An Adjoint Solver For An Industrial Cfd Code Via Automatic

Aerodynamic Shape Optimization of Complex Aircraft Configurations Via an Adjoint Formulation
Design and Development of Aerospace Vehicles and Propulsion Systems
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Topics in Modal Analysis, Volume 10
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Mesh Dependence in PDE-Constrained Optimisation
MEGAFLOW - Numerical Flow Simulation for Aircraft Design
Proceedings of SAROD 2018
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Computational Science and Its Applications - ICCSA 2006
Parallel Processing for Scientific Computing

DEANDRE DECKER

Aerodynamic Shape Optimization of Complex Aircraft Configurations Via an Adjoint Formulation
SIAM
"The adjoint method is an efficient approach to computing sensitivities, and has been successfully applied in many fields. However, this approach has not seen widespread acceptance for unsteady problems primarily due to very large storage requirements of present algorithms.

The fundamental challenge in unsteady adjoint approaches is the need to integrate the equations in reverse time, which requires all previous flow solutions to be available during the backwards integration. The straightforward treatment of storing all previous flow solutions is prohibitive for simulations with a large number of grid points and time steps. To alleviate this challenge, we propose to compress the flow solutions and store only the reduced bases and expansion coefficients. The flow solutions are recovered when needed in solving the unsteady adjoint equations. In this work, an unsteady discrete adjoint-based approach has been developed. Both continuous and discrete forms of the unsteady adjoint are presented and an adjoint solver based on the latter is validated against finite-difference based sensitivities. A novel adaptive-multi-window compression algorithm has been proposed, where the reduced bases are generated by solving a Proper Orthogonal Decomposition (POD) problem of a matrix consisting flow solutions within a time window. We propose an innovative algorithm that employs an error indicator to determine whether the current bases are sufficient to represent the solution at new time steps; thus saving both computational and storage cost. We apply the unsteady adjoint-based framework to evaluate sensitivity of functionals for turbulent flows in hydraulic turbine draft tubes. We conduct this research within a numerical framework based on the compressible Reynolds-averaged Navier-Stokes equations coupled with the stiffened gas equation of state to model incompressible flow, and a low-speed preconditioner to accelerate convergence. A secondary novel contribution, is an extended eddy-preserving limiter scheme to capture strong turbulent vortices within draft tubes. The numerical framework is first verified on three-dimensional vortex advection cases and then applied to flow simulations in a bulb turbine draft tube. Finally, sensitivities computed with the use of full and compressed flow solutions are compared to demonstrate the feasibility of the approach"--

Design and Development of Aerospace Vehicles and Propulsion Systems Springer Adjoint methods have found applications in several key areas of computational fluid dynamics (CFD), namely, shape optimization and goal based adaptive solutions. CFD has become an essential tool in the design process by enabling the rapid testing of multiple designs, and currently it is normal practice to use CFD in conjunction with optimization algorithms for design improvement. In the context of shape optimization problems based on CFD, adjoint methods offer the significant advantage of computing sensitivity derivatives of the optimization cost function with respect to the set of design parameters, at a cost that is essentially independent of the number of design parameters. Adjoint methods reduce the cost of obtaining the complete gradient vector at any point in the design space equivalent to that of a single flow solution at the same point in the design space. This immediately enables the use of all gradient based optimization algorithms and lifts any restrictions on the number of design parameters required for the adequate definition of the optimization problem. Adaptive techniques in CFD constitute the other aspect where adjoint methods have have made great inroads. Typical adaptive solutions of the governing flow equations rely on estimating the local error in an evolving solution to target regions of the computational mesh for increased discrete resolution. The main goal of any adaptive solution method is the overall increase in solution accuracy with minimal increase in computational cost. However, targeting local error in the solution does not translate into efficient use of computational resources, since ultimately it is the accurate estimation of boundary integrated functional quantities such as load coefficients that are of importance to the user. Contrary to local error-based methods, adjoint methods allow the adaptation of the computational mesh specifically for the improvement of functionals such as load coefficients. This is achieved by mathematically establishing a clear relationship between the functional of interest and the regions of the computational mesh that are most relevant to it. The current work extends the use of adjoint methods to multiple governing disciplines that are tightly coupled, and more importantly unsteady in nature. The adjoint method is derived in a very general form for the purpose of computing the gradient vector for use in shape optimization in the context of coupled multidisciplinary unsteady equations. It is shown that computing the gradient vector in unsteady problems involves solving the analysis problem forward in time and then solving the adjoint problem backward in time. While adjoint methods have been used successively to drive spatial mesh adaptation, the current work extends the use of the computed unsteady adjoint variables for estimating temporal discretization error, which is then applied to temporal mesh adaptation. Additionally, the computed adjoint variables are also used for the estimation of algebraic error in the solution arising due to intentional or nonintentional partial convergence of the governing equations. Results indicate that the adaptation of the temporal resolution and convergence tolerance limits using adjoint-based error estimates is able to outperform traditional adaptation methods such as uniform refinement and those based on local error estimates. All of the development is carried out in a fully unstructured mesh framework with dynamic deformation of the computational spatial mesh.

