JaSPEx: Speculative Parallel Execution of Java Applications

Ivo Anjo   João Cachopo

ESW
INESC-ID Lisboa/Instituto Superior Técnico

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Multicore Processors

Multicore Processors

- Are the future

Multicore Processors

- Are the future
- Are only fully used when all cores have work

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- New processors speed up all applications

Multicore Processors

- Are the future
- Are only fully used when all cores have work
- ~~New processors speed up all applications~~
  - Most existing code is not parallel

Problem

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- New processors do not speed up legacy applications

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- Problematic to rewrite or adapt these applications

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Solution

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Solution

- Automatic Parallelization

```java
void method() {
    doA();
    doB();
}
```

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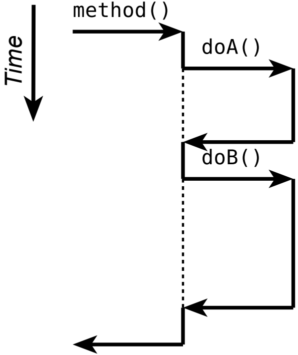
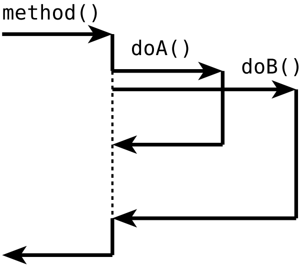
    doA();
    doB();
}
```



Sequential execution



Parallel execution

Problem

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- Can `doA()` and `doB()` be run in parallel?

Problem

- Can `doA()` and `doB()` be run in parallel?
    - Shared state

Problem

- Can `doA()` and `doB()` be run in parallel?

Parallelizing Compilers

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Parallelizing Compilers

- Only if we can prove that they can never interfere

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Speculative Parallelization

Problem

- Can `doA()` and `doB()` be run in parallel?

Parallelizing Compilers

- Only if we can prove that they can never interfere

Speculative Parallelization

- Maybe, let’s try and we’ll see how it goes

Speculative Parallelization

a.k.a. Thread-Level Speculation (TLS)

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- Parallelization system does not have to prove that a parallelization is valid

Speculative Parallelization

a.k.a. Thread-Level Speculation (TLS)

- Parallelization system does not have to prove that a parallelization is valid
- Uses memory transactions, that are aborted and undone if the original execution semantics are violated

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- Most TLS approaches need hardware support for transactions (HTM)

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    - Limits size

Speculative Parallelization

a.k.a. Thread-Level Speculation (TLS)

- Most TLS approaches need hardware support for transactions (HTM)
    - Limits duration
    - Limits size
    - Do not work on my new PC!!

Speculative Parallelization

a.k.a. Thread-Level Speculation (TLS)

- Most TLS approaches need hardware support for transactions (HTM)
    - Limits duration
    - Limits size
    - Mainstream architectures offer no such support

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- Our proposal: TLS using a Software Transactional Memory (STM)

JaSPEx

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Java Speculative Parallel Executor

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- TLS system for Java/JVM

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- TLS system for Java/JVM
- Works at the JVM bytecode level

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- Uses the JVSTM
  - Java Versioned Software Transactional Memory

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- TLS system for Java/JVM
- Works at the JVM bytecode level
- Uses the JVSTM
  - Java Versioned Software Transactional Memory
  - STM implemented in Java

JaSPEx

Java Speculative Parallel Executor

- TLS system for Java/JVM
- Works at the JVM bytecode level
- Uses the JVSTM
  - Java Versioned Software Transactional Memory
  - STM implemented in Java
- Also done in Java

JaSPEx

Static Modification Module

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Runtime Control Module

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Static Modification Module

- `ClassLoader` that rewrites bytecode

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- *Transactification*

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- Prevention of nontransactional operations

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Static Modification Module

- `ClassLoader` that rewrites bytecode
- *Transactification*
- Prevention of nontransactional operations

Runtime Control Module

- Controls speculation

Transactification

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- Application needs to be modified to use the JVSTM
  ⇒ "Transactification"

JVSTM Crash-course

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jvstm.VBox<E>

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- Container that keeps the version history of a memory position

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JVSTM Crash-course

`jvstm.VBox<E>`

- Container that keeps the version history of a memory position
    - Fields (class or instance)

`jvstm.Transaction`

JVSTM Crash-course

`jvstm.VBox<E>`

- Container that keeps the version history of a memory position
  - Fields (class or instance)
  - Array positions

`jvstm.Transaction`

JVSTM Crash-course

`jvstm.VBox<E>`

- Container that keeps the version history of a memory position
  - Fields (class or instance)
  - Array positions
  - Local variables

`jvstm.Transaction`

JVSTM Crash-course

`jvstm.VBox<E>`

- Container that keeps the version history of a memory position
- `E get()`

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- Container that keeps the version history of a memory position
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- `void put(E newE)`

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- `Transaction begin()`

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- Container that keeps the version history of a memory position
- `E get()`
- `void put(E newE)`

`jvstm.Transaction`

- `Transaction begin()`
- `void commit()`

JVSTM Crash-course

`jvstm.VBox<E>`

- Container that keeps the version history of a memory position
- `E get()`
- `void put(E newE)`

`jvstm.Transaction`

- `Transaction begin()`
- `void commit()`
- `void abort()`

Transactification

Transactification

