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Think Big, Aim High



Dear SAFARI friends,

2019 and the first three months of 2020 have been very positive eventful times for SAFARI. We have welcomed new students, interns, postdocs, and visitors from all over the world. We have also said goodbye to several group members who have graduated; some who have returned to their studies and academic positions elsewhere, and some who have moved on to new positions in industry and academia. We were honored and humbled with several research and technical impact awards. We presented and published new research on computer architecture, memory systems, hardware security, bioinformatics and beyond at top venues like ISCA, MICRO, ASPLOS, HPCA, SIGMETRICS, IEEE S&P, DSN, PLDI, DAC, and Bioinformatics. We have also written various invited articles on various topics for journals and books. We started new research projects and collaborations with industry partners, as well as with other research institutions. We delivered many lectures, courses, and talks at many venues and institutions around the world; we have shared all materials publicly as much as possible, including all the lecture materials as well as the research artifacts we develop.

In this inaugural edition of our SAFARI newsletter, we would like to share some of our group highlights from the past 15 months with you to reflect on our accomplishments and fruitful collaborations, and look ahead to new and inspiring research projects, collaborations, and educational activities in 2020. We hope it is useful and informative, and welcome any feedback and new ideas, as always.

Stay safe and healthy, and keep in touch.

Onur Mutlu



2020 has brought many new challenges to SAFARI and our community – we are continually adapting to new and creative ways of working together, teaching, and maintaining scientific rigor under the uncertainty of COVID-19.

News & Awards

Onur Mutlu Selected to Receive IEEE Computer Society 2020 Edward J. McCluskey Technical Achievement Award

IEEE Computer Society Edward J. McCluskey Technical Achievement Award 2020

Onur is this year's recipient of the [IEEE Computer Society](#) prestigious 2020 [Edward J. McCluskey Technical Achievement Award](#) for "innovative and impactful contributions to computer memory systems."

[Read More](#)



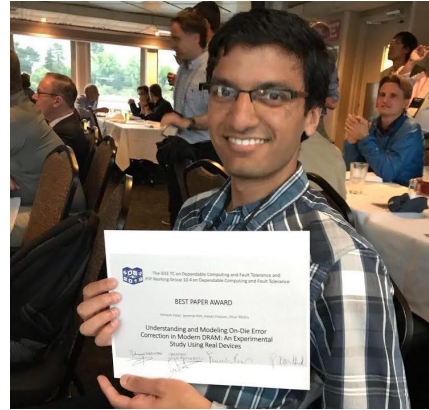
ACM Maurice Wilkes SIGARCH Award, ISCA 2019

Onur was honored with the [ACM SIGARCH Maurice Wilkes Award](#), for "innovative contributions in efficient and secure DRAM systems" at ISCA 2019 in June.

[Watch Interview](#)

[Watch Award Lecture](#)

[Read more](#)



Best Paper Award DSN 2019

Congratulations to Minesh Patel, Jeremie Kim, Hasan Hassan, and Onur Mutlu for the Best Paper Award at this year's IEEE/IFIP International Conference on Dependable Systems and Networks (DSN) [Understanding and Modeling On-Die Error Correction in Modern DRAM: An Experimental Study Using Real Devices](#) DSN, Portland, OR, June 2019

[Read more](#)

IEEE TCAD Top Pick Award

Our RowHammer paper was selected as a [Top Pick in Hardware and Embedded Security](#).

Read our recent retrospective:

Onur Mutlu and Jeremie Kim

[RowHammer: A Retrospective](#)

[IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems \(TCAD\) Special Issue on Top Picks in Hardware and Embedded Security, 2019.](#)

[Watch Rowhammer I Lecture](#)

[Watch Rowhammer II Lecture](#)

[Read more](#)

Announcing the winners

We were also honored to receive a **Facebook AI System Hardware/Software Co-Design Research Award** for our proposal on “Realistic Benefits of Near-Data Processing for Emerging ML Workloads”.

[Read more](#)



Best Student Presenter Award

Damla Senol Cali received the “Top 10 Best Student Presenter Award” at [SRC's TECHCON 2019](#) conference for her presentation of [BitMAC: An In-Memory Accelerator for Bitvector-Based Sequence Alignment of Both Short and Long Genomic Reads](#). Congratulations Damla!

Google Research Philosophy Research Areas

[OUTREACH](#) > [FACULTY RESEARCH AWARDS](#) >

Faculty Research Awards recipients

Our group was awarded a **Google Faculty Research Award** for our proposal on “Memory System Designs for Edge Machine Learning Accelerators”.

TO GENERATE TRUE RANDOM NUMBERS with Low Latency and High Throughput

Jeremie S. Kim^{1§} Minesh Patel[§] Hasan Hassan[§] Lois Orosa[§] Onur Mutlu^{§§}
¹Carnegie Mellon University [§]ETH Zürich

IEEE Micro Top Pick Honorable Mention

Our paper was an IEEE Micro Honorable Mention, congratulations to Jeremie S. Kim, Minesh Patel, Hasan Hassan, Lois Orosa, and Onur Mutlu, [D-RaNGe: Using Commodity DRAM Devices to Generate True Random Numbers with Low Latency and High Throughput](#)

HPCA, Washington, DC, February 2019

[Read more](#)

New SRC funding for our proposal on "Memory System Design for AI/ML Accelerators & ML/AI Techniques for Memory System Design"

We aim to solve two different yet related and synergistic problems in this project, both focusing on AI/ML and memory system design. In Problem 1, AI/ML is the workload and the memory system is a key tool to be rethought for making the workload much faster and more efficient. In Problem 2, the on-chip memory system is the design target and ML/AI is a key tool for making the designs much faster and much more efficient.

Onur was selected to [the Computer Architecture Aggregated Hall-of-Fame](#), 2019.

[Read more](#)

[Read more](#)

[Read more SAFARI news](#)

Industry Partners

Alibaba	Google	Intel
ASML	HiSilicon	Microsoft
Facebook	Huawei	SRC
Futurewei	IMEC	VMware

Selected Recent Publications

Are We Susceptible to Rowhammer? An End-to-End Methodology for Cloud Providers

Lucian Cojocar, Jeremie Kim, Minesh Patel, Lillian Tsai, Stefan Saroiu, Alec Wolman, Onur Mutlu

S&P, May 20 – 24 San Francisco, CA

[Read more](#)

Evanesco: Architectural Support for Efficient Data Sanitization in Modern Flash-Based Storage Systems

Myungsuk Kim, Jisung Park, Geonhee Cho, Yoona Kim, Lois Orosa, Onur Mutlu, Jihong Kim

ASPLOS, March 16 – 20 2020, Lausanne, Switzerland

[Read more](#)

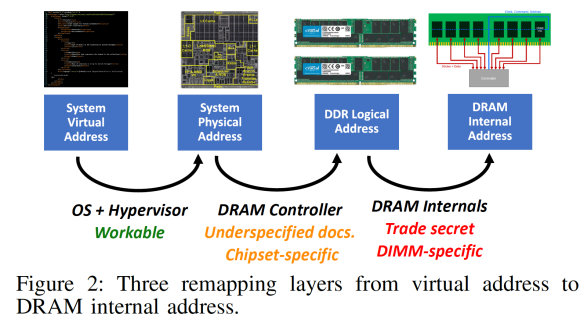
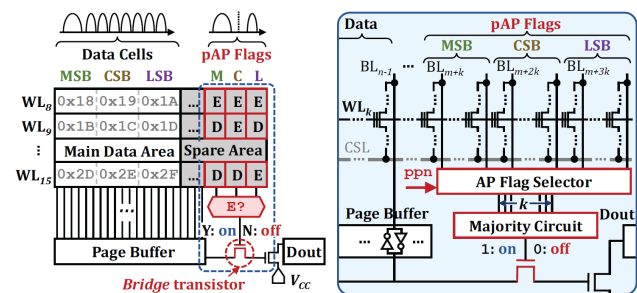


Figure 2: Three remapping layers from virtual address to DRAM internal address.



