# An Adjoint Solver For An Industrial Cfd Code Via Automatic

This book is a printed edition of the Special Issue "Lie Theory and Its Applications" that was published in Symmetry
Inverse problems can be found in many topics of engineering mechanics. There are many successful applications in the fields of inverse problems (non-destructive testing and characterization of material properties by ultrasonic or X-ray techniques, thermography, etc.). Generally speaking, the inverse problems are concerned with the determination of the input and the characteristics of a mechanical system from some of the output from the system. Mathematically, such problems are ill-posed and have to be overcome through development of new computational schemes, regularization techniques, objective functionals, and experimental procedures. Seventy-two papers were presented at the International Symposium on Inverse Problems in Mechanics (ISIP '98) held in March of 1998 in Nagano, where recent developments in the inverse problems in engineering mechanics and related topics were discussed. The main themes were: mathematical and computational aspects of the inverse problems, parameter or system identification, shape determination, sensitivity analysis, optimization, material property characterization, ultrasonic non-destructive testing, elastodynamic inverse problems, thermal inverse problems, and other engineering applications.
Parallel CFD 2000, the Twelfth in an International series of meetings featuring computational fluid dynamics research on parallel computers, was held May 22-25, 2000 in Trondheim, Norway. Following the trend of the past conferences, areas such as numerical schemes and algorithms, tools and environments, load balancing, as well as interdisciplinary topics and various kinds of industrial applications were all well represented in the work presented. In addition, for the first time in the Parallel CFD conference series, the organizing committee chose to draw special attention to certain subject areas by organizing a number of special sessions. We feel the emphasis of the papers presented at the conference reflect the direction of the research within parallel CFD at the beginning of the new millennium. It seems to be a clear tendency towards increased industrial exploitation of parallel CFD. Several presentations also demonstrated how new insight is being achieved from complex simulations, and how powerful parallel computers now make it possible to use CFD within a broader interdisciplinary setting. Obviously, successful application of parallel CFD still rests on the underlying fundamental principles. Therefore, numerical algorithms, development tools, and parallelization techniques are still as important as when parallel CFD was in is infancy. Furthermore, the novel concepts of affordable parallel computing as well as metacomputing show that exciting developments are still taking place. As is often pointed out however, the real power of parallel CFD comes from the combination of all the disciplines involved: Physics, mathematics, and computer science. This is probably one of the principal reasons for the continued popularity of the Parallel CFD Conferences series, as well as the inspiration behind much of the excellent work carried out on the subject. We hope that the papers in this book, both on an individual basis and as a whole, will contribute to that inspiration. Further details of Parallel CFD'99, as well as other conferences in this series, are available at http://www.parcfd.org
This book covers various aspects of Geometry and Graphics, from recent achievements on theoretical researches to a wide range of innovative applications, as well as new teaching methodologies and experiences, and reinterpretations and findings about the masterpieces of the past. It is from the 19th International Conference on Geometry and Graphics, which was held in São Paulo, Brazil. The conference started in 1978 and is promoted by the International Society for Geometry and Graphics, which aims to foster international collaboration and stimulate the scientific research and teaching methodology in the fields of Geometry and Graphics. Organized five topics, which are Theoretical Graphics and Geometry; Applied Geometry and Graphics; Engineering Computer Graphics; Graphics Education and Geometry; Graphics in History, the book is intended for the professionals, academics and researchers in architecture, engineering, industrial design, mathematics and arts involved in the multidisciplinary field.
Computers are used in today's technological world as a powerful tool to simulate many complex phenomena in various fields. This book is an introduction to some of these exciting developments. All the articles are written by experts in their respective fields. Each article teaches by example and the book contains case studies in fields as diverse as physics, biology, fluid dynamics, astrophysics, device modeling and weather simulation. This book should be of interest to a new researcher as an introduction to an exciting arena of computer applications. It should also benefit expert scientists, providing methods that may apply to their own problems or open up new research possibilities with unlimited promise.
This three-part book provides a comprehensive and systematic introduction to these challenging topics such as model calibration, parameter estimation, reliability assessment, and data collection design. Part 1 covers the classical inverse problem for parameter estimation in both deterministic and statistical frameworks, Part 2 is dedicated to system identification, hyperparameter estimation, and model dimension reduction, and Part 3 considers how to collect data and construct reliable models for prediction and decision-making. For the first time, topics such as multiscale inversion, stochastic field parameterization, level set method, machine learning, global sensitivity analysis, data assimilation, model uncertainty quantification, robust design, and goal-oriented modeling, are systematically described and summarized in a single book from the perspective of model inversion, and elucidated with numerical examples from environmental and water resources modeling. Readers of this book will not only learn basic concepts and methods for simple parameter estimation, but also get familiar with advanced methods for modeling complex systems. Algorithms for mathematical tools used in this book, such as numerical optimization, automatic differentiation, adaptive parameterization, hierarchical Bayesian, metamodeling, Markov chain Monte Carlo, are covered in details. This book can be used as a reference for graduate and upper level undergraduate students majoring in environmental engineering, hydrology, and geosciences. It also serves as an essential reference book for professionals such as petroleum engineers, mining engineers, chemists, mechanical engineers, biologists, biology and medical engineering, applied mathematicians, and others who perform mathematical modeling.
"Symposium Transsonicum" was founded by Klaus Oswatitsch four decades ago when there was clearly a need for a systematic treatment of flow problems in the higher speed regime in aeronautics. The first conference in 1962 brought together scientists concerned with fundamental problems involving the sonic flow speed regime. Results of the conference provided an understanding of some basic tran sonic phenomena by proposing mathematical methods that allowed for the de velopment of practical calculations. The "Transonic Controversy" (about shock free flows) was still an open issue after this meeting. In 1975 the second symposium was held, by then there was much understanding in how to avoid shocks in a steady plane flow to be designed, but still very little was known in unsteady phenomena due to a lack of elucidating experiments. A third meeting in 1988 reflected the availability oflarger computers which allowed the numerical analysis of flows with shocks to a reasonable accuracy. Because we are trying to keep Oswatitsch's heritage in science alive especially in Gottingen, we were asked by the aerospace research

