Differentiable Programming: Automatic Differentiation for State-of-the-Art CFD Solvers

M.Sc. Thesis, or IDP Project

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Introduction

Differentiable programming is seen by many as the coming unifying paradigm of scientific computing and machine learning, which will enable better surrogate modeling, faster sensitivity analysis, the solving of more complex inverse problems and a new level of inference on large-scale scientific simulations by utilizing automatic differentiation. A first generation of differentiable solvers is pursuing this by building on limited machine learning DSLs, such as Tensorflow, which are unfit for such purpose as they are too constrained for complex scientific models and require the rewrite of existing software. We hence seek to enable a new generation of differentiable programming by building on the absolute state-of-the-art in computational fluid dynamics solvers for HPC with our in-house solver ALPACA and introducing a new breed of communication protocol to interface state-of-the-art automatic differentiation engines with HPC solvers.

Objectives

In this project we will build on the next generation of automatic differentiation frameworks by using Zygote.jl in formulating a new communication protocol built on top of the LLVM IR to interact with our CFD solver ALPACA to calculate gradients over program executions. For this we will build a first prototype taking cues from the architecture of PPX, an execution protocol for probabilistic programming, and formulate optimized adjoint calculations using Zygote's pullback functionality. This will then be validated and optimized for successively more complex testcases.

Requirements

- Knowledge of Julia
- C++ 17 familiarity
- Familiarity with the concept of adjoints
- Familiarity with LLVM
  - LLVM-based compilers
  - LLVM intermediate representations

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