Solution Methods In Computational Fluid Dynamics

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Abstract

Implicit finite difference schemes for solving two dimensional and three dimensional Euler and Navier-Stokes equations will be addressed. The methods are demonstrated in fully vectorized codes for a CRAY type architecture. We shall concentrate on the Beam and Warming implicit approximate factorization algorithm in generalized coordinates. The methods are either time accurate or accelerated non-time accurate steady state schemes. Various acceleration and efficiency modifications such as matrix reduction, diagonalization and flux split schemes will be presented. Examples for 2-D inviscid and viscous calculations (e.g. airfoils with a deflected spoiler, circulation control airfoils and unsteady buffeting) and also 3-D viscous flow are included.

OUTLINE

Commentary, 1992

These notes were developed and put together in 1984-5 for a lecture series entitled "von Kármán Institute For Fluid Dynamics Lecture Series : Numerical Techniques for Viscous Flow Computation In Turbomachinery Bladings", von Kármán Institute, Rhode-St-Genese, Belgium , 1985. They may be a little dated today, but they still represent current algorithms and codes being used on a day to day basis for both research and development. I will update and correct some of the material, but I will not be attempting to completely modernize these lectures. Newer topics, e.g. TVD, ENO, are handled better in other forums and I will have to make my attempt at them some other time.

Finally, I would like to recognized the influence of one of my best friends and my mentor, Dr. Joseph L. Steger who passed away this year. I first met Joe in the early days of CFD at NASA Ames (circa 1974) when I started work on my thesis and Joe became my advisor. I consider myself Joe's first student and although Joe went on to teach at Stanford and U.C. Davis and produced many fine CFD researchers, I think my years with Joe will always be special since they were his and my first experiences as friends and teacher/student. Joseph Steger was a real pioneer for CFD, he did much of the ground breaking work in transonics and Euler/Navier-Stokes algorithms. I don't think he gets much credit for his transonic work, but if it wasn't for Joe many of the important advances made here at NASA Ames would never have happened. We always refer to the "Beam-Warming algorithm", but possibility it should be called the "Steger algorithm". Although, Beam and Warming can be credited with the initial development, Steger had much to do with the final developments and analysis. More importantly though, is the contribution Joe made in making the algorithm practical and popular. In 1976, Joe wrote what was then call AIR2D, based on the Beam-Warming algorithm and generalized coordinate transformations. That one effort has blossomed into the ARC2D and ARC3D codes and their subsequent impact on CFD today. Those kernels (gems of ideas) form the basis of most of the practical and useful codes in existence today. One only has to look anywhere in the literature to see that impact. Joe's other developments were equally as important to the whole picture. He developed elliptic grid generators (GRAPE) and hyperbolic grid generating algorithms. Joe can also be credited with producing the first practical Parabolized Navier-Stokes (PNS) codes and Incompressible Navier-Stokes (INS) based on psuedo-compressibility. His work on the Chimera approach for complicated geometry is currently the workhorse of computation here at NASA Ames and has been a significant part of the overall CFD effort. But besides all that, we really have suffered a great loss in losing Joe Steger, he always will be in my heart, his laugh and friendship are dear to me and I'm sure to all who knew him.