community to organize another symposium. Much had been achieved already in the knowledge, techno logy and applications in transonics, so IUT AM had to be convinced that a fourth meeting would not just be a reunion of old friends reminiscing some scientific past. The scientific committee greatly supported my efforts to invite scientists ac tively working in transonic problems which still pose substantial difficulties to ae rospace and turbomachinery industry.

The MIT mission - "to bring together Industry and Academia and to nurture the next generation in computational mechanics is of great importance to reach the new level of mathematical modeling and numerical solution and to provide an exciting research environment for the next generation in computational mechanics." Mathematical modeling and numerical solution is today firmly established in science and engineering. Research conducted in almost all branches of scientific investigations and the design of systems in practically all disciplines of engineering can not be pursued effectively without, frequently, intensive analysis based on numerical computations. The world we live in has been classified by the human mind, for descriptive and analysis purposes, to consist of fluids and solids, continua and molecules; and the analyses of fluids and solids at the continuum and molecular scales have traditionally been pursued separately. Fundamentally, however, there are only molecules and particles for any material that interact on the microscopic and macroscopic scales. Therefore, to unify the analysis of physical systems and to reach a deeper understanding of the behavior of nature in scientific investigations, and of the behavior of designs in engineering endeavors, a new level of analysis is necessary. This new level of mathematical modeling and numerical solution does not merely involve the analysis of a single medium but must encompass the solution of multi-physics problems involving fluids, solids, and their interactions, involving multi-scale phenomena from the molecular to the macroscopic scales, and must include uncertainties in the given data and the solution results. Nature does not distinguish between fluids and solids and does not ever repeat itself exactly. This new level of analysis must also include, in engineering, the effective optimization of systems, and the modeling and analysis of complete life spans of engineering products, from design to fabrication, to possibly multiple repairs, to end of service.

"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"--

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.

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.

Contributed presentations were given by over 50 researchers representing the state of parallel CFD art and architecture from Asia, Europe, and North America. Major developments at the 1999 meeting were: (1) the effective use of as many as 2048 processors in implicit computations in CFD, (2) the acceptance that parallelism is now the 'easy part' of large-scale CFD compared to the difficulty of getting good per-node performance on the latest fast-clocked commodity processors with cache-based memory systems, (3) favorable prospects for Lattice-Boltzmann computations in CFD (especially for problems that Eulerian and even Lagrangian techniques do not handle well, such as two-phase flows and flows with exceedingly multiple-connected demains with a lot of holes in them, but even for conventional flows already handled well with the continuum-based approaches of PDEs), and (4) the nascent integration of optimization and very large-scale CFD. Further details of Parallel CFD'99, as well as other conferences in this series, are available at http://www.parcfd.org

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.

