A Software-based Method-Level Speculation Framework for the Java Platform

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IBM POWER4 (**2C**)

Intel Pentium D (**2C**)
AMD Athlon 64 X2 (**2C**)
Sun UltraSPARC T1 (**8C**)
Azul Vega 1 (**24C**)

IBM Xenon 'X360' (**3C**)

Intel Xeon 'Beckton' (**8C**)
AMD Opteron 'Magny-Cours' (**12C**)

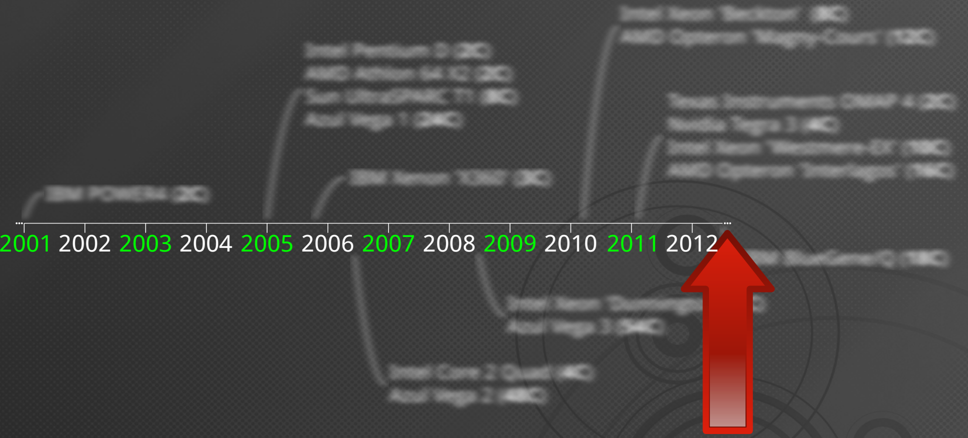
Texas Instruments OMAP 4 (**2C**)
Nvidia Tegra 3 (**4C**)
Intel Xeon 'Westmere-EX' (**10C**)
AMD Opteron 'Interlagos' (**16C**)

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

IBM BlueGene/Q (**18C**)

Intel Xeon 'Dunnington' (**6C**)
Azul Vega 3 (**54C**)

Intel Core 2 Quad (**4C**)
Azul Vega 2 (**48C**)



Many applications still single or lightly-threaded

Not feasible to rewrite many existing applications to work in parallel

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➜ Automatic Parallelization

Thread-Level Speculation

Employs speculation

- No need to prove that parallelization is valid

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➜ Uses some kind of in-memory transactions to buffer and validate tentative changes

JaSPEx-MLS

Our proposal: JaSPEx-MLS

- Software-based speculative parallelization framework for Java

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- Nested speculation

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JaSPEx-MLS

Target applications

- Existing single-threaded JVM bytecode

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- Existing single-threaded JVM bytecode
- Object-oriented / method-heavy
  - Limited support for loops

- Static analysis is hard or impossible

Why use OpenJDK?

- Modern open-source VM by Oracle and community contributors

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➜ JaSPEx-MLS works on commonly available hardware
➜ Same codebase used to run regular Java applications

Method-Level Speculation

```
int example1() {
    int x = computeValue();
    int y = 0;
    for (...) y += ...;
    return x+y;
}
```

- Run method call in parallel with code following its return

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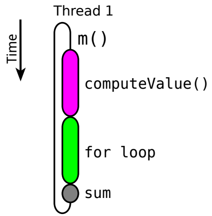

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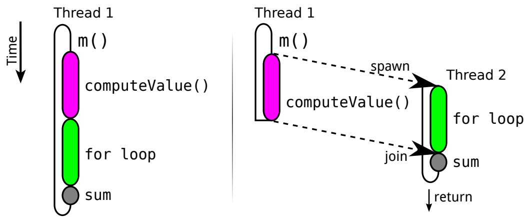

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JaSPEx-MLS

Classloader

- Prepares code for speculative parallelization

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Runtime Orchestration Library

- Coordinates all runtime events
  - Creation, validation, commit, abort, ...

JaSPEx-MLS Classloader

Transactification

- Intercept access to slots and arrays

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object.field = 100l;
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Transaction.storeLong(object, field, 100l);
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- Static and type-specific

➜ Designed to be inlined by the VM

JaSPEx-MLS Classloader

Handling Non-Transactional Operations

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```
...

