

SAFARI

SAFARI Research Group

Think Big, Aim High



ETH zürich

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December 2021



Dear SAFARI friends & colleagues,

We are very pleased to share our group highlights from 2021 with you in this holiday edition of the SAFARI newsletter.

2021 was another year of the COVID-19 pandemic. It tested us in many ways, but our research, education, service, and outreach activities continued at full speed and rigor. We adapted to the new environment and constraints. In terms of education, we transitioned all our classes to be livestreamed on [our YouTube channel](#) and catered to a global audience attending our classes freely. We have received very positive feedback (including from some of you) on helping democratize education and research, and I hope you find our efforts helpful; if so, please spread the word. We also started the [SAFARI Live Seminar Series](#) in Summer 2021, which hosts research and education talks by researchers, again livestreamed and freely available to anyone. In addition, we continued to deliver widely-accessible lectures and seminars at many events and conferences globally. You can continue to find almost all our educational and outreach activities on [our YouTube channel](#).

2021 was another productive year where we continued and expanded our major research thrusts. You can see below the full list of publications and associated conference & seminar talks as well as educational lectures. [Processing-in-Memory](#), Robust, Secure & Efficient DRAM, [RowHammer](#), Memory Systems, Hardware Security, [Fast & Efficient Genome Analysis](#), Storage Systems continued as some of our major thrusts, with many interesting new ideas, analyses, and results. We also expanded our research in [microarchitecture](#), [modeling & simulation](#), [benchmarking](#), [FPGAs](#), GPUs and more. Overall, we aim to continue to produce high-quality research at high quantity, thanks to rigorous and close collaboration within our group and with our industrial & academic partners. You can find a concise summary and analysis of our research and education activities in [this 4-page report](#) we prepared for our department evaluation.

We had 4 PhD graduates in 2021. Two of them are off to their advanced careers in industry, and two of them are continuing with us to do more advanced research. Two current and two past SAFARI PhD students were inducted into the prestigious [ISCA Hall of Fame](#), which is a list of authors who have published at least 8 papers at the ISCA conference, and one current SAFARI PhD student was inducted into the [MICRO Hall of Fame](#). We were honored and humbled to receive the [HPCA Test of Time Award](#) for the [Runahead Execution](#) paper Onur Mutlu first-authored as his first published paper in his research career.

We look forward to continuing our productive and impactful work in 2022 (collaboratively with hopefully many of you), expanding to new opportunities and collaborations, and always

maintaining a continued dedication to sharing our passion in both research and teaching globally. We look forward to your feedback -- you can feel free to contact us with any comments, questions, or feedback.

We wish you a wonderful holiday season, and a new year filled with good health, happiness, creativity, optimism, and many great ideas that can change the world positively!

Onur Mutlu & **the SAFARI team**

News & Awards

Congratulations to our 2021 PhD graduates!

Minesh Patel, October 2021

Enabling Effective Error Mitigation in Modern Memory Chips that Use On-Die Error-Correcting Codes

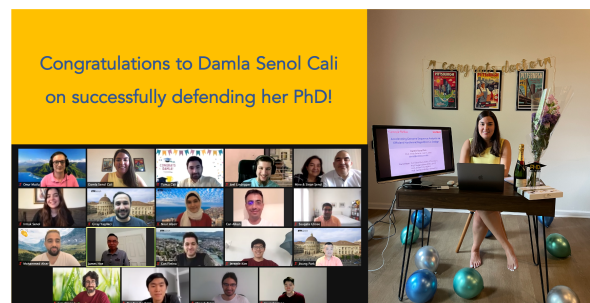
[Slides \(pptx\)](#) | [pdf](#) | [SAFARI Live Seminar Video](#) | [Read more](#)



Damla Senol Cali, July 2021

Accelerating Genome Sequence Analysis via Efficient Hardware/Algorithm Co-Design

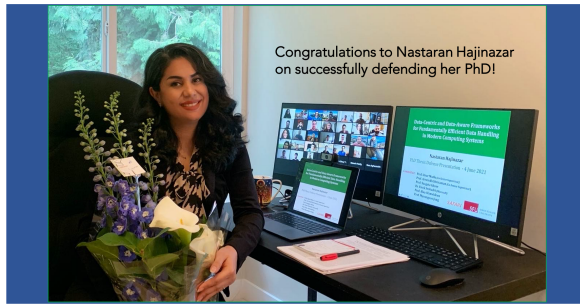
[Slides \(pptx\)](#) | [pdf](#) | [Thesis \(pdf\)](#) | [SAFARI Live Seminar Video](#) | [Read more](#)



Nastaran Hajinazar, June 2021

**Data-Centric and Data-Aware
Frameworks for Fundamentally Efficient
Data Handling in Modern Computing
Systems**

[Slides \(pptx\) \(pdf\)](#) | [Thesis \(pdf\)](#) | [SAFARI
Live Seminar Video](#) | [Read more](#)



Gagandeep Singh, March 2021

**Designing, Modeling, and Optimizing
Data-Intensive Computing Systems**

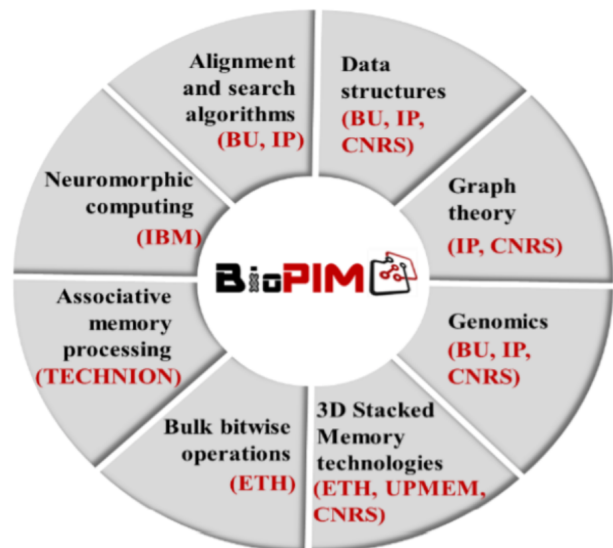
[Slides \(pptx\) \(pdf\)](#) | [Read more](#)



All SAFARI PhD Theses

EU Horizon Project BioPIM funded

We are excited to announce our participation in the successfully funded EU Horizon research project, **BioPIM**, led by **Can Alkan** at Bilkent University, together with 5 other institutions. **Juan Gómez Luna** and **Mohammed Alser** will lead the research activities at ETH. The goal of BioPIM is the realization of cheap, ultra-fast, and ultra-low energy mobile genomics that eliminates the current dependence of sequence analysis on large and power-hungry computing clusters/data centers commonly based on FGPA or GPUs.



Newly founded ETH Future Computing Laboratory (EFCL)

We are pleased to be part of the newly founded **ETH Future Computing Laboratory (EFCL)**, along with five other professors in D-ITET and D-INFK, and managing director Thyla

van der Merwe. The EFCL is an industry-funded research center that aims to spearhead the development of advanced computing systems that have the potential to change the world's technological trajectory. With a focus on hardware and software, the EFCL plans to engage in long-term research on next-generation technologies that span many domains, including but not limited to computer architecture, computer vision, integrated circuits, high performance computing, and security.

We thank the EFCL Industrial Partners for funding our forward-looking research projects:

- 1. A New Methodology and Open-Source Benchmark Suite for Evaluating Data Movement Bottlenecks: A Processing-in-Memory Case Study**
- 2. Machine-Learning-Assisted Intelligent Microarchitectures to Reduce Memory Access Latency**
- 3. Cross-Layer Hardware/Software Techniques to Enable Powerful Computation and Memory Optimizations**



HPCA Test of Time Award 2021

Onur Mutlu and co-authors were awarded the **HPCA Test of Time Award** for their HPCA 2003 paper on "Runahead Execution"!



The paper was Onur Mutlu's first publication during his PhD at the University of Texas with his PhD advisor Professor Yale Patt and colleagues from Intel, Dr. Jared Stark and Chris Wilkerson. Recognition from the award committee: "Runahead Execution is a pioneering paper that opened up new avenues in dynamic prefetching. The basic idea of run ahead execution effectively increases the instruction window very significantly, without having to increase physical resource size (e.g. the issue queue). This seminal paper spawned off a new area of ILP-enhancing microarchitecture research. This work has had strong industry impact as evidenced by IBM's POWER6 – Load Lookahead, NVIDIA Denver, and Sun ROCK's hardware scouting."

Onur Mutlu, Jared Stark, Chris Wilkerson, and Yale N. Patt, **"Runahead Execution: An Alternative to Very Large Instruction Windows for Out-of-order Processors"**,

Proceedings of the 9th International Symposium on High-Performance Computer Architecture (HPCA), February 2003.

[Talk Slides (pdf)]

[Lecture Slides (pptx) (pdf)]

[Lecture Video (1 hr 54 mins)]

[Retrospective HPCA Test of Time Award Talk Slides (pptx) (pdf)]

[Retrospective HPCA Test of Time Award Talk Video (14 minutes)]

One of the 15 computer architecture papers of 2003 selected as Top Picks by IEEE Micro HPCA Test of Time Award (2021)



Seal of Excellence Horizon 2020

Behzad Salami received the Seal of Excellence from the EU for his project proposal in Horizon 2020 on "ARENA: An ExtRemely Flexible and ENergy-Efficient Processing-in-Memory Architecture".
Congratulations Behzad!

Hall of Fame: ISCA & MICRO

Congratulations to our SAFARI members & alumni who were inducted into both the ISCA & MICRO Halls of Fame this year!

The award is given to those who publish at least eight papers at either ISCA & MICRO conferences, both top-tier venues for computer architecture research.

Awards went to:

Jeremie Kim MICRO Hall of Fame

Jeremie Kim ISCA Hall of Fame

Minesh Patel ISCA Hall of Fame

SAFARI PhD Alumni

Gennady Pekhimenko ISCA Hall of Fame

Nandita Vijaykumar ISCA Hall of Fame

[Read more SAFARI news](#)



We thank our industry partners for their support in 2021

Our group was generously supported with new and continuing projects and donations this year from Google, Huawei, Intel, SRC and VMware. We thank all of our industry partners for their continued support of our research, and our partners who have generously supported us with new donations this year. We also wish to thank the [ETH Foundation](#) and [ETH Transfer](#) for facilitating and supporting our industry relations, projects, and gift funding.