```
public class Person {
    public String name;

    public Person(String name) {
        this.name = name;
    }

    public String name() {
        return name;
    }
}
```

Transactification

```
public class Person {
    public VBox<String> $box_name;

    public Person(String name) {
        this.name = name;
    }

    public String name() {
        return name;
    }
}
```

- Replace the original fields with VBoxes

Transactification

```
public class Person {
    private VBox<String> $box_name;

    public Person(String name) {
        this.name = name;
    }

    public String name() {
        return name;
    }
}
```

- Replace the original fields with VBoxes

Transactification

```
public class Person {
    private VBox<String> $box_name = new VBox<String>();

    public Person(String name) {
        this.name = name;
    }

    public String name() {
        return name;
    }
}
```

- Add VBox initializations

Transactification

```
public class Person {
    private VBox<String> $box_name = new VBox<String>();

    public Person(String name) {
        this.name = name;
    }

    public String name() {
        return name;
    }

    String $box_name_get() { return $box_name.get(); }
    void $box_name_put(String name) { $box_name.put(name); }
}
```

- Add get and put methods, that control access to the VBox

Transactification

```
public class Person {
    private VBox<String> $box_name = new VBox<String>();

    public Person(String name) {
        this.name = name;
    }

    public String name() {
        return name;
    }

    public String $box_name_get() { return $box_name.get(); }
    public void $box_name_put(String name) { $box_name.put(name); }
}
```

- Add `get` and `put` methods, that control access to the `VBox`

Transactification

```
public class Person {
    private VBox<String> $box_name = new VBox<String>();

    public Person(String name) {
        $box_name_put(name);
    }

    public String name() {
        return $box_name_get();
    }

    public String $box_name_get() { return $box_name.get(); }
    public void $box_name_put(String name) { $box_name.put(name); }
}
```

- Replace accesses to the original fields with calls to the get and put methods

Transactification Problems

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- `native methods`

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⇒ Nontransactional operations need to be detected and handled

Prevention of nontransactional operations

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- Before executing each nontransactional operation, add a call to the framework

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

Prevention of nontransactional operations

Idea

- Before executing each nontransactional operation, add a call to the framework

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

Speculation

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- Speculative execution of methods

Speculation

- Speculative execution of methods
- When a method is invoked, some of the methods it invokes may be run speculatively

```java
public static int fib(int n) {
    if (n <= 1) return n;
    return fib(n-1) + fib(n-2);
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public static int fib(int n) {
    if (n <= 1) return n;
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public static int fib(int n) {
    SpeculationId specId =
        SpeculationControl.entryPointReached(ENTRY_POINT_ID,
public static int fib(int n) {
    if (n <= 1) return n;
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}
```

```
public static int fib(int n) {
    SpeculationId specId =
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            new Object[] { new Object[] { n-1 },
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    if (n <= 1) {
        SpeculationControl.exitPointReached(specId);
```

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        return n;
    }
    Future f0 = SpeculationControl.getResult(specId, ID0);
```

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    int temp = f0.get() + f1.get();
```

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    return temp;
}
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Doing Speculation

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    - `fib(n-1)`

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    - `fib(n-2)`

Doing Speculation

- Call to `entryPointReached(...)` generates tasks
  - `fib(n-1)`
  - `fib(n-2)`

- Each task is executed inside an STM transaction

Transaction Commit

Transaction Commit

- Tasks wait permission for commit

Transaction Commit

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Transaction Commit

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    - Execute nontransactional operations
    - Termination

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  ⇒ Threads commit in program-order

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  $\Rightarrow$ Threads commit in program-order

- At each moment, only one thread is running in program-order, and it can yield the program-order to other tasks

Transaction Commit

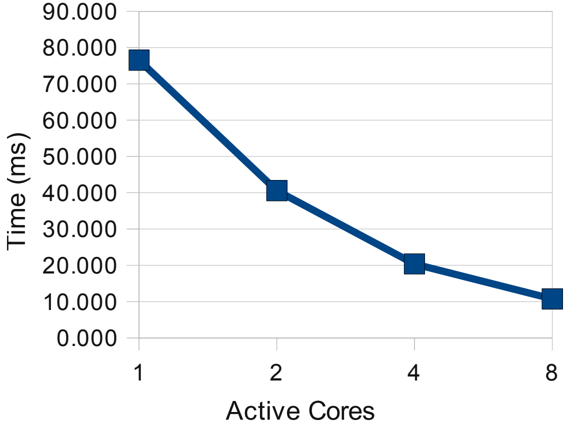
- Tasks wait permission for commit
  - Execute nontransactional operations
  - Termination
  - Join with child speculation task

- Commit needs to guarantee the original semantics
  $\Rightarrow$ Threads commit in program-order

- At each moment, only one thread is running in program-order, and it can yield the program-order to other tasks
  - Which can then try to commit

Preliminary Experimental Results

Preliminary Experimental Results



Time for calculating `fib(50)` with 1..8 cores.
A fib version modified with a threshold was used.

Conclusions

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- *Transactification* of Java/JVM applications

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Conclusions

- *Transactification* of Java/JVM applications
- *Transactification* without support from the JVM
  - Hard
  - Imposes limitations
- It is possible to achieve speedups for some applications

Future Work

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- Realistic benchmarks

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- Realistic benchmarks
- Reducing overheads

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    - Optimize the JVSTM for our use-case

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- Realistic benchmarks
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  - Optimize the JVSTM for our use-case
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- Support *transactification* at the JVM-runtime level

Thank you!

Questions?