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**47th Annual IEEE/ACM International
Symposium on Microarchitecture**

MICRO 2014

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MICRO 2014

Table of Contents

Message from the General Chair	x
Message from the Program Co-Chairs	xi
Organizing Committee	xiii
Program Committee	xiv
External Reviewer Committee	xvi
External Reviewers	xix
Keynote Abstracts	xx

Session 1A: Stacked DRAM

CAMEO: A Two-Level Memory Organization with Capacity of Main Memory and Flexibility of Hardware-Managed Cache	1
<i>Chia Chen Chou, Aamer Jaleel, and Moinuddin K. Qureshi</i>	
Transparent Hardware Management of Stacked DRAM as Part of Memory	13
<i>Jaewoong Sim, Alaa R. Alameldeen, Zeshan Chishti, Chris Wilkerson, and Hyesoon Kim</i>	
Unison Cache: A Scalable and Effective Die-Stacked DRAM Cache	25
<i>Djordje Jevdjic, Gabriel H. Loh, Cansu Kaynak, and Babak Falsafi</i>	
Bi-Modal DRAM Cache: Improving Hit Rate, Hit Latency and Bandwidth	38
<i>Nagendra Gulur, Mahesh Mehendale, R. Manikantan, and R. Govindarajan</i>	
Citadel: Efficiently Protecting Stacked Memory from Large Granularity Failures	51
<i>Prashant J. Nair, David A. Roberts, and Moinuddin K. Qureshi</i>	

Session 1B: GPGPU and Data Parallel Architectures

Locality-Aware Mapping of Nested Parallel Patterns on GPUs	63
<i>Hyoukjoong Lee, Kevin J. Brown, Arvind K. Sujeeth, Tiark Rumpf, and Kunle Olukotun</i>	
Accelerating Irregular Algorithms on GPGPUs Using Fine-Grain Hardware Worklists	75
<i>Ji Yun Kim and Christopher Batten</i>	

PORPLE: An Extensible Optimizer for Portable Data Placement on GPU	88
<i>Guoyang Chen, Bo Wu, Dong Li, and Xipeng Shen</i>	
Exploring the Design Space of SPMD Divergence Management on Data-Parallel Architectures	101
<i>Yunsup Lee, Vinod Grover, Ronny Krashinsky, Mark Stephenson, Stephen W. Keckler, and Krste Asanović</i>	
Managing GPU Concurrency in Heterogeneous Architectures	114
<i>Onur Kayiran, Nachiappan Chidambaram Nachiappan, Adwait Jog, Rachata Ausavarungnirun, Mahmut T. Kandemir, Gabriel H. Loh, Onur Mutlu, and Chita R. Das</i>	
Session 2A: Memory Systems, Scheduling, and Optimization	
Load Value Approximation	127
<i>Joshua San Miguel, Mario Badr, and Natalie Enright Jerger</i>	
Arbitrary Modulus Indexing	140
<i>Jeffrey R. Diamond, Donald S. Fussell, and Stephen W. Keckler</i>	
FIRM: Fair and High-Performance Memory Control for Persistent Memory Systems	153
<i>Jishen Zhao, Onur Mutlu, and Yuan Xie</i>	
Short-Circuiting Memory Traffic in Handheld Platforms	166
<i>Praveen Yedlapalli, Nachiappan Chidambaram Nachiappan, Niranjan Soundararajan, Anand Sivasubramaniam, Mahmut T. Kandemir, and Chita R. Das</i>	
Efficient Memory Virtualization: Reducing Dimensionality of Nested Page Walks	178
<i>Jayneel Gandhi, Arkaprava Basu, Mark D. Hill, and Michael M. Swift</i>	
Session 2B: Security	
Iso-X: A Flexible Architecture for Hardware-Managed Isolated Execution	190
<i>Dmitry Evtyushkin, Jesse Elwell, Meltem Ozsoy, Dmitry Ponomarev, Nael Abu Ghazaleh, and Ryan Riley</i>	
Random Fill Cache Architecture	203
<i>Fangfei Liu and Ruby B. Lee</i>	
CC-Hunter: Uncovering Covert Timing Channels on Shared Processor Hardware	216
<i>Jie Chen and Guru Venkataramani</i>	
Continuous, Low Overhead, Run-Time Validation of Program Executions	229
<i>Erdem Aktas, Furat Afram, and Kanad Ghose</i>	
A Practical Methodology for Measuring the Side-Channel Signal Available to the Attacker for Instruction-Level Events	242
<i>Robert Callan, Alenka Zajić, and Milos Prvulovic</i>	

