Parallel Architecture and System Software Research Laboratory

http://passlab.github.io/
https://github.com/passlab/

Department of Computer Science and Engineering
Yonghong Yan

http://www.cse.sc.edu/~yanyh

Fall 2018

PASSLab Team

- Faculty
  - Yonghong Yan
- Ph.D. Graduate Students and Starting Semester
  - Chrisognas Mc'Odhiambo, Spring 2018
  - Kewei Yan, Spring 2018
  - Philip Conrad, Spring 2018
  - Nattapon Donratanapat, Summer 2018
  - Anjia Wang, Summer 2018

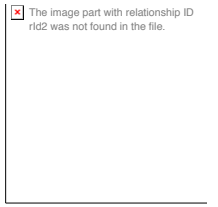
  - Yudong Sun, Fall 2018
  - Yaying Shi, Fall 2018
  - Xin Zhao, Fall 2018

- Master Students: TBA
- Undergraduate Students: TBA

- Senior People (postdoc or research scientist): TBA
- Visiting scholar: Welcome

http://passlab.github.io/people/

Our Research Areas in General



- Address **Performance**, **Power** and **Programmability** challenges of **Parallel** computing
  - Target High Performance Computing (HPC) and emerging applications such as image processing and machine learning

- Advance state of the art of computer systems
  - Parallel programming models and compiler
  - Computer architecture and systems
  - Parallel performance tools
- Support interdisciplinary research for computational and data scientists
  - Developing and optimizing applications for parallel hardware
  - Developing domain-specific programming languages and system support

What We Do:

- Develop intra-/inter-node parallel programming models, compiler, runtime systems and performance tools
  - Work with OpenMP, MPI and domain-specific languages
  - OpenMP compiler based on ROS and runtime based on LLVM/Intel OpenMP runtime
- Develop tools for performance analysis and optimization
  - OpenMP tool via hardware counters (PAPI or perf), OMPT, LTTng, Eclipse TraceCompass
  - Binary analysis and instrumentation using Intel Pin
- Architecture for parallel and domain-specific computing
  - FPGA implementation for kernels of material science and other domains
  - Emerging memory and cache systems
  - RISC-V-based research (NVDLA+Rocket, SMT BOOM, etc)

What We Do:

- Big data and jupyter
  - Data management framework based on CKan and integration with other data analysis tools and cloud storage
- Jupyter-related
  - Web-based parallel programming
- Collaborate with scientists to parallelize and optimize real problem
  - Medical imaging applications on GPU using CUDA
    - Deformable image registration for radiation dose calculation
  - SNL for HPCG and mini-/proxy-apps for DoE
  - Material science
- Interact and educate students, peers and community to know the area of parallel computing and HPC
- To support existing and emerging hardware for HPC
  - Multicore CPUs, NVIDIA GPUs, and Intel Xeon Phi
  - Intel/Xilinx FPGA using OpenCL and Mexler dataflow FPGA
  - HBM/HMC memory in GPU and Xeon Phi, and NV RAM
  - Cluster and heterogeneous systems of CPU/GPU/Phi/FPGA

Current Project

- CAREER: Programming the Existing and Emerging Memory Systems for Extreme-scale Parallel Performance
  - NSF, 5 years till 2022
- SHF: Medium: Compute on Data Path: Combating Data Movement in High Performance Computing
  - NSF, one year left till 2019
- SHF: Small: Collaborative Research: Application-aware Energy Modeling and Power Management for Parallel and High Performance Computing
  - NSF, one year left till 2019
- Connecting ROSE to LLVM OpenMP Runtime
  - LLNL, one hear till May 2019, extensions based on progress

Current Project

- Hardware Design and Computer Architecture
  - RISC-V (https://riscv.org/) based on Rocket and BOOM chips
    - https://github.com/freechipsproject/rocket-chip
    - https://github.com/ucb-bar/riscv-boom
  - NVIDIA Deep Learning Accelerator (NVDLA) (http://nvdla.org/)
  - FPGA with High Bandwidth Memory from Intel/Xilinx and Maxeler
    - FPGA development for bio-informatics and material science