(a) Organizational overview. (b) A pAP implementation.

Figure 8. Our pLock implementation.

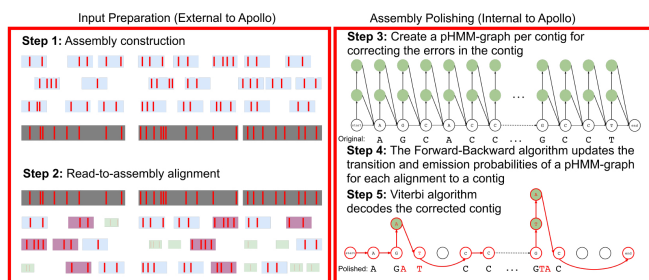
Apollo: A Sequencing-Technology-Independent, Scalable, and Accurate Assembly Polishing Algorithm

Can Firtina, Jeremie S. Kim, Mohammed Alser, Damla Senol Cali, A. Ercument Cicek, Can Alkan, Onur Mutlu

Bioinformatics, online March 13 2020

Source Code: Apollo

[Read more](#)



Invited: In-DRAM Bulk Bitwise Execution Engine

Vivek Seshadri, Onur Mutlu

Book Chapter: Advances in Computers, to appear in 2020.

[Read more](#)

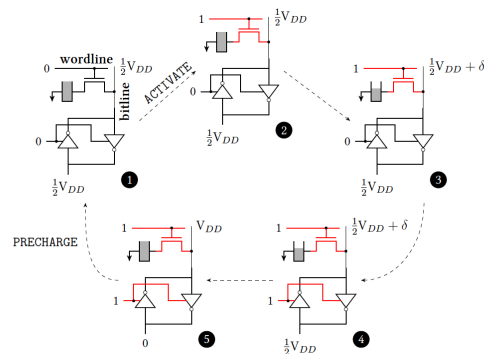
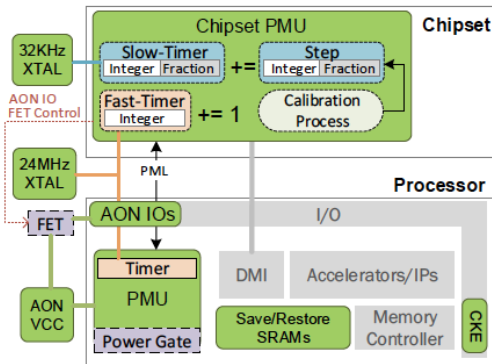


Figure 6: Operation of a DRAM cell and sense amplifier. ① precharged state, ② wordline enable, ③ charge sharing, ④ sense amplifier enable, ⑤ activated state.



Techniques for Reducing the Connected-Standby Energy Consumption of Mobile Devices

Jawad Haj-Yahya, Yanos Sazeides, Mohammed Alser, Efraim Rotem, Onur Mutlu

HPCA, Feb 22 – 26 2020, San Diego, CA
[Slides \(pptx\)](#) ([pdf](#))

[Read more](#)

Processing-in-Memory: A Workload-Driven Perspective

Saugata Ghose, Amirali Boroumand, Jeremie S. Kim, Juan Gómez-Luna, Onur Mutlu

IBM Journal of Research and Development (63 (6), Nov-Dec 2019)

[Read more](#)

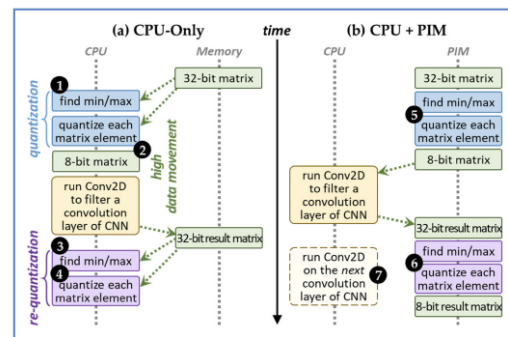


Figure 4

Quantization on (a) CPU versus (b) PIM. Reproduced from [16].

Shouji: A Fast and Efficient Pre-Alignment Filter for Sequence Alignment

Mohammed Alser, Hasan Hassan, Akash Kumar, Onur Mutlu, Can Alkan

Bioinformatics, 35 (21), 1 November 2019

Source Code: Shouji

[Read more](#)

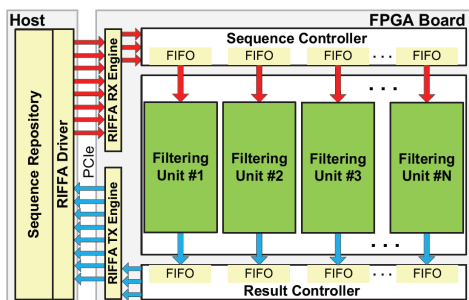


Fig. 2: Overview of our hardware accelerator architecture. The filtering units can be replicated as many times as possible based on the resources available on the FPGA.

SMASH: Co-designing Software Compression and Hardware-Accelerated Indexing for Efficient Sparse Matrix Operations

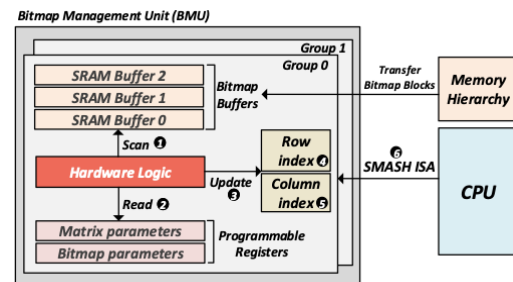
Konstantinos Kanellopoulos, Nandita Vijaykumar, Christina Giannoula, Roknoddin Azizi, Skanda Koppula, Nika Mansouri Ghiasi, Taha Shahroodi, Juan Gómez-Luna, Onur Mutlu

MICRO, Oct 12 –16, 2019, Columbus, OH

Slides (pptx) (pdf)

[Talk Lecture](#)

[Read more](#)



EDEN: Enabling Energy-Efficient, High-Performance Deep Neural Network Inference Using Approximate DRAM

Skanda Koppula, Lois Orosa, A.Giray Yağlikçi, Roknoddin Azizi, Taha Shahroodi, Konstantinos Kanellopoulos, Onur Mutlu

MICRO, Oct 12 – 16, 2019, Columbus, OH

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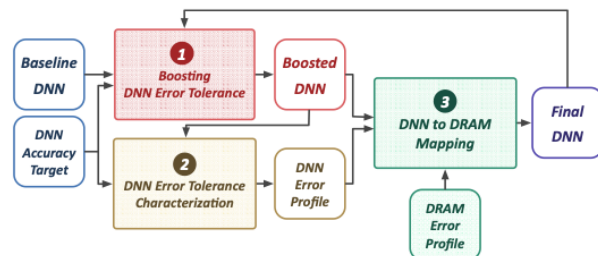


Figure 4: Overview of the EDEN framework.