From Simulation to Optimization Springer Nature

"This work proposes a framework for fully-automatic gradient-based constrained aerodynamic shape optimization in a multistage turbomachinery environment. A turbomachinery solver which solves the Reynolds-averaged Navier-Stokes (RANS) equations to a steady-state in both rotating and stationary domains is developed. Characteristic-based inlet and outlet boundary conditions are imposed, while adjacent rotor and stator rows are coupled by mixing-plane interfaces. To allow for an efficient but accurate gradient calculation, the turbomachinery RANS solver is adjointed at a discrete level. The systematic approach for the development of the discrete adjoint solver is discussed. Special emphasis is put on the development of the turbomachinery specific features of the adjoint solver, i.e. on the derivation of flow-consistent adjoint inlet and outlet boundary conditions and, to allow for a concurrent rotor-stator optimization and stage coupling, on the development of an exact adjoint counterpart to the non-reflective, conservative mixing-plane formulation used in the flow solver. The adjoint solver is validated by comparing its sensitivities with finite-difference gradients obtained from the flow solver. A parallelized, automatic grid perturbation scheme utilizing radial basis functions, which is accurate and robust as well as able to handle complex multi-block grid configurations, is employed to calculate the gradient from the adjoint solution. A sequential quadratic programming algorithm is utilized to determine an improved blade shape based on the gradient information. The functionality of the proposed optimization method is demonstrated by the redesign of two different transonic compressor configurations. The design objective is to maximize the isentropic efficiency while constraining the mass flow rate and the total pressure ratio. The influence of the constraints on the design problem is investigated by comparing the results with those of an unconstrained optimization." -- *Proceedings of the 13th International Marine Design Conference (IMDC 2018), June 10-14, 2018, Helsinki, Finland* Springer Nature Design Optimization of Fluid Machinery: Applying Computational Fluid Dynamics and Numerical Optimization Drawing on extensive research and experience, this timely reference brings together numerical optimization methods for fluid machinery and its key industrial applications. It logically lays out the context required to understand computational fluid dynamics by introducing the basics of fluid mechanics, fluid machines and their components. Readers are then introduced to single and multi-objective optimization methods, automated optimization, surrogate models, and evolutionary algorithms. Finally, design approaches and applications in the areas of pumps, turbines, compressors, and other fluid machinery systems are clearly explained, with special emphasis on renewable energy systems. Written by an international team of leading experts in the field Brings together optimization methods using computational fluid dynamics for fluid machinery in one handy reference Features industrially important applications, with key sections on renewable energy systems Design Optimization of Fluid Machinery is an essential guide for graduate students, researchers, engineers working in fluid machinery and its optimization methods. It is a comprehensive reference text for advanced students in mechanical engineering and related fields of fluid dynamics and aerospace engineering.