This volume presents several multidisciplinary approaches to the visual representation of data acquired from experiments. As an expansion of these approaches, it is also possible to include data examination generated by mathematical-physical modeling. Imaging Systems encompass any subject related to digital images, from fundamental requirements for a correct image acquisition to computational algorithms that make it possible to obtain relevant information for image analysis. In this context, the book presents selected contributions of a special session at the Conference on Advanced Computational Engineering and Experimenting (ACE-X) 2016.

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.

The three-volume set, LNCS 2667, LNCS 2668, and LNCS 2669, constitutes the refereed proceedings of the International Conference on Computational Science and Its Applications, ICCSA 2003, held in Montreal, Canada, in May 2003. The three volumes present more than 300 papers and span the whole range of computational science from foundational issues in computer science and mathematics to advanced applications in virtually all sciences making use of computational techniques. The proceedings give a unique account of recent results in computational science.

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.

The 20th century saw tremendous achievements and progress in science and technology. Undoubtedly, computers and computer-related technologies acted as one of vital catalysts for accelerating this progress in the latter half of the century. The contributions of mathematical sciences have been equally profound, and the synergy between mathematics and computer science has played a key role in accelerating the progress of both fields as well as science and engineering. Mathematical sciences will undoubtedly continue to play this vital role in this new century. In particular, mathematical modeling and numerical simulation will continue to be among the essential methodologies for solving massive and complex problems that arise in science, engineering and manufacturing. Underpinning this all from a sound, theoretical perspective will be numerical algorithms. In recognition of this observation, this volume focuses on the following specific topics. (1) Fundamental numerical algorithms (2) Applications of numerical algorithms (3) Emerging technologies. The articles included in this issue by experts on advanced scientific and engineering computations from numerous countries elucidate state-of-the-art achievements in these three topics from various angles and suggest the future directions. Although we cannot hope to cover all the aspects in scientific and engineering computations, we hope that the articles will interest, inform and inspire members of the science and engineering community.

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.

This collection of papers presents a broad range of topics in DNS and LES, from new developments in LES modeling to DNS and LES for supersonic and hypersonic boundary layers. The book provides an extensive view of the state of the art in the field.

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.

"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." --

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

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.

Standard 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.

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

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."

The International Conference on Computational Fluid Dynamics (ICCFD) is the merger of the International Conference on Numerical Methods in Fluid Dynamics, ICNMFD (since 1969) and International Symposium on Computational Fluid Dynamics, ISCFD (since 1985). It is held every two years and brings together physicists, mathematicians and engineers to review and share recent advances in mathematical and computational techniques for modeling fluid dynamics. The proceedings of the 2006 conference (ICCFD4) held in Gent, Belgium, contain a selection of refereed contributions and are meant to serve as a source of reference for all those interested in the state of the art in computational fluid mechanics.

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.

"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"--

This book presents the proceedings of the International Conference on Aerospace System Science and Engineering (ICASSE 2019), held in Toronto, Canada, on July 30–August 1, 2019, and jointly organized by the University of Toronto Institute for Aerospace Studies (UTIAS) and the Shanghai Jiao Tong University School of Aeronautics and Astronautics. ICASSE 2019 provided a forum that brought together experts on aeronautics and astronautics to share new ideas and findings. These proceedings present high-quality contributions in the areas of aerospace system science and engineering, including topics such as trans-space vehicle system design and integration, air vehicle systems, space vehicle systems, near-space vehicle systems, aerospace robotics and unmanned systems, communication, navigation and surveillance, aerodynamics and aircraft design, dynamics and control, aerospace propulsion, avionics systems, optoelectronic systems, and air traffic management.

This volume contains results of the German CFD initiative MEGADESIGN which combines CFD development activities from DLR, universities and aircraft industry. Based on the DLR flow solvers FLOWer and TAU the main objectives of the four-years project is to ensure the prediction accuracy with a guaranteed error bandwidth for certain aircraft configurations at design conditions, to reduce the simulation turn-around time for large-scale applications significantly, to improve the reliability of the flow solvers for full aircraft configurations in the complete flight regime, to extend the flow solvers to allow for multidisciplinary simulations and to establish numerical shape optimization as a vital tool within the aircraft design process. This volume highlights recent improvements and enhancements of the flow solvers as well as new developments with respect to aerodynamic and multidisciplinary shape optimization. Improved numerical simulation capabilities are demonstrated by several industrial applications.

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.

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.

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.