basque center for applied mathematics

Mathematical and computational challenges in aeronautics engineering: simulation and design

Lecturers: Francisco Palacios[1], Markus Widhalm[2]

Dates: 22–26 February 2010

Abstract:

In the past decade, Computational Fluid Dynamics (CFD) became a common tool in applied aeronautics where many different numerical techniques are currently used. The main areas are in the geometrical definition (CAD) of the model to be analyzed, the numerical solution of the flow field (Mesh generation and CFD) including grid adaptation and which can then be combined with other disciplines like shape optimization or structural analysis. The scientific area of CFD includes technical advances for accurate numerical methods for resolving flow phenomena, and realistic physical modeling of the flow itself. Further, the development of mathematical techniques to handle moving grids or surface deformations will require a deeper knowledge of the mathematical basis of the problem.

In this series of lectures we will give a better insight into the extended chain including the definition of geometrical data, grid generation, and flow solver, to compute the external flow around an aircraft. We will explain the overall procedures during the flow simulation and the used numerical algorithms in general. Additionally we will spend time on special subjects to focus on newer mathematical and computational challenges.

At first, we will derive the different formulations of flow equations used within an industrial flow solver. The second part deals with the geometrical data and grid generation. This part will be followed by the discretization in space and time. The final part shows applications and the difficulties that arise when dealing with real world problems.

Nevertheless, the presentation will give useful hints to handle complex flows and their setup for a successful solution and the mathematical basis behind the industrial application that allow further developments for complex applications for aeronautics.

The course is oriented to researchers with a basic background in the theory of Numerical resolution of Partial Differential Equations and computer programming.

Program:

1. Introduction to the flow equations (Euler equations and Reynolds averaged Navier-Stokes equations).
2. Grid Generation (structured grids vs. unstructured, problems and benefits when creating grids).
3. Introduction to space and time discretization in the aeronautical case.
4. Industrial applications.
5. Some ideas about the optimal shape design in aeronautics.

[1]ETSI Aeronáuticos. Madrid Polytechnic University (UPM). Plaza del Cardenal Cisneros, 3. 28040 Madrid - Spain. Email: fpalacios@gmail.com

[2]German Aerospace Center (DLR). Institute of Aerodynamics and Flow Technology. Center for Computer Applications in AeroSpace Science and Engineering ($C^2A^2S^2E$). Lilienthalplatz, 7. 38108 Braunschweig - Germany. Email: markus.widhalm@dlr.de

Bibliography:

[1] C. Castro, C. Lozano, F. Palacios, and E. Zuazua. A systematic continuous adjoint approach to viscous aerodynamic design on unstructured grids. *AIAA Journal* **45** (2007) 2125–2139.

[2] C. Hirsch. *Numerical computation of internal and external flows*. John Wiley and Sons, Inc., 1988.

[3] A. Jameson. The present status, challenges, and future developments in computational fluid dynamics. In AGARD, editor, Progress and challenges in CFD methods and algorithms, 1995.

[4] A. Jameson and J. C. Vassberg. Computational Fluid Dynamics for Aerodynamic Design: Its Current and Future Impact, AIAA 01-0538.

[5] R. J. LeVeque. *Numerical Methods for Conservation Laws*. Birkhäuser Verlag, 2006, Lectures in Mathematics.

[6] L. D. Landau and E. M. Lifshitz. *Fluid Mechanics*. 2nd Edition. Pergamon Press, 1993.

[7] B. Mohammadi and O. Pironneau. Shape optimization in fluid mechanics. *Annual Rev. Fluids Mechanics* **36** (2004) 255–279.

[8] A. Quarteroni and A. Valli. Numerical aproximation of partial differential equations, volume 23 of Springer series in computational mathematics. Springer-Verlag Berlin Heidelberg New York, 1997.

[9] E. F. Toro. *Riemann Solvers and Numerical Methods for Fluid Dynamics: a Practical Introduction*. Springer-Verlag, 1999.

[10] P. Wesseling. *Principles of computational fluid dynamics*. Vol. 29 of Springer series in computational mathematics. Springer-Verlag Berlin Heidelberg New York, 2000.