Automatic Differentiation of Algorithms Springer Science & Business Media

14th International Conference on Turbochargers and Turbocharging addresses current and novel turbocharging system choices and components with a renewed emphasis to address the challenges posed by emission regulations and market trends. The contributions focus on the development of air management solutions and waste heat recovery ideas to support thermal propulsion systems leading to high thermal efficiency and low exhaust emissions. These can be in the form of internal combustion engines or other propulsion technologies (eg. Fuel cell) in both direct drive and hybridised configuration. 14th International Conference on Turbochargers and Turbocharging also provides a particular focus on turbochargers, superchargers, waste heat recovery turbines and related air managements components in both electrical and mechanical forms.

Adjoint Methods for Aerodynamic Shape Optimization Wiley-Blackwell

The five-volume set LNCS 3980-3984 constitutes the refereed proceedings of the International Conference on Computational Science and Its Applications, ICCSA 2006. The volumes present a total of 664 papers organized according to the five major conference themes: computational methods, algorithms and applications high performance technical computing and networks advanced and emerging applications geometric modelling, graphics and visualization information systems and information technologies. This is Part V.

Adjoint-based Constrained Aerodynamic Shape Optimization for Multistage Turbomachines Research & Education Assoc.

This study seeks to reduce the degree of uncertainty that often arises in computational fluid dynamics simulations about the computed accuracy of functional outputs. An error estimation methodology based on discrete adjoint sensitivity analysis is developed to provide a quantitative measure of the error in computed outputs. The developed procedure relates the local residual errors to the global error in output function via adjoint variables as weight functions. The three major steps in the error estimation methodology are: (1) development of adjoint sensitivity analysis capabilities; (2) development of an efficient error estimation procedure; (3) implementation of an output-based grid adaptive scheme. Each of these steps are investigated. For the first step, parallel discrete adjoint capabilities are developed for the variable Mach version of the U2NCLE flow solver. To compare and validate the implementation of adjoint solver, this study also develops direct sensitivity capabilities. A modification is proposed to the commonly used unstructured flux-limiters, specifically, those of Barth-Jespersen and Venkatakrishnan, to make them piecewise continuous and suitable for sensitivity analysis. A distributed-memory message-passing model is employed for the parallelization of sensitivity analysis solver and the consistency of linearization is demonstrated in sequential and parallel environments. In the second step, to compute the error estimates, the flow and adjoint solutions are prolongated from a coarse-mesh to a fine-mesh using the meshless Moving Least Squares (MLS) approximation. These error estimates are used as a correction to obtain highly-accurate functional outputs and as adaptive indicators in an iterative grid adaptive scheme to enhance the accuracy of the chosen output to a prescribed tolerance. For the third step, an output-based adaptive strategy that takes into account the error in both the primal (flow) and dual (adjoint) solutions is implemented. A second adaptive strategy based on physics-based feature detection is implemented to compare and demonstrate the robustness and effectiveness of the output-based adaptive approach. As part of the study, a general-element unstructured mesh adaptor employing h-refinement is developed using Python and C++. Error estimation and grid adaptation results are presented for inviscid, laminar and turbulent flows.

Contributions to the 19th STAB/DGLR Symposium Munich, Germany, 2014 CRC Press

An aerodynamic shape optimisation capability based on a discrete adjoint solver for Navier- Stokes flows is developed and applied to a Blended Wing-Body future transport aircraft. The optimisation is gradient-based and employs either directly a Sequential Quadratic

Programming optimiser or a variable-fidelity optimisation method that combines low- and high-fidelity models. The shape deformations are parameterised using a Bþezier-Bernstein formulation and the structured grid is automatically deformed to represent the design changes. The flow solver at the heart of this optimisation chain is a Reynolds averaged Navier- Stokes code for multiblock structured grids. It uses Osher approximate Riemann solver for accurate shock and boundary layer capturing, an implicit temporal discretisation and the algebraic turbulence model of Baldwin-Lomax. The discrete Navier-Stokes adjoint solver based on this CFD code shares the same implicit formulation but has to calculate accurately the flow Jacobian. This implies a linearisation of the Baldwin-Lomax model. The accuracy of the resulting adjoint solver is verified through comparison with finitedifference. The aerodynamic shape optimisation chain is applied to an aerofoil drag minimisation problem. This serves as a test case to try and reduce computing time by simplifying the fidelity of the model. The simplifications investigated include changing the convergence level of the adjoint solver, reducing the grid size and modifying the physical model of the adjoint solver independently or in the entire optimisation process. A feasible optimiser and the use of a penalty function are also tested. The variable-fidelity method proves to be the most ef- ficient formulation so it is employed for the three-dimensional optimisations in addition to parallelisation of the flow and adjoint solvers with OpenMP. A three-dimensional Navier-Stokes optimisation of the ONERA M6 wing is presented. After describing the concept of Blended Wing-Body and.