Pending or Upcoming Project

- BIGDATA: F: Polyglot Programming and Execution Environment to Synergize Computational Simulation and Big Data Analytics for Scientific Discovery
  - NSF, Four Years till 2022/2023
- In-situ Performance Analysis and Optimization for Automated Performance Tuning of Extreme-scale Applications:
  - NSF, 3-4 years till 2022/2023
- High Performance Implementation using GPU and FPGA
  - Deformable Image Registration for Cancer Treatment
    - on-hold for a good CUDA development person
  - FPGA/CUDA implementation for material science kernel
- Datarex Ckan based data management and deep learning framework
  - Work with MD Anderson

Exploration

- Validation and Performance Optimization of AV Software System and Algorithms Using NVIDIA DRIVE Constellation
  - NVIDIA Equipment donation, at least one year till 2019
  - System software and algorithms for AV systems, algorithms, and DL
- Cognitive drone using NVIDIA Jetson
- Deep learning framework and integration with HPC system stack
- New computational paradigm: quantum computing, blockchains, etc

Sponsor and Collaborators

- Sponsor:
  - National Science Foundation
  - DoE/LLNL
  - Industries: NVIDIA/Xilinx/Intel, etc

- Collaborators
  - DoE/LLNL ROSE Team
  - DoE Sandia, Ron Brightwell
  - Virginia Tech, Texas Tech, Stony Brook
  - Industries: via OpenMP ARB

Software and Hardware Resources

- Each of you have a development desktop

- {fornax, carina, pivo}.cse.sc.edu
  - https://github.com/passlab/passlab.github.io/wiki/Hardware-and-Resources
  - High-end server with GPUs
- RCI cluster
  - https://www.sc.edu/about/offices_and_divisions/division_of_information_technology/rci/
- XSEDE bridges
  - https://github.com/passlab/passlab.github.io/wiki/Hardware-and-Resources#nsf-xsede-bridges-from-psc

https://github.com/passlab

- Github organization for almost all of our work
  - People: passlab team and collaborators
  - Teams/subteams in passlab for access control
  - Maillist: passlab@googlegroups.com

- https://github.com/passlab/passlab.github.io repo:
  - Public website at http://passlab.github.io/
    - Add your name and photo
  - Internal wiki shared by all the passlab members
    - https://github.com/passlab/passlab.github.io/wiki
    - You should update often

- Repos for our development and papers/proposals

- Each of you can have your private repo
  - For your own notes (I can see it if I want to ☺).
  - For creating your public website linked as: http://passlab.github.io/yanyh

Meeting and Organization

- Weekly 1:1 meeting on Monday or Tuesday
  - 30-minutes with each of you
    - Take notes in the group wiki site
  - Second meeting if needed on Thursday or Friday
- Monthly group meeting
    - Thursday

- Meeting as needed

Responsibility

- 20 hours/week work officially as full-time RA
  - Concentrate on delivering your work and being productive
- Your work:
  - **Research**: search and re-search related work and write study doc about what others do and their pros/cons
  - **Development**: write code that work
  - **Learning**: study and teach, learn something and teach others
  - **Outreach**: promote, marketing, volunteer, etc.
- Weekly report due Monday 12:00PM of the following week
  - 1/3 to half page (~100-300 words), sent to me by email
    - https://github.com/passlab/passlab.github.io/wiki/Information-About-Weekly-Work-Notes
  - Keep your worknote on wiki as well

Publications

- Publications are what you put on your resume

- You should set yourself a goal to produce at least one ***thing*** per semester as first author including
  - Workshop/conference/journal paper, and technical report
  - We set goals at the beginning of the semester

- Check for conferences/workshops and due date
  - https://github.com/passlab/passlab.github.io/wiki/Conference-for-submissions

Ph.D. Study and Graduation

- ~ 5 years and it depends
  - Qualifying exam
  - Research, development, publication and others
  - Preliminary defense
  - Dissertation and oral defense

- Publications expectation as first author
  - > 1 journal
  - 2 tier 1 conference/journal papers
  - >3 workshop papers and joint papers

  - Demonstrate your research scholarship, development skills, presentation, service and maturity in professional level

Research Topics and Research Project

- You have a research project that support your study as RA

- Your research topics will be based on the research project that funds you.
  - Likely that you research topics span multiple research projects
  - Likely you will work on more than one research project

- Your development will definitely used for multiple projects.