DSPatch: Dual Spatial Pattern Prefetcher

Rahul Bera, Anant Nori, Onur Mutlu, Sreenivas Subramoney

MICRO, Oct 12 – 16, 2019, Columbus, OH

[Slides \(pptx\) \(pdf\)](#)

[Lightning Talk Video](#)

[Read more](#)

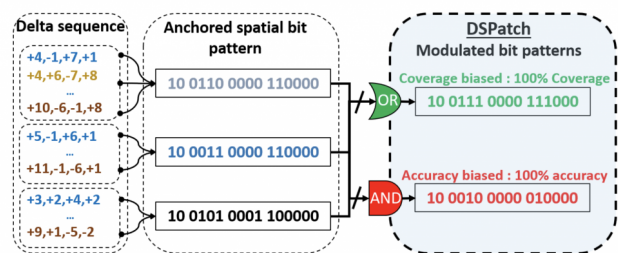


Figure 3: Illustration of two modulated bit-patterns that DSPatch takes advantage of

Binary Star: Coordinated Reliability in Heterogeneous Memory Systems for High Performance and Scalability

Xiao Liu, David Roberts, Rachata Ausavarungnirun, Onur Mutlu, Jishen Zhao

MICRO, Oct 12 – 16, 2019, Columbus, OH

[Slides \(pptx\)](#) ([pdf](#))

[Lightning Talk Video](#)

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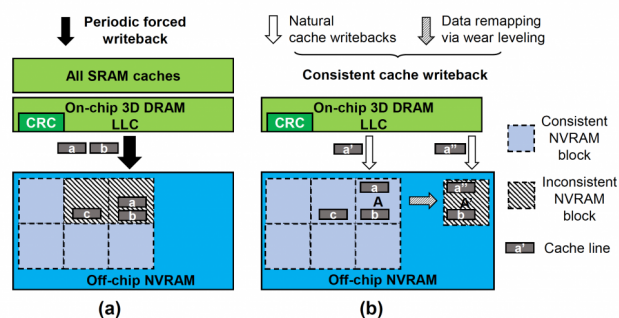


Figure 4: Binary Star design overview.

Invited: Processing Data Where It Makes Sense: Enabling In-Memory Computation

Onur Mutlu, Saugata Ghose, Juan Gómez-Luna, Rachata Ausavarungnirun

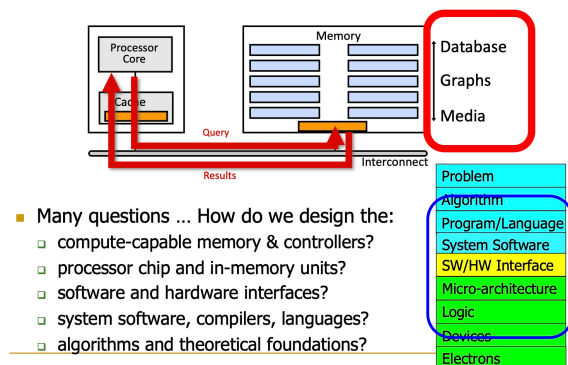
MICPRO, Volume 67, June 2019

[Slides \(pptx\)](#)

[Talk Video](#)

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Goal: Processing Inside Memory



- Many questions ... How do we design the:
 - compute-capable memory & controllers?
 - processor chip and in-memory units?
 - software and hardware interfaces?
 - system software, compilers, languages?
 - algorithms and theoretical foundations?

Understanding and Modeling On-Die Error Correction in Modern DRAM: An Experimental Study Using Real Devices

Minesh Patel, Jeremie S. Kim, Hasan Hassan, Onur Mutlu

DSN, June 24 – 27, 2019, Portland, OR

[Slides \(pptx\)](#) ([pdf](#))

[Talk Video](#)

[Source Code: EINSim](#)

[Read more](#)

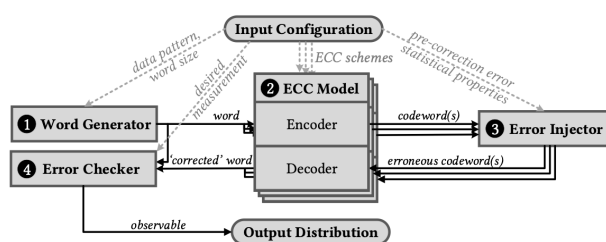


Figure 4: High-level block diagram showing the logical flow of data through the different components in our simulator.

Demystifying Workload-DRAM Interactions: An Experimental Study

Saugata Ghose, Tianshi Li, Nastaran Hajinazar, Damla Senol Cali, Onur Mutlu

SIGMETRICS, June 24 – 28 2019,

Phoenix, AZ

[Slides \(pptx\)](#) ([pdf](#))

[MemBen Benchmark Suite](#)

[Source Code: GPGPUSim-Ramulator](#)

[Read more](#)

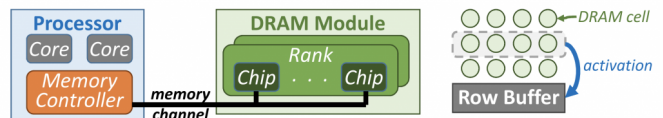


Fig. 1. Memory hierarchy (left) and bank structure (right).

CROW: A Low-Cost Substrate for Improving DRAM Performance, Energy Efficiency, and Reliability

Hasan Hassan, Minesh Patel, Jeremie S. Kim, A. Giray Yaglikci, Nandita Vijaykumar, Nika Mansourighiasi, Saugata Ghose, Onur Mutlu

ISCA, June 22 – 26, 2019, Phoenix, AZ

[Slides \(pptx\)](#) ([pdf](#))

[Full Talk Video](#)

[Source Code: CROW](#)

[Read more](#)

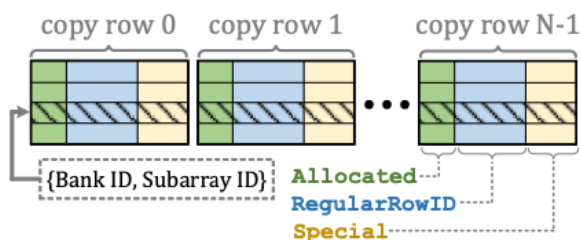


Figure 4: Organization of the CROW-table.

CoNDA: Efficient Cache Coherence Support for Near-Data Accelerators

Amirali Boroumand, Saugata Ghose, Minesh Patel, Hasan Hassan, Brandon Lucia, Rachata Ausavarungnirun, Kevin Hsieh, Nastaran Hajinazar, Krishna T. Malladi, Hongzhong Zheng, Onur Mutlu,

ISCA, June 22 – 26, 2019, Phoenix, AZ

[Slides \(pptx\)](#) ([pdf](#))

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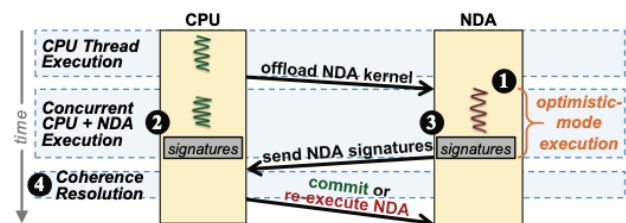


Figure 5: High-level operation of CoNDA.