Results of the Second Phase of the German CFD Initiative MEGAFLOW, Presented During Its Closing Symposium at DLR, Braunschweig, Germany, December 10 and 11, 2002

Design Optimization of Periodic Flows Using a Time-spectral Discrete Adjoint MethodStandard methods for unsteady optimization carry heavy computational costs and large storage requirements, mostly due to the lengthy time integration involved in the unsteady flow simulations. Such difficulties limit its practical application to cases where the time integration is performed over only a smaller segment of the entire period. The result is a loss of accuracy in the representation of the physical model. For certain unsteady flows with periodicity, a dramatic reduction in both compu- tational cost and required storage is realized through implementing the Time Spectral method. Furthermore, by introducing an adjoint-based method as an alternative way of obtaining gradient information, computational cost is further reduced. This combi- nation of Time-Spectral and adjoint-based methodology therefore allows for unsteady optimization within a reasonable time frame while maintaining accuracy. In this dissertation, the Discrete Adjoint method is implemented and applied to unsteady flows with periodicity, in the context of the Time Spectral Method. The acquired adjoint gradient information is fed into an optimizer and truly unsteady optimization work is carried out for the first time on a realistic test case. The devel- opment and implementation of necessary boundary conditions prove crucial for the successful implementation of the Discrete Adjoint method. As a simple test case, the NACA 0012 airfoil is selected for simulation in steady inviscid, unsteady inviscid, steady viscous, and unsteady viscous flows. In each case, the resulting gradient information obtained from both the adjoint and finite difference method is compared. Upon completion of the airfoil test case, the adjoint-based method is applied to a helicopter blades, UH60, for both steady and unstaedy inviscid flows. The gradient information obtained by the adjoint-based method shows good agreement with the conventional, Finite Difference gradient information. The design methodology was developed for a single processor, however, multi-processor capability is also implemented. In order to accommodate realistic meshes, multi-block capability is added as well. With all of the necessary components implemented, optimization is carried out on the UH60 helicopter blade. The objective function is time-averaged torque over all time instances and the optimized result shows an improvement of 5 % over the current configuration. Stanford University Multi-block (SUmb), while implementing the unsteady Reynolds-Averaged Navier Stokes equations with multi-block and multi-processor algorithms, is the chosen flow solver. PETSc is employed as the adjoint solver. Successful implementation of the Discrete Adjoint method to unsteady fluids with periodicity provides the gradient information more easilty than the traditional finite difference method which is hindered by its heavy computational cost and large storage requirements. This research establishes a new optimization methodology which utilizes Discrete Adjoint gradient information derived from flow solutions, obtained using the Time Spectral method.Aerodynamic Shape Optimization of Complex Aircraft Configurations Via an Adjoint FormulationAbstract: "This work describes the implementation of optimization techniques based on control theory for complex aircraft configurations. Here control theory is employed to derive the adjoint differential equations, the solution of which allows for a drastic reduction in computational costs over previous design methods [13, 12, 43, 38]. In our earlier studies [19, 20, 22, 23, 39, 25, 40, 41, 42] it was shown that this method could be used to devise effective optimization procedures for airfoils, wings and wing-bodies subject to either analytic or arbitrary meshes. Design formulations for both potential flows and flows governed by the Euler equations have been demonstrated, showing that such methods can be devised for various governing equations [39, 25]. In our most recent works [40, 42] the method was extended to treat wing-body configurations with a large number of mesh points, verifying that significant computational savings can be gained for practical design problems. In this paper the method is extended for the Euler equations to treat complete aircraft configurations via a new multiblock implementation. New elements include a multiblock-multigrid flow solver, a multiblock-multigrid adjoint solver, and a multiblock mesh perturbation scheme. Two design examples are presented in which the new method is used for the wing redesign of a transonic business jet."A Discrete Navier-Stokes Adjoint Method for Aerodynamic Optimisation of BlendedWing-Body ConfigurationsAn aerodynamic shape optimisation capability based on a discrete adjoint solver for Navier- Stokes flows is developed and applied to a Blended Wing-Body future transport aircraft. The optimisation is gradient-based and employs either directly a Sequential Quadratic Programming optimiser or a variable-fidelity optimisation method that combines low- and high-fidelity models. The shape deformations are parameterised using a Bþezier-Bernstein formulation and the structured grid is automatically deformed to represent the design changes. The flow solver at the heart of this optimisation chain is a Reynolds averaged Navier- Stokes code for multiblock structured grids. It uses Osher approximate Riemann solver for accurate shock and boundary layer capturing, an implicit temporal discretisation and the algebraic turbulence model of Baldwin-Lomax. The discrete Navier-Stokes adjoint