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

We always welcome new project collaborations, donations and gifts to support our research. Please contact [Onur Mutlu](#) for more information on donating and being a SAFARI Research Group supporter.

2021 Publications

2021 Research Summary and Position Papers

Onur Mutlu, Saugata Ghose, Juan Gomez-Luna, and Rachata Ausavarungnirun, "[A Modern Primer on Processing in Memory](#)", Invited Book Chapter in **Emerging Computing: From Devices to Systems - Looking Beyond Moore and Von Neumann**, Springer, *to appear in* 2022.

[\[Tutorial Video on "Memory-Centric Computing Systems" \(1 hour 51 minutes\)\]](#)

[\[arXiv version\]](#)

Gagandeep Singh, Mohammed Alser, Damla Senol Cali, Dionysios Diamantopoulos, Juan Gómez-Luna, Henk Corporaal, and Onur Mutlu, "[FPGA-based Near-Memory Acceleration of Modern Data-Intensive Applications](#)" **IEEE Micro** 41(4): 39-48, June 2021.

[\[arXiv version\]](#)

Onur Mutlu, "[Intelligent Architectures for Intelligent Computing Systems](#)", Invited Paper in Proceedings of the **Design, Automation, and Test in Europe Conference (DATE)**, Virtual, February 2021.

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

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

[\[Short DATE Talk Video \(11 minutes\)\]](#)

[\[Longer IEDM Tutorial Video \(1 hr 51 minutes\)\]](#)

2021 Conference and Journal Papers

Nandita Vijaykumar, Ataberk Olgun, Konstantinos Kanellopoulos, Nisa Bostanci, Hasan Hassan, Mehrshad Lotfi, Phillip B Gibbons, Onur Mutlu, "[MetaSys: A Practical Open-Source Metadata Management System to Implement and Evaluate Cross-Layer Optimizations](#)" *To appear in ACM Transactions on Architecture and Code Optimization (TACO)*, 2022.

[\[arXiv version\]](#)

[\[MetaSys Source Code\]](#)

Gagandeep Singh, Dionysios Diamantopoulos, Juan Gómez-Luna, Christoph Hagleitner, Sander Stuijk, Henk Corporaal, Onur Mutlu, "[Accelerating Weather Prediction using Near-](#)

Memory Reconfigurable Fabric” *To appear in* ACM Transactions on Reconfigurable Technology and Systems (TRETs), 2022.

[\[arXiv version\]](#)

Can Firtina, Jisung Park, Jeremie S. Kim, Mohammed Alser, Damla Senol Cali, Taha Shahroodi, Nika Mansouri Ghiasi, Gagandeep Singh, Konstantinos Kanellopoulos, Can Alkan, Onur Mutlu, **"BLEND: A Fast, Memory-Efficient, and Accurate Mechanism to Find Fuzzy Seed Matches"** Preprint in arXiv, 16 December 2021.

[\[arXiv version\]](#)

[\[BLEND Source Code\]](#)

Juan Gomez-Luna, Izzat El Hajj, Ivan Fernandez, Christina Giannoula, Geraldo F. Oliveira, and Onur Mutlu, **"Benchmarking Memory-Centric Computing Systems: Analysis of Real Processing-in-Memory Hardware"**, Invited Paper at Workshop on Computing with Unconventional Technologies (CUT), Virtual, October 2021.

[\[arXiv version\]](#)

[\[PRIM Benchmarks Source Code\]](#)

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

[\[Talk Video \(37 minutes\)\]](#)

[\[Lightning Talk Video \(3 minutes\)\]](#)

Ataberk Olgun, Juan Gómez Luna, Konstantinos Kanellopoulos, Behzad Salami, Hasan Hassan, Oğuz Ergin, Onur Mutlu, **"PiDRAM: A Holistic End-to-end FPGA-based Framework for Processing-in-DRAM"** Preprint in arXiv, 29 October 2021.

[\[arXiv version\]](#)

[\[PiDRAM Source Code\]](#)

Lois Orosa, Abdullah Giray Yaglikci, Haocong Luo, Ataberk Olgun, Jisung Park, Hasan Hassan, Minesh Patel, Jeremie S. Kim, and Onur Mutlu, **"A Deeper Look into RowHammer's Sensitivities: Experimental Analysis of Real DRAM Chips and Implications on Future Attacks and Defenses"**, Proceedings of the 54th International Symposium on Microarchitecture (MICRO), Virtual, October 2021.

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

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

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

[\[Talk Video \(21 minutes\)\]](#)

[\[Lightning Talk Video \(1.5 minutes\)\]](#)

[\[arXiv version\]](#)

Hasan Hassan, Yahya Can Tugrul, Jeremie S. Kim, Victor van der Veen, Kaveh Razavi, and

Onur Mutlu, **"Uncovering In-DRAM RowHammer Protection Mechanisms: A New Methodology, Custom RowHammer Patterns, and Implications"**, Proceedings of the 54th International Symposium on Microarchitecture (MICRO), Virtual, October 2021.

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

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

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

[\[Talk Video \(25 minutes\)\]](#)

[\[Lightning Talk Video \(100 seconds\)\]](#)

[\[arXiv version\]](#)

Rahul Bera, Konstantinos Kanellopoulos, Anant Nori, Taha Shahroodi, Sreenivas Subramoney, and Onur Mutlu, **"Pythia: A Customizable Hardware Prefetching Framework Using Online Reinforcement Learning"**, Proceedings of the 54th International Symposium on Microarchitecture (MICRO), Virtual, October 2021.

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

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

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

[\[Talk Video \(20 minutes\)\]](#)

[\[Lightning Talk Video \(1.5 minutes\)\]](#)

[\[Pythia Source Code \(Officially Artifact Evaluated with All Badges\)\]](#)

[\[arXiv version\]](#)

Minesh Patel, Geraldo F. de Oliveira Jr., and Onur Mutlu, **"HARP: Practically and Effectively Identifying Uncorrectable Errors in Memory Chips That Use On-Die Error-Correcting Codes"**, Proceedings of the 54th International Symposium on Microarchitecture (MICRO), Virtual, October 2021.

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

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

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

[\[Talk Video \(20 minutes\)\]](#)

[\[Lightning Talk Video \(1.5 minutes\)\]](#)

[\[HARP Source Code \(Officially Artifact Evaluated with All Badges\)\]](#)

[\[arXiv version\]](#)

Jawad Haj-Yahya, Jisung Park, Rahul Bera, Juan Gomez Luna, Taha Shahroodi, Jeremie S. Kim, Efraim Rotem, and Onur Mutlu, **"BurstLink: Techniques for Energy-Efficient Conventional and Virtual Reality Video Display"**, Proceedings of the 54th International Symposium on Microarchitecture (MICRO), Virtual, October 2021.

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

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

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

[\[Talk Video \(11 minutes\)\]](#)

[\[Lightning Talk Video \(2 minutes\)\]](#)

[\[arXiv version\]](#)

Maciej Besta, Raghavendra Kanakagiri, Grzegorz Kwasniewski, Rachata Ausavarungnirun, Jakub Beránek, Konstantinos Kanellopoulos, Kacper Janda, Zur Vonarburg-Shmaria, Lukas Gianinazzi, Ioana Stefan, Juan Gómez-Luna, Marcin Copik, Lukas Kapp-Schwoerer, Salvatore Di Girolamo, Nils Blach, Marek Konieczny, Onur Mutlu, and Torsten Hoefler, **"SISA: Set-Centric Instruction Set Architecture for Graph Mining on Processing-in-Memory Systems"**, Proceedings of the 54th International Symposium on Microarchitecture (MICRO), Virtual, October 2021.

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

[\[Talk Video \(22 minutes\)\]](#)

[\[Lightning Talk Video \(1.5 minutes\)\]](#)

[\[Full arXiv version\]](#)

Amirali Boroumand, Saugata Ghose, Berkin Akin, Ravi Narayanaswami, Geraldo F. Oliveira, Xiaoyu Ma, Eric Shiu, and Onur Mutlu, **"Google Neural Network Models for Edge Devices: Analyzing and Mitigating Machine Learning Inference Bottlenecks"**, Proceedings of the 30th International Conference on Parallel Architectures and Compilation Techniques (PACT), Virtual, September 2021.

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

[\[Talk Video \(14 minutes\)\]](#)

[\[Older arXiv version\]](#)

Lukas Breitwieser, Ahmad Hesam, Jean de Montigny, Vasileios Vavourakis, Alexandros Iosif, Jack Jennings, Marcus Kaiser, Marco Manca, Alberto Di Meglio, Zaid Al-Ars, Fons Rademakers, Onur Mutlu, and Roman Bauer, **"BioDynaMo: a modular platform for high-performance agent-based simulation"**, Bioinformatics, 16 September 2021.

[\[Online link at Bioinformatics Journal\]](#)

[\[Preprint in arXiv and bioRxiv, 5 February 2021\]](#)

[\[bioRxiv preprint\]](#)

[\[arXiv preprint\]](#)

[\[BioDynaMo Source Code and Data\]](#)

Mohammed Alser, Jeremy Rotman, Dhrithi Deshpande, Kodi Taraszka, Huwenbo Shi, Pelin Icer Baykal, Harry Taegyung Yang, Victor Xue, Sergey Knyazev, Benjamin D. Singer, Brunilda Balliu, David Koslicki, Pavel Skums, Alex Zelikovsky, Can Alkan, Onur Mutlu, and Serghei Mangul, **"Technology Dictates Algorithms: Recent Developments in Read Alignment"**

Genome Biology, 26 August 2021.

