

## Proposed Java Thread Spec

### Revising the Java Thread/Memory Model

See

<http://www.cs.umd.edu/~pugh/java/memoryModel>  
for more information

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### Audience

- This will be an advanced talk
- Helpful if
  - you've been aware of the discussion,
  - have implemented a JVM,
  - know what sequential consistency is, and that most processors don't support it, or
  - have read Doug Lea's book
- The easy version of this talk is Thursday, 1:30, Hall C.

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### Java Thread Specification

- Chapter 17 of the Java Language Spec
  - Chapter 8 of the Virtual Machine Spec
- Very, very hard to understand
  - not even the authors understood it
  - doubtful that anyone entirely understands it
  - has subtle implications
    - that forbid standard compiler optimizations
  - all existing JVMs violate the specification
    - some parts should be violated

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### Revising the Thread Spec

- Work is underway to consider revising the Java Thread Spec
  - <http://www.cs.umd.edu/~pugh/java/memoryModel>
- Goals
  - Clear and easy to understand
  - Foster reliable multithreaded code
  - Allow for high performance JVMs
- Will effect JVMs
  - and badly written existing code
    - including parts of Sun's JDK

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### When's the JSR?

- Very hard and technical problems need to be solved
  - formal specification is difficult
  - not appropriate for JSR process
- Once we get technically solid proposals
  - we will start JSR process
  - aiming to start this fall
- Will miss Merlin cutoff
- Workshop at OOPSLA

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### Proposed Changes

- Make it clear
- Allow standard compiler optimizations
- Remove corner cases of synchronization
  - enable additional compiler optimizations
- Strengthen volatile
  - make easier to use
- Strengthen final
  - Enable compiler optimizations
  - Fix security concerns

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## Proposed Java Thread Spec

### VM Safety

- Type safety
- Not-out-of-thin-air safety
  - (except for longs and doubles)
- No new VM exceptions
- Only thing lack of synchronization can do is produce surprising values for getfields/getstatics/array loads

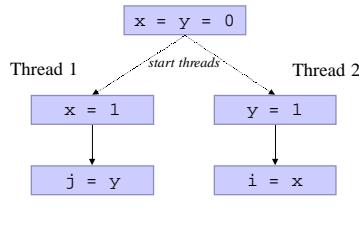
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### VM Safety implications

- Problems on SMPs with weak memory models
- Could see uninitialized objects created by another thread
  - need to initialize memory during GC
  - worry about seeing null vptr
  - worry about seeing zero array length
- Class loading and initialization issues

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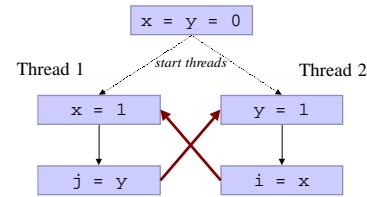
### Weird Behavior of Improperly Synchronized Code



Can this result in **i = 0** and **j = 0**?

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### Answer: Yes!



How can **i = 0** and **j = 0**?

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### How Can This Happen?

- Compiler can reorder statements
  - or keep values in registers
- Processor can reorder them
- On multi-processor, values not synchronized in global memory
- Must use synchronization to enforce visibility and ordering
  - as well as mutual exclusion

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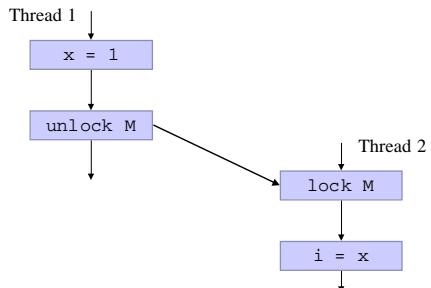
### Synchronization

- Synchronization on thread local objects
  - e.g., synchronized(new Object()) {}
  - is not a no-op under current semantics
  - but it isn't a memory barrier
- Proposal: make it a no-op
  - and allow other compiler optimizations
- Programming model is release consistency

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## Proposed Java Thread Spec

### When Are Actions Visible to Other Threads?



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### New Optimizations Allowed

- Turning synchronizations into no-ops
  - locks on objects that aren't ever locked by any other threads
  - reentrant locks
  - enclosed locks
- Lock coarsening
  - merging two calls to synchronized methods on same object
    - need to be careful about starvation issues

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### Double-check - DO NOT USE

**Doesn't work under either existing or proposed semantics**

```

class Service { // DO NOT USE
    Parser parser = null;
    Parser getParser() {
        if (parser == null)
            synchronized(this) {
                if (parser == null)
                    parser = new Parser();
            }
        return parser;
    }
}
  