solver based on this CFD code shares the same implicit formulation but has to calculate accurately the flow Jacobian. This implies a linearisation of the Baldwin-Lomax model. The accuracy of the resulting adjoint solver is verified through comparison with finitedifference. The aerodynamic shape optimisation chain is applied to an aerofoil drag minimisation problem. This serves as a test case to try and reduce computing time by simplifying the fidelity of the model. The simplifications investigated include changing the convergence level of the adjoint solver, reducing the grid size and modifying the physical model of the adjoint solver independently or in the entire optimisation process. A feasible optimiser and the use of a penalty function are also tested. The variable-fidelity method proves to be the most ef- ficient formulation so it is employed for the three-dimensional optimisations in addition to parallelisation of the flow and adjoint solvers with OpenMP. A three-dimensional Navier-Stokes optimisation of the ONERA M6 wing is presented. After describing the concept of Blended Wing-Body and.Robust and Stable Discrete Adjoint Solver Development for Shape Optimisation of Incompressible Flows with Industrial ApplicationsEstimation of Precursors for Extreme Events Using the Adjoint Based Optimization ApproachWe formulate a generalized optimization problem for a non-linear dynamical system governed by a set of differential equations. The plant under focus is the 2-D Kolmogorov flow, as this flow has inherent turbulence which would give rise to chaos and intermittent bursts in a selected observable. As a first step, an observable with potential extreme events in its time series is selected. In our case, we choose the kinetic energy of the flow field as the observable under study. The next step is to derive the adjoint equations for the kinetic energy that is the quantity of interest with the velocity field as the optimizing variable. This obtained velocity field forms the precursor for extreme events in the kinetic energy. The prediction capabilities for this precursor are then explored in more detail. The goal is to select the precursor such that it predicts the extreme events in a given time horizon which can generate warning signals effectively. We also present a coupled flow solver in Nek5000 and adjoint solver in MATLAB, the latter can be applied to any dynamical system to study the extreme events and obtain the relevant precursor. In a consecutive section, the results for extreme events in the kinetic energy and the lift coefficient for the flow over a 2-D airfoil are presented. As part of future work, the implementation and application of the solver for the flow past the airfoil and over a 3-D Ahmed body are proposed.Automatic Mesh Adaptation Using the Continuous Adjoint Approach and the Spectral Difference MethodIn this thesis, mesh adaptation using continuous adjoint is tested on two-dimensional Euler equations. Both the flow solver and the adjoint solver are implemented with the high order spectral difference (SD) method. Both h and p adaptation are studied. The test cases include a half-cylinder in subsonic flow and a NACA 0012 airfoil in subsonic and transonic flows. It is found that h-refinement is more suitable for flow discontinuities while p-refinement offers a better performance in smooth flows. Both adaptation methods lead to a faster functional convergence than uniformly h or p refined meshes. In addition, the adapted meshes show similar patterns as those arrived at using the discrete adjoint method. Comparisons between different adjoint target output functionals are also made.Adjoint-based Constrained Aerodynamic Shape Optimization for Multistage Turbomachines"This work proposes a framework for fully-automatic gradient-based constrained aerodynamic shape optimization in a multistage turbomachinery environment. A turbomachinery solver which solves the Reynolds-averaged Navier-Stokes (RANS) equations to a steady-state in both rotating and stationary domains is developed. Characteristic-based inlet and outlet boundary conditions are imposed, while adjacent rotor and stator rows are coupled by mixing-plane interfaces. To allow for an efficient but accurate gradient calculation, the turbomachinery RANS solver is adjointed at a discrete level. The systematic approach for the development of the discrete adjoint solver is discussed. Special emphasis is put on the development of the turbomachinery specific features of the adjoint solver, i.e. on the derivation of flow-consistent adjoint inlet and outlet boundary conditions and, to allow for a concurrent rotor-stator optimization and stage coupling, on the development of an exact adjoint counterpart to the non-reflective, conservative mixing-plane formulation used in the flow solver. The adjoint solver is validated by comparing its sensitivities with finite-difference gradients obtained from the flow solver. A parallelized, automatic grid perturbation scheme utilizing radial basis functions, which is accurate and robust as well as able to handle complex multi-block grid configurations, is employed to calculate the gradient from the adjoint solution. A sequential quadratic programming algorithm is utilized to determine an improved blade shape based on the gradient information. The functionality of the proposed optimization method is demonstrated by the redesign of two different transonic compressor configurations. The design objective is to maximize the isentropic efficiency while constraining the mass flow rate and the total pressure ratio. The influence of the constraints on the design problem is investigated by comparing the results with those of an unconstrained optimization." --The Second-Order Adjoint Sensitivity Analysis Methodology

