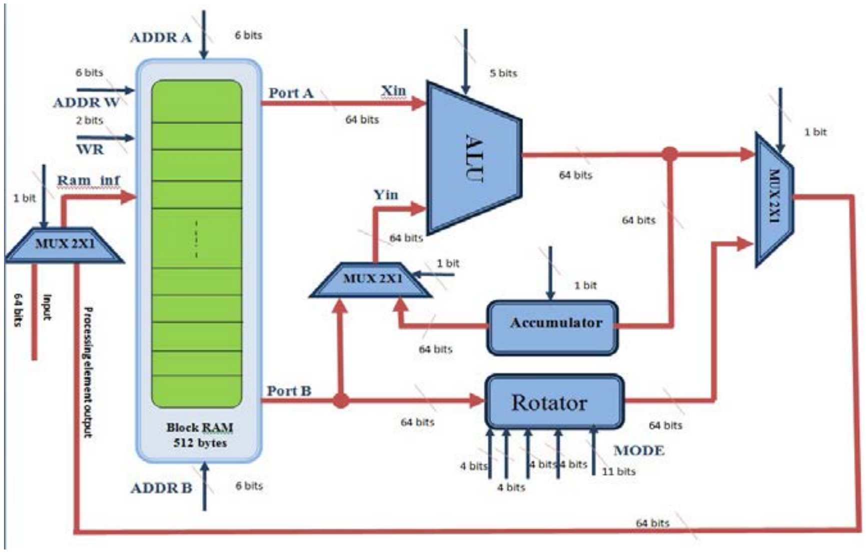
Laboratory for Computer Architecture



Our research focuses on how to design and program for multicore architectures in the presence of severe physical constraints, especially thermal, power delivery, process variations, and wear-out. We are chiefly focusing on these issues in the context of heterogeneous designs, in which a CPU is combined with various hardware accelerators. Such architectures provide the best balance between high single-thread performance and high throughput for parallel tasks. Our power, thermal, and reliability research has led to a suite of widely used research tools, such as HotSpot, VoltSpot, and ArchFP. Our research on system architecture and programming for heterogeneous systems especially focuses on GPUs, FPGAs, and Micron's new Automata Processor as test cases, and together with Micron Technology, we have co-founded the Center for Automata Processing (CAP). We are also one of the first groups to explore the use of graphics processors (GPUs) for general-purpose computing, the first to develop an architectural simulation infrastructure-Qsilver-for performance, power, and thermal studies on GPUs, and have released Rodinia as a benchmark suite for GPGPU research. FPGAs are also useful as a testbed for novel accelerators, such as a programmable cryptographic processor we developed. Most of this work is done in collaboration with Mircea Stan.

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"Sequentiality is an illusion."

University of Virginia

School of Engineering & Applied Science

Heterogeneous Computing

Computer systems are increasingly exposing a heterogeneous programming model consisting of conventional CPUs and various accelerators, such as GPUs. In fact, today's mobile SoCs include a wide variety of accelerators. This trend is driven both by the speedups these platforms afford as wells as energy-efficiency and cooling considerations. However, suitable programming models, effective compilation, decisions on which tasks to run where, and associated hardware design decisions for heterogeneous systems are poorly understood. We are studying all these issues. We have also developed the Rodinia suite of applications that support research and development in heterogeneous systems.

Architectures for Managing Power, Temperature, and Reliability

High power densities and their effects in silicon semiconductors today already pose significant challenges to circuit and system designers. As semiconductor manufacturing processes scale to smaller transistor sizes, circuit operating temperatures will continue to rise. Thermal management and improved on-chip power delivery have become vital to continued innovation in IT, energy efficiency, and economic health. Since their initial development and release, HotSpot and VoltSpot, the thermal and voltage modeling tools developed through our work, have played a critical role in assisting researchers worldwide with the design and validation of thermal and voltage management techniques. We are continuing to extend these models to support the next generation of thermal and voltage modeling and other related research.

Architectural Modeling and Simulation Methodology

We are working to develop new capabilities for accelerating simulation in order to achieve quantum leaps in our understanding of complex systems (such as the heart and other organs) by automatically partitioning the work among the heterogeneous processing units that are now becoming commonplace in commodity computer systems, in particular GPUs, FPGAs, and the Micron Automata Processor—each of which target different bottlenecks.

Automata Processing

Together with Micron Technology, we recently founded the Center for Automata Processing. As part of our research in this center, we are evaluating how to use native hardware support for non-deterministic finite automata to dramatically accelerate a wide variety of algorithms that involve symbolic pattern matching, especially algorithms involving inexact pattern matching, which is difficult to perform efficiently on conventional von Neumann architectures.

RECENT RESEARCH DEVELOPMENTS

- We have shown the dramatic speedups possible with the Micron Automata Processor on various pattern-mining algorithms.
- We have developed a new programming language, RAPID, for inexact pattern matching. It can target a variety of hardware architectures.
- A new extension to our HotSpot framework, VoltSpot, allows modeling of a chip's power distribution network, including support for 3D chips. Our preliminary analysis suggests that power stability is just as much a threat to future technology scaling as total power and thermal limits.

RECENT GRANTS

- NSF: MultiSpot - Closing the Power-Delivery/Heat-Removal Cycle For Heterogeneous Multiscale Systems
- Virginia CIT: Automata Processing for Association Mining on Massive Data Sets
- Virginia CIT: Accelerating Machine Learning with FPGAs

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