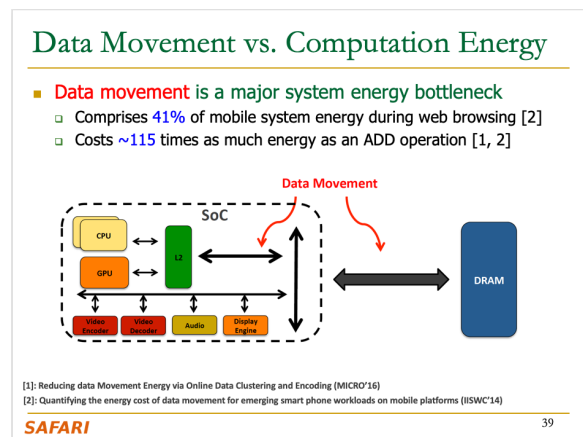
Invited: Enabling Practical Processing in and near Memory for Data-Intensive Computing

Onur Mutlu, Saugata Ghose, Juan Gómez-Luna, Rachata Ausavarungnirun

DAC, June 3 – 5 2019, Las Vegas, NV

[Slides \(pptx\)](#)

[Read more](#)



NAPEL: Near-Memory Computing Application Performance Prediction via Ensemble Learning

Gagandeep Singh, Juan Gómez-Luna, Giovanni Mariani, Geraldo F. Oliveira, Stefano Corda, Sander Stujik, Onur Mutlu, Henk Corporaal

DAC, June 3 – 5 2019, Las Vegas, NV

[Slides \(pptx\) \(pdf\)](#)

[Source Code: Ramulator-PIM](#)

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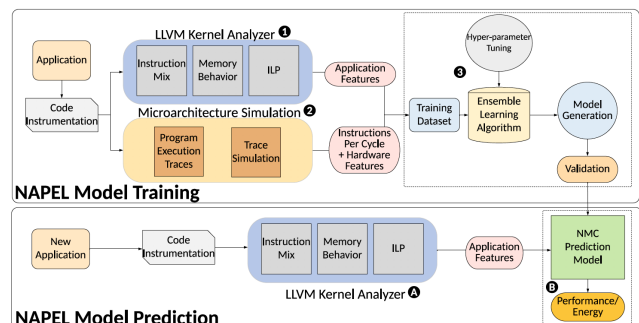


Figure 1: Overview of NAPEL training and prediction

RowHammer: A Retrospective

Onur Mutlu, Jeremie Kim

TCAD Special Issue on Top Picks in
Hardware and Embedded Security, 2019.

[Slides \(pptx\)](#)

[Rowhammer I Lecture](#)

[Rowhammer II Lecture](#)

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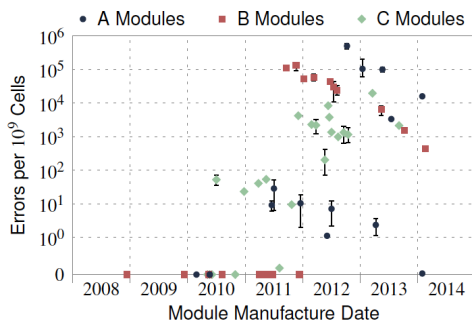


Fig. 1: RowHammer error rate vs. manufacturing dates of 129 DRAM modules we tested (reproduced from [133]).

A Framework for Memory Oversubscription Management in Graphics Processing Units

Chen Li, Rachata Ausavarungnirun,
Christopher J. Rossbach, Youtao Zhang,
Onur Mutlu, Yang Guo, Jun Yang

ASPLOS, April 2019, Providence, RI

[Slides \(pptx\) \(pdf\)](#)

[Lightning Talk Video](#)

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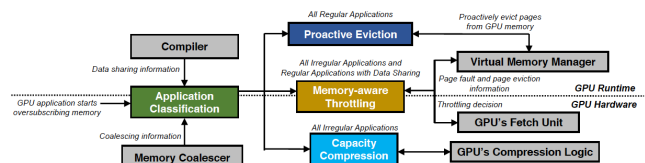


Figure 9. High level overview of ETC showing its four components: Application Classification (AC), Proactive Eviction (PE), Memory-aware Throttle (MT) and Capacity Compression (CC).

ITAP: Idle-Time-Aware Power Management for GPU Execution Units

Mohammad Sadrosadati, Seyed Borna Ehsani, Hajar Falahati, Rachata Ausavarungnirun, Arash Tavakkol, Mojtaba Abaee, Lois Orosa, Yaohua Wang, Hamid Sarbazi-Azad, Onur Mutlu

ACM Transactions on Architecture and Code Optimization (TACO), vol. 16, March 2019.

Slides (pptx) (pdf)

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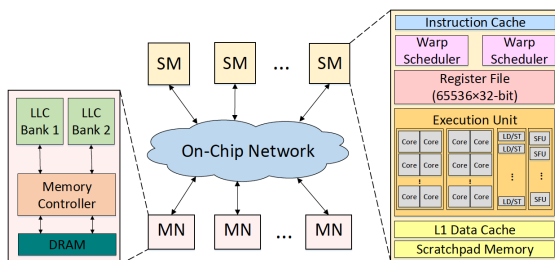


Fig. 1. Baseline GPU architecture.

A Scalable Priority-Aware Approach to Managing Data Center Server Power

Yang Li, Charles R. Lefurgy, Karthick Rajamani, Malcolm S. Allen-Ware, Guillermo J. Silva, Daniel D. Heimsoth, Saugata Ghose, Onur Mutlu

HPCA, Feb 16 – 20 2019, Washington DC

Slides (pdf)

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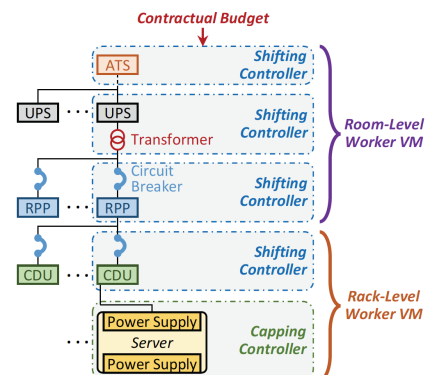


Figure 3. Mapping physical equipment from a single power feed to controllers in the power control tree, and to worker VMs.

D-RaNGe: Using Commodity DRAM Devices to Generate True Random Numbers with Low Latency and High Throughput

Jeremie S. Kim, Minesh Patel, Hasan Hassan, Lois Orosa, Onur Mutlu

HPCA, Feb 16 – 20 2019, Washington DC

[Slides \(pptx\)](#) ([pdf](#))

[Full Talk Video](#)

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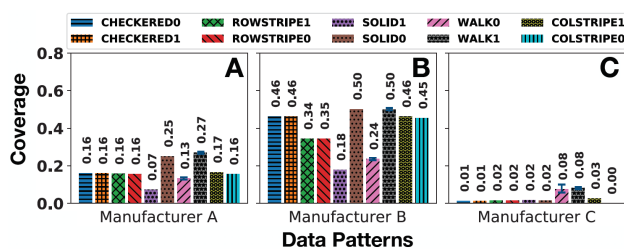


Figure 5: Data pattern dependence of DRAM cells prone to activation failure over 100 iterations

AVPP: Address-first Value-next Predictor with Value Prefetching for Improving the Efficiency of Load Value Prediction

Lois Orosa, Rodolfo Azevedo, Onur Mutlu

HiPEAC, Jan 21 – 23 2019, Valencia, Spain

[Slides \(pptx\)](#) ([pdf](#))

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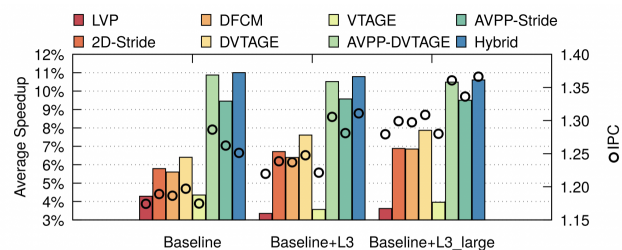


Fig. 22. Speedup of load value prediction with the three cache configurations shown in Table 5.

All SAFARI Publications

PhD Defense



Enhancing Programmability, Portability, and Performance with Rich Cross-Layer Abstractions

Nandita Vijaykumar

Carnegie Mellon University, ECE
PhD Defense — October 11, 2019

Programmability, performance portability, and resource efficiency have emerged as critical challenges in harnessing complex and diverse architectures today to obtain high performance and energy efficiency. While there is abundant research, and thus significant improvements, at different levels of the stack that address these very challenges, in this thesis, we observe that we are fundamentally limited by the interfaces and abstractions between the application and the underlying system/hardware—specifically, the hardware-software interface.