Marine Design XIII collects the contributions to the 13th International Marine Design Conference (IMDC 2018, Espoo, Finland, 10-14 June 2018). The aim of this IMDC series of conferences is to promote all aspects of marine design as an engineering discipline. The focus is on key design challenges and opportunities in the area of current maritime technologies and markets, with special emphasis on: • Challenges in merging ship design and marine applications of experience-based industrial design • Digitalisation as technological enabler for stronger link between efficient design, operations and maintenance in future

• Emerging technologies and their impact on future designs • Cruise ship and icebreaker designs including fleet compositions to meet new market demands To reflect on the conference focus, Marine Design XIII covers the following research topic series: •State of art ship design principles - education, design methodology, structural design, hydrodynamic design; •Cutting edge ship designs and operations - ship concept design, risk and safety, arctic design, autonomous ships; •Energy efficiency and propulsions - energy efficiency, hull form design, propulsion equipment design; •Wider marine designs and practices - navy ships, offshore and wind farms and production. Marine Design XIII contains 2 state-of-the-art reports on design methodologies and cruise ships design, and 4 keynote papers on new directions for vessel design practices and tools, digital maritime traffic, naval ship designs, and new tanker design for arctic. Marine Design XIII will be of interest to academics and professionals in maritime technologies and marine design.

The Second-Order Adjoint Sensitivity Analysis Methodology

Springer

In this thesis, mesh adaptation using continuous adjoint is tested on two-dimensional Euler equations. Both the flow solver and the adjoint solver are implemented with the high order spectral difference (SD) method. Both h and p adaptation are studied. The test cases include a half-cylinder in subsonic flow and a NACA 0012 airfoil in subsonic and transonic flows. It is found that h-refinement is more suitable for flow discontinuities while p-refinement offers a better performance in smooth flows. Both adaptation methods lead to a faster functional convergence than uniformly h or p refined meshes. In addition, the adapted meshes show similar patterns as those arrived at using the discrete adjoint method. Comparisons between different adjoint target output functionals are also made.

