NAG® Automatic Differentiation Solutions

NAG are pioneers in providing AD technologies. We help organisations apply AD to their computation - blue chip clients in finance are reaping the benefits of NAG's expertise in this field, and other industries could benefit extensively from implementing NAG AD Solutions.

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Get fast, accurate sensitivities of any order

Automatic Differentiation (AD) is a Mathematical/Computer Science technique for computing accurate sensitivities quickly. For many models, Adjoint AD (AAD) can compute sensitivities 10s, 100s or even 1000s of times faster than finite differences.

AD and AAD are extremely powerful technologies - unfortunately they are demanding to use. Applying them by hand to production sized codes is a serious, lengthy undertaking and requires a team of specialists. Code maintenance and updating also becomes more expensive and complex. For this reason, most people have turned to AD tools to get sensitivities of their simulation codes.

AD SOFTWARE TOOLS →

AD SERVICES →

AD: REPORTS, RESEARCH & POSTERS →

Case Study: Reverse-mode AD = Faster Risk Management, Better Pricing, and Cheaper Compute.

Learn how one bank is leveraging NAG's products and expertise in AD, task orchestration, GPU accelerators and core analytics by downloading NAG's latest case study featuring our Automatic Differentiation (AD) Technology, NAG® dco/c++.

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Industries and areas where AD adds substantial benefits

Our world is increasingly driven by simulation. Computer programs simulate the behaviour of systems, and the results are used to make business decisions, control machines, or are fed into further simulations. However, in many industries it has become important not only to compute the simulation value, but also its sensitivity (mathematical derivative) to the model inputs.

- In **machine learning**, the sensitivity of the model error is used to fit the network parameters
- In **seismic applications**, the derivative of the demigration operator is needed for Least Squares Reverse Time Migration (LS-RTM)

- In **disaster modelling (flood, tsunamis, fire)** the sensitivities of the simulation with respect to the geometry of the city or countryside can help in designing defences
- In **finance,** sensitivities are used to hedge risk and explain exposures
- In **portfolio management**, sensitivities show how robust a portfolio is to changes in market conditions, and how quickly it could lose value in a down turn
- In **aerodynamics (Formula 1, consumer automotive, aerospace, marine, defence)** sensitivities of drag, lift or ballistic profile with respect to geometry are used to optimise vehicle shape
- In **flood defense and river management**, sensitivities with respect to pebble size show how river paths can change over time, and how quickly
- In **climate modelling**, model sensitivities give new insights into weather patterns and show how quickly and severely local conditions can change

AD MATHEMATICAL DETAIL →

Implementing 'in-house' AD technologies is expensive

The power of AD comes at a price; positive outcomes of using AD methods are costly for organizations. Adopting a hand-written ‘in-house’ approach to AD means writing (adjoint) AD versions of all your simulation codes. This is expensive, time consuming and requires skilled developers who understand AD very well. In addition, if any changes are made to the simulation codes, the AD codes must be updated or else they will give incorrect results.

LEARN ABOUT NAG AD SERVICES →

NAG® AD Benefits

Accuracy

- AD gives more accurate sensitivities than finite differences. This is especially true in second and higher order derivatives.

Robustness

- AD is more robust than finite differences: there is no bump size that needs to be tweaked. AD can handle any (differentiable) model, with any set of input data.

Efficiency

- For models with many inputs and few outputs, adjoint AD is fundamentally more efficient than finite differences. This means reduced runtimes, reduced hardware costs, reduced energy costs and faster turnarounds, which typically translates into more timely business decisions.

Enabling cutting edge innovation

- AD enables things which were previously unimaginable. Eg. in Formula 1, adjoint methods allow teams to design precise car geometry to achieve desired levels of downforce and drag. With classic wind tunnel experiments, the same degree of insight was just not possible. In renewable energy, adjoint methods allow optimal placement of wind and tidal turbines so as to maximize electricity production. With finite differences, this type of optimization would be just too expensive.

AD REPORTS, RESEARCH & POSTERS →

NAG® AD Solutions & Services

Overview

NAG® AD Proof of Concept Studies

NAG® AD Software Tools

NAG® Custom AD Software

Adapted to your specific requirements

NAG® AD Software Tools are very efficient. However, it is sometimes desirable to produce an AD implementation in a different way, often to handle computationally expensive sections of code. Typically, this is through hand-writing an adjoint implementation, or using a high-performance tool such as dco/map to make the AD implementation, or even porting the AD code to a

GPU. NAG AD Solution services can assist in all these cases, whether it be writing adjoints for particular pieces of code, or porting to GPU and making GPU adjoint implementations.

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Real-world examples showing the benefits of AD and AAD

AAD Weather Model

AAD Engineering Model

AAD Financial Risk Model

AD helps our understanding of climate change and improves weather predictions

Case study highlights: Obtaining the gradient through finite differences took a month and a half. The adjoint AD

code obtained the gradient in less than 10 minutes.

