Title: Domain Specific Languages for Automating Finite Element Methods

Hours per week: 10

Department: EECS

Required Skills/Classes: Python, a proof-based linear algebra class, and ideally one of (18.330 (Introduction to Numerical Analysis) or 18.335 (Introduction to Numerical Methods) or 18.336 (Fast Methods for Partial Differential and Integral Equations) or (6.106 or 6.1100 or 6.1120 or 6.5110 or 6.5120 or 6.5150 or 6.5151) or 18.952 (Theory of Differential Forms) or 18.965 (Geometry of Manifolds I) or 8.962 (General Relativity))

Preferred Skills/Classes:

PIs: Saman Amarasinghe

Supervisor: Teodoro F. Collin

The COMMIT group is developing a domain specific language for the automation of finite element methods. Our DSL is built on a collection of abstractions that seek to mathematically model aspects of finite elements and partial differentiation equations. These abstractions span a language for coordinate free linear to a language of pointwise expressions on a mesh to a flexible system for computing & storing data on meshes to a simple language for simplicial geometries. The core idea underlying this approach is that implementations can be deduced from a specification if the specification is represented in a mathematically accurate and expressive system. The core goal of this approach is to facilitate the automatic generation of superior algorithms for solving PDEs.

We seek highly motivated students with a strong background in linear algebra and Python. Given the breadth of the approach, there are a number of opportunities for students from low level performance engineering to formalization of some of the underlying languages to the application of the overall system to difficult numerical problems. Here are some example projects:

- Build a Jax Based GPU Backend
- Improve one of the underlying algorithms at the intersection of mathematics and performance (e.g. estimate the quadrature degree required to integrate a given function)
- Build a prototype distributed extension.
- Implement and investigate the application of a specific class of finite elements to a specific problem (e.g. the application of the finite element exterior calculus to fluids problems). This could involve just working with an existing tool or it could involve an end to end effort where additional capabilities are added to each level of the system.
- Help formalize one of the underlying subsystems and re-implement it in a more robust way.

If successful, this could result in a coauthor position on a publication on the programming language or on its application to a specific field (e.g. currently we are pursuing computer graphics work). We imagine this project will be over in a single term, but extensions could easily be found if the student wishes to continue, potentially into an MEng thesis.

Please email teoc@mit.edu if you are interested with a cv + transcript.

Title: GPU Performance Engineering for Lattice Quantum Chromodynamics

Hours per week: 10

Department: EECS

Required Skills/Classes: (Python and/or C++), 6.106/(other strong experience with performance engineering)

Preferred Skills/Classes: Cuda, 6.S894, Halide/TVM/MLIR, some experience with GPUs

PIs: Saman Amarasinghe

Supervisor: Teodoro F. Collin

The COMMIT group is developing a DSL that produces codes for applications in Lattice Quantum Chromodynamics (LQCD). The DSL takes a specification of a LQCD problem and produces code in another DSL (currently Halide) where the code can be engineered for performance. The goal of this project is to optimize a complex example produced by this process for a specific GPU in the Frontier supercomputer (https://www.top500.org/system/180047/).

We seek a highly motivated student with experience in performance engineering and ideally with GPUs. The project is a challenging performance engineering problem where the performance of the application translates a budget of computing power to knowledge. Given the complexity of the code, we expect to investigate semi-automated ways of transforming the code or applying various programming languages that facilitate high performance code in addition to traditional performance engineering strategies. If successful, this could result in a coauthor position on a publication and/or advance to an MEng opportunity.

Please email teoc@mit.edu if you are interested with a cv + transcript.