Session 3A: Methodology, Modeling, and Tools

RpStacks: Fast and Accurate Processor Design Space Exploration Using Representative Stall-Event Stacks	255
<i>Jaewon Lee, Hanhwi Jang, and Jangwoo Kim</i>	
GPUMech: GPU Performance Modeling Technique Based on Interval Analysis	268
<i>Jen-Cheng Huang, Joo Hwan Lee, Hyesoon Kim, and Hsien-Hsin S. Lee</i>	
PyMTL: A Unified Framework for Vertically Integrated Computer Architecture Research	280
<i>Derek Lockhart, Gary Zibrat, and Christopher Batten</i>	

Session 3B: Reliability and Fault Tolerance

Calculating Architectural Vulnerability Factors for Spatial Multi-Bit Transient Faults	293
<i>Mark Wilkening, Vilas Sridharan, Si Li, Fritz Previlon, Sudhanva Gurumurthi, and David R. Kaeli</i>	
Using ECC Feedback to Guide Voltage Speculation in Low-Voltage Processors	306
<i>Anys Bacha and Radu Teodorescu</i>	
Harnessing Soft Computations for Low-Budget Fault Tolerance	319
<i>Daya Shanker Khudia and Scott Mahlke</i>	

Session 4A: TLB and Cache Optimization

Skewed Compressed Caches	331
<i>Somayeh Sardashti, André Seznec, and David A. Wood</i>	
Adaptive Cache Management for Energy-Efficient GPU Computing	343
<i>Xuhao Chen, Li-Wen Chang, Christopher I. Rodrigues, Jie Lv, Zhiying Wang, and Wen-Mei Hwu</i>	
Futility Scaling: High-Associativity Cache Partitioning	356
<i>Ruisheng Wang and Lizhong Chen</i>	

Session 4B: Managing Voltage and Time

Voltage Noise in Multi-Core Processors: Empirical Characterization and Optimization Opportunities	368
<i>Ramon Bertran, Alper Buyuktosunoglu, Pradip Bose, Timothy J. Slegel, Gerard Salem, Sean Carey, Richard F. Rizzolo, and Thomas Strach</i>	
Enabling Realistic Fine-Grain Voltage Scaling with Reconfigurable Power Distribution Networks	381
<i>Waclaw Godycki, Christopher Torng, Ivan Bukreyev, Alyssa Apsel, and Christopher Batten</i>	
Micro-Sliced Virtual Processors to Hide the Effect of Discontinuous CPU Availability for Consolidated Systems	394
<i>Jeongseob Ahn, Chang Hyun Park, and Jaehyuk Huh</i>	

Session 5A: Energy-Efficient Computation

SMiTe: Precise QoS Prediction on Real-System SMT Processors to Improve Utilization in Warehouse Scale Computers	406
<i>Yunqi Zhang, Michael A. Laurenzano, Jason Mars, and Lingjia Tang</i>	
A Front-End Execution Architecture for High Energy Efficiency	419
<i>Ryota Shioya, Masahiro Goshima, and Hideki Ando</i>	
Execution Drafting: Energy Efficiency through Computation Deduplication	432
<i>Michael Mckeown, Jonathan Balkind, and David Wentzlaff</i>	
PPEP: Online Performance, Power, and Energy Prediction Framework and DVFS Space Exploration	445
<i>Bo Su, Junli Gu, Li Shen, Wei Huang, Joseph L. Greathouse, and Zhiying Wang</i>	