An Efficient Numerical Framework for Sensitivity Analysis for Unsteady Flows

Elsevier

Topics in Modal Analysis, Volume 10: Proceedings of the 33rd IMAC, A Conference and Exposition on Structural Dynamics, 2015, the tenth volume of ten from the Conference brings together contributions to this important area of research and engineering. The collection presents early findings and case studies on fundamental and applied aspects of Structural Dynamics, including papers on: Experimental Techniques Processing Modal Data Rotating Machinery Acoustics Adaptive Structures

Biodynamics Damping Differential Equations Problem Solver CRC Press

Design Optimization of Periodic Flows Using a Time-spectral Discrete Adjoint Method

Results of the closing symposium of the MEGADESIGN and MegaOpt projects, Braunschweig, Germany, May 23 and 24, 2007

Springer Science & Business Media

A survey book focusing on the key relationships and synergies between automatic differentiation (AD) tools and other software tools, such as compilers and parallelizers, as well as their applications. The key objective is to survey the field and present the recent developments. In doing so the topics covered shed light on a variety of perspectives. They reflect the mathematical aspects, such as the differentiation of iterative processes, and the analysis of nonsmooth code. They cover the scientific programming aspects, such as the use of adjoints in optimization and the propagation of rounding errors. They also cover "implementation" problems.

MEGADESIGN and MegaOpt - German Initiatives for Aerodynamic Simulation and Optimization in Aircraft Design Springer

This volume contains the contributions to the 17th Symposium of STAB (German Aerospace

Aerodynamics Association). STAB includes German scientists and engineers from universities, research establishments and industry doing research and project work in numerical and experimental fluid mechanics and aerodynamics, mainly for aerospace but also for other applications. Many of the contributions collected in this book present results from national and European Community sponsored projects. This volume gives a broad overview of the ongoing work in this field in Germany and spans a wide range of topics: airplane aerodynamics, multidisciplinary optimization and new configurations, hypersonic flows and aerothermodynamics, flow control (drag reduction and laminar flow control), rotorcraft aerodynamics, aeroelasticity and structural dynamics, numerical simulation, experimental simulation and test techniques, aeroacoustics as well as the new fields of biomedical flows, convective flows, aerodynamics and acoustics of high-speed trains.

Automatic Mesh Adaptation Using the Continuous Adjoint Approach and the Spectral Difference Method Elsevier

Parallel processing has been an enabling technology in scientific computing for more than 20 years. This book is the first in-depth discussion of parallel computing in

10 years; it reflects the mix of topics that mathematicians, computer scientists, and computational scientists focus on to make parallel processing effective for scientific problems. Presently, the impact of parallel processing on scientific computing varies greatly across disciplines, but it plays a vital role in most problem domains and is absolutely essential in many of them. Parallel Processing for Scientific Computing is divided into four parts: The first concerns performance modeling, analysis, and optimization; the second focuses on parallel algorithms and software for an array of problems common to many modeling and simulation applications; the third emphasizes tools and environments that can ease and enhance the process of application development; and the fourth provides a sampling of applications that require parallel computing for scaling to solve larger and realistic models that can advance science and engineering.

Marine Design XIII

Springer Science & Business Media

We formulate a generalized optimization problem for a non-linear dynamical system governed by a set of differential equations. The plant under focus is the 2-D Kolmogorov flow, as this flow has inherent turbulence which would give rise to chaos and intermittent bursts in a selected observable.

As a first step, an observable with potential extreme events in its time series is selected. In our case, we choose the kinetic energy of the flow field as the observable under study. The next step is to derive the adjoint equations for the kinetic energy that is the quantity of interest with the velocity field as the optimizing variable. This obtained velocity field forms the precursor for extreme events in the kinetic energy. The prediction capabilities for this precursor are then explored in more detail. The goal is to select the precursor such that it predicts the extreme events in a given time horizon which can generate warning signals effectively. We also present a coupled flow solver in Nek5000 and adjoint solver in MATLAB, the latter can be applied to any dynamical system to study the extreme events and obtain the relevant precursor. In a consecutive section, the results for extreme events in the kinetic energy and the lift coefficient for the flow over a 2-D airfoil are presented. As part of future work, the implementation and application of the solver for the flow past the airfoil and over a 3-D Ahmed body are proposed.