[\[Source Code and All Data\]](#)

[\[Online link at Genome Biology\]](#)

[\[Full arXiv version\]](#)

Maciej Besta, Zur Vonarburg-Shmaria, Yannick Schaffner, Leonardo Schwarz, Grzegorz Kwasniewski, Lukas Gianinazzi, Jakub Beránek, Kacper Janda, Tobias Holenstein, Sebastian Leisinger, Peter Tatkowski, Esref Ozdemir, Adrian Balla, Marcin Copik, Philipp Lindenberger, Pavel Kalvoda, Marek Konieczny, Onur Mutlu, and Torsten Hoefer, **"GraphMineSuite: Enabling High-Performance and Programmable Graph Mining Algorithms with Set Algebra"**, Proceedings of the 45th International Conference on Very Large Databases (VLDB), Copenhagen, Denmark, August 2021.

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

[\[Full arXiv version\]](#)

A. Giray Yaglikci, Jeremie S. Kim, Fabrice Devaux, and Onur Mutlu, **"Security Analysis of the Silver Bullet Technique for RowHammer Prevention"**, Preprint in arXiv, 13 June 2021.

[\[arXiv preprint\]](#)

Juan Gomez-Luna, Izzat El Hajj, Ivan Fernandez, Christina Giannoula, Geraldo F. Oliveira, and Onur Mutlu, **"Benchmarking a New Paradigm: An Experimental Analysis of a Real Processing-in-Memory Architecture"**, Preprint in arXiv, 9 May 2021.

[\[arXiv preprint\]](#)

[\[PRIM Benchmarks Source Code\]](#)

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

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

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

[\[SAFARI Live Seminar Slides \(pptx\) \(pdf\)\]](#)

[\[SAFARI Live Seminar Video \(2 hrs 57 mins\)\]](#)

[\[Lightning Talk Video \(3 minutes\)\]](#)

Geraldo F. Oliveira, Juan Gomez-Luna, Lois Orosa, Saugata Ghose, Nandita Vijaykumar, Ivan fernandez, Mohammad Sadrosadati, and Onur Mutlu, **"DAMOV: A New Methodology and Benchmark Suite for Evaluating Data Movement Bottlenecks"**, Preprint in arXiv, 8 May 2021.

[\[arXiv version\]](#)

[\[DAMOV Suite and Simulator Source Code\]](#)

[\[SAFARI Live Seminar Video \(2 hrs 40 mins\)\]](#)

[\[Short Talk Video \(21 minutes\)\]](#)

Nour Almadhoun Alserr, Gulce Kale, Onur Mutlu, Oznur Tastan, Erman Ayday, **"Near-Optimal Privacy-Utility Tradeoff in Genomic Studies Using Selective SNP Hiding"**, Preprint in arXiv, 9 June 2021.

[\[arXiv version\]](#)

[\[SNP-Selective-Hiding Source Code\]](#)

Ataberk Olgun, Minesh Patel, A. Giray Yaglikci, Haocong Luo, Jeremie S. Kim, F. Nisa Bostanci, Nandita Vijaykumar, Oguz Ergin, and Onur Mutlu, **"QUAC-TRNG: High-Throughput True Random Number Generation Using Quadruple Row Activation in Commodity DRAM Chips"**, Proceedings of the 48th International Symposium on Computer Architecture (ISCA), Virtual, June 2021.

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

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

[\[Talk Video \(25 minutes\)\]](#)

[\[SAFARI Live Seminar Video \(1 hr 26 mins\)\]](#)

Jawad Haj-Yahya, Jeremie S. Kim, A. Giray Yaglikci, Ivan Puddu, Lois Orosa, Juan Gomez Luna, Mohammed Alser, and Onur Mutlu, **"IChannels: Exploiting Current Management Mechanisms to Create Covert Channels in Modern Processors"**, Proceedings of the 48th International Symposium on Computer Architecture (ISCA), Virtual, June 2021.

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

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

[\[Talk Video \(21 minutes\)\]](#)

Lois Orosa, Yaohua Wang, Mohammad Sadrosadati, Jeremie S. Kim, Minesh Patel, Ivan Puddu, Haocong Luo, Kaveh Razavi, Juan Gomez-Luna, Hasan Hassan, Nika Mansouri-Ghiasi, Saugata Ghose, and Onur Mutlu, **"CODIC: A Low-Cost Substrate for Enabling Custom In-DRAM Functionalities and Optimizations"**, Proceedings of the 48th International Symposium on Computer Architecture (ISCA), Virtual, June 2021.

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

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

[\[Talk Video \(22 minutes\)\]](#)

Nastaran Hajinazar, Geraldo F. Oliveira, Sven Gregorio, Joao Dinis Ferreira, Nika Mansouri Ghiasi, Minesh Patel, Mohammed Alser, Saugata Ghose, Juan Gomez-Luna, and Onur Mutlu, **"SIMDRAM: An End-to-End Framework for Bit-Serial SIMD Computing in DRAM"** Proceedings of the 26th International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS), Virtual, March-April 2021.

[\[2-page Extended Abstract\]](#)

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

[\[Talk Slides \(pptx\) \(pdf\)\]](#)
[\[Short Talk Video \(5 mins\)\]](#)
[\[Full Talk Video \(27 mins\)\]](#)

Jisung Park, Myungsuk Kim, Myoungjun Chun, Lois Orosa, Jihong Kim, and Onur Mutlu, **"Reducing Solid-State Drive Read Latency by Optimizing Read-Retry"**, Proceedings of the 26th International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS), Virtual, March-April 2021.

[\[2-page Extended Abstract\]](#)
[\[Short Talk Slides \(pptx\) \(pdf\)\]](#)
[\[Full Talk Slides \(pptx\) \(pdf\)\]](#)
[\[Short Talk Video \(5 mins\)\]](#)
[\[Full Talk Video \(19 mins\)\]](#)

Irina Calciu, M. Talha Imran, Ivan Puddu, Sanidhya Kashyap, Hasan Al Maruf, Onur Mutlu, and Aasheesh Kolli, **"Rethinking Software Runtimes for Disaggregated Memory"** Proceedings of the 26th International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS), Virtual, March-April 2021.

[\[2-page Extended Abstract\]](#)
[\[Source Code \(Officially Artifact Evaluated\)\]](#)

Feng Zhang, Zaifeng Pan, Yanling Zhou, Jidong Zhai, Xipeng Shen, Onur Mutlu, and Xiaoyong Du, **"G-TADOC: Enabling Efficient GPU-Based Text Analytics without Decompression"** Proceedings of the 37th International Conference on Data Engineering (ICDE), Virtual, April 2021.

[\[arXiv version\]](#)
[\[Slides \(pptx\) \(pdf\)\]](#)
[\[Talk Video \(12 mins\)\]](#)

Mohammed Alser, Jeremie S. Kim, Nour Almadhoun Alserr, Stefan W. Tell, and Onur Mutlu, **"COVIDHunter: An Accurate, Flexible, and Environment-Aware Open-Source COVID-19 Outbreak Simulation Model"** Preprint in arXiv and medRxiv, 6 February 2021.

[\[medRxiv preprint\]](#)
[\[arXiv preprint\]](#)
[\[COVIDHunter Source Code and Data\]](#)
[\[Switzerland Case Study\]](#)
[\[Talk Video ISMB/ECCB 2021, Virtual, July 2021\]](#)
[\[Talk Slides \(pptx\)\(pdf\)\]](#)

Jeremie S. Kim, Can Firtina, Meryem Banu Cavlak, Damla Senol Cali, Nastaran Hajinazar,

Mohammed Alser, Can Alkan, and Onur Mutlu, **"AirLift: A Fast and Comprehensive Technique for Remapping Alignments between Reference Genomes"** Preprint in arXiv and bioRxiv, 17 February 2021.

[\[bioRxiv preprint\]](#)

[\[arXiv preprint\]](#)

[\[AirLift Source Code and Data\]](#)

Onur Mutlu, Saugata Ghose, Juan Gomez-Luna, and Rachata Ausavarungnirun, **"A Modern Primer on Processing in Memory"**, Invited Book Chapter in Emerging Computing: From Devices to Systems - Looking Beyond Moore and Von Neumann, Springer, to be published in 2021.

[\[Tutorial Video on "Memory-Centric Computing Systems" \(1 hour 51 minutes\)\]](#)

Christina Giannoula, Nandita Vijaykumar, Nikela Papadopoulou, Vasileios Karakostas, Ivan Fernandez, Juan Gómez-Luna, Lois Orosa, Nectarios Koziris, Georgios Goumas, and Onur Mutlu, **"SynCron: Efficient Synchronization Support for Near-Data-Processing Architectures"** Proceedings of the 27th International Symposium on High-Performance Computer Architecture (HPCA), Virtual, February-March 2021.

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

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

[\[Talk Video \(21 minutes\)\]](#)

[\[Short Talk Video \(7 minutes\)\]](#)

[\[SAFARI Live Seminar Video \(1 hr 29 mins\)\]](#)

A. Giray Yaglikci, Minesh Patel, Jeremie S. Kim, Roknoddin Azizi, Ataberk Olgun, Lois Orosa, Hasan Hassan, Jisung Park, Konstantinos Kanellopoulos, Taha Shahroodi, Saugata Ghose, and Onur Mutlu, **"BlockHammer: Preventing RowHammer at Low Cost by Blacklisting Rapidly-Accessed DRAM Rows"** Proceedings of the 27th International Symposium on High-Performance Computer Architecture (HPCA), Virtual, February-March 2021.

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

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

[\[Talk Video \(22 minutes\)\]](#)

[\[Short Talk Video \(7 minutes\)\]](#)

Onur Mutlu, **"Intelligent Architectures for Intelligent Computing Systems"** Invited Paper in Proceedings of the Design, Automation, and Test in Europe Conference (DATE), Virtual, February 2021.

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

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

[\[Short DATE Talk Video \(11 minutes\)\]](#)

[Longer IEDM Tutorial Video (1 hr 51 minutes)]

Seyed Saber Nabavi Larimi, Behzad Salami, Osman S. Unsal, Adrian Cristal Kestelman, Hamid Sarbazi-Azad, and Onur Mutlu, "[Understanding Power Consumption and Reliability of High-Bandwidth Memory with Voltage Underscaling](#)" Proceedings of the Design, Automation, and Test in Europe Conference (DATE), Virtual, February 2021.

