Proposal 2016-2017

Topic #4 - Development of an accelerated Discrete Vortex Method for unsteady aerodynamic and aeroelastic simulations of bluff-bodies

Contacts

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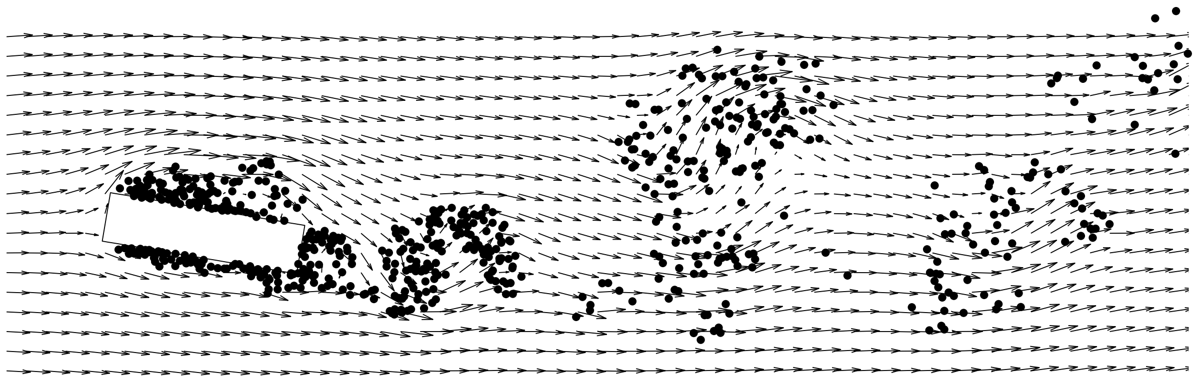
Context

The investigation of unsteady aerodynamics and aeroelastic behaviour of bluff-structures can be advantageously carried out using the Discrete Vortex Method (DVM). This method consists in a Lagrangian approach where discrete vortical particles are tracked after being shed from the surface of the body. As such, it does not require the meshing of the computational domain and, thus, constitutes an interesting alternative to classical CFD methods (e.g., finite volume), and is of great advantage for moving and/or deforming bodies.



The major drawback of the method is the relatively high computational cost of the velocity evaluation. In particular, the calculation of the displacement of the vortices induced by all other vortices requires the pairwise interaction of the N vortices, which amounts to $O(N^2)$ operations. In other words, the computational cost increases rapidly with the number of vortices used. Different acceleration techniques exist such as the Tree algorithm and the Fast Multipole method (FMM), which reduces the cost of the velocity calculation to O(N log N) or O(N) operations. This leads to a tremendous reduction in computation time.

The combined Tree algorithm and the FMM is a hierarchical method. It relies on four key features: (i) a specified accuracy, (ii) a hierarchical subdivision of space into panels/clusters of sources, (iii) a far-field expansion of a kernel, and (iv) the conversion of the far-field expansions into local expansions. As such, the method is only an approximation of the exact solution.

Objectives

The objective of this project is to implement a performant 2D DVM method in Matlab. In particular, the project will focus on the implementation of the Tree algorithm and the Fast Multipole Method for the velocity evaluation. Additionally, some of the core routines of the code could be translated into C and linked to Matlab through MEX-files to further increase the computational speed of the code. Finally, the implementation should be verified and validated on existing cases and available experimental measurements carried out at the Wind Tunnel Laboratory (Tr-PIV and unsteady pressure measurements).

Tasks

- Perform a literature survey
- Implement an 2D DVM code in Matlab
- Implement the new acceleration algorithm
- Test and demonstrate the improvement achieved by the new implementation
- Validate the code by performing comparisons with existing experimental measurements

Profile

The student must have some familiarity with fluid mechanics and Matlab, and be highly motivated. Following course is recommended:

- AERO0032 - Aeroelasticity and Experimental Aerodynamics (fall semester)

References

- Vortex methods for separated flows, P. R. Spalart, NASA Report 100068, 1988.
- Experimental and Numerical Investigation of Aeroelastic Stability of Bluff Structures, T. Andrianne, PhD thesis, 2012.
- The Rapid Evaluation of Potential Fields in Particle Systems, L. Greengard, MIT Press, Cambridge (1988).
- An Implementation of the Fast Multipole Method Without Multipoles, C.R. Anderson, SIAM J. Sci. Stat. Comput. 13, 923Ð947 (1992).