Session 5B: Interconnects

NoC Architectures for Silicon Interposer Systems: Why Pay for more Wires when you Can Get them (from your interposer) for Free?	458
<i>Natalie Enright Jerger, Ajaykumar Kannan, Zimo Li, and Gabriel H. Loh</i>	
Hi-Rise: A High-Radix Switch for 3D Integration with Single-Cycle Arbitration	471
<i>Supreet Jeloka, Reetuparna Das, Ronald G. Dreslinski, Trevor Mudge, and David Blaauw</i>	
Multi-GPU System Design with Memory Networks	484
<i>Gwangsun Kim, Minseok Lee, Jiyun Jeong, and John Kim</i>	
Dodec: Random-Link, Low-Radix On-Chip Networks	496
<i>Haofan Yang, Jyoti Tripathi, Natalie Enright Jerger, and Dan Gibson</i>	

Session 6A: Branch Prediction and Prefetching

Wormhole: Wisely Predicting Multidimensional Branches	509
<i>Jorge Albericio, Joshua San Miguel, Natalie Enright Jerger, and Andreas Moshovos</i>	
Bias-Free Branch Predictor	521
<i>Dibakar Gope and Mikko H. Lipasti</i>	
Loop-Aware Memory Prefetching Using Code Block Working Sets	533
<i>Adi Fuchs, Shie Mannor, Uri Weiser, and Yoav Etsion</i>	
BuMP: Bulk Memory Access Prediction and Streaming	545
<i>Stavros Volos, Javier Picorel, Babak Falsafi, and Boris Grot</i>	

Session 6B: Compilation and Code Generation

Protean Code: Achieving Near-Free Online Code Transformations for Warehouse Scale Computers	558
<i>Michael A. Laurenzano, Yunqi Zhang, Lingjia Tang, and Jason Mars</i>	
Compiler Support for Optimizing Memory Bank-Level Parallelism	571
<i>Wei Ding, Diana Guttman, and Mahmut Kandemir</i>	
Architectural Specialization for Inter-Iteration Loop Dependence Patterns	583
<i>Shreesha Srinath, Berkin Ilbeyi, Mingxing Tan, Gai Liu, Zhiru Zhang, and Christopher Batten</i>	
Specializing Compiler Optimizations through Programmable Composition for Dense Matrix Computations	596
<i>Qing Yi, Qian Wang, and Huimin Cui</i>	

Session 7: Best Paper Nominees

DaDianNao: A Machine-Learning Supercomputer	609
<i>Yunji Chen, Tao Luo, Shaoli Liu, Shijin Zhang, Liqiang He, Jia Wang, Ling Li, Tianshi Chen, Zhiwei Xu, Ninghui Sun, and Olivier Temam</i>	
B-Fetch: Branch Prediction Directed Prefetching for Chip-Multiprocessors	623
<i>David Kadjo, Jinchun Kim, Prabal Sharma, Reena Panda, Paul Gratz, and Daniel Jimenez</i>	
Pipe Check: Specifying and Verifying Microarchitectural Enforcement of Memory Consistency Models	635
<i>Daniel Lustig, Michael Pellauer, and Margaret Martonosi</i>	
Equalizer: Dynamic Tuning of GPU Resources for Efficient Execution	647
<i>Ankit Sethia and Scott Mahlke</i>	
COMP: Compiler Optimizations for Manycore Processors	659
<i>Linhai Song, Min Feng, Nishkam Ravi, Yi Yang, and Srimat Chakradhar</i>	
Author Index	672

Message from the General Chair

It is my pleasure to welcome all Micro47 delegates to Cambridge in the United Kingdom, which, as of this proceedings, still includes Scotland. I also have the honor of organizing Micro in The UK for the first time. Cambridge is a relatively small town located 50 miles north of London, and boasts of having the World's third oldest university along with a large concentration of high-tech companies in computers, electronics and biotechnology. The university has a great number of colleges (Kings, Trinity, St John etc.) in walking distance from the conference venue. In fact Micro47 will be held in one of these colleges: Robinson College. Cambridge offers visitors historic buildings and colleges, punting on the river Cam, a great variety of restaurants and the famous "real ale" in traditional English pubs.

