An Adjoint Solver For An Industrial Cfd Code Via Automatic

BRIANA AHMED

MEGADESIGN and MegaOpt - German Initiatives for Aerodynamic Simulation and Optimization in Aircraft Design Elsevier
This master thesis investigated the applicability of the Hicks-Henne bump functions and Free-Form Deformation as shape deformation methods used for aerodynamic shape optimization by the adjoint method. In order to alleviate user effort in the setup of simulations and post-processing of results, a MatLab framework has been developed. This framework integrated shape definition, meshing, file management, flow solver and post-processing tools. The external tools were open-source software. to allow the use of arbitrary cell and processor core numbers. The computational fluid dynamics solver, SU2 was used to obtain direct flow and adjoint solutions and to perform shape deformations using the built in nonlinear constrained optimization function. Automatic mesh generation was done using GMSH. The thesis focused on inviscid and viscous 2D problems in the transonic and supersonic flow regimes. The definition of the initial aerodynamic shapes was done using the Class-Shape Transformation method. The test cases optimization problems with the NACA0012 airfoil as the initial airfoil for deformation, with drag reduction as the objective function. The test cases involved different constraints e.g. airfoil thickness, lift coefficient and pitching moment coefficient. Comparisons were made between the two methods in terms of performance in the minimization of the objective function. The results of the optimization problems were compared to reference airfoils from literature. Both deformation methods proved to be effective, clear superiority of one method over the other could not be shown.*****This master thesis investigated the applicability of the Hicks-Henne bump functions and Free-Form Deformation as shape deformation methods used for aerodynamic shape optimization by the adjoint method. In order to alleviate user effort in the setup of simulations and post-processing of results, a MatLab framework has been developed. This framework integrated shape definition, meshing, file manage

Computational Science and Engineering SIAM
This is volume 1 of a 2-volume set. 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.

Proceedings of the 13th International Marine Design Conference (IMDC 2018), June 10-14, 2018, Helsinki, Finland CRC Press

This book presents selected papers presented in the Symposium on Applied Aerodynamics and Design of Aerospace Vehicles (SAROD 2018), which was jointly organized by Aeronautical Development Agency (the nodal agency for the design and development of combat aircraft in India), Gas-Turbine Research Establishment (responsible for design and development of gas turbine engines for military applications), and CSIR-National Aerospace Laboratories (involved in major aerospace programs in the country such as SARAS program, LCA, Space Launch Vehicles, Missiles and UAVs). It brings together experiences of aerodynamicists in India as well as abroad in Aerospace Vehicle Design, Gas Turbine Engines, Missiles and related areas. It is a useful volume for researchers, professionals and students interested in diversified areas of aerospace engineering.

A Coupled-adjoint Method for High-fidelity Aero-structural Optimization Research & Education Assoc.

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.

Proceedings of the 13th International Marine Design Conference (IMDC 2018), June 10-14, 2018, Helsinki, Finland 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.

Proceedings of the International Conference on Turbochargers and Turbocharging (London, UK, 2021) Research & Education Assoc.

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.

MEGAFLOW - Numerical Flow Simulation for Aircraft Design Springer Science & Business Media

Each Problem Solver is an insightful and essential study and solution guide chock-full of clear, concise problem-solving gems. All your questions can be found in one convenient source from one of the most trusted names in reference solution guides. More useful, more practical, and more informative, these study aids are the best review books and textbook companions available. Nothing remotely as comprehensive or as helpful exists in their subject anywhere. Perfect for undergraduate and graduate studies. Here in this highly useful reference is the finest overview of differential equations currently available, with hundreds of differential equations problems that cover everything from integrating factors and Bernoulli's equation to variation of parameters and undetermined coefficients. Each problem is clearly solved with step-by-step detailed solutions. DETAILS - The PROBLEM SOLVERS are unique - the ultimate in study guides. - They are ideal for helping students cope with the toughest subjects. - They greatly simplify study and learning tasks. - They enable students to come to grips with difficult problems by showing them the way, step-by-step, toward solving problems. As a result, they save hours of frustration and time spent on groping for answers and understanding. - They cover material ranging from the elementary to the advanced in each subject. - They work exceptionally well with any text in its field. - PROBLEM SOLVERS are available in 41 subjects. - Each PROBLEM SOLVER is prepared by supremely knowledgeable experts. - Most are over 1000 pages. - PROBLEM SOLVERS are not meant to be read cover to cover. They offer whatever may be needed at a given time. An excellent index helps to locate specific problems rapidly. 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Circuits Simple Circuits RL Circuits RC Circuits LC Circuits Complex Networks Chapter 23: Power Series Some Simple Power Series Solutions May Be Expanded Finding Power Series Solutions Power Series Solutions for Initial Value Problems Chapter 24: Power Series about an Ordinary Point Initial Value Problems Special Equations Taylor Series Solution to Initial Value Problem Chapter 25: Power Series about a Singular Point Singular Points and Indicial Equations Frobenius Method Modified Frobenius Method Indicial Roots: Equal Special Equations Chapter 26: Laplace Transforms Exponential Order Simple Functions Combination of Simple Functions Definite Integral Step Functions Periodic Functions Chapter 27: Inverse Laplace Transforms Partial Fractions Completing the Square Infinite Series Convolution Chapter 28: Solving Initial Value Problems by Laplace Transforms Solutions of First Order Initial Value Problems Solutions of Second Order Initial Value Problems Solutions of Initial Value Problems 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Matrix Solving Systems by Matrix Methods Chapter 34: Simultaneous Linear Differential Equations Definitions Solutions of 2 x 2 Systems Checking Solution and Linear Independence in Matrix Form Solution of 3 x 3 Homogenous System Solution of Non-homogenous System Chapter 35: Method of Perturbation Chapter 36: Non-Linear Differential Equations Reduction of Order Dependent Variable Missing Independent Variable Missing Dependent and Independent Variable Missing Factorization Critical Points Linear Systems Non-Linear Systems Liapunov Function Analysis Second Order Equation Perturbation Series Chapter 37: Approximation Techniques Graphical Methods Successive Approximation Euler's Method Modified Euler's Method Chapter 38: Partial Differential Equations Solutions of General Partial Differential Equations Heat Equation Laplace's Equation One-Dimensional Wave Equation Chapter 39: Calculus of Variations Index WHAT THIS BOOK IS FOR Students have generally found differential equations a difficult subject to understand and learn. Despite the pub.