[Slides (pptx) (pdf)]

[Talk Video (10 minutes)]

Shihao Song, Anup Das, Onur Mutlu, and Nagarajan Kandasamy, "[Aging-Aware Request Scheduling for Non-Volatile Main Memory](#)" Proceedings of the 26th Asia and South Pacific Design Automation Conference (ASP-DAC), Virtual, January 2021.

Mohammad Sadrosadati, Amirhossein Mirhosseini, Seyed Borna Ehsani, Hamid Sarbazi-Azad, Mario Drumond, Babak Falsafi, Rachata Ausavarungrun, and Onur Mutlu, "[Highly Concurrent Latency-Tolerant Register Files for GPUs](#)" ACM Transactions on Computer Systems (TOCS), January 2021.

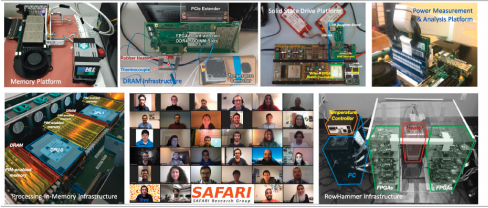
To our publications

SAFARI highlight: Promoting diversity

SAFARI embraces and actively promotes heterogeneity and diversity in our group. We believe that it is critical to be diverse, accepting, and inclusive, and promote diversity in our group, e.g. age, gender, experience level, education level, geography, culture. Through encouraging diversity in our group, and team collaboration, we believe these elements promote new perspectives, ways of thinking, idea generation, and unique ways of problem solving. We actively foster collaboration within our group, across groups, with companies and regularly host interns from all over the world. We aim to create an inclusive environment that values free exploration, openness, collaboration, hard work, and creativity for all our group members.

Departmental Evaluation

DITET



SAFARI Research Group Professor Onur Mutlu

The SAFARI Research Group conducts cutting-edge research and education in computer architecture, computing systems, hardware security, bioinformatics, and software/hardware co-design. The major goal is to design fundamentally better computing architectures. Our work spans the boundaries between applications, systems, languages, system software, compilers, and hardware, with architecture at the core. We tackle many fundamental issues in high performance, energy efficiency, hardware security, fault tolerance, predictable systems, dependable systems, hardware/software cooperation, and genome analysis. We are especially excited about novel, fundamentally secure and fundamentally efficient computation, communication and memory/storage paradigms. Recent impactful examples of the group's work include leading research into memory/storage systems and new computing paradigms, e.g. the discovery of the DRAM RowHammer vulnerability and the development of a comprehensive Processing-in-Memory paradigm.



Prof. Onur Mutlu

Curriculum vitae

Degrees/Higher education

2004 PhD in Computer Engineering, University of Texas at Austin, USA
2002 MSE in Computer Engineering, University of Texas at Austin, USA
2000 BSE in Computer Engineering,
BS in Psychology with Highest Distinction,
University of Michigan, Ann Arbor, USA

Professional experience

since 2015 Full Professor, ETH Zurich
since 2016 Carnegie Mellon University, Adjunct Professor
2009-2016 Carnegie Mellon University, Strecker Early Career Professor
2016 Google & VMware, Visiting Research Scientist
since 2015 Bilkent University, Adjunct Professor
2012 Intel, Visiting Researcher
2004-2009 Microsoft Research, Researcher
2001-2005 Intel & AMD, Coop Engineer

We participated in the evaluation of our department, D-ITET, this fall. Several professors from all over the world were asked to carry out the evaluation over one week to gain insights into our research, teaching, administrative, IT, lab and workshop activities.

Our contribution to the evaluation report gives an overview of our research impact, teaching and other group contributions.

Read the report

[Evaluation talk slides (pptx) (pdf)]

Videos: Talks & Courses

We have a strong commitment to democratize education through our dedicated posting of course lectures and talk videos online. We livestream lectures and talks on YouTube and make all lectures, talks and course material freely available on both our course website and YouTube channels. Our YouTube channels have thousands of subscribers, and our online materials are used by students, universities, and industry leaders over the globe. We are particularly dedicated to sharing our resources with those without access to state-of-the-art computer architecture classes.

Subscribe to our **YouTube Channel**:
Onur Mutlu Lectures



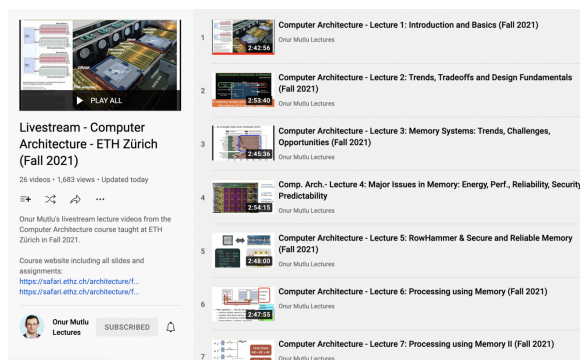
Courses Fall 2021

Computer Architecture

Course Website

Lecture Videos (YouTube Playlist)

This is a Master's level course taken by Bachelor's/Masters/PhD students. We look in-depth at cutting-edge research topics + fundamentals in Computer Architecture, including 5 simulator-based lab assignments, potential research exploration and many research readings.

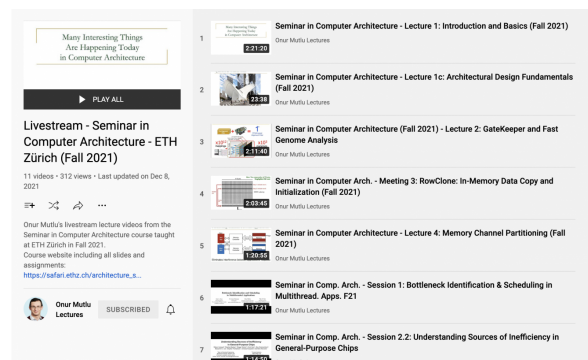


Seminar in Computer Architecture

Course Website

Lecture Videos (YouTube Playlist)

This is a critical analysis course taken by Bachelor's/Masters/PhD students where we look in-depth at cutting-edge research topics + fundamentals in Computer Architecture, including 20+ research papers, presentations and analyses.



SAFARI Projects & Seminars Fall & Spring 2021

Fall 2021: [P&S Course Listings and Websites](#)

Spring 2021: [P&S Course Listings and Websites](#)



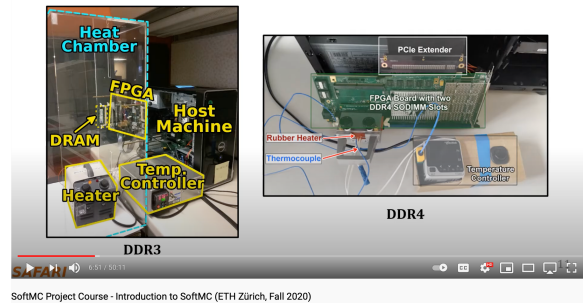
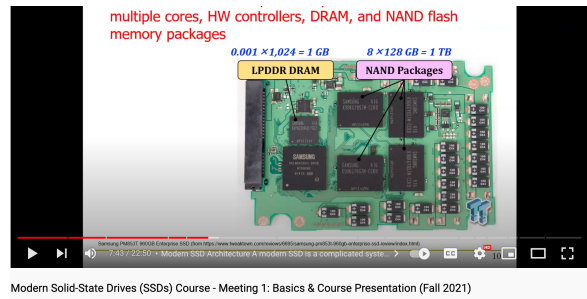
Understanding and Improving Modern DRAM Performance, Reliability, and Security with Hands-On Experiments

Course Website

Lecture Videos: YouTube Playlist

Lecturer: Hasan Hassan

Current SoftMC Setups



Designing and Evaluating Memory Systems and Modern Software Workloads with Ramulator

Lecture Videos: YouTube Playlist

Course Website

Lecturer: Hasan Hassan

Complete SAFARI Course Listing

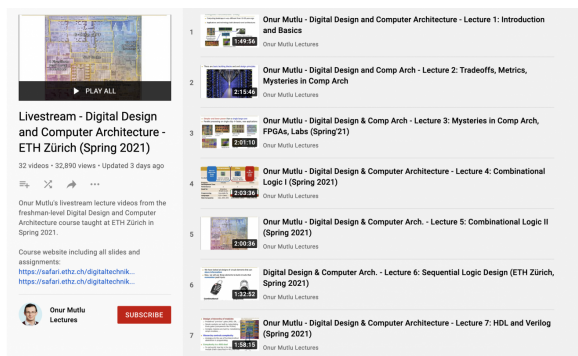
Courses Spring 2021

Digital Design and Computer Architecture

Course Website

Lecture Videos (YouTube Playlist)

This is a 2nd semester Bachelor's course and provides a rigorous introduction into "How Computers Work", with 10 FPGA Lab Assignments.

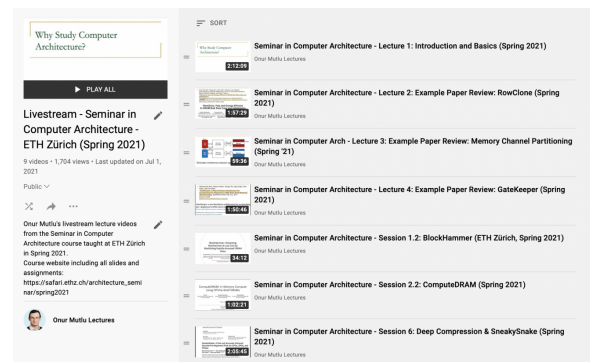


Seminar in Computer Architecture

Course Website

Lecture Videos (YouTube Playlist)

This is a critical analysis course taken by Bachelor's/Masters/PhD students where we look in-depth at cutting-edge research topics + fundamentals in Computer Architecture, including 20+ research papers, presentations and analyses.



