An Adjoint Solver For An Industrial Cfd Code Via Automatic

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PEREZ PATRICIA

Differential Equations Problem Solver
Research & Education Assoc.
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.

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 Equations and Perturbation Algorithms in Nonlinear Problems BoD – Books on Demand

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.

Monte Carlo and Quasi-Monte Carlo Methods John Wiley & Sons

This volume contains the articles presented at the 22nd International Meshing Roundtable (IMR) organized, in part, by Sandia National Laboratories and was held on Oct 13-16, 2013 in Orlando, Florida, USA. The first IMR was held in 1992, and the conference series has been held annually since. Each year the IMR brings together researchers, developers, and application experts in a variety of disciplines, from all over the world, to present and discuss ideas on mesh generation and related topics. The technical papers in this volume present theoretical and novel ideas and algorithms with practical potential, as well as technical applications in science and engineering, geometric modeling, computer graphics and visualization.

Semismooth Newton Methods for Variational Inequalities and Constrained Optimization Problems in Function Spaces CRC Press

This book contains thirty-five selected papers presented at the International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control with Applications to Industrial and Societal Problems (EUROGEN 2017). This was one of the Thematic Conferences of the European Community on Computational Methods in Applied Sciences (ECCOMAS). Topics treated in the various chapters reflect the state of the art in theoretical and numerical methods and tools for optimization, and engineering design and societal applications. The volume focuses particularly on intelligent systems for multidisciplinary design optimization (mdo) problems based on multi-hybridized software, adjoint-based and one-shot methods, uncertainty quantification and optimization, multidisciplinary design optimization, applications of game theory to industrial optimization problems, applications in structural and civil engineering optimum design and surrogate models based optimization methods in aerodynamic design.

A Discrete Navier-Stokes Adjoint Method for Aerodynamic Optimisation of BlendedWing-Body Configurations SIAM

This book explores the outcomes on flow control research activities carried out within the framework of two EU-funded projects focused on training-through-research of Marie Sklodowska-Curie doctoral students. The main goal of the projects described in this monograph is to assess the potential of the passive- and active-flow control methods for reduction of fuel consumption by a helicopter. The research scope encompasses the fields of structural dynamics, fluid flow dynamics, and actuators with control. Research featured in this volume demonstrates an experimental and numerical approach with a strong emphasis on the verification and validation of numerical models. The book is ideal for engineers, students, and researchers interested in the multidisciplinary field of flow control.

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

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.

Parallel Processing for Scientific Computing Springer Science & Business Media

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 Mesh Adaptation Using the Continuous Adjoint Approach and the Spectral Difference Method Springer Science & Business Media

The proceedings represent the state of knowledge in the area of algorithmic differentiation (AD). The 31 contributed papers presented at the AD2012 conference cover the application of AD to many areas in science and engineering as well as aspects of AD theory and its implementation in tools. For all papers the referees, selected from the program committee and the greater community, as well as the editors have emphasized accessibility of the presented ideas also to non-AD experts. In the AD tools arena new implementations are introduced covering, for example, Java and graphical modeling environments or join the set of existing tools for Fortran. New developments in AD algorithms target the efficiency of matrix-operation derivatives, detection and exploitation of sparsity, partial separability, the treatment of nonsmooth functions, and other high-level mathematical aspects of the numerical computations to be differentiated. Applications stem from the Earth sciences, nuclear engineering, fluid dynamics, and chemistry, to name just a few. In many cases the applications in a given area of science or engineering share characteristics that require specific approaches to enable AD capabilities or provide an opportunity for efficiency gains in the derivative computation. The description of these characteristics and of the techniques for successfully using AD should make the proceedings a valuable source of information for users of AD tools.

Optimization and Computational Fluid Dynamics Springer Nature

Sparked by demands inherent to the mathematical study of pollution, intensive industry, global warming, and the biosphere, Adjoint Equations and Perturbation Algorithms in Nonlinear Problems is the first book ever to systematically present the theory of adjoint equations for nonlinear problems, as well as their application to perturbation algorithms. This new approach facilitates analysis of observational data, the application of adjoint equations to retrospective study of processes governed by imitation models, and the study of computer models themselves. Specifically, the book discusses: Principles for constructing adjoint operators in nonlinear problems Properties of adjoint operators and solvability conditions for adjoint equations Perturbation algorithms using the adjoint equations theory for nonlinear problems in transport theory, quasilinear motion, substance transfer, and nonlinear data assimilation Known results on adjoint equations and perturbation algorithms in nonlinear problems This groundbreaking text contains some results that have no analogs in the scientific literature, opening unbounded possibilities in construction and application of adjoint equations to nonlinear problems of mathematical physics.

Supersonic Wing and Wing-body Shape Optimization Using an Adjoint Formulation Springer Nature

This special collection highlights some of the best technical papers that represent the breadth of the entire technical program. Leading industry perspectives are reflected by the corporate contributions that are included in this group, along with a specific focus on connectivity, the theme of the 2016 event. The commercial vehicle industry has always been focused on improving efficiency. These ten characteristic offerings present cutting-edge trends, technologies, and solutions that provide greater benefit and the application of knowledge to solve problems and guide future innovation. These studies are presented by experts from industrial, governmental, and academic partners on topics that include: • Autonomous commercial vehicles • Computational fluid dynamics and aerodynamics for heavy-duty, on-road applications • Fuel and emissions efficiency of medium-duty powertrain configurations • Intelligently controlled air-suspension systems • Improving total cost of ownership by gains in thermal efficiency • New simulation and testing techniques enabling next generation commercial vehicle technology The leadership team has focused on bringing in a broad mixture of participants to COMVEC to discuss current technologies and the future challenges of the commercial vehicle industry. This first of its kind special publication draws on the strength of the event's program and features ten of the best technical papers from the SAE International Congress.

