Kaushik G Kulkarni

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Education

Aug '17 – Present	Ph.D. student in Computer Science University of Illinois at Urbana-Champaign, Urbana, IL Adviser: Prof. Andreas Klöckner
Aug '13 – May '17	Bachelor of Technology in Mechanical Engineering Indian Institute of Technology, Bombay Adviser: Prof. Shiva Gopalakrishnan

Experience

Aug '20 – Present	Research Assistant *National Center for Supercomputing Applications, UIUC*
Aug '17 – Aug' 20	Graduate Research/Teaching Assistant *Computer Science Dept., UIUC*
May '19 – Aug '19	Givens Associate *Argonne National Laboratory, Illinois* Improved the implementation of Nonlinear optimization algorithms on multi-core systems.
Jan '16 – May '17	Teaching Assistant for Introduction to Numerical Analysis *Mathematics Dept., IITB*
May '16 – July '16	Software Engineering Intern *Morgan Stanley Strats and Modelling, Mumbai* Developed internal tools to aid cash flow visualizations for traders.

Publications

[1] T. Sun, L. Mitchell, K. Kulkarni, A. Klöckner, D. A. Ham, and P. H. Kelly, A study of vectorization for matrix-free finite element methods, 2019.

[2] A. Bhati, R. Sawanni, K. Kulkarni, and R. Bhardwaj, "Role of skin friction drag during flow-induced reconfiguration of a flexible thin plate," Journal of Fluids and Structures, vol. 77, pp. 134–150, 2018.

Talks

[1] K. Kulkarni, "Transforming (not just) DG-FEM Array Expressions (not just) on GPUs," UIUC Compiler Seminar, 2022.

[2] K. Kulkarni and A. Klöckner, "Transforming (not just) DG-FEM Array Expressions (not just) on GPUs," ser. Flexible, Performance Portable Software for Partial Di erential Equations, SIAM Conference on Parallel Processing for Scientific Computing, 2022.

[3] ——, "UFL to GPU: Generating near-roofline action kernels," ser. Minisymposterium: Automatic Simulation Code Generation Tools and Their Applications, SIAM Conference on Computational Science and Engineering, 2021.

[4] ——, "UFL to GPU: Generating near-roofline actions kernels," FEniCS 2021, online, 22–26 March, 2021.

[5] K. Kulkarni, "Optimizing finite element operator evaluation on GPUs," Firedrake USA, 2020.

[6] K. Kulkarni and A. Klöckner, "Transformation-based code optimization for finite element methods," ser. Minisymposium on Performance Portability through Source-to-source code translation, SIAM Conference on Computational Science and Engineering, 2019.

Awards and Achievements

2022	Graduate College Presentation Award to present at SIAM Conference on Parallel Processing for Scientific Computing
2021	SIAM Travel Award for Conference on Computational Science and Engineering
2019	SIAM Travel Award for Conference on Computational Science and Engineering (Spokane, WA)
2016	Undergraduate Research Award (URA01) by Indian Institute of Technology, Bombay
2013	Kishore Vaigyanik Protsahan Yojana Fellowship Award
2013	Certificate of Merit for being among the State Top 1% in National Standard examination in Physics and Chemistry

Research

Optimizing Einstein-Summation Subprograms

Advised by Prof. Andreas Klöckner, UIUC

Einstein-summations provide a simple notation to express a wide-range of Linear-Algebra primitives. Achieving roofline FlOp-throughput for these operations still remains challenging. We employ a combination of techniques from auto-tuning to pattern-matching to generate efficient `OpenCL` code for computational kernels containing expressions that have `einsum`-like memory access patterns.

Array Programming Languages and Intermediate Representations

Advised by Prof. Andreas Klöckner, UIUC

Array Programming Languages have been an important vehicle for driving scientific applications from as early as the 1960s. Besides providing a close-to-math expressibility, their intermediate representations are closer to SIMD architectures making it easier to engineer optimizing compilers targeting such hardwares. Pytato provides one such IR that lowers $n - d$ array programs to computation graphs comprising of *pure*-Array Ops that can be targeted to `OpenCL` / `CUDA` / `JAX`.

Near-Roofline Discontinuous Galerkin Action Operators

Advised by Prof. Andreas Klöckner, UIUC

Discontinuous Galerkin operator applications comprise of many fine-grained array operations that can push them into the memory-bound regime. With kernel and loop fusion we can bump up the workload's Arithmetic Intensity, however, performing fusion might also negatively affect the kernel's performance by inhibiting device's latency hiding abilities by further introducing dependency edges and increasing the working set size of the inner loops. In the MIRGE-Com framework we address such trade-offs for GPU systems.

Finite Element Assembly on GPUs

Advised by Prof. Andreas Klöckner, UIUC

Evaluation of Finite Element operators result in a diverse set of computational kernels making it a difficult problem to find one optimization strategy that achieves near-peak performance for all the kernels on GPUs. We solve this problem by using high level code generation tools that select the optimization strategy based on the loop structure of the kernel.

Solving Eikonal Equations on Unstructured Grids

Advised by Prof. S Baskar, IIT Bombay

Characteristic Fast Marching Method is widely used in solving the Eikonal equations, however previous work had been only formulated for structured grids. We developed a solver that extended the algorithm for unstructured grids as well. Used the solver to solve known problems in literature with skew grids so that the activity of the solution could be efficiently observed in the region of activity.

Link: `https://github.com/kaushikcfd/eikonal-unstructured`

Discontinuous Galerkin Framework for Hyperbolic PDEs

Advised by Prof. Shiva Gopalakrishnan, IIT Bombay

We developed a `C++` library for solving Hyperbolic Equations through Discontinuous Galerkin ("DG") methods on structured grids. Performed a series of convergence tests to verify that the framework satisfied $hp-$convergence. Eventually, used the framework to simulate problems in Fluid Dynamics like the dam-break problem using high order DG elements.

Link: `https://github.com/kaushikcfd/Discontinuous-Galerkin`

Flow Induced Reconfiguration of Aquatic Vegetation

Advised by Prof. Rajneesh Bharadwaj, IIT Bombay

Corrected the existing models for Fluid Structure Interaction for a Flexible plate by including the Skin friction coefficient in the computations. Implemented a "*Predictor-Corrector*" based Finite Difference scheme for the computation of coefficient of drag on the plate.

Link: `https://arxiv.org/abs/1712.00441`

Last updated on November 10, 2022