SAFARI Live Seminar Series

SAFARI Live Seminars in Computer Architecture

Rahul Bera, ETH Zurich

Pythia: A Customizable Hardware Prefetching Framework Using Online Reinforcement Learning



Brief Overview of Pythia

Pythia formulates prefetching as a **reinforcement learning** problem

```
graph TD
    Agent -->|Action A_t| Environment
    Environment -->|State S_t| Agent
    Environment -->|Reward R_{t+1}| Agent
    Environment --> Prefetcher
    Prefetcher -->|Prefetch from address A+offset O_t| Processor
    Processor -->|Features of memory request to address A n.b. PC| Prefetcher
    Processor -->|Reward| Prefetcher
```

20 Mo Dec 2021

SAFARI Live Seminars in Computer Architecture

Sergei Mangul, Mangul Lab, USC

Opportunities and challenges of computational data-driven immunology



Opportunities and challenges of computational data-driven immunology

Sergei Mangul, Ph.D
Assistant Professor,
University of Southern California

<https://mangul-lab.usc.edu/bera.html>

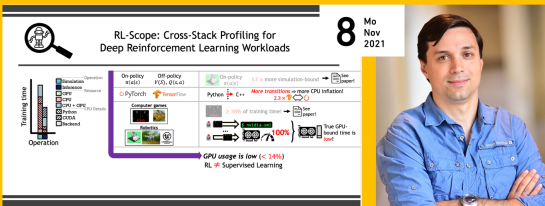


11 Thu Nov 2021

SAFARI Live Seminars in Computer Architecture

Gennady Pekhimenko, University of Toronto
Machine Learning Tools in Action

ETH zürich
SAFARI
SAFARI Research Group



SAFARI Live Seminars in Computer Architecture

Damla Senol Cali, Bionano Genomics
Accelerating Genome Sequence Analysis via Efficient Hardware/Algorithm Co-Design

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Our Goal & Approach

- Our Goal: Accelerating genome sequence analysis by efficient hardware/algorithm co-design
- Our Approach:
 - Analyze the multiple steps and the associated tools in the genome sequence analysis pipeline,
 - Expose the tradeoffs between accuracy, performance, memory usage and scalability, and
 - Co-design fast and efficient algorithms along with scalable and energy-efficient customized hardware accelerators for the key bottleneck steps of the pipeline

Damla Senol Cali

SAFARI

7 Sun Nov 2021



SAFARI Live Seminars in Computer Architecture

Nastaran Hajinazar, ETH Zurich
Data-Centric and Data-Aware Frameworks for Fundamentally Efficient Data Handling in Modern Computing Systems

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Overview of Our Approach

Data and the efficient computation of data should be the ultimate priority of the system

- Data-Centric Architectures
 - Enable computation with minimal data movement
 - Compute where data resides
- Data-Aware Architectures
 - Understand what they can do with and to each piece of data
 - Make use of different properties of data to improve performance, efficiency, etc.

SAFARI

15



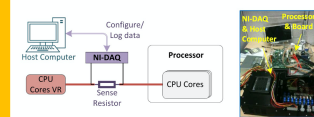
SAFARI Live Seminars in Computer Architecture

Jawad Haj-Yahya, Huawei Research Center Zurich
Security Implications of Power Management Mechanisms in Modern Processors, Current Studies and Future Trends

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Experimental Methodology

- We experimentally study three modern Intel processors
 - Haswell, Coffee Lake, and Cannon Lake
- We measure voltage and current using a Data Acquisition Card (NI-DAQ)

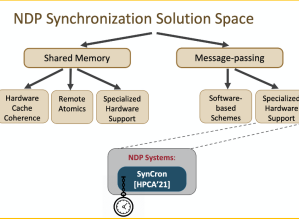


4 Mo Okt 2021

SAFARI Live Seminars in Computer Architecture

Christina Giannoula, National Technical University of Athens
Efficient Synchronization Support for Near-Data-Processing Architectures

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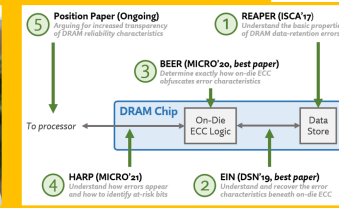


27 Mo Sep 2021

SAFARI Live Seminars in Computer Architecture

Minesh Patel, ETH Zurich
Enabling Effective Error Mitigation in Memory Chips That Use On-Die ECCs

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SAFARI Research Group

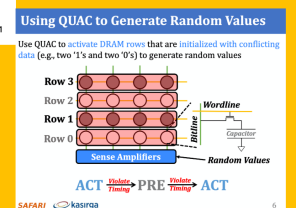


21 Tues Sep 2021

SAFARI Live Seminars in Computer Architecture

Ataberk Olgun, TOBB & ETH Zurich
QUAC-TRNG: High-Throughput True Random Number Generation Using Quadruple Row Activation in Commodity DRAM Chips

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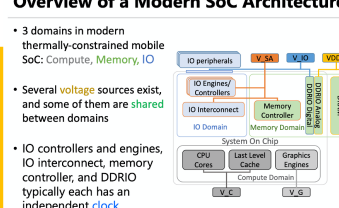


15 Hi Sep 2021

SAFARI Live Seminars in Computer Architecture

Jawad Haj-Yahya, Huawei Research Center Zurich
Power Management Mechanisms in Modern Microprocessors and Their Security Implications

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SAFARI Research Group

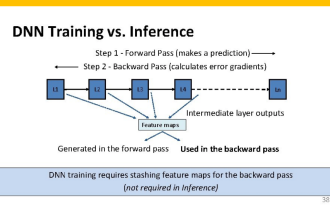


16 Mo Aug 2021

SAFARI Live Seminars in Computer Architecture

Gennady Pekhimenko, University of Toronto
Efficient DNN Training at Scale: from Algorithms to Hardware

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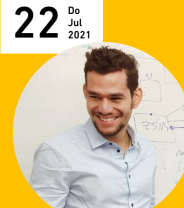


5 Do Aug 2021

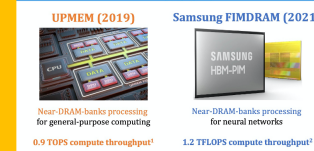
SAFARI Live Seminars in Computer Architecture

Geraldo F. Oliveira, ETH Zurich
DAMOQ: A New Methodology and Benchmark Suite for Evaluating Data Movement Bottlenecks

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SAFARI Research Group

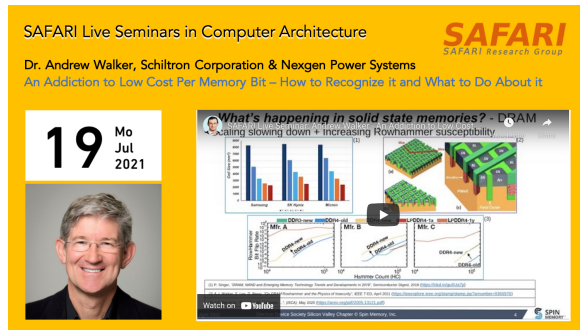
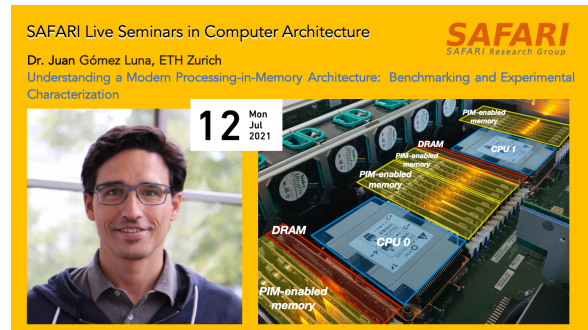


Near-Data Processing (2/2)



The goal of Near-Data Processing (NDP) is to mitigate data movement

SAFARI



SAFARI Talk Highlights

Visit [Onur's talks page](#) for more talks & more information.

Onur Mutlu, "Applying to Graduate School & Doing Impactful Research"

Invited Panel Talk at the 3rd Undergraduate Mentoring Workshop, held with the 48th International Symposium on Computer Architecture (ISCA), Virtual, 18 June 2021.

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

[\[Talk Video \(50 minutes\)\]](#)



Arch. Mentoring Workshop @ISCA'21 - Doing Impactful Research - Onur Mutlu

Onur Mutlu, "Runahead Execution: A Short Retrospective"

HPCA Test of Time Award Ceremony, Virtual, 2 March 2021.

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

[\[Talk Video \(10 minutes\)\]](#)

[\[Original HPCA 2003 Paper\]](#)



Onur Mutlu - Runahead Execution: A Short Retrospective (HPCA Test of Time Award Talk @ HPCA 2021)

Onur Mutlu, "Intelligent Architectures for Intelligent Systems"

Public Lecture at Frontiers of AI Accelerators: Technologies, Circuits and Applications, Croucher Advanced Study Institute Workshop (FAI-ASI), Virtual, 25 August 2021.

[Slides (pptx) (pdf)]

[Talk Video (1 hour 12 minutes, including Q&A)]



Mohammed Alser, "Accelerating Genome Analysis: A Primer on an Ongoing Journey Speaker"

Research Highlights talk @RECOMB2021, Virtual, 30 August 2021.

[Slides (pptx) (pdf)]

[Talk Video (22 minutes)]

[Related Survey paper, IEEE Micro]

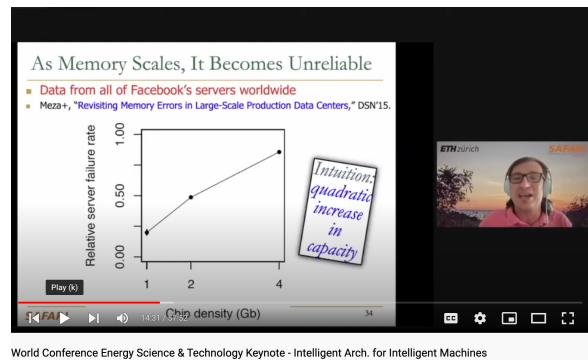


Onur Mutlu, "Intelligent Architectures for Intelligent Machines"

Keynote Talk at TUBA World Conference on Energy Science and Technology (WCEST), Virtual, 11 August 2021.

[Slides (pptx) (pdf)]

[Talk Video (58 minutes, including Q&A)]



Onur Mutlu, **"Future Computing Platforms: Challenges and Opportunities"**

Invited Seminar at IEEE Egypt & IEEE Future University in Egypt Student Branch, Virtual, 16 May 2021.