On the technical side, Micro47 has a stimulating program with 53 full papers. I would like to thank the Program Co-chairs Thomas Wensich and Emre Ozer for planning, organising and scheduling an exciting Micro47 technical program. This year, we have three outstanding invited speakers: Mike Muller, CTO of ARM, Trevor Mudge, University of Michigan and James Smith, University of Wisconsin-Madison. We also have a total of 7 workshops and tutorials scheduled on Sat and Sun. I thank the Workshops and Tutorials Chair Jason Mars for his diligent work.

On the social side, we planned a guided tour of Cambridge followed by punting on the river. You will sip your mulled wine under the blanket on the boat, and enjoy the great atmosphere of the ancient Cambridge colleges. As for the stories that the punt-guides will tell: feel free to be skeptical but some may actually have a grain of truth buried somewhere deep. This outing will be followed by a hot-topic debate in Cambridge Union Debating Chamber, using a traditional format. Finally, the day will be finished with a lavish dinner in Kings College.

I would like to thank the organising committee: Registration Chair Tim Jones for undertaking a great responsibility for handling the conference registration and accounts, Publication Chair Mike Ferdman for preparing the conference proceedings, Finance Chair Bruno Jansen for planning the conference budget, Publicity Chair Ron Dreslinski for reaching wide audience to announce Micro47, Submission Chair Anthony Gutierrez for managing the paper submission process, and Web Chair Marios Kleanthous for maintaining the conference website. Special thanks to Emre Ozer for shouldering most of the burden of keeping things on track day to day on my behalf.

I also thank the Micro Steering Committee Chair Rich Belgard and the entire Steering Committee for their guidance and advice.

Finally, I would like to express my gratitude to the corporate sponsors for their generous donations, and our society sponsors IEEE TC-uARCH and ACM SIGMICRO.

I am looking forward to seeing you in Cambridge!

Krisztian Flautner

The General Chair, MICRO-47

Message from the MICRO-47 Program Co-Chairs

Welcome to Cambridge and to MICRO-47! On behalf of the Program Committee, we are delighted to present you the technical program for MICRO-47.

The program includes 53 papers selected from 279 submissions. The program committee (PC) of 42 distinguished experts used a two-round review process. In the first round, all papers received 2 reviews from PC members and one review from an external expert. The 202 papers with at least one review with a positive score for overall merit were promoted to the second round. This year, for the first time, we notified authors of papers that did not advance to the second round shortly after these decisions were made, to provide more timely feedback. In the second round, papers received at least one review from a PC member and one review from an external expert, for a minimum total of 5 reviews per paper. Overall, 200 reviewers submitted 1,646 paper reviews.

The PC Co-Chairs personally selected all PC and external reviewers for each paper after careful examination of the papers. Papers for which only one of the Co-Chairs had a conflict-of-interest were handled by the other Co-Chair. For the 10 papers where both of us had conflicts, Milos Prvulovic made all reviewer selections and led any discussion at the PC meeting.

At the conclusion of the review process, authors were given the opportunity to respond to the review comments and scores via the rebuttal process. We made the author rebuttals available to all reviewers for a 10-day online discussion. During the online discussion, PC and external reviewers were required to enter a second “Post-Discussion” merit score and reach a preliminary recommendation to accept, reject, or discuss the paper further at the meeting. The online discussions lead to 17 accept recommendations, 92 reject recommendations, and 93 discuss recommendations. The “Post-Discussion” merit scores were used to design the PC meeting agenda. A total of 1,851 comments were entered during the online discussion.

The Program Committee met on August 29, 2014 at the Westin at Detroit Metro Airport. The PC considered the papers with “discuss” recommendations and discussed 63 of them in detail during the PC meeting. Where possible, decisions were made by discussing a paper with the full PC until a unanimous consensus was reached among the assigned reviewers. PC members with a conflict of interest on a paper were excused from the discussion. If unanimous consensus could not be reached, all non-conflicted PC members were asked to vote on the paper outcome. A small number of papers were conditionally accepted with shepherds to help address specific shortcomings in otherwise excellent pieces of research.

In an effort to improve transparency and capture key feedback from the online and PC meeting discussion, a brief “post-discussion summary” comment to the authors was entered for all papers considered in the online and PC discussion process, in addition to the reviews and scores. We hope that this information will help all authors improve their research, regardless of the outcome for their submission.

