



# 北京大学高能效计算与应用中心学术报告

Invited Talk, Center for Energy-Efficient Computing and Applications

## ENABLING COMPUTATION WITH MINIMAL DATA MOVEMENT: CHANGING THE COMPUTING PARADIGM FOR HIGH EFFICIENCY

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**ABSTRACT:** Today's systems are overwhelmingly designed to move data to computation. This design choice goes directly against at least three key trends in systems that cause performance, scalability and energy bottlenecks: 1) data access from memory is already a key bottleneck as applications become more data-intensive and memory bandwidth and energy do not scale well, 2) energy consumption is a key constraint in especially mobile and server systems, 3) data movement is very expensive in terms of bandwidth, energy and latency, much more so than computation. These trends are especially severely felt in the data-intensive server and energy-constrained mobile systems of today. At the same time, conventional memory technology is facing many scaling challenges in terms of reliability, energy, and performance. As a result, memory system architects are open to organizing memory in different ways and making it more intelligent, at the expense of slightly higher cost. The emergence of 3D-stacked memory plus logic, the adoption of error correcting codes inside the latest DRAM chips, and intelligent memory controllers to solve the RowHammer problem are an evidence of this trend. In this talk, I will discuss some recent research that aims to practically enable computation close to data. After motivating trends in applications as well as technology, we will discuss at least two promising directions: 1) performing massively-parallel bulk operations in memory by exploiting the analog operational properties of DRAM, with low-cost changes, 2) exploiting the logic layer in 3D-stacked memory technology in various ways to accelerate important data-intensive applications. In both approaches, we will discuss relevant cross-layer research, design, and adoption challenges in devices, architecture, systems, applications, and programming models. Our focus will be the development of in-memory processing designs that can be adopted in real computing platforms and real data-intensive applications, spanning machine learning, graph processing, data analytics, and genome analysis, at low cost. If time permits, we will also discuss and describe simulation and evaluation infrastructures that can enable exciting and forward-looking research in future memory systems, including Ramulator and SoftMC.

**BIOGRAPHY:** Onur Mutlu is a Professor of Computer Science at ETH Zurich. He is also a faculty member at Carnegie Mellon University, where he previously held the Strecker Early Career Professorship. His current broader research interests are in computer architecture, systems, hardware security, and bioinformatics. A variety of techniques he, along with his group and collaborators, has invented over the years have influenced industry and have been employed in commercial microprocessors and memory/storage systems. He obtained his PhD and MS in ECE from the University of Texas at Austin and BS degrees in Computer Engineering and Psychology from the University of Michigan, Ann Arbor. He started the Computer Architecture Group at Microsoft Research (2006-2009), and held various product and research positions at Intel Corporation, Advanced Micro Devices, VMware, and Google. He received the ACM SIGARCH Maurice Wilkes Award, the inaugural IEEE Computer Society Young Computer Architect Award, the inaugural Intel Early Career Faculty Award, US National Science Foundation CAREER Award, Carnegie Mellon University Ladd Research Award, faculty partnership awards from various companies, and a healthy number of best paper or "Top Pick" paper recognitions at various computer systems, architecture, and hardware security venues. He is an ACM Fellow "for contributions to computer architecture research, especially in memory systems", IEEE Fellow for "contributions to computer architecture research and practice", and an elected member of the Academy of Europe (Academia Europaea).