[Slides (pptx) (pdf)]

[Talk Video (2 hours 2 minutes, with Q&A)]



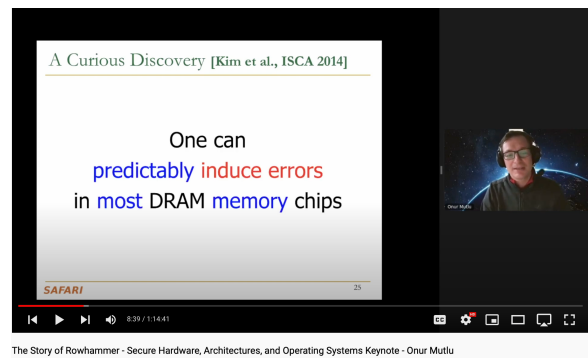
Onur Mutlu, **"The Story of RowHammer"**

Keynote Talk at Secure Hardware, Architectures, and Operating Systems Workshop (SeHAS), held with HiPEAC 2021 Conference, Virtual, 19 January 2021.

[Slides (pptx) (pdf)]

[Talk Video (1 hr 15 minutes, with Q&A)]

[Related Survey Paper from IEEE TCAD 2019]

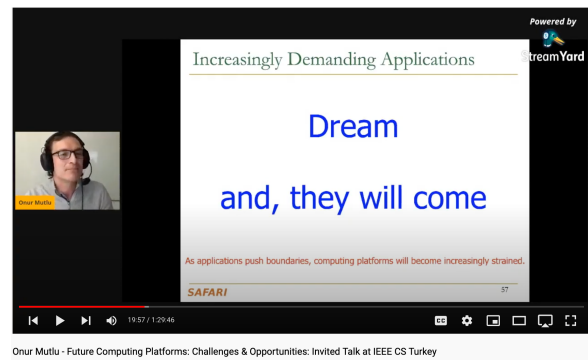


Onur Mutlu, **"Future Computing Platforms: Challenges and Opportunities"**

Invited Lecture at IEEE Computer Society Turkey Chapter, Virtual, 20 February 2021.

[Slides (pptx) (pdf)]

[Talk Video (1 hour 30 minutes, including Q&A)]



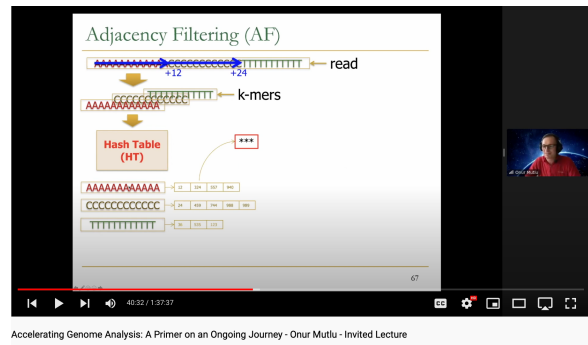
Onur Mutlu, **"Accelerating Genome Analysis: A Primer on an Ongoing Journey"**

Invited Lecture at Technion, Virtual, 26 January 2021.

[Slides (pptx) (pdf)]

[Talk Video (1 hour 37 minutes, including Q&A)]

[Related Invited Paper (at IEEE Micro, 2020)]



Onur Mutlu, **"Memory-Centric Computing"**

Education Class at Embedded Systems Week (ESWEEK), Virtual, 9 October 2021.

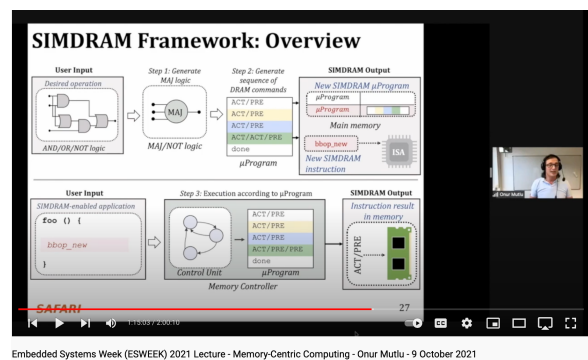
[Slides (pptx) (pdf)]

[Abstract (pdf)]

[Talk Video (2 hours, including Q&A)]

[Invited Paper at DATE 2021]

["A Modern Primer on Processing in Memory" paper]



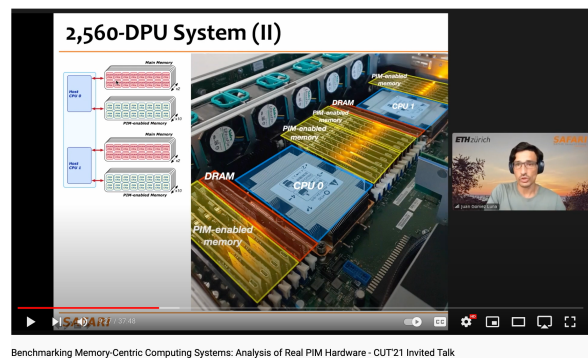
Juan Gómez Luna, **"Benchmarking Memory-Centric Computing Systems: Analysis of Real Processing-in-Memory Hardware"** Invited Talk at the Workshop on Computing with Unconventional Technologies (CUT 2021), October 2021

[Slides (pptx) (pdf)]

[Talk Video]

[CUT 2021 Paper]

[PriM benchmarks Source Code]



Onur Mutlu, "Intelligent Architectures for Intelligent Systems"

Invited Talk at Supercomputing Frontiers Europe (SCFE), Virtual, 21 July 2021.

[Slides (pptx) (pdf)]

[Talk Video (52 minutes)]



Selected Open Source Releases



We released many research artifacts and tools in 2021. All are available on GitHub **CMU-SAFARI**

DAMOV Suite and Simulator Source

Code: DAMOV is a benchmark suite and a methodical framework targeting the study of data movement bottlenecks in modern applications. It is intended to study new architectures, such as near-data processing.

Oliveira, et al. <https://arxiv.org/abs/2105.03725>

BioDynaMo Source Code and Data

Breitwieser, et al., Supporting information for "BioDynaMo: a general platform for scalable agent-based simulation". Zenodo.

<https://doi.org/10.5281/zenodo.4501515>
<https://biodynomo.org>

PrIM Benchmarks Source Code:

PrIM is the first benchmark suite for a real-world processing-in-memory (PIM) architecture. PrIM provides a common set of workloads to evaluate the UPMEM PIM architecture with and can be useful for programming, architecture and system researchers all alike to improve multiple aspects of future PIM hardware and software. This repository also contains baseline CPU and GPU implementations of PrIM benchmarks for comparison purposes. Gómez-Luna et al., <https://arxiv.org/abs/2105.03814>

COVIDHunter Source Code and Data:

COVIDHunter is a COVID-19 outbreak simulation model that evaluates the current mitigation measures (i.e., non-pharmaceutical intervention) that are applied to a region and provides insight into what strength the upcoming mitigation measure should be and for how long it should be applied, while considering the potential effect of environmental conditions. Our model accurately forecasts the numbers of cases, hospitalizations, and deaths for a given day. [Alser et al. <https://arxiv.org/abs/2102.03667>](https://arxiv.org/abs/2102.03667)

BLEND Source Code: BLEND is a mechanism that can efficiently find fuzzy seed matches between sequences to significantly improve the performance and accuracy while reducing the memory space usage of two important applications: 1) finding overlapping reads and 2) read mapping. Finding fuzzy seed matches enable BLEND to find both 1) exact-matching seeds and 2) highly similar seeds. We integrate the BLEND mechanism into Minimap2.

[Firtina et al. <https://arxiv.org/abs/2112.08687>](https://arxiv.org/abs/2112.08687)

SNF-Selective-Hiding Source Code:

SNF-Selective-Hiding is a near-optimal optimization-based mechanism to mitigate the vulnerabilities of the inference attacks on differentially private query results from genomic datasets including dependent tuples. We propose a utility-maximizing and privacy-preserving approach for sharing

AirLift Source Code and Data: AirLift is a fast and comprehensive technique for moving alignments from one genome to another. AirLift reduces 1) the number of reads that need to be fully mapped from the entire read set by up to 99.99% and 2) the overall execution time to remap read sets between two reference genome versions by 19.6x, 6.6x, and 2.7x for large (human), medium (*C. elegans*), and small (yeast) reference genomes, respectively. We validate our remapping results with GATK and find that AirLift provides similar rates of identifying ground truth SNPs and INDELs as fully mapping a read set.

[Kim et al., <http://arxiv.org/abs/1912.08735>](http://arxiv.org/abs/1912.08735)

PiDRAM Source Code: PiDRAM is the first flexible end-to-end framework that enables system integration studies and evaluation of real Processing-using-Memory (PuM) techniques. PiDRAM, at a high level, comprises a RISC-V system and a custom memory controller that can perform PuM operations in real DDR3 chips. This repository contains all sources required to build PiDRAM and develop its prototype on the Xilinx ZC706 FPGA boards. [Olgun et al. <https://arxiv.org/abs/2111.00082>](https://arxiv.org/abs/2111.00082)

Pythia Source Code: Pythia formulates hardware prefetching as a reinforcement learning task. For every demand request, Pythia observes multiple different types of program context information to take a prefetch decision. For every prefetch decision, Pythia receives a numerical

privacy-preserving approach for sharing statistics by hiding selective SNPs of the family members as they participate in a genomic dataset. [Almadhoun Alserr et al. https://arxiv.org/abs/2106.05211](https://arxiv.org/abs/2106.05211)

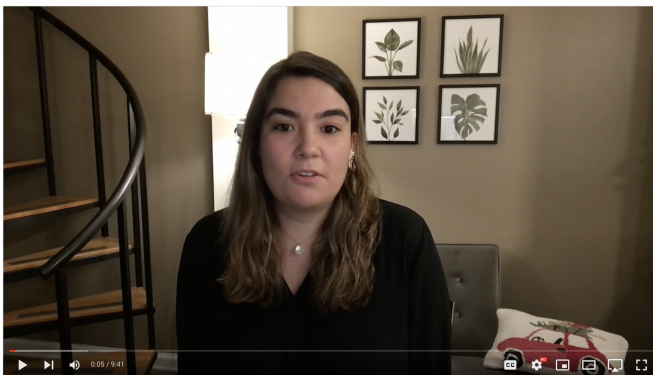
HARP Source Code: HARP provides the artifacts for evaluating Hybrid Active-Reactive Profiling (HARP) as described in our MICRO 2021 academic paper to appear [1]. The HARP tool that we provide uses a combination of Monte-Carlo simulation and a SAT solver to study the effectiveness of different strategies for profiling for memory errors. [Patel et al.:https://arxiv.org/abs/2109.12697](https://arxiv.org/abs/2109.12697)

decision, Pythia receives a numerical reward that evaluates prefetch quality under the current memory bandwidth utilization. Pythia uses this reward to reinforce the correlation between program context information and prefetch decision to generate highly accurate, timely, and system-aware prefetch requests in the future. [Bera & Kanellopoulos et al. https://arxiv.org/abs/2109.12021](https://arxiv.org/abs/2109.12021)

Pythia-HDL: Implementation of Pythia: A Customizable Hardware Prefetching Framework Using Online Reinforcement Learning in Chisel HDL.