[Read more](#)

PhD Defense



Machine Learning Systems for Highly-Distributed and Rapidly-Growing Data

Kevin Hsieh

Carnegie Mellon University, ECE
PhD Defense — September 5, 2019

The usability and practicality of any machine learning (ML) applications are largely influenced by two critical but hard-to-attain factors: low latency and low cost. Unfortunately, achieving low latency and low cost is very challenging when ML depends on real-world data that are highly distributed and rapidly growing (e.g., data collected by mobile phones and video cameras all over the world). Such real-world data pose many challenges in communication and computation. For example, when training data are distributed across data centers that span multiple continents, communication among data centers can easily overwhelm the limited wide-area network bandwidth, leading to prohibitively high latency and high cost.

[Read more](#)

Talks & Courses

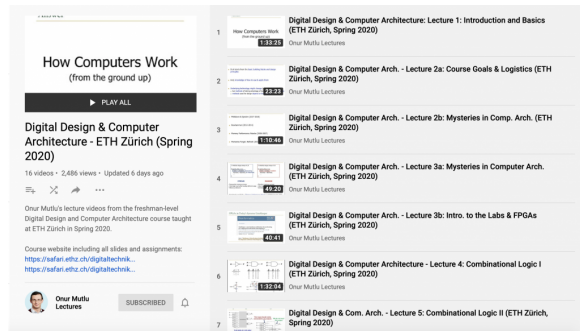
We regularly post new videos of talks and lectures on our **YouTube Channels**. We want everyone to have access to and benefit from these videos, and encourage you to subscribe, comment and give us feedback on our channels!



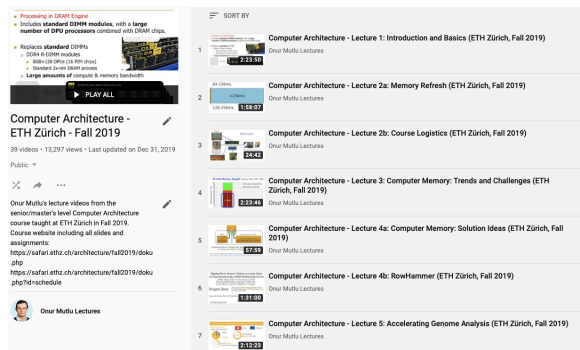
All our course materials (slides, videos, exams, homeworks, labs, etc.) are online and freely available.

Subscribe to our newest **YouTube Channel: Onur Mutlu Lectures** to watch **lectures and keynote talks**, and **SAFARI group member presentations**

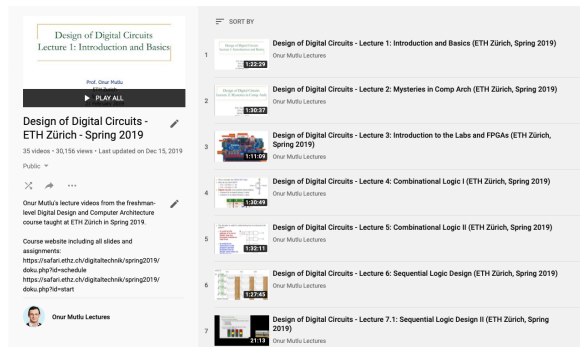
Recent Courses



Lecture Videos: Digital Design and Computer Architecture, Spring 2020, ETH Course Website



Lecture Videos: Computer Architecture, Fall 2019, ETH Course Website



Lecture Videos: Design of Digital Circuits, Spring 2019, ETH Course Website

Recent Talks



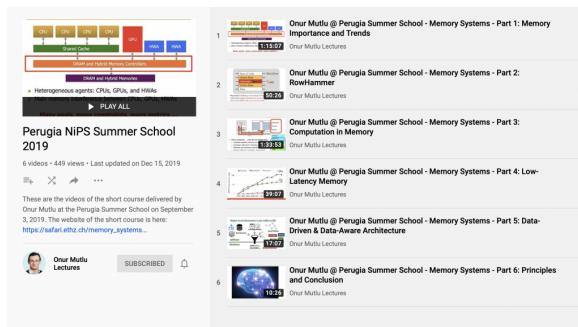
Onur Mutlu - Intelligent Architectures for Intelligent Machines, ChinaSys, Dec 2019 Keynote Talk



Onur Mutlu - Processing Data Where It Makes Sense: Enabling In - Memory Computation, ICCD, Nov 2019 Keynote Talk



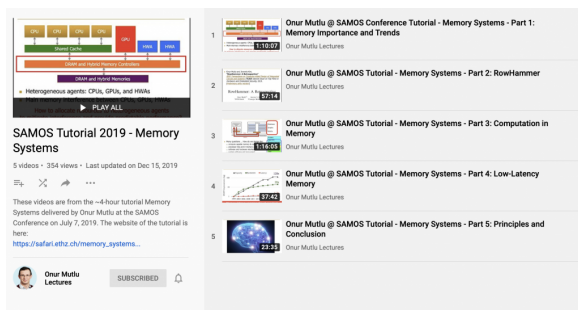
Onur Mutlu - Maurice Wilkes Award interview at ISCA'19, June 2019



Onur Mutlu Lecture Videos:
Memory Systems and Memory-Centric Computing Systems: Challenges and Opportunities, Summer School Sept 2019, Perugia [Course Website](#)



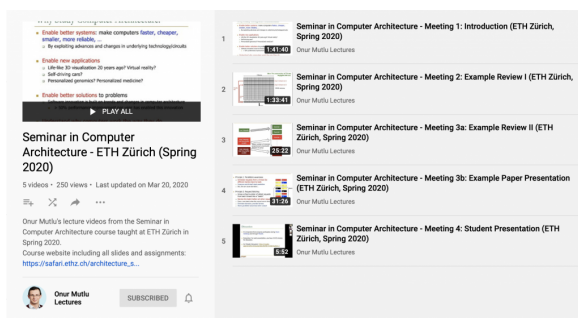
Onur Mutlu - Processing Data Where It Makes Sense in Modern Computing Systems: Enabling In-Memory Computation, APPT, Tianjin, China, Aug 2019 Keynote Talk



Onur Mutlu Lecture Videos:
Memory Systems and Memory-Centric Computing Systems: Challenges and Opportunities, Summer School July 2019, Samos Island, Greece [Course Website](#)



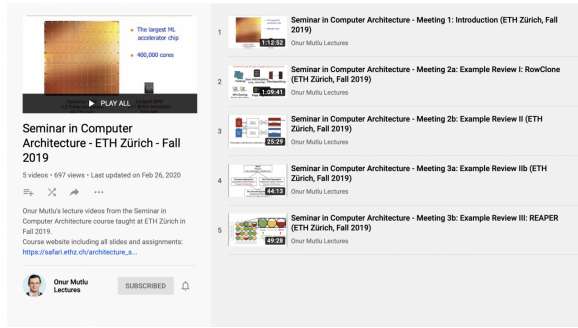
Mohammed Alser - A Roadmap for Fast and Efficient Genome Analysis, Univ. of Tokyo, Shirokanedai, Dec 2019



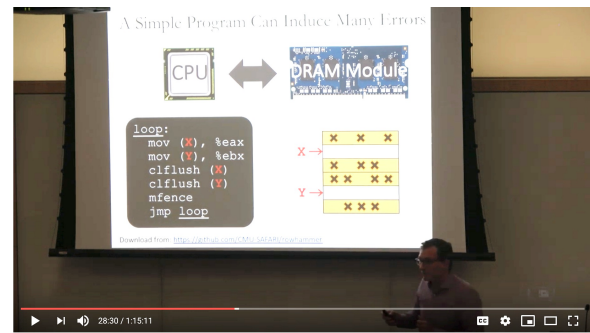
Lecture Videos: Seminar in Computer Architecture, Spring 2020, ETH
[Course Website](#)



