High-Level Languages for High-Performance Computing

Semyon Grigorev

Saint Petersburg State University

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High-Level Languages For High-Performance Computing (HLL for HPC)

- Functional, functional-first programming languages for
  - GPGPU programming
  - FPGA programming (program specific processors)
  - Hardware synthesis

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- Type safety, static code checks
- Specific optimizations
  - Fusion (stream fusion)
  - Partial evaluation
  - Deforestation

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- Specific hardware

HLL for HPC: Projects

- LIFT: high-level functional data parallel language for portable HPC
  - University of Edinburgh, University of Glasgow
  - Supported by HIRP FLAGSHIP
- Haflang: special purpose processor for accelerating functional programming languages
  - Heriot Watt University
  - Supported by Xilinx and QBayLogic
- AnyDSL: A partial evaluation framework for programming high-performance libraries
  - Saarland University, German Research Center for Artificial Intelligence (DFKI)
- Futhark: high-performance purely functional data-parallel array programming
  - University of Copenhagen
- ...

Our projects

- Brahma.FSharp: F# to OpenCL C translator and respective runtime

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- Software-hardware platform for sparse linear algebra
  - Fusion-like optimization for sparse linear algebra routines (distillation)
  - Special hardware for functional programming language and sparse linear algebra

Brahma.FSharp

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High-Level Languages For High-Performance Computing (HLL for HPC)

- Research directions
  - Fusion-like optimization for sparse linear algebra routines (distillation)
  - Sparse linear algebra in functional language: type safe, fusion-friendly, natural divide-and-conquer parallelism
  - Special hardware for sparse linear algebra

HLL for HPC: Team

- Members
  - Daniil Berezun
  - Master students: Alexey Turin
  - Ekaterina Vinnik, Kirill Garbar, Artiom Chernikov
- Skills
  - Algorithm design, data structures
  - Program optimization, program transformation
  - Linear algebra, sparse linear algebra, GraphBLAS
  - Functional programming (Haskell, F#), OpenCL, GPGPU, FPGA
- Collaboration
  - Geoff William Hamilton

HLL for HPC: Results

- Tools
  - Distiller: fusion-like optimization for sparse linear algebra routines
  - Contribution to FHW: functional program to hardware translator
  - Contribution to Reduceron: specialized processor for functional programms
  - Brahma.FSharp: F# to OpenCL C translator and respective runtime
- Papers
  - Optimizing GPU programs by partial evaluation (PPoPP, Core A)
  - Distilling Sparse Linear Algebra (SRC@ICFP)

HLL for HPC: Results

- `addMask m1 m2 m3 = mask (mtxAdd m1 m2) m3`
- `kronMask m1 m2 m3 = mask (kron m1 m2) m3`
- `addMap m1 m2 = map f (mtxAdd m1 m2)`
- `kronMap m1 m2 = map f (kron m1 m2)`
- `seqAdd m1 m2 m3 m4 = mtxAdd (mtxAdd (mtxAdd m1 m2) m3) m4`

HLL for HPC: Results

Function	Matrix size				Interpreter		Reduceron	FHW
	m1	m2	m3	m4	Red-s	Reads	Ticks	Ticks
seqAdd	64×64	64×64	64×64	64×64	2.7	1.9	1.8	1.4
addMask	64×64	64×64	64×64	–	2.1	1.8	1.4	1.4
kronMask	64×64	2×2	128×128	–	2.2	1.9	1.4	2.7
addMap	64×64	64×64	–	–	2.5	1.7	1.7	1.5
kronMap	64×64	2×2	–	–	2.9	2.2	1.8	2.0

Table: Evaluation results: original program to distilled one ratio of measured metrics

Contact Info

- Lead: Semyon Grigorev
  - PhD (2016), Associate professor (2016, SPbSU)
  - dblp: https://dblp.org/pid/181/9903.html
  - h-index (scopus): 5
  - s.v.grigoriev@spbu.ru
- In collaboration with Daniil Berezun