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Book Review

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Computational Aeroacoustics: A Wave Number Approach

C. K. W. Tam, Cambridge Aerospace Series, Vol. 33, Cambridge University Press, New York, 2012, 492 pp., $125.

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This is probably the first book entirely dedicated to computational aeroacoustics. The main achievements of Christopher Tam and his colleagues obtained since the 1990s in this field are presented in a structured way. The author has played a fundamental role by stimulating researchers for the development of accurate algorithms in aeroacoustics, especially through the co-organization of the four computational aeroacoustics workshops on benchmark problems [1–4]. These problems have now become numerical exercises that are widely used to evaluate the accuracy of computational codes.

The book is organized into 15 chapters, each including theoretical or computational problems. To begin, I will give an overview of the book. The first seven chapters constitute a part in which all of the basic ingredients required for solving the linearized Euler equations are presented. Explicit finite-difference equations in space are introduced in the first chapter. The concept of a dispersion-relation-preserving scheme is explained in the second chapter through the optimization of the spatial discretization in wave number space, by considering the group velocity. A similar study is performed for the time discretization in Chapter 3. A whole picture of the numerical dispersion and dissipation induced by space and time discretizations is then provided in Chapter 4. The finite-difference discretization of the linearized Euler equations are studied in Chapter 5 for a uniform mean flow to derive a dispersion relation analytically. A formulation of these equations in curvilinear coordinates is also briefly presented. Chapter 6 is devoted to the derivation and implementation of boundary conditions and, in particular, radiation and outflow boundary conditions. The last chapter of this first part introduces the filtering step, which must be associated with centered finite-difference schemes in space. As already mentioned in Chapter 4, the author recommends here to keep centered schemes and thus to remove short waves by means of a filter, again optimized in wave number space.

The second part gathers more advanced topics, such as nonlinear propagation in Chapter 8, or more subtle boundary conditions with the perfectly matched layer technique, for instance, in Chapter 9. The formulation of an impedance condition in the time domain is specifically studied in Chapter 10 with applications involving hard-wall splices in acoustic liners. Optimized one-dimensional extrapolation and interpolation schemes based on Lagrangian polynomials are considered in Chapter 11. In Chapter 12, optimized finite-difference schemes are generalized to multisize meshes to treat the interface between two domains where the grid size is doubled. In connection with Chapter 11, the overset grid approach is introduced in Chapter 13, and a multidimensional interpolation formulation is optimized. The extrapolation of the sound field to the far field is described in Chapter 14, and the adjoint Green's function is also introduced. Finally, general considerations are collected in Chapter 15 for the design of aeroacoustic simulation codes, including a short discussion about the simulation of turbulent flows. A number of appendices have been added, in particular a large one containing Fortran programs, which could be more useful to find in a website.

The outstanding teaching abilities of the author are recognizable in the text and figures of this book. The first part, as described above, is an excellent introduction to the properties of finite-difference algorithms, including boundary conditions for aeroacoustics in the same spirit as proposed by Trefethen [5] or Vichnevetsky and Bowles [6]. In the second part of the book, the reader can more easily jump into different covered topics and focus on a specific subject. Various exercises are proposed and can be extended as homework for graduate students. No specific prior knowledge is required, but a general understanding of applied mathematics and acoustics is assumed. In my opinion, the only thing missing is an overview of other contributions, also in connection with compact schemes, which would made the book more attractive to researchers. Finally, the scope of this book is not the simulation of compressible turbulent flows, but it can be noted that the numerical strategy established by the author can also be found in large-eddy simulation solvers based on compact or explicit filtering, which are currently used by several research teams.

In summary, this book is a good first course in computational aeroacoustics. All of the practical aspects necessary to design a finite-difference algorithm are examined, including advanced boundary conditions, and can be easily understood. For more expert readers, this is also a nice compilation of the main achievements of

Christopher Tam in this field, and a number of lessons learned can be adapted to other numerical frameworks. I definitely recommend this book for students and researchers in the field of aeroacoustics.

References

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Christophe Bailly
École Centrale de Lyon