System.out.println("Hello World!");
...
```

JaSPEx-MLS Classloader

Handling Non-Transactional Operations

➜ Operations outside the control of the transactional system

- native methods
- JDK code

```
...
SpeculationControl.nonTransactionalActionAttempted();
System.out.println("Hello World!");
...
```

JaSPEx-MLS Classloader

Modifications for MLS

- Replace method calls with call to `spawnSpeculation()`

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```java
int mlsExample1() {
    return compute(0) + compute(1);
}
```

```java
int mlsExample1() {
    Future temp1 = spawnSpeculation(...);  // compute(0)
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- Usually needs control flow analysis and code duplication

JaSPEx-MLS Classloader

STM support for Futures

- Allow Futures to be “written” to memory locations
- Delay obtaining value until it is needed (read or commit)

JaSPEx-MLS Classloader

STM support for Futures

```
// Original Method
void doCompute(Object[] results) {
  for (int i = 0; i < results.length; i++) {
    results[i] = compute(i);
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// *Attempted* parallelization
void doCompute(Object[] results) {
  for (int i = 0; i < results.length; i++) {
    Future f0 = spawnSpeculation(...); // compute(i)
    TM.storeObjectArray(results, i, f0.get());
  }}
```

JaSPEx-MLS Classloader

... let's try this again

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// *Successful* parallelization
void doCompute(Object[] results) {
  for (int i = 0; i < results.length; i++) {
    Future f0 = spawnSpeculation(...); // compute(i)
    TM.storeFutureObjectArray(results, i, f0); // f0 handed
  }}                                           // to the STM
```

JaSPEx-MLS Runtime Orchestration

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- Check threadpool state

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JaSPEx-MLS Runtime Orchestration

Committing a speculation:

- Task completed work

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- If exception ➜ abort
- Else try to commit

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Distinguish between

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Transaction commit is simpler, because only one transaction may commit at a time

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Transaction commit is simpler, because only one transaction may commit at a time

➜ No synchronization needed

Benchmarks

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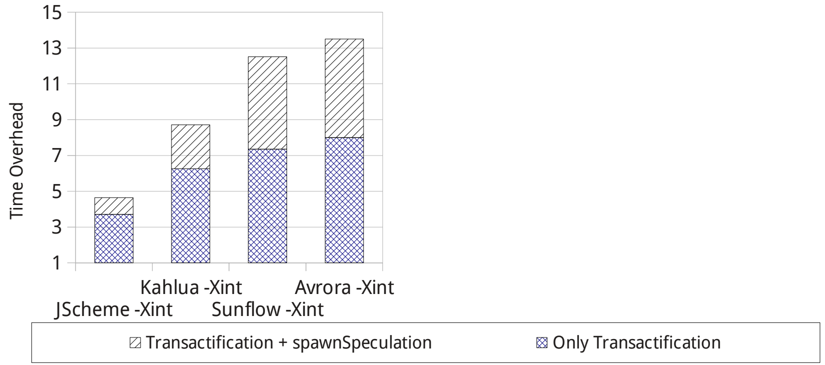
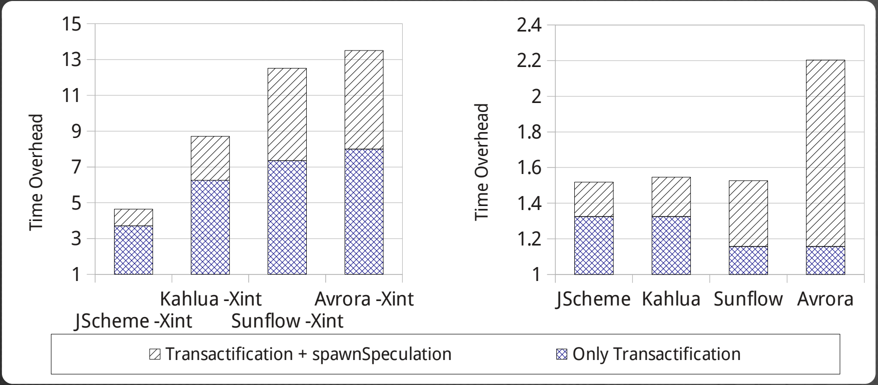
- Test overheads from bytecode changes
- Early results from full system

- Test system: Intel Core i5 750, 8GB RAM, Ubuntu Linux 12.04 64-bit

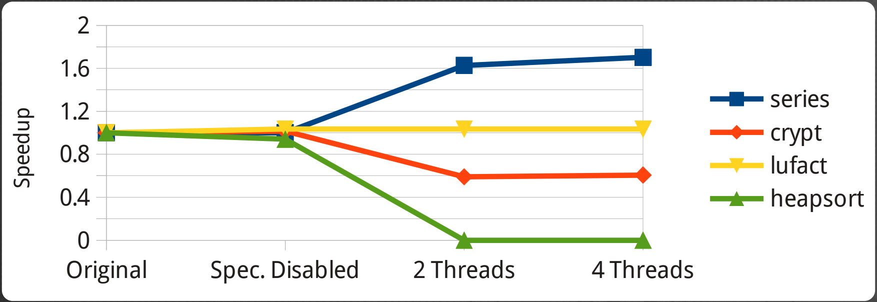
Benchmarks — Overhead with Interpreter



Benchmarks — Overhead with JIT



Benchmarks — Parallelization



- Benchmarks from Java Grande Framework
- Source was **not** modified

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- Integrating Futures with the STM unlocks more parallelism
- Optimizing VM makes ***all*** the difference
  - Able to hide much of the added overhead
- Already able to extract parallelism in some benchmarks

Future Work

- Lift some limitations imposed by non-transactional ops

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- Add support for profiling pass, and to save statistic information between runs

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- Re-use waiting threads by returning them to the thread-pool

Thank you!