The final program includes papers that represent all aspects of our field: branch prediction and prefetching, stacked DRAM, reliability and fault tolerance, security, interconnects, compilation and code generation, energy-efficient computation, memory scheduling and optimization, methodology and modeling tools, TLB and cache optimizations, GPGPU and data parallel architectures, virtualization, and power management. In addition to the paper presentations, the program includes a

single-track session with brief presentations on the key idea in every paper (lightning talks) and a poster session. We hope that these two sessions will enable attendees to get exposure to the whole program and delve into the detailed contributions of the papers with their authors during the conference.

We are also particularly excited about the three keynote talks. The first keynote is by Mike Muller, Chief Technology Officer of ARM, Ltd. The second keynote is by Prof. Trevor Mudge, from the University of Michigan, and will address past and present predictions of the “End of Moore’s Law”. Finally, Prof. James Smith of the University of Wisconsin will discuss ongoing investigation of the brain’s computational paradigm and how it relates to computer architecture research.

Finally, the program includes a moderated debate entitled “End of the Road for von Neumann Architecture?” which will be held in the traditional English debating chamber at the storied Cambridge Union. We also invite attendees to a social program including the tradition of “Punting on the Cam”.

The MICRO-47 program is the result of the hard work of the PC members that sacrificed a significant portion of their free time this summer to provide service to our community. We are grateful for their professionalism in all aspects of their duties. We would also like to thank the members of the External Review Committee and additional external reviewers for their thorough reviews, often at a very short notice. We are particularly thankful to the PC members that diligently shepherded papers, working closely with the authors for weeks past the program selection. We would also like to recognize the PC members that volunteered to be session chairs during the conference.

Special thanks to Milos Prvulovic who handled all aspects of submissions for which the Co-chairs had conflicts. Finally, we are grateful to Anthony Gutierrez, our submission chair, for providing both authors and reviewers with a very smooth experience. He also handled preparations for the PC meeting and note-taking and time management during the meeting. He deserves a lot of credit for a well-organized and productive meeting.

We would also like to thank the members of the organizing committee, in particular Kris Flautner, the general chair, for the continuous support to all program committee activities and requests. We thank the past program and general chairs, especially Matt Farrens, Chris Nitta, and Christos Kozyrakis for guidance. We are grateful to all the members of the steering committee for their valuable advice, and in particular Rich Belgard and Onur Mutlu for fielding numerous questions.

Finally, we would like to thank all the authors that submitted papers to MICRO-47. The strong program is a reflection of a thriving research community with hardworking members with broad interests. We hope you all enjoy the technical program of MICRO-47 and the opportunity to exchange ideas and interact with colleagues in beautiful Cambridge, UK.

Emre Ozer
Thomas F. Wenisch

Program Co-Chairs, MICRO-47

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David A. Roberts	Mahdi Nazm Bojnordi	Xiaochen Guo
Dmitry Ponomarev	Martin Dimitrov	Xiaochen Guo
Domagoj Babic	Matt Horsnell	Xuan Zhang
E Lewis	Matthew Fojtik	Xuehai Qian
Efi Rotem	Mikko Lipasti	Yan Solihin
Faissal Sleiman	Mohit Tiwari	Yi Yang
Francois Irigoin	Moty Mehalet	Yoonseo Choi
Fred Chong	Naser Sedaghati	Yuan Chou
Ganesh Dasika	Neha Agarwal	

Keynotes

From IoT to Services – Efficiency Matters

Mike Muller, *Chief Technology Officer, ARM Holdings plc*

The Internet of Things is driving developments from near threshold lowest power and energy sensors through to highest performance servers and networking infrastructure enabling cloud services. Despite the diversity of different products they all share the same common requirement namely efficiency. But more than just products it is the transformation of business models that make IoT an exciting opportunity.

Bio:

Mike was one of the founders of ARM. Before joining the Group, he was responsible for hardware strategy and the development of portable products at Acorn Computers. He was previously at Orbis Computers. At ARM he was VP, Marketing from 1992 to 1996 and EVP, Business Development until October 2000 when he was appointed Chief Technology Officer. In October 2001, he was appointed to the Board. He is also a non-executive director of Intelligent Energy an intellectual property company specializing in the development of modular, low carbon fuel cell systems for their partners.