Meet our members: on research and career



SAFARI December 2021 Newsletter - Interview with Damla Senol Cali

Damla Senol Cali defended her PhD in July (as the last SAFARI PhD student from CMU!). She recently started a new position in industry with [Bionano Genomics](#), where she is a Staff Software Engineer, Hardware Acceleration.

In this video interview, she discusses her thesis and defense preparations, highlighting the importance of coming up with a cohesive and impactful story of your research during your PhD, and while looking ahead. She also gives some great advice on her job search process, with tips for finding a job in industry, including building your network and reaching out, using resources that are available to you (like the university career centre), and having a list of

prioritizations of what you want from your new job.

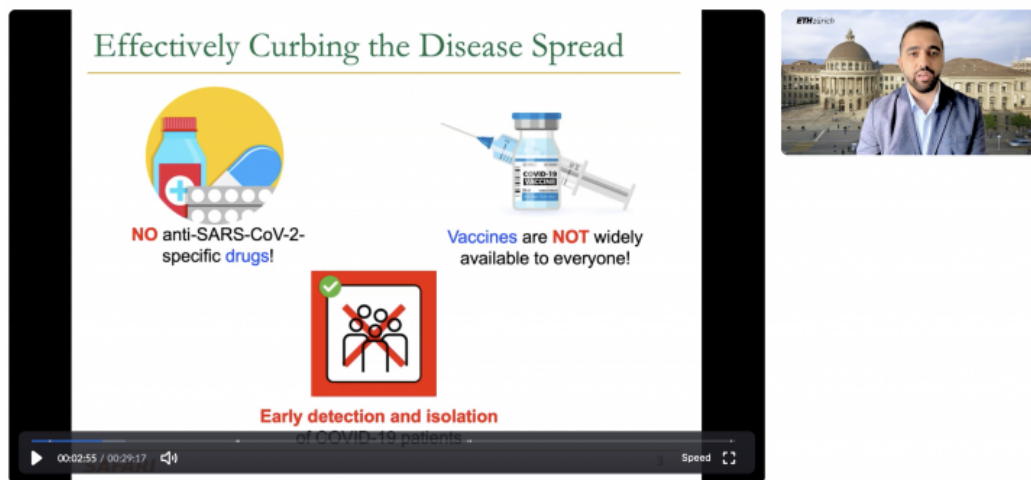
Watch Damla's video [here](#)

Additional reading and videos:

[Interview: SAFARI Newsletter January 2021](#): Damla discusses her research, life as a PhD student with SAFARI, and looking ahead

[SAFARI News: Congratulations Damla](#): Thesis Overview & Links to her PhD work

[SAFARI Live Seminar Nov 7 2021](#): Accelerating Genome Sequence Analysis via Efficient Hardware/Algorithm Co-Design

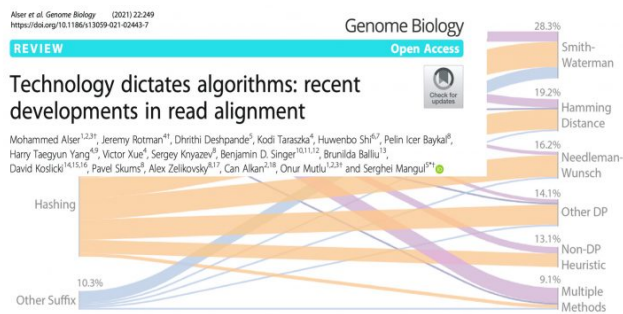


Mohammed Alser is a Lecturer and Senior Researcher in SAFARI leading our bioinformatics research activities. In this video "Architecting for the Pandemic: Rethinking Genome Analysis at Population Scale", he highlights his work in 2021 and looks forward to his impactful research to come.

Watch Mohammed's video [here](#)

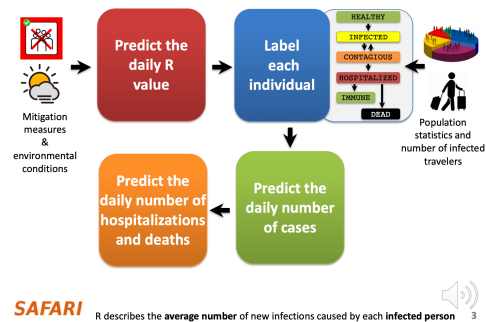
[Talk Slides \(pptx\)](#) [\(pdf\)](#)

Read more



Mohammed Alser, Jeremy Rotman, Dhriti Deshpande, Kodi Taraszka, Huwenbo Shi, Pelin Icer Baykal, Harry Taegyun Yang, Victor Xue, Sergey Knyazev, Benjamin D. Singer, Brunilda Balliu, David Koslicki, Pavel Skums, Alex Zelikovsky, Can Alkan, Onur Mutlu, and Serghei Mangul, **"Technology Dictates Algorithms: Recent Developments in Read Alignment"** *Genome Biology*, 26 August 2021. [Source Code and All Data](#) | [Online link at Genome Biology](#) | [Full arXiv version](#)

How Does COVIDHunter Work?



Mohammed Alser, Jeremie S. Kim, Nour Almadhoun Alserr, Stefan W. Tell, and Onur Mutlu, **"COVIDHunter: An Accurate, Flexible, and Environment-Aware Open-Source COVID-19 Outbreak Simulation Model"** Preprint in arXiv and medRxiv, 6 February 2021. [medRxiv preprint](#) | [arXiv preprint](#) | [COVIDHunter Source Code and Data](#) | [Switzerland Case Study](#) | [Talk Video ISMB/ECCB 2021, Virtual, July 2021](#) | [Talk Slides \(pptx\)\(pdf\)](#)



Accelerating Genome Analysis: A Primer on an Ongoing Journey; Research Highlight @RECOMB'21 M. Alser

Mohammed Alser, **"Accelerating Genome Analysis: A Primer on an Ongoing Journey Speaker"** Research Highlights talk @RECOMB2021, Virtual, 30 August 2021. [Slides \(pptx\) \(pdf\)](#) | [Talk Video \(22 minutes\)](#) | [Related Survey paper, IEEE Micro](#)



Mohammed Alser, **"Architecting for the Pandemic: Rethinking Genome Analysis at Population Scale"** Keynote talk @IC3INA, Virtual, 5 October 2021. [Slides \(pptx\)\(pdf\)](#) | [Talk Video](#)



Gagandeep Singh is a postdoc in SAFARI and recently defended his PhD remotely in March 2021. He completed his thesis on "Designing, Modeling, and Optimizing Data-Intensive Computing Systems" from **TU Eindhoven** in the Netherlands supervised by Henk Corporaal, while working as an academic guest in SAFARI. Gagan shared some of his insights from his PhD journey with us below. You can read more on Gagan's thesis [in this SAFARI News](#).

Ph.D. Journey

From using FPGAs for accelerating weather/climate simulations to applying machine learning to computer architecture, my Ph.D. thesis goes in breadth to cover aspects in both data-centric and data-driven paradigms. Throughout my Ph.D., instead of staying in my comfort zone, I always pushed myself to work on different problems. This approach was certainly not easy as I had to constantly climb through the learning curve to acquire the skills required to helm a project. However, in the end, I have acquired a broad range of skills that allows me to assimilate concepts from different levels of computer architecture. We are in an era where hardware and software designers cannot work in isolation to build an efficient solution. Therefore, having these wide-ranging skills helps me connect these two worlds.

At the end of this journey, I believe a Ph.D. is more than just a thesis. It is who you have become. Certainly, I would not have gotten this far without the support of many excellent people around me. I am deeply indebted to my family, who have done everything in their power to support me in both my academic and personal life.

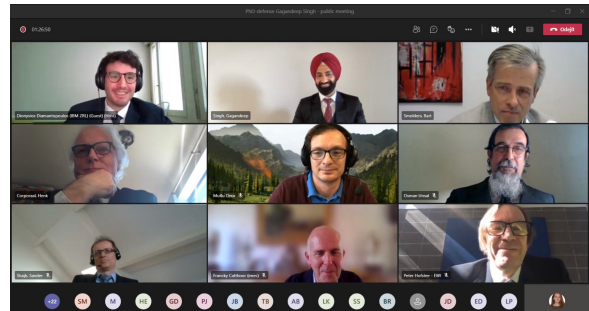
My time at ETH with the SAFARI research group took my research career to the next level. I am deeply indebted to Prof. Onur Mutlu for his invaluable scientific discussions, feedback, and support. His passion for computer architecture intrigued me to pursue research in this domain. I am grateful to have experienced the rigor, thought, and care Onur puts into every scientific task. Further, he always makes sure that extraneous issues do not constraint us in any way, so we can focus on high-impact research and realize our true potential. From brainstorming sessions to reading groups, SAFARI provides a nurturing environment that

pushes you to do cutting-edge research.

During my secondment at IBM Research Zurich, I had invaluable experiences that shaped me personally and professionally. One of the greatest joys of working at IBM is the presence of many talented individuals who I called upon numerous times for their expertise during my research.

