MSWAT: Low-Cost Hardware Fault Detection and Diagnosis for Multicore

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Resilient Theme, Task # 1.2.2.5

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Motivation

SoftWare Anomaly Treatment (SWAT) effective for HW faults in single-threaded apps

> Low SDC rate of 0.2% (dedicated poster)

But multicore systems w/ multithreaded apps here to stay

Does the SWAT approach work for multicore?

Key Challenge: Cross-Core Fault Propagation

Multithreaded apps share data across threads

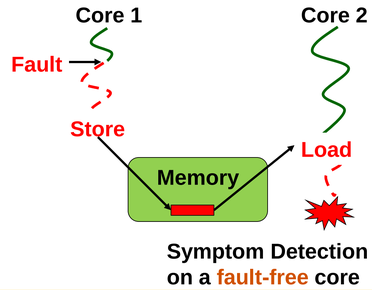
⇒ Fault may propagate across cores

⇒ Is SWAT effective in detecting these faults?

⇒ Symptom causing core is no longer faulty

Implicit assumption in prior SWAT work

Need to detect fault and diagnose faulty core



MSWAT Fault Detection

Symptom Detection

Fatal Traps, Hangs, High OS, Kernel Panic, No-Forward-Progress

Key Results

>99% of unmasked permanent faults detected

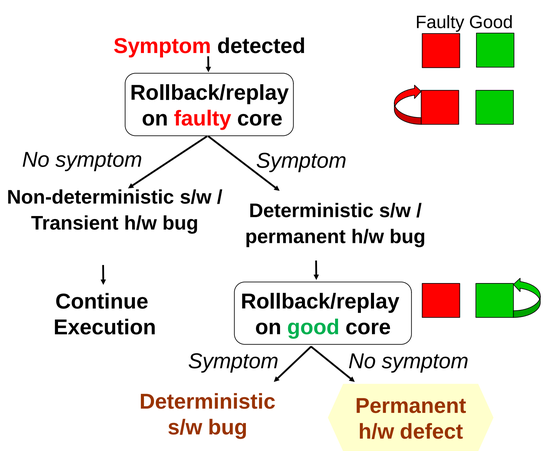
Low SDC rate of 0.2% of injected faults

Several detections from fault-free cores

MSWAT: Diagnosis Challenges and Approaches

Previous SWAT diagnosis

Distinguish HW/SW faults



Challenge in multicore: No known good core

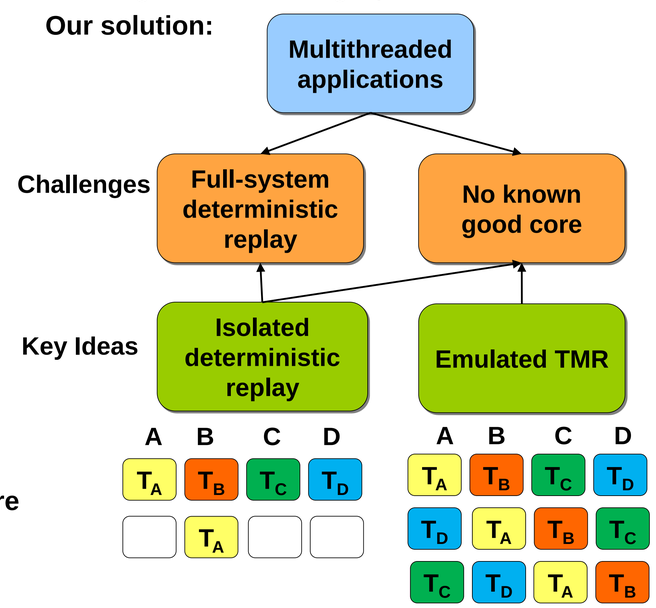
Comparison requires known good core

Isolating the faulty core

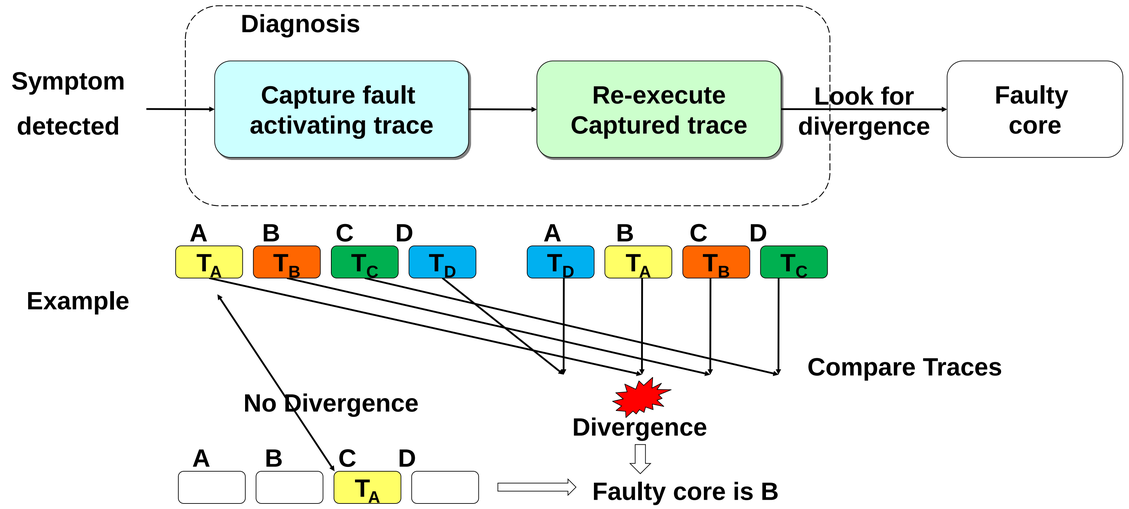
Naïve solution: One spare core

High overhead, single point of failure

Our solution:



MSWAT Fault Diagnosis Algorithm



Capture fault activating trace

Native execution ⇒ No added support for replay

Record inputs to each thread (loads) for replay

Low hardware overhead for buffering

Re-Execute Captured Trace

Firmware emulated isolated deterministic replay ⇒ Zero hardware overhead

Compare retiring mem/ctrl instructions for divergence ⇒ Less comparisons

Iterative Diagnosis to reduce overheads

E.g., capture replay every 100k instructions till divergence

Diagnosis Results

>95% of detected faults successfully diagnosed

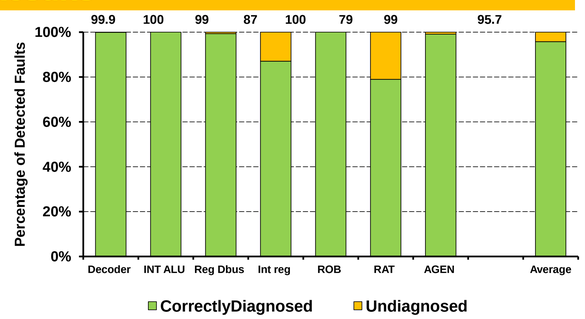
μarch non-determinism ⇒ undiagnosed faults

97% faults diagnosed in <10m cycles

<10ms on a 1GHz processor ⇒ invisible

93% diagnosed in 1 iteration w/ 100k instructions

<200kB logs ⇒ fit in lower level caches



Conclusions and Future Work

SWAT effective even for multicore systems with multithreaded apps

Future Work

Studying SWAT for faults in memory and off-core components

Distributed Client/Server Applications

Prototyping SWAT on FPGA in collaboration with University of Michigan

Faulty trace is a test vector ⇒ Apply SWAT for post-silicon debug and test