The End of Moore's Law – Again

Trevor Mudge, *Bredt Professor of Computer Engineering, the University of Michigan, Ann Arbor*

Claims that Moore's Law is about to end occur with surprising regularity. Each time the claims have been proved wrong. Is it different this time? There are some indicators that it may be: Dennard scaling is breaking down and the skyrocketing cost of semiconductor fabs may stop progress before technical limits.

We will review some of the past claims that prematurely forecast Moore's Law's demise, and the developments that overcame those barriers. Those developments also resulted in significant changes to the criteria we use to design computers. We will discuss them too.

Discussion about the "end of Moore's Law" raises the question of physical limits for computer design in general. We will include them in the talk and show how they may shed light on the current claim that Moore's Law is ending.

We will review promising technologies for memories and die stacking that will allow us to move forward in the immediate future. Finally, we will discuss newer technologies that

Bio:

Trevor Mudge received the Ph.D. degrees in Computer Science from the University of Illinois, Urbana in 1977. Since then he has been on the faculty of the University of Michigan, Ann Arbor. In 2003 he was named the first Bredt Family Professor of Electrical Engineering and Computer Science. Previously he served a ten-year term as the Director of the Advanced Computer Architecture Laboratory, which is a group of eight faculty and about 60 graduate students. He is author of numerous papers on computer architecture, programming languages, VLSI design, and computer vision. He has also chaired 49 theses in these areas. His research interests include computer architecture, computer-aided design, and compilers.

In 2014 he was the recipient of ACM/IEEE CS Eckert-Mauchly Award "For pioneering contributions to low-power computer architecture and its interaction with technology." In addition to his position as a faculty member, he runs Idiot Savants, a chip design consultancy. Trevor Mudge is a Life Fellow of the IEEE, a member of the ACM, the IET, and the British Computer Society.

Investigating the Brain's Computational Paradigm

James E. Smith, Professor Emeritus, the University of Wisconsin-Madison

Understanding and implementing the brain's computational paradigm is the grand challenge facing computer researchers. Not only does it provide computational capabilities far beyond those of conventional computers, its energy efficiency is truly remarkable. The brain's neocortex is constructed of massively interconnected neurons that compute and communicate via voltage spikes, and a strong argument can be made that precise spike timing is an essential element of the paradigm. This argument leads to the seeming paradox that the way we naturally reason about computation is an obstacle to understanding the way our brain, itself, computes. I will describe a small set of biologically plausible computational elements based on precise spike timing. Then, through examples using these computational elements, I will illustrate some features of spike-based temporal computation and how it differs from other brain-inspired approaches. This is only one person's first step toward understanding the brain's computational paradigm, and as such it is one of many divergent theories. However, it illustrates important aspects of this grand challenge research area and serves as a case study in the way a computer researcher can participate in addressing the challenge.

Bio:

James E. Smith is Professor Emeritus in the Department of Electrical and Computer Engineering at the University of Wisconsin-Madison. He received his PhD from the University of Illinois in 1976. He then joined the faculty of the University of Wisconsin-Madison, teaching and conducting research – first in fault-tolerant computing, then in computer architecture. He has been involved in a number of computer research and development projects both as a faculty member at Wisconsin and in industry (Control Data Corporation, Astronautics Corporation, Cray Research, Google, and Intel).

Prof. Smith has made a number of significant contributions to the development of superscalar processors. These contributions include basic mechanisms for dynamic branch prediction and implementing precise traps. He has also studied vector processor architectures and worked on the development of innovative microarchitecture paradigms. He received the 1999 ACM/IEEE Eckert-Mauchly Award for these contributions.

More recently, Prof. Smith focused on the virtual machine abstraction as a technique for providing high performance and power efficiency through co-design and tight coupling of virtual machine hardware and software. He is co-author of a book on virtual machines. Currently, he is studying computational neuroscience at home along the Clark Fork near Missoula, Montana.