

# Thomas Shull

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**RESEARCH INTERESTS** Hardware and software designs to improve the performance of managed languages. Development of new persistent programming frameworks. Virtual Machine modifications to utilize emerging byte-addressable persistent memory technologies. Profiling-based compiler optimizations. Techniques to reduce the overhead of automatic memory management.

**EDUCATION** **University of Illinois at Urbana-Champaign** August 2012 - August 2020  
Ph.D. in Computer Science  
**Advisor:** Prof. Josep Torrellas  
**Thesis:** *Making Non-Volatile Memory Programmable*  
**Committee:** Prof. Josep Torrellas, Prof. Jian Huang, Prof. David Padua, Prof. James Larus, and Prof. Steven Swanson

**Washington University of St. Louis** June 2008 - May 2012  
B.Sc. in Computer Science and B.Sc. in Computer Engineering  
Summa Cum Laude

## PUBLICATIONS

### CONFERENCE PAPERS

#### **Execution Dependence Extension (EDE): ISA Support for Eliminating Fences** ISCA 2021

*Thomas Shull, Ilias Vougioukas, Nikos Nikoleris, Wendy Elsasser, and Josep Torrellas*

By allowing loads and stores to complete out of order, relaxed memory models can provide significant performance improvements. Unfortunately, far too often coarse-grain fences must be inserted for fine-grain correctness requirements, thereby negating these performance gains. In this paper we propose a new technique to describe instruction-level orderings as *execution dependences* that can be encoded within the ISA, and show how hardware can be modified to honor such execution dependences.

#### **UniHeap: Managing Persistent Objects Across Managed Runtimes for Non-Volatile Memory** SYSTOR 2021

*Dairuan Li, Benjamin Reidys, Jinghan Sun, Thomas Shull, Josep Torrellas, and Jian Huang*

Current proposals for NVM support within managed languages runtimes are often implementation specific. To remedy this, in this paper we introduce a new runtime-agnostic NVM framework named UniHeap. We also show how UniHeap can be used to provide persistent support for diverse environments, including Java, Python and JavaScript.

#### **P-INSPECT: Architectural Support for Programmable Non-Volatile Memory Frameworks** MICRO 2020

*Apostolos Kokolis, Thomas Shull, Jian Huang, and Josep Torrellas*

Emerging persistence by reachability NVM frameworks have compelling usability traits but are complicated to implement and can have high performance overheads. A significant portion of this complexity and slowdown is due to runtime persistence checks required by such frameworks. In this paper we introduce new simple hardware primitives which significantly accelerate these runtime checks and simplify the runtime implementation.

#### **AutoPersist: An Easy-To-Use Java NVM Framework Based on Reachability** PLDI 2019

*Thomas Shull, Jian Huang, and Josep Torrellas*

Emerging NVM technologies have led to the creation of many frameworks to assist developers in creating persistent applications. Unfortunately, we find existing NVM frameworks are still too burdensome for programmers and require many markings. To remedy this, we propose AutoPersist, a new Java NVM framework which requires substantially fewer markings by relying on the JVM runtime to perform much of the heavy lifting of creating a persistent application.

## Reusable Inline Caching for JavaScript Performance

PLDI 2019

*Jiho Choi, Thomas Shull, and Josep Torrellas*

Fast JavaScript startup time is paramount to a user's web browsing experience. Unfortunately, in current implementations, most of the profiling results observed in previous executions cannot be reused to improve the startup time of subsequent runs. To fix this, we develop a new technique which allows inline caching data to be reused, significantly improving website initialization times.

## Using Speculation to Reduce the Checking Overhead of Persistent Objects in NVM Frameworks

VEE 2019

*Thomas Shull, Jian Huang, and Josep Torrellas*

Emerging programmer-friendly NVM frameworks have many actions predicated on whether an object is persistent or not. We find that even if these actions are not taken, performing checks to determine an object's persistent state is very expensive. Based on online profiling information, we devise a technique to *bias* each persistent check towards its expected behavior, thereby minimizing performance overhead.

## NoMap: Speeding-Up JavaScript Using Hardware Transactional Memory

HPCA 2019

*Thomas Shull, Jiho Choi, María J. Garzarán, and Josep Torrellas*

JavaScript implementations use multiple compilers to ensure "hot" code regions are fully optimized without prohibitive startup times. We recognize a significant performance overhead in multi-tiered compiler codes is their inter-tier jump points, in spite of these jump points rarely being invoked. To this end, we propose to use hardware transactional memory to limit the number of inter-tier jump points needed, thereby allowing the compiler to generate more efficient code.

## Biased Reference Counting: Minimizing Atomic Operations in Garbage Collection

PACT 2018

*Jiho Choi, Thomas Shull, and Josep Torrellas*

We profile Apple's Swift reference counting implementation and find its use of atomic compare-and-swap operations for reference counting updates to be a significant source of overheads. Furthermore, we find often an object's counter is only updated by one thread. Based on these insights, we split each object's reference count into two counters: a *biased counter* which a single thread can update without atomic operations, and a *shared counter* which is updated atomically by all other threads.

## Defining a High-level Programming Model for Emerging NVRAM Technologies

ManLang 2018

*Thomas Shull, Jian Huang, and Josep Torrellas*

We find that existing NVRAM framework models are inappropriate for managed languages. To correct this, we propose a new NVRAM programming model which offloads much of the heavy-lifting of creating a persistent application to the managed language implementation's runtime.

