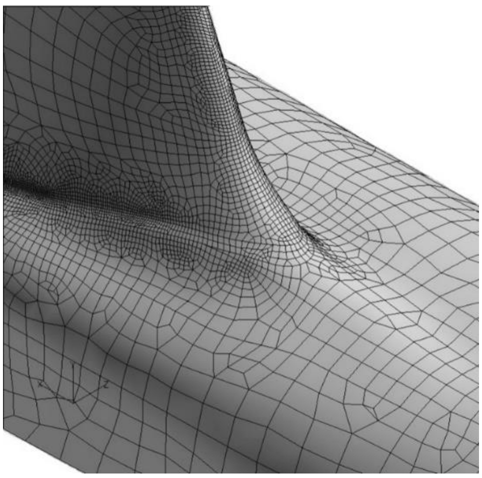
- The work will be carried out at University of Twente
- The duration will be 9 months

5. Literature

Some links to literature on surface gradients, panel methods, numerical approaches, and unstructured grid data structures:

- J. Katz, A. Plotkin, “*Low-Speed Aerodynamics*”, Cambridge University Press, 2001.
- A. van Garrel, “*Multilevel Panel Method for Wind Turbine Rotor Flow Simulation*”, PhD thesis, University of Twente, 2016.
- J. D’Elia, M. Storti, S. Idelsohn, “*Smoothed surface gradients for panel methods*”, 2000.
- T.S. Vaidyanathan, "*A flow analysis procedure based on velocity potentials*", paper AIAA-83-1818, 1983.
- E.D. Lutz, “*Systematic derivation of contour integration formulae for Laplace and elastostatic gradient BIE's*”, 1994.
- A. Syrakos, etal., “*A critical analysis of some popular methods for the discretisation of the gradient operator in finite volume methods*”, Physics of Fluids 29, 127103, 2017.
- Y-L. Shao, O.M. Faltinsen, "*Towards efficient fully-nonlinear potential-flow solvers in marine hydrodynamics*", Proceedings of the ASME 2012 31st International Conference on Ocean, Offshore and Arctic Engineering OMAE2012, 2012.
- W. Zhu, M. Greco, Y. Shao, "*Improved HPC method for nonlinear wave tank*", International Journal of Naval Architecture and Ocean Engineering, Volume 9, Issue 6, Pages 598-612, 2017.
- L. Guibas, J. Stolfi, “*Primitives for the manipulation of general subdivisions and the computation of Voronoi diagrams*”, ACM Transactions on Graphics, Vol. 4, No. 2, Pages 74-123, April 1985.
- P. Heckbert, “*Quad-Edge Data Structure and Library*”, Computer Graphics 2, 15-463, 2001.

6. Contact information



For details and general info please feel free to contact Dr.ir. Arne van Garrel:

E-mail a.vangarrel@utwente.nl
Phone +31 (0) 6 41161569