```

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### Existing Semantics of Volatile

- No compiler optimizations
  - Can't hoist read out of loop
  - reads/writes go directly to memory
- Reads/writes of volatile are sequentially consistent
  - can not be reordered
  - but access to volatile and non-volatile variables can be reordered
- Reads/writes of long/doubles are atomic

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### Existing Volatile Compliance

- Very poor
  - some JVMs completely ignore volatile
- No one enforces sequential consistency
- Atomic longs/doubles isn't enforced on most
- New compliance tests will likely be rolled out soon

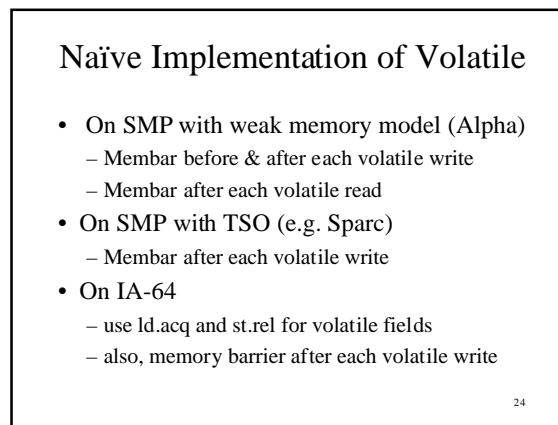
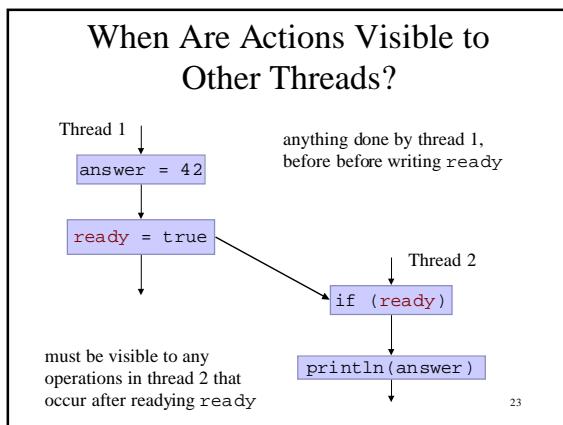
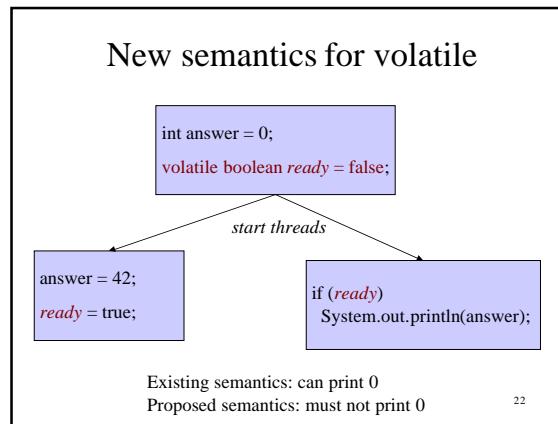
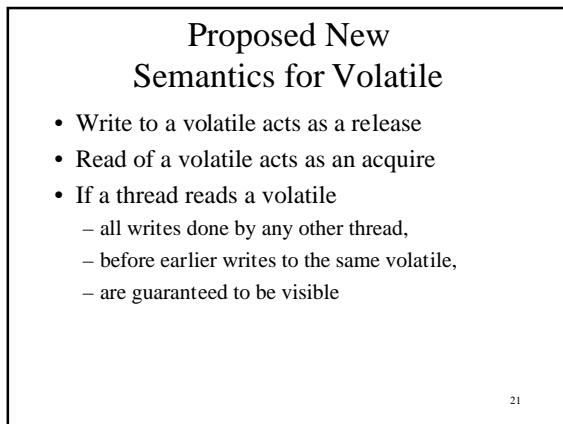
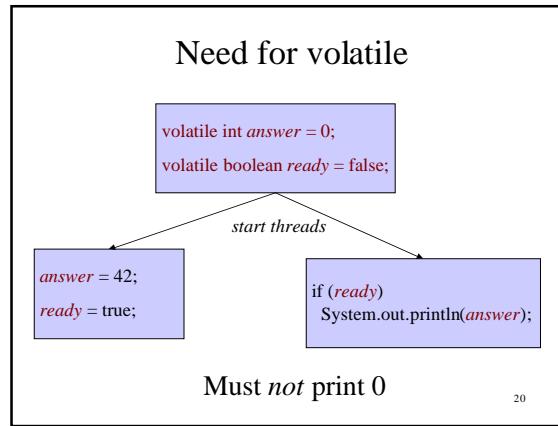
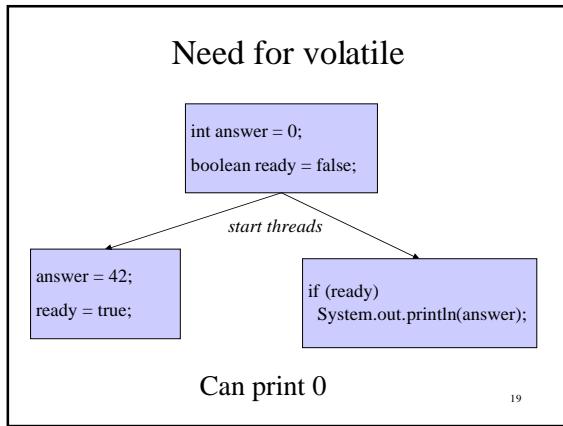
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### Volatile Compliance