Adjoint Methods for Aerodynamic Shape Optimization Springer Science & Business Media

A comprehensive treatment of semismooth Newton methods in function spaces: from their foundations to recent progress in the field. This book is appropriate for researchers and practitioners in PDE-constrained optimization, nonlinear optimization and numerical analysis, as well as engineers interested in the current theory and methods for solving variational inequalities.

New Results in Numerical and Experimental Fluid Mechanics XII Springer Science & Business Media

Simulation technology, and computational fluid dynamics (CFD) in particular, is essential in the search for solutions to the modern challenges faced by humanity. Revolutions in CFD over the last decade include the use of unstructured meshes, permitting the modeling of any 3D geometry. New frontiers point to mesh adaptation, allowing not only seamless meshing (for the engineer) but also simulation certification for safer products and risk prediction. Mesh Adaptation for Computational Dynamics 2 is the second of two volumes and introduces topics including optimal control formulation, minimizing a goal function, and extending the steady algorithm to unsteady physics. Also covered are multi-rate strategies, steady inviscid flows in aeronautics and an extension to viscous flows. This book will be useful to anybody interested in mesh adaptation pertaining to CFD, especially researchers, teachers and students.

14th International Conference on Turbochargers and Turbocharging Springer

The numerical optimization of practical applications has been an issue of major importance for the last 10 years. It allows us to explore reliable non-trivial configurations, differing widely from all known solutions. The purpose of this book is to introduce the state-of-the-art concerning this issue and many complementary applications are presented.

OpenFOAM® Springer Science & Business Media

This book is intended to provide valuable information for the analysis and design of various gas turbine engines for different applications. The target audience for this book is design, maintenance, materials, aerospace and mechanical engineers. The design and maintenance engineers in the gas turbine and aircraft industry will benefit immensely from the integration and system discussions in the book. The chapters are of high relevance and interest to manufacturers, researchers and academicians as well.

Gas Turbines SIAM

Abstract: "This paper describes the implementation of optimization techniques based on control theory for wing and wing-body design of supersonic configurations. The work represents an extension of our earlier research in which control theory is used to devise a design procedure that significantly reduces the computational cost by employing an adjoint equation. In previous studies it was shown that control theory could be used to devise transonic design methods for air-foils and wings in which the shape and the surrounding body-fitted mesh are both generated analytically, and the control is the mapping function [5, 6, 8]. The method has also been implemented for both transonic potential flows and transonic flows governed by the Euler equations using an alternative formulation which employs numerically generated grids, so that it can treat more general configurations [16, 9, 17]. Here results are presented for three-dimensional design cases subject to supersonic flows governed by the Euler equation."

Extension of the ADjoint Approach to a Laminar Navier-Stokes Solver Springer Nature

"Due to advances in computing, engineers in the aerospace industry over the past decade have incorporated more advanced numerical algorithms into their computational fluid dynamics (CFD) codes. These advancements have not only allowed routine numerical investigation on the aerodynamic performance of complete aircraft configurations but the redesign of aircraft geometries through aerodynamic shape optimization (ASO). A fundamental step required for ASO is the computation of gradients of objective functions with respect to design variables; where, adjoint-based methods form the predominant choice. An essential stage in adjoint-based aerodynamic shape optimization is to obtain the Lagrange multiplier by solving a sparse linear adjoint system of equations based on the Jacobian matrices from the converged flow states. Such an approach has been applied widely within the aerospace community for the design of aircraft and other optimization problems for aerospace applications. However, the need to resolve the flow over complex geometries often requires highly stretched grids and gives rise to anisotropic flow fields which increase the stiffness of the discrete Jacobian needed for the solution of the adjoint system. When a generalized minimal residual (GMRES) algorithm preconditioned by an Incomplete LU factorization is used, this stiff linear system requires the use of a large number of Krylov subspace vectors and a high level of fill-in; both require an increase in the amount of memory. Deflated restarting, which distributes spectral eigen-pairs, has proven to be an effective method to enhance the convergence rates when solving an ill-conditioned linear system of equations. In this thesis, a novel adjoint solver based on the Krylov-subspace method is proposed where Krylov subspace basis vectors are dynamically evaluated. The solver is applied within two Krylov subspace solvers; GMRES and the generalized conjugate residual method with an inner orthogonalization (GCRO). The efficiency of the solvers is demonstrated on a series of two-dimensional and three-dimensional benchmark test cases"--

Low-cost Unsteady Discrete Adjoint Techniques for Aeroacoustic Optimization John Wiley & Sons

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.

Adjoint Equations and Analysis of Complex Systems Springer Nature

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.

Proceedings of the 22nd International Meshing Roundtable Springer
This book contains selected papers of the 11th OpenFOAM® Workshop that was held in Guimarães, Portugal, June 26 - 30, 2016. The 11th OpenFOAM® Workshop had more than 140 technical/scientific presentations and 30 courses, and was attended by circa 300 individuals, representing 180 institutions and 30 countries, from all continents. The OpenFOAM® Workshop provided a forum for researchers, industrial users, software developers, consultants and academics working with OpenFOAM® technology. The central part of the Workshop was the two-day conference, where presentations and posters on industrial applications and academic research were shown. OpenFOAM® (Open Source Field Operation and Manipulation) is a free, open source computational toolbox that has a larger user base across most areas of engineering and science, from both commercial and academic organizations. As a technology, OpenFOAM® provides an extensive range of features to solve anything from complex fluid flows involving chemical reactions, turbulence and heat transfer, to solid dynamics and electromagnetics, among several others. Additionally, the OpenFOAM technology offers complete freedom to customize and extend its functionalities.