From Simulation to Optimization CRC Press

"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." --

Application of the Discrete Adjoint Method to Coupled Multidisciplinary Unsteady Flow Problems for Error Estimation and Optimization Elsevier

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.

Estimation of Precursors for Extreme Events Using the Adjoint Based Optimization Approach World Scientific

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.

Adjoint-based Constrained Aerodynamic Shape Optimization for Multistage Turbomachines Wellesley-Cambridge Press

The aerospace industry increasingly relies on advanced numerical simulation tools in the early design phase. This volume provides the results of a German initiative which combines many of the CFD development activities from the German Aerospace Center (DLR), universities, and aircraft industry. Numerical algorithms for structured and hybrid Navier-Stokes solvers are presented in detail. The capabilities of the software for complex industrial applications are demonstrated.

Adjoint Methods for Aerodynamic Shape Optimization Springer

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 Springer

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.

Contributions to the 17th STAB/DGLR Symposium Berlin, Germany 2010 CRC Press

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.

Elsevier

Encompasses the full range of computational science and engineering from modelling to solution, both analytical and numerical. It develops a framework for the equations and numerical methods of applied mathematics. Gilbert Strang has taught this material to thousands of engineers and scientists (and many more on MIT's OpenCourseWare 18.085-6). His experience is seen in his clear explanations, wide range of examples, and teaching method. The book is solution-based and not formula-based: it integrates analysis and algorithms and MATLAB codes to explain each topic as effectively as possible. The topics include applied linear algebra and fast solvers, differential equations with finite differences and finite elements, Fourier analysis and optimization. This book also serves as a reference for the whole community of computational scientists and engineers. Supporting resources, including MATLAB codes, problem solutions and video lectures from Gilbert Strang's 18.085 courses at MIT, are provided at math.mit.edu/cse.

Implementations and Experiences on Large Scale and Grid Computing 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 im- plemented, 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 stor- age 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

The Second-Order Adjoint Sensitivity Analysis Methodology generalizes the First-Order Theory presented in the author’s previous books published by CRC Press. This breakthrough has many applications in sensitivity and uncertainty analysis, optimization, data assimilation, model calibration, and reducing uncertainties in model predictions. The book has many illustrative examples that will help readers understand the complexity of the subject and will enable them to apply this methodology to problems in their own fields. Highlights: • Covers a wide range of needs, from graduate students to advanced researchers • Provides a text positioned to be the primary reference for high-order sensitivity and uncertainty analysis • Applies to all fields involving numerical modeling, optimization, quantification of sensitivities in direct and inverse problems in the presence of uncertainties. About the Author: Dan Gabriel Cacuci is a South Carolina SmartState Endowed Chair Professor and the Director of the Center for Nuclear Science and Energy, Department of Mechanical Engineering at the University of South Carolina. He has a Ph.D. in Applied Physics, Mechanical and Nuclear Engineering from Columbia University. He is also the recipient of many awards including four honorary doctorates, the Ernest Orlando Lawrence Memorial award from the U.S. Dept. of Energy and the Arthur Holly Compton, Eugene P. Wigner and the Glenn Seaborg Awards from the American Nuclear Society.

Proceedings of the 33rd IMAC, A Conference and Exposition on Structural Dynamics, 2015 Springer Science & Business Media

This book provides an introduction to PDE-constrained optimisation using finite elements and the adjoint approach. The practical impact of the mathematical insights presented here are demonstrated using the realistic scenario of the optimal placement of marine power turbines, thereby illustrating the real-world relevance of best-practice Hilbert space aware approaches to PDE-constrained optimisation problems. Many optimisation problems that arise in a real-world context are constrained by partial differential equations (PDEs). That is, the system whose configuration is to be optimised follows physical laws given by PDEs. This book describes general Hilbert space formulations of optimisation algorithms, thereby facilitating optimisations whose controls are functions of space. It demonstrates the importance of methods that respect the Hilbert space structure of the problem by analysing the mathematical drawbacks of failing to do so. The approaches considered are illustrated using the optimisation problem arising in tidal array layouts mentioned above. This book will be useful to readers from engineering, computer science, mathematics and physics backgrounds interested in PDE-constrained optimisation and their real-world applications.

Contributions to the 19th STAB/DGLR Symposium Munich, Germany, 2014 Springer Science & Business Media

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.

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."

Low-cost Unsteady Discrete Adjoint Techniques for Aeroacoustic Optimization CRC Press

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.