ESR7: Source transformation AD tools

INRIA Sophia-Antipolis, France (INR)

The hosting group

INRIA is the French national research institute for Computer Science and Control. Its research covers all aspects of Computer Science, from theoretical (semantics, languages, networks, complexity, proofs...) to applied (Life Sciences, Earth Sciences, Robotics, Telecom, Scientific Computing...). INRIA hosts an average 3,000 researchers in 8 research centers. The researchers at Inria published over 4,800 articles in 2010. They are behind over 270 active patents and 105 start-ups.

The INRIA research center in Sophia-Antipolis is one of the largest, with 600 people and 37 research teams. Many are joint teams with other French universities or research institutes. It has strong links with the neighbor universities in Nice, Marseilles, and Montpellier. It is now located inside the new campus for Computer Science of university of Nice, and in the middle of the Sophia-Antipolis science park, one of the first and most successful science parks in the country.

The Tropics research team has a strong experience in software tools for Scientific Computing. It specializes in Automatic Differentiation (AD) by source transformation, and its application to engineering with strong links with the CFD community. The team's research on AD is validated by the development of the TAPENADE AD tool, which is quite popular in the Academy and sees increasing usage in the Industry. Among the current frontiers of AD, the team intends to explore AD of MPI-parallel codes, AD models for Object-Oriented languages, efficient adjoints of large unsteady simulations, and use of AD for Uncertainty Quantification.

The work is supervised by Dr Laurent Hascoet, Research Director at INRIA, head of the Tropics team, and by Dr. Valerie Pascual, Researcher at INRIA. Their research focuses on the adjoint mode of AD by source transformation, on the AD models, and on the static data-flow analysis that make AD more efficient.

Context

Modern optimization platforms in CFD rely heavily on accurate derivatives to find every possible improvement of a current design. Of paramount importance are the gradients, central to the adjoint models, but developing such an adjoint by hand is long and error-prone. On the other hand, Automatic Differentiation (AD) by source transformation can mechanically turn the source of any model into a new source that computes its derivatives. Specifically the "reverse mode" of AD is tailored to compute gradients efficiently

However, the CFD models themselves become increasingly complex and sophisticated: Implementing their adjoint model and consequently their gradient remains a challenge. We will address two of the most frustrating limitations of AD at the moment: (1) the need to better take into account the high-level structure of the source, more specifically the presence of fixed-point solvers and (2) the need to adapt to popular programming paradigms, more specifically MPI-parallel architectures.

In the current state of AD research, these objectives are now within reach. Still, from a research point of view, the answer cannot be just an extension to some AD tool. In addition to an implementation, validated on a large CFD application that will be chosen within the project, we need to come up with formal justifications and proofs of these answers. Therefore, this work will involve several aspects of computer science: compiler theory, program analysis (mostly static), parallel models and parallelization theory. It will also involve a deep understanding of the mathematics behind CFD solvers.

The work

- Familiarize with Automatic Differentiation (AD) by Source Transformation. Master the compiler technology involved in AD and the specific architecture, Data-Flow analysis and algorithms of Tapenade.
- Familiarize with adjoint-based optimization. Focus on the existing flow code and on its prototype adjoint code from the FlowHead project. 2 months secondment to QMUL (UK) to study the needs to be met by the AD tool. Formalize these needs to specify corresponding new functionnalities.
- Formalize adjoint AD tailored for fixed-point time stepping codes.
- Develop the adjoint AD model for MPI-parallel codes. Explore the use of user-given directives to compensate the limitations of static data-flow analysis.
- Validate AD models tailored for fixed-point codes and for MPI-parallel codes, through implementation in Tapenade and application to the existing flow, in particular through a 2M secondment to RR (Germany).
- Publication about the models and algorithms to extend AD to fixed-point codes and to MPI-parallel codes. PhD thesis.

The project will be conducted in close liaison with network partners QMUL and RWTH.

Required background

Essential: You need to have

- A good Masters degree (or equivalent) in Computer Science, preferably in fields such as compiler theory, program analysis, automatic parallelization, partial evaluation, abstract interpretation, code optimization. Candidates with a Masters-level background in Applied Mathematics will also be considered if they have an acceptable background in Computer Science and programming.
- The ability to give presentations and write scientific publications
- The willingness and ability to attend the regular network training events in the EU and to spend two 2 months secondments at network partners.

Desired: it would be good if you had experience with

- Programming in Fortran90 and Linux environment.
- Software development methodology.
- Numerical optimisation.

Salary, conditions and environment

The salary is approx. 40,000 € per annum of which taxes, social contributions and pension payments have to be paid. The network will provide a range of workshops on scientific aspects relevant to adjoint-based optimisation that will be directly or indirectly relevant to the work in this research position, see the About Flow webpage for details. You will also be offered a range of skills complementary to your core research area such as project management, thesis writing and entrepreneurial skills. INRIA and the About Flow project are committed to Equal Opportunities for all candidates and will follow the principles of the European Charter for Researchers.

How to inquire and apply

Applications for the position are open. For informal enquiries about this position please contact Laurent Hascoet
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To apply for the position please send a CV and two signed reference letters to the following address:
Dr. Laurent HASCOET
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France
Or by email to Laurent.Hascoet@inria.fr

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