Implementations and Experiences on Large Scale and Grid Computing Research & Education Assoc.
At the 19th Annual Conference on Parallel Computational Fluid Dynamics held in

Antalya, Turkey, in May 2007, the most recent developments and implementations of large-scale and grid computing were presented. This book, comprised of the invited and selected papers of this conference, details those advances, which are of particular interest to CFD and CFD-related communities. It also offers the results related to applications of various scientific and engineering problems involving flows and flow-related topics. Intended for CFD researchers and graduate students, this book is a state-of-the-art presentation of the relevant methodology and implementation techniques of large-scale computing.

Inverse Problems in Engineering Mechanics

Springer Science & Business Media

This book presents contributions to the 19th biannual symposium of the German Aerospace Aerodynamics Association (STAB) and the German Society for Aeronautics and Astronautics (DGLR). The individual chapters reflect ongoing research conducted by the STAB members in the field of numerical and experimental fluid mechanics and aerodynamics, mainly for (but not limited to) aerospace applications, and cover both nationally and EC-funded projects. Special emphasis is given to collaborative research projects conducted by German scientists and engineers from universities, research-establishments and industries. By addressing a number of cutting-edge applications, together with the relevant physical and mathematics fundamentals, the book provides readers with a comprehensive overview of the current research work in the field. Though the book's primary emphasis is on the aerospace context, it also addresses further important applications, e.g. in ground transportation and energy.

An Application in Tidal Turbine Array Layouts Elsevier

With the rapid growth of aircraft traffic and the new modes of transport such as Urban Air Mobility systems crowding the air space, aircraft noise is no longer a mere design constraint but an important factor to design and optimize for. Reducing aircraft noise however requires efficient coupling of simulation tools with design methods to be able to meet the stringent future aircraft noise requirements that allow for sustainable growth. Gradient-based design optimization based on adjoint method for sensitivity analysis offers a feasible design approach. Adjoint methods based on steady state physics have been widely in practice in industrial applications mainly for aerodynamic optimization so far. However, extending this approach to aeroacoustic optimization is not straightforward and not a common practice in industrial settings due the requirement of unsteady adjoint solutions that is prohibitively expensive. This dissertation presents temporal and spatial coarsening techniques for the computation of low-cost unsteady adjoints to obtain sensitivities for aeroacoustic shape optimization. The effects of the coarsening techniques on the accuracy of the gradients are analyzed by using different levels of temporal and spatial coarsening using multiple two dimensional and three dimensional test cases. Computational cost savings as well as reduction of memory storage requirements up to 10% of the base adjoint solutions are presented while maintaining reasonable accuracy in the gradients driving the optimization for these test cases. Finally, an extension to the temporal coarsening technique is proposed with non-uniform time stepping of adjoint solver based on the local flow truncation error estimates of the flow solver. The proposed extension is demonstrated to further improve the accuracy of the low-cost gradients providing motivations for the future directions of the work done in this thesis.

Some New Directions in Science on Computers

Springer Science & Business Media

Abstract: "This work describes the

implementation of optimization techniques based on control theory for complex aircraft configurations. Here control theory is employed to derive the adjoint differential equations, the solution of which allows for a drastic reduction in computational costs over previous design methods [13, 12, 43, 38]. In our earlier studies [19, 20, 22, 23, 39, 25, 40, 41, 42] it was shown that this method could be used to devise effective optimization procedures for airfoils, wings and wing-bodies subject to either analytic or arbitrary meshes. Design formulations for both potential flows and flows governed by the Euler equations have been demonstrated, showing that such methods can be devised for various governing equations [39, 25]. In our most recent works [40, 42] the method was extended to treat wing-body configurations with a large number of mesh points, verifying that significant computational savings can be gained for practical design problems. In this paper the method is extended for the Euler equations to treat complete aircraft configurations via a new multiblock implementation. New elements include a multiblock-multigrid flow solver, a multiblock-multigrid adjoint solver, and a multiblock mesh perturbation scheme. Two design examples are presented in which the new method is used for the wing redesign of a transonic business jet."

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