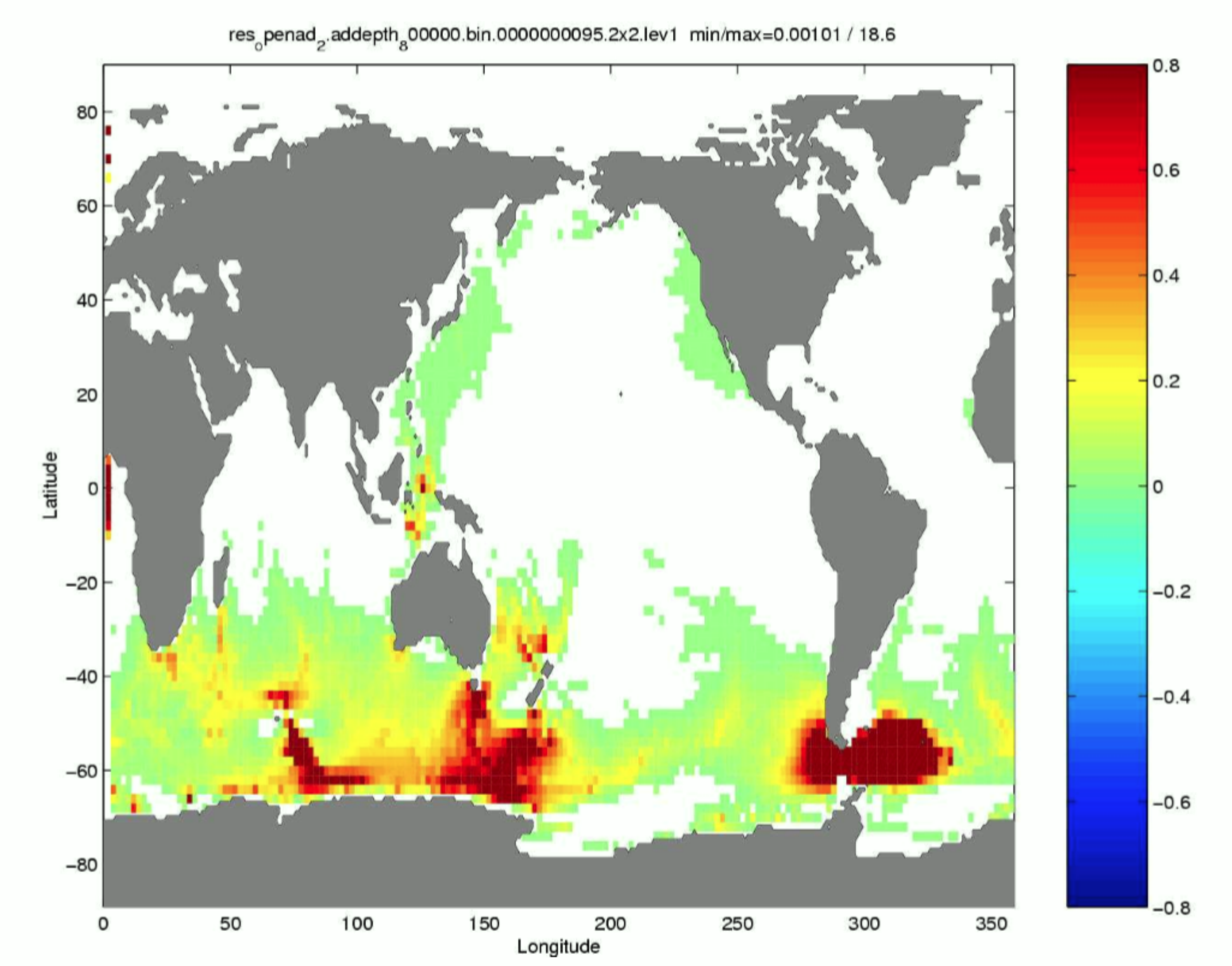

Figure 2: MITgcm sensitivities of zonal ocean water flow through the Drake Passage to changes in bottom topography.

AD helps our understanding of climate change and improves weather predictions.

Figure 2 shows the sensitivity of the amount of water flowing through the Drake passage to changes in the topography of the ocean floor. The simulation was performed with the AD-enabled MIT Global Circulation Model (MITgcm) run on a supercomputer. The ocean was meshed with 64,800 grid points. (2) (/content/nag-and-algorithmic-differentiation#2)

Obtaining the gradient through finite differences took a month and a half. The adjoint AD code obtained the gradient in less than 10 minutes.

The gradient information can be used to further refine climate prediction models and our understanding of global weather, for example the high sensitivity over the South Pacific Ridge and Indonesian Throughflows even though these are far away from the Drake Passage.

Utke J, Naumann U, Wunsch C, Hill C, Heimbach P, Fagan M, Tallent N and Strout M. (2008). OpenAD/F: A modular, open-source tool for automatic differentiation of Fortran codes. *ACM Trans. Math. Softw*, **34(4)** 18:1-18:36.

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