Onur Mutlu - Accelerating Genome Analysis: A Primer on an Ongoing Journey, AACBB Washington, DC, Feb 2019 Keynote Talk

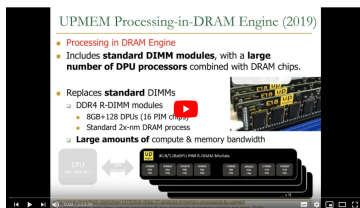


Lecture Videos: Seminar in Computer Architecture, Fall 2019, ETH
Course Website

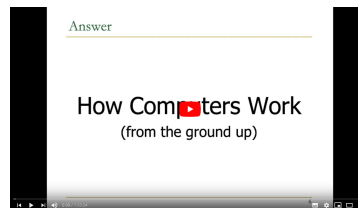


Onur Mutlu - Processing Data Where It Makes Sense in Modern Computing Systems: Enabling In-Memory Computation, George Washington University, Feb 2019
Distinguished Lecture

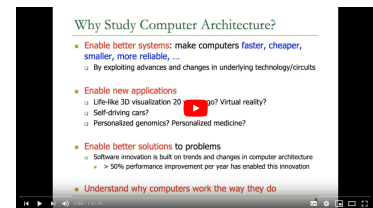
Selected Introductory Lectures



Onur Mutlu - Computer Architecture Lecture 1: Introduction and Basics, Fall 2019

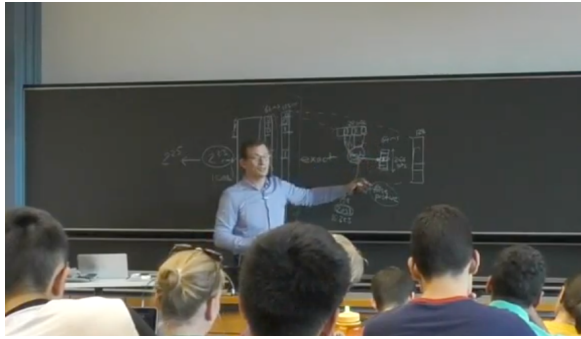


Onur Mutlu - Digital Design & Computer Architecture: Lecture 1: Introduction and Basics, Spring 2020



Onur Mutlu - Seminar in Computer Architecture - Meeting 1: Introduction, Spring 2020

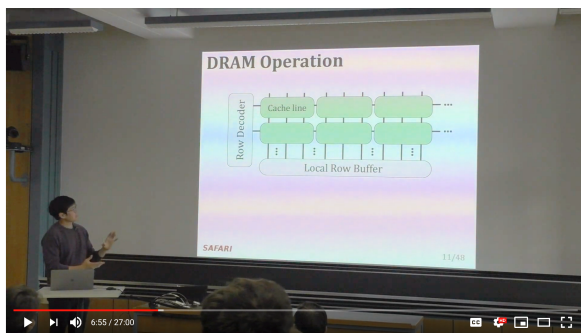
Selected Lectures: Computer Architecture ETH Fall 2019



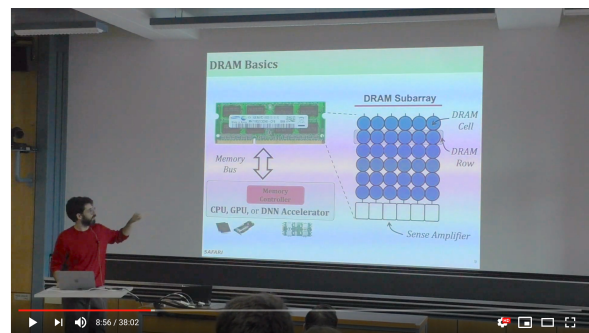
Onur Mutlu - Lecture 2a: Memory Refresh



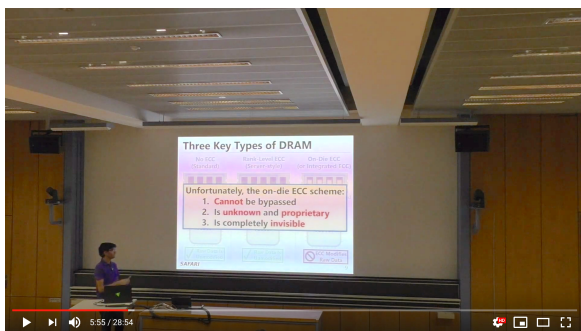
Onur Mutlu - Lecture 6b: Computation in Memory



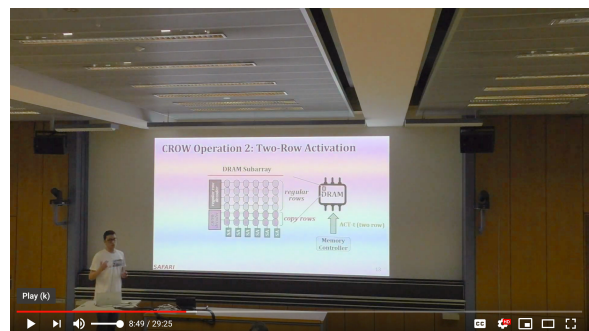
Jeremie Kim - Lecture 11b: D-RaNGe: True Random Number Generation



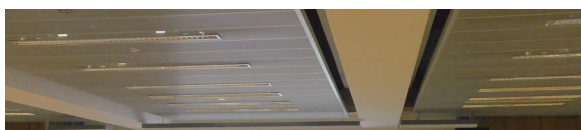
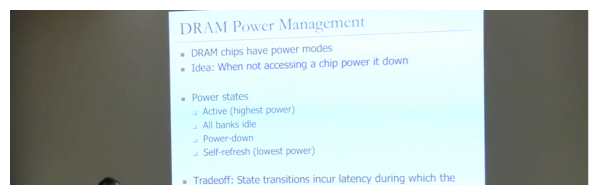
Lois Orosa - Lecture 11d: EDEN: Reducing Memory Energy in DNNs

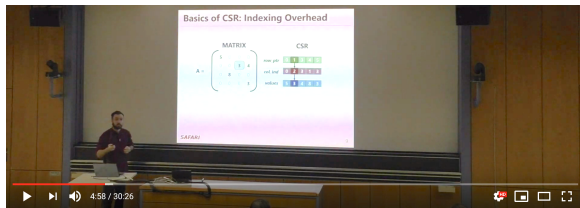


Minesh Patel - Lecture 12a: EIN: Understanding and Modeling Error Correction in DRAM

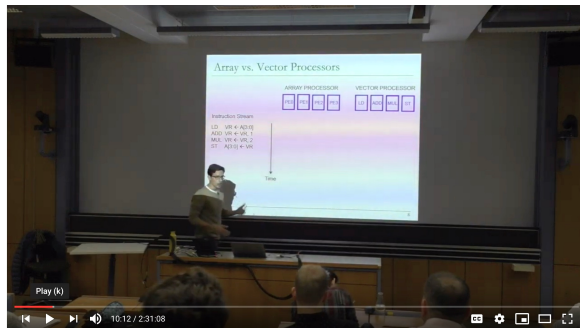


Hasan Hassan - Lecture 12c: CROW: Improving DRAM Performance and Energy Efficiency Using Copy Rows





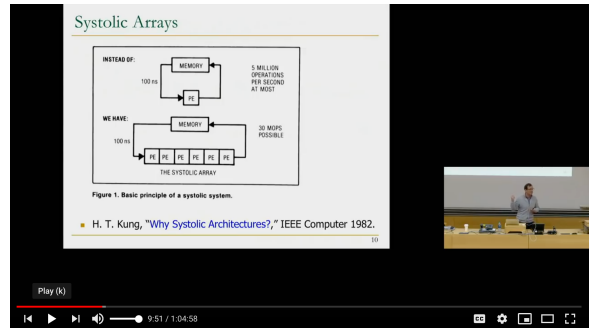
Konstantinos Kanellopoulos - Lecture 12d: SMASH: Hardware-software Co-design for Sparse Matrix Compression



Juan Gómez Luna - Lecture 14: SIMD Processors and GPUs



Onur Mutlu - Lecture 13a: Memory Controllers



Onur Mutlu - Design of Digital Circuits - Lecture 19b: Systolic Arrays and Beyond, Spring 2019

Selected Open Source Releases



We have released many research artifacts and tools in 2019-2020 that are available on GitHub **CMU-SAFARI**

Ramulator-PIM

A fast and flexible simulation infrastructure for exploring general-purpose processing-in-memory (PIM) architectures.