Development and Tools

- Programming Languages
  - OpenMP, MPI, Python, C/C++/Fortran and CUDA; OpenCL/OpenACC/etc
- Compiler:
  - ROSE, Clang/Flang/LLVM
- Runtime library system
  - LLVM OpenMP runtime, Open MPI, and runtime library for various other languages
- Performance and tools:
  - OMPT, MPI_T, PAPI, Linux perf, LTTng, pintools, (hpctoolkit, TAU, Score-P, etc).
  - SENSEI in-situ, VisIt, Eclipse/Compass, Jupyter notebook
- Hardware and FPGA development
  - RISC-V, Chisel, Verilog, vendor tools

Software Development and Release

- Developing and releasing robust software are VERY IMPORTANT
  - Encourage collaboration
  - Sharing with community
  - Demonstrate professionalism
- We will release our compiler, runtime and tools
- To note:
  - Following coding/naming guideline
  - Write good document
  - Develop easy-to-read code
  - Sharing from github

Development Environment

- Familiar with Linux command line development
  - make/cmake, and autotools
  - Compiler: ROSE, Clang/LLVM, GNU, Intel
  - How to use those performance tools mentioned before
  - IDE: CLion/Eclipse for C/C++ development

- Git and github
  - Git commands for branch, remote, push/pull, merge, pull request, etc
  - github source code/wiki development workflow

- Documentation
  - Wiki in markdown format, tutorial in markdown and Jupyter notebook
  - Presentation using MS powerpoint or Mac Keynote, or google presentation
  - Sheet using MS Excel sheet, or Google sheet
  - Short paper or document: MS words or google doc
  - Technical paper or proposal: Latex

Education and Outreach

- You will be asked to give lectures or tutorial in some of my course, in our group meeting or for other group in the university, e.g. RCI.
- You may be requested to give talks/tutorials to external groups.

- Subscribe to magazine, mail-list, etc
  - ROSE, LLVM, OpenMP, hpc-announce, hpcwire, nextplatforms

- Participate and volunteer in outreach activities related to engineering and our research area
  - Promote our research
  - Service the community

Travel

- Your travel to attend conference/workshop to present published paper will be covered by our research funding
  - Talk with me before you plan to submit to specific place
    - E.g. We normally do not send you to international place for just presenting a poster

- Let me know as early as possible your personal travel plan during the semester and summer

Internship and External Collaboration

- Internship are encouraged if it is related to your research topic and project
- I will help to find internship opportunity during your study
  - Industries and national lab

- External collaboration are encouraged and required
  - Know the people who work in the area like you
  - Find opportunity to interact with them.

Support for you

- Advising
  - Weekly meeting
  - Group meeting
- Your study plan (Ph.D. or master) and your career plan
- Collaboration and outreach opportunities
  - Internship, attending conference
- Financial support
  - RA and TA, we may put you as TA based on the funding situation and your performance
  - RA Salary will be based on performance
- Other help
  - Let me know

You

- Ambition and goals
  - To make impact
- Achieving excellence through self-motivation and dedication
  - Lack of background or resources is not an issue
  - Work hard and work smart
  - Open-minded

- Laziness and dishonesty are not tolerable

Training Needed

- For all (2 to 4 weeks)
  - Linux, C and vim
  - Compilation, linking, make/makefile/cmake/autotools study and practice
  - Git and github (branches, pull request), diff and patch
  - IDE: CLion for C/C++, IntelliJ IDE for Java/Scala, Python IDE
  - Markdown, wiki, ppt, excel, google docs/sheet
  - OpenMP programming
  - PThread programming (assignment for implementing basic OpenMP fork-join/barrier/single/master using pthreads)

- For specific area
  - Compiler: ROSE
  - Runtime: LLVM OpenMP runtime, REX, cilkplus runtime
  - Tools: OMPT, RTune, etc
  - Computer architecture: Scala/Chisel, RISC-V, Rocket-chips, ARM embedded design
  - Applications and benchmarks: AXPY (stream), matvec, mm, LU/Cholesky/QR, Rodinia, mini-apps, proxy-apps
  - Fortran/CUDA/MPI programming
  - Jupyter notebook
  - Spark/Datarex related

What is HPC and Parallel Computing

- Talk Friday 2:30PM at 2A31 Swearingen
- Slides will be published on our wiki