Adjoint Compiler Technology and Standards

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One of the most powerful available tools for oceanographic state estimation (data assimilation), for understanding the sensitivity of models to perturbations in parameters and forcings, and for simulating the global ocean circulation is the adjoint to the MIT model [1,2]. In the past, adjoints have been hard to develop and difficult to use. In the mid-90s, we developed the forward model parameterization and adjoint code. We then used the forward model Portran code to develop a useful adjoint. The mathematical idea that was used is referred to as Automatic Differentiation (AD). Its use is generally useful for models in almost any scientific discipline. Both for estimation and sensitivity studies, we have formed a consortium to produce a new easier to use, versatile, open-source adjoint tool. This tool, which should be available in preliminary form in about one year will support both Portran and C.

Given a Forward Model

\[ f : \mathbb{R}^n \rightarrow \mathbb{R}^m, \quad y = f(x), \]

adjoint compilers can produce either a simple-linear model

\[ df : \mathbb{R}^m \rightarrow \mathbb{R}^n, \quad dy = df(x) \cdot dx, \]

or an adjoint model

\[ \tilde{f} : \mathbb{R}^m \rightarrow \mathbb{R}^n, \quad \tilde{y} = \tilde{f}(x) \cdot \tilde{y} = (f^T \cdot \tilde{x}). \]

The adjoint model enables the efficient computation of the sensitivities of the model output w.r.t. a given parameter \( x \). The sensitivities of a given model output \( y \) w.r.t. all parameters \( x \) can be computed efficiently using the adjoint model. Furthermore, the gradient of an adjoint model w.r.t. all model parameters can be obtained efficiently. Hessian matrices can be computed by the adjoint-linearized version of the adjoint model.

Basic Idea and an Example

- Automatic Differentiation [4]
  - decomposition into elementary assignments
  - augmentation with local partial derivatives
  - chain rules in forward mode
  - chain rules in reverse mode

where \( \alpha \) means that \( \alpha \) appears on the right-hand side of the elementary assignment that computes \( \alpha \).

Reference:

NSF-ITR Project “ACTS”

... is a three-year (Oct 2002 - Sep 2005) collaborative adjoint compiler technology research and development project between MIT, Rice University, and the University of Chicago / Argonne National Laboratory

Main Objectives:
- Language-independent platform for development of adjoint compilers (XADP)
- Portray 90 and C/C++-like tool based on XADP
- Efficient program reversal through automatic checkpointing
- Static and dynamic performance analysis
- Efficient handling of MPI

See also: http://www.autodi.org/ACTS

Interested in becoming a beta-tester of the compiler’s prototypes?
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