Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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EARTH SCIENCES

Using Julia in geophysical fluid dynamics for visco-elasto-plastic materials

Project Proposal for Bachelor's or Master's Thesis

Motivation: Numerical modeling is essential in geosciences and in geodynamics since human observations are very limited in time and space. To fill these gaps with observations, data points for depth up to 6000 km and over a period up to 4.5 billion years have to be obtained.
Since this is not possible, numerical geodynamic models are developed with many different approaches like finite difference/element/volume methods as well as spectral methods to compensate for missing observations.
These models have to cover a wide range of parameters and variations of them, e.g. huge pressure and temperature differences between the surface and the interior of the Earth. Models need to cover Earth's mantle which is elastic (solid like) on human time scales and viscous (fluid like) on geological ones (> 10.000 years) and can be heavily internally deformed.
Many models are prototyped in MATLAB and then reimplemented in C or Fortran for example StagYY and I3Elvis. The emergence of Julia, a general-purpose high performance programming language and newly published packages with APIs to existing libararies and solvers, allows programming of next generation geodynamic models.

Objective: We aim to re-implement existing (prototype) MATLAB codes from the I3Elvis family in Julia. These codes cover solving Navier-Stokes, continuity and temperature equation in primitive variable formulation with variable viscosity and thermal conductivity or visco-elasto-plastic material using finite differences with a staggered grid and marker in cell technique.
Newly developed Julia packages like GeoParams.jl, PETSc.jl, ParallelStencil.jl and ImplicitGlobalGrid.jl allow fast and parallel solving of the equations on CPUs and GPUs.
After re-implementation single processor performance and utilization will be investigated as well as soft and hard scaling of the new code.
The code and testing base can be extented to make it a suitable BSc or MSc project.

Background:
Strong background in programming, especially MATLAB or Julia. An understanding of geodynamics is an advantage but not a prerequisite.

Supervision: Prof. Dr. Taras Gerya, Dominic Stemmler
Start of project: As soon as the candidate is available.

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