Described in our paper:

Singh et al., DAC 2019

MemBen

Benchmark suite containing cache filtered traces for use with Ramulator. These include some of the workloads used in our paper: Ghose et al., SIGMETRICS 2019

CROW

Source code for the architectural and circuit-level simulators used for modeling the CROW (Copy-ROW DRAM) mechanism.

Described in our paper:

[Hassan et al., ISCA 2019](#)

EINSim

DRAM error-correction code (ECC) simulator incorporating statistical error properties and DRAM design characteristics for inferring pre-correction error characteristics using only the post-correction errors. Described in our paper: [Patel et al., DSN 2019](#)

Apollo

Apollo is an assembly polishing algorithm that attempts to correct the errors in an assembly. It can take multiple set of reads in a single run and polish the assemblies of genomes of any size.

Described in our paper:

[Firtina et al., Bioinformatics 2020](#)

Shouji

Shouji is fast and accurate pre-alignment filter for banded sequence alignment calculation. Described in our paper:

[Alser et al., Bioinformatics 2019](#)

How to Build an Impactful Research Group

Onur was invited to give a talk during the [Design Automation Conference Early Career Workshop](#), in Las Vegas, June 2019. He answered several questions on "How to Build an Impactful Research Group":

Q1: What are the best practices that you would suggest to your peers as being essential for the success of an academic team?

Onur: There is no single way of having impact. The critical thing is finding the way that works well for you and your goals, that you can own, cherish and optimize. Find the methods that work for you.

Start out with the right motivation and mindset: **Mindset 1:** change the world positively, have high influence; **Mindset 2:** enable students to achieve a potential that they did not even think they could ever achieve. **Motivation correction may be needed at times – be ready.**

Get motivated students, build a team of excellence

Focus on Learning and Scholarship:

Learning by example, learning by doing, learning by open, critical discussion

Focus on insight, encourage new ideas

Set the bar high

Choose Great Problems and guide your group toward them (but give them freedom)

Emphasize clarity and rigor in communication (critical for high impact)

Foster collaboration within group, across groups, with companies

Inspire and reach out, be resilient, follow your passion,

Build infrastructure to enable your passion (Big Projects)

Q2: How important is the heterogeneity of the group?

Onur: Diversity is very important, no two people are the same -- everyone brings perspective. It is critical to be diverse, accepting, and inclusive, e.g. age, gender, experience level, education level, geography (natural in our field).

Create an environment that values

free exploration, openness, collaboration, hard work, creativity

Q3: What are the main characteristics and skills one should take into account when choosing PhD students and researchers for new and impactful research groups?

Onur: Motivation and Mindset; Creativity; Resilience; Hard work; Boldness; Perseverance, commitment; Intellectual strength; Openness to feedback; Communicativeness

Our group is very heterogenous and diverse. This encourages creative diversity and helps to generate new and different ideas. We embrace diversity and team collaboration, and regularly host interns from all over the world. If you are interested in working with SAFARI, **apply to work with us!**

Onur Mutlu, "How to Build an Impactful Research Group", Design Automation Conference Early Career Workshop, Las Vegas, NV, USA, June 2019.
[Slides (pptx) (pdf)]

Onur Mutlu's Recent Selected Keynote Talks & Short Courses

Onur Mutlu, **Intelligent Architectures for Intelligent Machines**, Keynote talk at the 17th

ChinaSys Workshop, Zhuhai, China, 20 December 2019. [Slides \(pptx\)](#) ([pdf](#)); [Talk Video](#)

Onur Mutlu, **Intelligent Architectures for Intelligent Machines**, Invited talk at the Huawei European Research Symposium, Paris, France, 26 November 2019.

[Slides \(pptx\)](#) ([pdf](#)); [Talk Video](#)

Onur Mutlu, **Processing Data Where It Makes Sense in Modern Computing Systems: Enabling In-Memory Computation**, Keynote talk at 37th IEEE International Conference on Computer Design (ICCD), Abu Dhabi, UAE, 19 November 2019. [Slides \(pptx\)](#) ([pdf](#)); [Related Overview Paper I](#); [Related Overview Paper II](#); [Talk Video](#)

Onur Mutlu, **RowHammer and Beyond**, Keynote talk at the HiPEAC Computing Systems Week Autumn 2019 Resilience in High Performance Computing Thematic Session (RESILIENTHPC), Bilbao, Spain, 28 October 2019.

[Slides \(pptx\)](#) ([pdf](#)); [Related Overview Paper \(IEEE TCAD 2019\)](#)

Onur Mutlu, **Processing Data Where It Makes Sense in Modern Computing Systems: Enabling In-Memory Computation**, *Keynote talk at International Symposium on Advanced Parallel Processing Technology (APPT)*, Tianjin, China, 16 August 2019.

[Slides \(pptx\)](#) ([pdf](#)); [Talk Video](#); [Related Overview Paper](#)

Onur Mutlu, **Memory Systems and Memory-Centric Computing Systems**, *Invited Tutorial at the 19th International Conference on Embedded Computer Systems: Architectures, Modeling, and Simulation (SAMOS)*, Samos, Greece, 7 July 2019.

Part 1: Memory Importance and Trends: [Slides \(pptx\)](#) ([pdf](#)); [Video \(1 hr 10 mins\)](#)

Part 2: RowHammer: [Slides \(pptx\)](#) ([pdf](#)); [Video \(57 mins\)](#)

Part 3: Computation in Memory: [Slides \(pptx\)](#) ([pdf](#)); [Video \(1 hr 16 mins\)](#)

Part 4: Low-Latency Memory: [Slides \(pptx\)](#) ([pdf](#)); [Video \(38 mins\)](#)

Part 5: Principles and Conclusion: [Slides \(pptx\)](#) ([pdf](#)); [Video \(24 mins\)](#)

[SAMOS Tutorial Course Website](#)

For a full list of **lectures and keynote talks**, visit [Onur's website](#)

Additional Publications 2019 - April 2020

Muhammad Shafique, Mahum Naseer, Theocharis Theocharides, Christos Kyrkou, Onur Mutlu, Lois Orosa, and Jungwook Choi, **Robust Machine Learning Systems: Challenges, Current Trends, Perspectives, and the Road Ahead**, IEEE Design & Test, to appear in

2020.

Pietro Frigo, Emanuele Vannacci, Hasan Hassan, Victor van der Veen, Onur Mutlu, Cristiano Giuffrida, Herbert Bos, and Kaveh Razavi, **TRRespass: Exploiting the Many Sides of Target Row Refresh**, Proceedings of the [41st IEEE Symposium on Security and Privacy \(S&P\)](#), San Francisco, CA, USA, May 2020.