## ShortCut: Architectural Support for Fast Object Access in Scripting Languages

ISCA 2017

*Jiho Choi, Thomas Shull, and Josep Torrellas*

Popular JavaScript implementations use a technique for fast property accesses which requires a level of indirection and does not effectively utilize hardware branch predictors. To this end, we propose new hardware which is able to store (access site  $\Rightarrow$  final destination) mappings for better branch prediction and fold this software level of indirection. We also propose advanced hardware which is able to elide the entire object property lookup routine.

## Secure Hierarchy-Aware Cache Replacement Policy (SHARP): Defending Against Cache-Based Side Channel Attacks

ISCA 2017

*Mengjia Yan, Bhargava Gopireddy, Thomas Shull and Josep Torrellas*

Cross core cache based side channel attacks rely on the creation of "inclusion" victims. Based on this observation, we propose modifications to the last level cache replacement scheme that can successfully defend against such attacks. Our solution does not require any software support and has no performance overhead.

## **Improving JavaScript Performance by Deconstructing the Type System** PLDI 2014

*Wonsun Ahn, Jiho Choi, Thomas Shull, María J. Garzarán, and Josep Torrellas*

We discover that JavaScript performance across page refreshes is significantly hampered by JavaScript objects' internal representation within popular implementations. We propose a new internal representation for JavaScript objects which resolves this slowdown by introducing a level of indirection to access context-sensitive data.

## WORKSHOP SUBMISSIONS

### **Developing Programmer-Friendly Frameworks for NVM**

PIRL 2019

*Thomas Shull, Jian Huang, and Josep Torrellas*

### **Designing a User-Friendly Java NVM Framework**

NVMW 2019

*Thomas Shull, Jian Huang, and Josep Torrellas*

## TALKS

- Developing Programmer-Friendly Frameworks for NVM. PIRL. July 2019.
- Reusable Inline Caching for JavaScript Performance. PLDI. June 2019.
- Using Speculation to Reduce the Checking Overhead of Persistent Objects in NVM Frameworks. VEE. April 2019.
- Designing a User-Friendly Java NVM Framework. NVMW. March 2019.
- NoMap: Speeding-Up JavaScript Using Hardware Transactional Memory. HPCA. February 2019.
- Biased Reference Counting: Minimizing Atomic Operations in Garbage Collection. PACT. November 2018.
- Defining a High-level Programming Model for Emerging NVRAM Technologies. ManLang. September 2018.

## RESEARCH PROJECTS

### **Developing a new Java programming model for emerging non-volatile memories**

- Developed a new programming model which relies on the JVM to search the transitive closures of objects and identify all objects which require persistence.
- Implemented proposed model within the Maxine Research JVM. Required changes to both of its compilers, additional runtime support, and augmented heap management.
- Developed compiler/runtime optimizations to maximize model's performance.

### **Improving JavaScript Performance**

- Contributed to a software approaches to limit the startup-time performance overheads.
- Contributed to a hardware proposal to improve the performance of object property lookups.
- Developed a new optimizing approach which leverages emerging hardware transactional memory technologies.

## PROFESSIONAL EXPERIENCE

### **Oracle Labs**

June 2020 – Present

#### **Senior Researcher with GraalVM Team**

- Responsible for maintaining and improving the GraalVM AArch64 port.
- Added features to improve performance of Substrate VM (SVM) runtime operations. SVM is a framework and runtime environment for the ahead-of-time compilation of Java applications.

### **Arm Ltd.**

July 2019 – April 2020

#### **Open Source Software**

- Worked on AArch64 port of Substrate VM (SVM).
- Identified and fixed multiple bugs within the SVM AArch64 port.
- Added multiple performance improvements to SVM.
- Enabled SVM AArch64 runtime code installation.

## Non-Volatile Memory Research

- Improved and fixed AArch64 port of the Persistent Memory Development Kit (PMDK). PMDK is the primary framework available to create persistent applications leveraging byte-addressable non-volatile memory (NVM).
- Proposed ISA extensions to improve crash-consistent application performance by enabling more aggressive instruction reordering.
- Implemented proposed ISA extension within the gem5 simulator. Initial evaluation shows promising performance gains.

## AWARDS & HONORS

- Feng Chen Memorial Award (April 2015)
- PLDI Distinguished Paper Award (June 2014)
- Outstanding Senior Award in Computer Science and Engineering (Spring 2012)
- Outstanding Student Award in Computer Science and Engineering (Spring 2011)
- Awarded travel grants to attend ISCA in 2014, 2015, 2017; PACT in 2018; HPCA in 2019; VEE/ASPLOS in 2019; and PLDI in 2019

## TECHNICAL SKILLS

*Programming Skills:* C/C++, Java, Python.

*Managed Language Implementations:* JavaScript-V8, JavaScriptCore; Swift; Java-HotSpot, Maxine, Substrate VM

*Compiler Implementations:* Graal, LLVM

## REFERENCES

Christian Wimmer, christian.wimmer@oracle.com

Stuart Monteith, stuart.monteith@arm.com

Josep Torrellas, torrella@illinois.edu

Additional references available upon request

Oracle Labs

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