

An Adjoint Solver for an Industrial CFD Code via Automatic Differentiation

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1 Introduction

Industrial use of CFD is now routine and the current challenge is to incorporate large scale CFD codes into the engineering design cycle via design optimisation. The associated use of gradients is non-trivial and is the subject of the monograph [6]. Aerodynamic designs may have 100's of design variables making adjoint methods, which compute gradients in time proportional to the (small) number of design objectives [4], attractive. Here we concentrate on discrete adjoint methods, in which the discretised flow solver is adjointed, since it may be generated and maintained by automatic differentiation (AD) [5] tools. Previously [7] we described using the Odyssey AD tool [3] to obtain and validate a discrete forward sensitivity version of the BAE SYSTEMS/AIRBUS UK unstructured mesh CFD code FLITE3D. In this paper we report on the generation, validation and performance optimisation of the corresponding adjoint solver.

2 The Flite3D CFD Package

Neglecting RK time-stepping and multigrid, FLITE3D's solver is described by (1–4).

$$\left. \begin{array}{l} \text{Surface Mesh Generator} \\ \text{Given design parameters } \underline{\beta} \\ \text{Surface mesh generation } \mathbf{x}_S = \mathbf{X}_S(\underline{\beta}) \end{array} \right\} \quad (1)$$

$$\left. \begin{array}{l} \text{Volume Mesh Generator} \\ \text{Volume Mesh generation } \mathbf{x} = \mathbf{X}(\mathbf{x}_S) \end{array} \right\} \quad (2)$$

$$\left. \begin{array}{l} \text{Geometric Pre-Processor} \\ \text{Calculate point and face surface normals } \mathbf{n}(\mathbf{x}_S, \underline{\beta}), \mathbf{n}(\mathbf{x}_S) \\ \text{Calculate Volume Mesh normals } \mathbf{w}(\mathbf{x}, \mathbf{x}_S) \end{array} \right\} \quad (3)$$

$$\left. \begin{array}{l} \text{Flow Solver} \\ \text{Initialise flow variables } \mathbf{u}^0 \\ \text{Do } \quad \mathbf{n} = 0, n_{\max} - 1 \\ \quad \text{Finite volume residual } \mathbf{r}^n = \mathbf{R}(\mathbf{u}^n, \mathbf{x}, \mathbf{w}, \mathbf{n}) \\ \quad \text{If (converged) Exit Do Loop} \\ \quad \mathbf{u}^{n+1} = \mathbf{u}^n - \mathbf{P}_L(\mathbf{u}^n, \mathbf{x})\mathbf{r}^n \\ \quad \text{Aerodynamic Coefficients } [C_L, C_D, M_y] = C(\mathbf{u}^n, \mathbf{x}, \mathbf{n}) \\ \text{EndDo} \end{array} \right\} \quad (4)$$

Given design parameters $\underline{\beta}$, for example B-spline coefficients, a surface mesh $\mathbf{x}_S(\underline{\beta})$ is generated, followed by the volume mesh \mathbf{x} using Delaunay techniques. A geometric pre-processor then calcu-

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S Ben Porath



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Table of Contents An Adjoint Solver For An Industrial Cfd Code Via Automatic

1. Understanding the eBook An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - The Rise of Digital Reading An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Advantages of eBooks Over Traditional Books
2. Identifying An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - User-Friendly Interface
4. Exploring eBook Recommendations from An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Personalized Recommendations
 - An Adjoint Solver For An Industrial Cfd Code Via Automatic User Reviews and Ratings
 - An Adjoint Solver For An Industrial Cfd Code Via Automatic and Bestseller Lists
5. Accessing An Adjoint Solver For An Industrial Cfd Code Via Automatic Free and Paid eBooks
 - An Adjoint Solver For An Industrial Cfd Code Via Automatic Public Domain eBooks
 - An Adjoint Solver For An Industrial Cfd Code Via Automatic eBook Subscription Services
 - An Adjoint Solver For An Industrial Cfd Code Via Automatic Budget-Friendly Options

6. Navigating An Adjoint Solver For An Industrial Cfd Code Via Automatic eBook Formats
 - ePub, PDF, MOBI, and More
 - An Adjoint Solver For An Industrial Cfd Code Via Automatic Compatibility with Devices
 - An Adjoint Solver For An Industrial Cfd Code Via Automatic Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Highlighting and Note-Taking An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Interactive Elements An Adjoint Solver For An Industrial Cfd Code Via Automatic
8. Staying Engaged with An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers An Adjoint Solver For An Industrial Cfd Code Via Automatic
9. Balancing eBooks and Physical Books An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection An Adjoint Solver For An Industrial Cfd Code Via Automatic
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Setting Reading Goals An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Fact-Checking eBook Content of An Adjoint Solver For An Industrial Cfd Code Via Automatic
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements

- Interactive and Gamified eBooks

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