Feng Zhang, Jidong Zhai, Xipeng Shen, Onur Mutlu, and Xiaoyong Du, **Enabling Efficient Random Access to Hierarchically-Compressed Data**, Proceedings of the [36th International Conference on Data Engineering \(ICDE\)](#), Dallas, TX, USA, April 2020.

Jiantong Jiang, Zeke Wang, Xue Liu, Juan Gómez-Luna, Nan Guan, Qingxu Deng, Wei Zhang, and Onur Mutlu, **Boyi: A Systematic Framework for Automatically Deciding the Right Execution Model of OpenCL Applications on FPGAs**, Proceedings of the [28th International Symposium on Field-Programmable Gate Arrays \(FPGA\)](#), Seaside, CA, USA, February 2020.

Shihao Song, Anup Das, Onur Mutlu, and Nagarajan Kandasamy, **Enabling and Exploiting Partition-Level Parallelism (PALP) in Phase Change Memories**, Proceedings of the [International Conference on Compilers, Architecture, and Synthesis for Embedded Systems \(CASES\)](#), New York City, NY, USA, October 2019.

Zeke Wang, Kaan Kara, Hantian Zhang, Gustavo Alonso, Onur Mutlu, and Ce Zhang, **Accelerating Generalized Linear Models with MLWeaving: A One-Size-Fits-All System for Any-Precision Learning**, Proceedings of the [45th International Conference on Very Large Databases \(VLDB\)](#), Los Angeles, CA, USA, August 2019.

Chenxi Wang, Huimin Cui, Ting Cao, John Zigman, Haris Volos, Onur Mutlu, Fang Lv, Xiaobin Feng, and Guoqing Harry Xu, **Panthera: Holistic Memory Management for Big Data Processing over Hybrid Memories**, Proceedings of the [ACM SIGPLAN Conference on Programming Language Design and Implementation \(PLDI\)](#), Phoenix, AZ, USA, June 2019.

Irina Calciu, Ivan Puddu, Aasheesh Kolli, Andreas Nowatzky, Jayneel Gandhi, Onur Mutlu, and Pratap Subrahmanyam, **Project PBerry: FPGA Acceleration for Remote Memory**, Proceedings of the [17th Workshop on Hot Topics in Operating Systems \(HOTOS\)](#), Bertinoro, Italy, May 2019.

Reza Salkhordeh, Onur Mutlu, and Hossein Asadi, **An Analytical Model for Performance and Lifetime Estimation of Hybrid DRAM-NVM Main Memories**, [IEEE Transactions on Computers](#)

(TC), Aug. 2019, pp. 1114-1130, vol. 68.

Sitao Huang, Li-Wen Chang, Izzat El Hajj, Simon Garcia De Gonzalo, Juan Gomez-Luna, Sai Rahul Chalamalasetti, Mohamed El-Hadedy, Dejan Milojicic, Onur Mutlu, Deming Chen, and Wen-mei Hwu, [Analysis and Modeling of Collaborative Execution Strategies for Heterogeneous CPU-FPGA Architectures](#), Proceedings of the [10th ACM/SPEC International Conference on Performance Engineering](#) (ICPE), Mumbai, India, April 2019.

Simon Garcia De Gonzalo, Sitao Huang, Juan Gomez-Luna, Simon Hammond, Onur Mutlu, and Wen-mei Hwu, [Automatic Generation of Warp-Level Primitives and Atomic Instructions for Fast and Portable Parallel Reduction on GPUs](#), Proceedings of the [International Symposium on Code Generation and Optimization](#) (CGO), Washington, DC, USA, February 2019.

All SAFARI Publications

Meet our members: on research and career

[Nandita Vijaykumar](#) defended her PhD in October, and will start a position as Assistant Professor at the [University of Toronto](#) in 2020.

Q1: What are the main things you learned during your PhD on how to do great research, write well, and publish strong papers?



Selecting topics well is very important. Half the battle is won by choosing the right problems to work on and by asking the right questions. This is unfortunately a slightly esoteric art that only comes with experience, continuously learning from other people, and persistence. An easy way to avoid pitfalls here is to always get **early** feedback on your work.

Write for your readers not for yourself. This has many aspects: using simple and very

concise language; structured writing (SAFARI has great guidelines for this); articulating contributions well and up front; avoiding red herrings; and focusing on what you want to convey to the reader.

Persistence, persistence, persistence. Regardless of how good the idea is or how interesting the problem is, publishing a great paper requires tremendous hard work and persistence. This includes many late nights, dealing with failures, improving your work by taking criticism constructively, and relentless optimism.

Q2: What are the main tips you could give for a successful job search?

My thoughts here are focused on an academic or research-oriented job search. Some tips:

Preparation is key: It is absolutely critical to position your research contributions well and to be able to articulate it very effectively in different settings -- whether a 1 minute elevator pitch, 30 minute 1:1 discussion, a job talk, or a research statement. Doing this requires a *lot* of practice and getting feedback from different people. It helps tremendously to position and establish yourself as a leader/expert in some small and important sub-area within the broader field. Similarly, it is important to position and articulate future research directions well.

Networking and connecting with people: I cannot stress the importance of this, not only in an academic job search but also in industry (more so for jobs higher up the ladder). It is tremendously helpful to use every opportunity right from the beginning (conferences, visits, etc.) to meet people, leave good impressions, and build useful connections. This is probably the hardest and most overlooked part of being a PhD student. The only way to learn is to observe how others do it and work on doing it well right from the beginning. It gets easier with time.

Be confident: A professor/researcher is a leader in research and a mentor to budding researchers. It is thus very important to believe in yourself and your research. If you yourself do not believe in your abilities to be a leader at the forefront of research, it's hard to convince others to invest in you and believe in your future success. Building confidence comes from understanding your own strengths and abilities to grow in the future, avoiding direct comparisons to others, and learning to internalize criticism constructively.



Minesh Patel is the lead author on a recent paper that won the Best Paper Award at DSN in June 2019:

Understanding and Modeling On-Die Error Correction in Modern DRAM: An Experimental Study Using Real Devices, DSN, June 24 - 27, 2019, Portland, Oregon

Q: What writing advice can you give to students who might be drafting their first paper?

Minesh: We try to approach writing with the audience always in mind. Readers range from expert reviewers to unfamiliar students, and every sentence balances on an edge between presenting a convincing argument and opening up potential attacks, whether this be through poor writing or misleading and incorrect claims. I am pleased that we have a diverse enough group to help ensure that the final paper is sufficiently polished to bring out the best in our work while retaining the voice and style of the project lead.



Haocong Luo is a bachelor student at ShanghaiTech University and was an intern with SAFARI for 8 months in 2019:

Q: How was your experience as an intern with SAFARI? How do you think the internship might help you in your future studies and future career path?

As an undergraduate student, my internship at SAFARI was an invaluable experience of getting my hands on computer architecture research, cultivating a proper research mindset, and working with other smart minds.

Doing research differs a lot from regular course works. To be honest, not every part of research is as ideal as I expected. However, SAFARI has taught me to enjoy the creative part of generating ideas and critical thinking while working hard and rigorously to make sure that the value of the work is demonstrated at its best. Professor Mutlu was a great help to me in guiding me on research methodologies and providing vital feedback and insights.

Learning is also an essential part of SAFARI. I have significantly extended my horizon on various computer architecture topics through reading groups and frequent discussions with other members of the group. People in SAFARI have diverse backgrounds, but all of them

are very kind and helpful when I turned to them. My work could have been much tougher without their generous sharing of expertise and experiences. I really enjoyed the easy-going atmosphere where group members are encouraged to share their progress, and the discussions of new ideas, no matter big or small, are always promoted.

My experience at SAFARI plays an essential role in determining what to do next for me. By having some substantial research experience, I have verified that I do like doing research and would like to continue doing so in my graduate studies.



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