I would like to thank the members of the doctoral committee for agreeing to participate in my defense during times of a global pandemic and for taking the time to read my drafts and provide constructive feedback, which helped improve the quality of my thesis. Being a Dutch Ph.D., I definitely missed the traditional Dutch defense ceremony where the committee is dressed in caps and gowns. Moreover, I could not have the quirk of having two *paranimphs* at my side. *Paranimphs* (comparable to a best man) can answer questions on your behalf or even physically defend you in case of an argument! Though my defense did not get to that point, we did have a *beadle* (master of the ceremony) who asserted *Hora est* after exactly an hour, abruptly marking the end of the Ph.D. examination. The committee's deliberation was followed by a *laudatio* (a speech from Prof. Henk Corporaal, my first promotor), which took us on a delightful trip down memory lane.

My tip for a young Ph.D. is not to be scared of the unknown. No one expects you to know everything; you “just” need to focus on asking the *right* question!



Read more

Gagandeep Singh, Mohammed Alser, Damla Senol Cali, Dionysios Diamantopoulos, Juan Gómez-Luna, Henk Corporaal, and Onur Mutlu, "[FPGA-based Near-Memory Acceleration of Modern Data-Intensive Applications](#)" **IEEE Micro** 41(4): 39-48, June 2021.

[\[arXiv version\]](#)

Gagandeep Singh, Dionysios Diamantopoulos, Juan Gómez-Luna, Christoph Hagleitner, Sander Stuijk, Henk Corporaal, Onur Mutlu, "[Accelerating Weather Prediction using Near-Memory Reconfigurable Fabric](#)" *ACM Transactions on Reconfigurable Technology and Systems (TRETs)*, to appear, 2022.

[\[arXiv version\]](#)

On the job market

Our most recent PhD graduate, **Minesh Patel** is currently on the job market. He is seeking a research position in an industry lab in the area of computer systems and architecture. His graduate work focuses primarily on improvements to memory systems. Going forward, Minesh is interested in broader topics pertaining to cutting-edge computing systems.



Watch Minesh's recent **SAFARI Live Seminar Video** on his PhD work.

Minesh Patel, defended his thesis in October 2021 on "**Enabling Effective Error Mitigation in Modern Memory Chips that Use On-Die Error-Correcting Codes**".

[Slides \(pptx\) \(pdf\)](#) | [SAFARI Live Seminar Video](#) | [Read more](#)

Onur Mutlu's Keynote Talks & Short Courses 2021

Onur Mutlu Public Lectures Playlist on YouTube

Onur Mutlu, "**Intelligent Architectures for Intelligent Systems**"

Invited Webinar at IEEE SSCS & CAS Central Texas Chapter, Virtual, 2 December 2021.

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

Onur Mutlu, "**Future Computing Platforms: Challenges and Opportunities**"

Closing Talk at IEEE Data & Storage Symposium (DSS), Virtual, 1 December 2021.

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

Onur Mutlu, "**Future Computing Platforms: Challenges and Opportunities**"

Invited Lecture at the 10th EdukCircle International Convention on Engineering and Computer Technology, Virtual, 10 November 2021.

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

Onur Mutlu, "**Memory-Centric Computing**"

Invited Lecture at IEEE Electron Devices Society Fall School (EDS FALL SCHOOL), Virtual, 26 October 2021.

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

Onur Mutlu, **"Intelligent Architectures for Intelligent Systems"**

Keynote Talk at 15th International Conference on Networking, Architecture, and Storage (NAS), Virtual, 25 October 2021.

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

Onur Mutlu, **"Microarchitecture Research Panel"**

Panel Talk at the 54th International Symposium on Microarchitecture (MICRO), Virtual, 20 October 2021.

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

Onur Mutlu, **"Intelligent Architectures for Intelligent Machines"**

Distinguished Lecture at Ontario Tech Engineering Research Distinguished Speaker Series, Virtual, 19 October 2021.

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

Onur Mutlu, **"SAFARI Research Group: Introduction & Research"**

Invited Talk at the ETH Future Computing Laboratory Huawei Day, Virtual, 19 October 2021.

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

Onur Mutlu, **"Future Computing Platforms: Challenges and Opportunities"**

Invited Talk at Huawei Strategy & Technology Workshop, Virtual, 15 October 2021.

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

Onur Mutlu, **"Intelligent Architectures for Intelligent Systems"**

Invited Talk at Huawei Strategy & Technology Workshop, Virtual, 14 October 2021.

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

Onur Mutlu, **"Memory-Centric Computing"**

Education Class at Embedded Systems Week (ESWEEK), Virtual, 9 October 2021.

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

[\[Abstract \(pdf\)\]](#)

[\[Talk Video \(2 hours, including Q&A\)\]](#)

[\[Invited Paper at DATE 2021\]](#)

[\["A Modern Primer on Processing in Memory" paper\]](#)

Onur Mutlu, **"Memory-Centric Computing Systems"**

Invited Talk at Korea Computing Industry Association PIM Software Workshop (KCIA), Virtual, 7 October 2021.

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

Onur Mutlu, **"Intelligent Architectures for Intelligent Systems"**

Public Lecture at Frontiers of AI Accelerators: Technologies, Circuits and Applications, Croucher Advanced Study Institute Workshop (FAI-ASI), Virtual, 25 August 2021.

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

[\[Talk Video \(1 hour 12 minutes, including Q&A\)\]](#)

Onur Mutlu, **"Intelligent Architectures for Intelligent Machines"**

Keynote Talk at TUBA World Conference on Energy Science and Technology (WCEST), Virtual, 11 August 2021.

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

[\[Talk Video \(58 minutes, including Q&A\)\]](#)

Onur Mutlu, **"Intelligent Architectures for Intelligent Systems"**

Invited Talk at Supercomputing Frontiers Europe (SCFE), Virtual, 21 July 2021.

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

[\[Talk Video \(52 minutes\)\]](#)

Onur Mutlu, **"SAFARI Research Group: Introduction & Research"**

Talk at ETH Future Computing Laboratory Welcome Workshop (EFCL), Virtual, 6 July 2021.

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

Onur Mutlu, **"Intelligent Architectures for Intelligent Machines"**

Closing Talk at IEEE Data & Storage Symposium (DSS), Virtual, 30 June 2021.

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

[\[Talk Video \(1 hour\)\]](#)

Onur Mutlu, **"Applying to Graduate School & Doing Impactful Research"**

Invited Panel Talk at the 3rd Undergraduate Mentoring Workshop, held with the 48th International Symposium on Computer Architecture (ISCA), Virtual, 18 June 2021.

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

[\[Talk Video \(50 minutes\)\]](#)

Onur Mutlu, **"Future Computing Platforms: Challenges and Opportunities"**

Invited Seminar at IEEE Egypt & IEEE Future University in Egypt Student Branch, Virtual, 16 May 2021.

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

[\[Talk Video \(2 hours 2 minutes, with Q&A\)\]](#)

Onur Mutlu, **"Intelligent Architectures for Intelligent Machines"**

Opening Talk at TU Vienna Mondays in Memory Webinar Series (MiM), Virtual, 3 May 2021.

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

[\[Talk Video \(57 minutes\)\]](#)

Onur Mutlu, **"Intelligent Architectures for Intelligent Machines"**

Keynote Talk at Future of Information and Communication Conference (FICC), Virtual, 29 April 2021.

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

[\[Talk Video \(48 minutes\)\]](#)

Onur Mutlu, **"Future Computing Platforms: Challenges and Opportunities"**

Distinguished Seminar at Koc University College of Engineering, Virtual, 9 April 2021.

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

[\[Talk Video \(1 hour 8 minutes\)\]](#)

Onur Mutlu, **"Future Computing Architectures: Challenges and Opportunities"**

Keynote Talk at CSCON IEEE Turkey Computer Society Student Branch Conference (CSCON), Virtual, 2 April 2021.

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

[\[Talk Video \(1 hour 22 minutes\)\]](#)

Onur Mutlu, **"Future Computing Architectures: Challenges and Opportunities"**

Invited Lecture at Koc University ACM Student Chapter, Virtual, 22 March 2021.

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

[\[Talk & Interview Video \(2 hours 24 minutes, including Q&A and interview\)\]](#)

Onur Mutlu, **"Runahead Execution: A Short Retrospective"**

HPCA Test of Time Award Ceremony, Virtual, 2 March 2021.

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

[\[Talk Video \(10 minutes\)\]](#)

[\[Original HPCA 2003 Paper\]](#)

Onur Mutlu, **"Future Computing Platforms: Challenges and Opportunities"**

Invited Lecture at IEEE Computer Society Turkey Chapter, Virtual, 20 February 2021.

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

[\[Talk Video \(1 hour 30 minutes, including Q&A\)\]](#)

Onur Mutlu, **"Accelerating Genome Analysis: A Primer on an Ongoing Journey"**

Invited Lecture at Technion, Virtual, 26 January 2021.

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

[\[Talk Video \(1 hour 37 minutes, including Q&A\)\]](#)

[\[Related Invited Paper \(at IEEE Micro, 2020\)\]](#)

Onur Mutlu, **"Intelligent Architectures for Intelligent Computing Systems"**

Invited Special Session Talk at Design, Automation and Test in Europe (DATE), Virtual, 2 February 2021.

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

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

[\[Short Talk Video \(11 minutes\)\]](#)

[\[Longer IEDM Tutorial Video \(1 hr 51 minutes\)\]](#)

[\[Abstract and Bio\]](#)

[\[Invited Paper at DATE 2021\]](#)

[\[Related Review Paper on Processing in Memory\]](#)

Onur Mutlu, **"The Story of RowHammer"**

Keynote Talk at Secure Hardware, Architectures, and Operating Systems Workshop (SeHAS), held with HiPEAC 2021 Conference, Virtual, 19 January 2021.

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

[\[Talk Video \(1 hr 15 minutes, with Q&A\)\]](#)

[\[Related Survey Paper from IEEE TCAD 2019\]](#)

Onur Mutlu, **"Intelligent Architectures for Intelligent Machines"**

Invited Talk at Seoul National University Neural Processing Research Center, Virtual, 12 January 2021.

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

[\[Talk Video \(1 hr 30 minutes, with Q&A\)\]](#)

[\[Related Keynote Paper from VLSI-DAT 2020\]](#)

[\[Related Review Paper on Processing in Memory\]](#)

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

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