	No Compiler Optimizations	Sequential Consistency	Atomic Longs/Doubles
Solaris JDK 1.2.2 EVM	Pass	Fail	Pass
Solaris JDK 1.3.0 beta Hotspot Client	Fail	Fail	Fail
Windows JDK 1.3.0 Hotspot Client	Fail	Fail	Fail
Solaris JDK 1.3.0 beta Hotspot Server	Pass	Fail	Fail
Windows JDK 1.3.0 Hotspot Server	Pass	Fail	Fail
Windows IBM JDK 1.1.8	Pass	Fail	Fail

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## Proposed Java Thread Spec



### Implementation Cost of Proposed Change in Semantics

- Naïve implementation handles new semantics
  - unclear if only enforcing only existing semantics would incur fewer memory barriers
- New semantics will prohibit some compiler optimizations
  - reading a volatile will force all values cached in registers to be reloaded

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### Volatile Summary

- These semantics make volatile rather heavy weight
  - may not be cheaper than synchronization
- Few programmers will use all these features
  - Do we really need sequential consistency, on top of acquire/release semantics?
- But it is simple and easy to understand
  - more likely to be used correctly

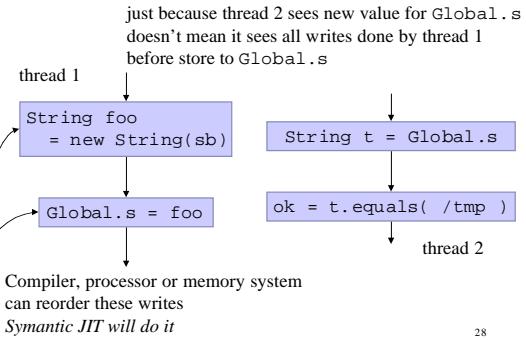
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### Immutable Objects

- Many Java classes represent immutable objects
  - e.g., String
- Creates many serious security holes if Strings are not truly immutable
  - probably other classes as well
  - should do this in String implementation, rather than in all uses of String

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### Strings aren't immutable



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### Why aren't Strings immutable?

- A String object is initialized to have default values for its fields
- *then* the fields are set in the constructor
- Thread 1 could create a String object
- pass it to Thread 2
- which calls a sensitive routine
- which sees the fields change from their default values to their final values

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### Making String immutable

- Could make String methods synchronized
  - most programmers don't think methods for immutable objects need to be synchronized
  - synchronization would slow down String methods on all platforms
    - only needs to be synchronized on SMP's with weak memory models
    - doesn't need synchronization on SPARC or MAJC(?) SMP's

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## Proposed Java Thread Spec

### Final = Immutable?

- Existing Java memory model doesn't mention final
  - no special semantics
- Would be nice if compiler could treat final fields as constant
  - Don't have to reload at memory barrier
  - Don't have to reload over unknown function call

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Existing semantics require that final fields need to be reloaded at synchronization points

```
class A extends Thread {  
    public void run() {  
        int i,j;  
        i = x;  
        synchronized(this) {  
            j = x;  
        }  
        synchronized(this) {  
            start();  
            sleep(10);  
        }  
        System.out.println(i+j);  
    }  
    x = 42;  
}
```

Must *not* print 0

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### Proposed Semantics for Final

- Read of a final field always sees the value set in constructor
  - If,
    - a final field is read before set
      - (by the constructing thread)
    - or, a reference to the object becomes visible to another thread before object is constructed
      - semantics are ugly
- Can assume final fields never change
- Makes string immutable?

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### Problems

- JNI code can change final fields
  - setIn, setOut, setError
  - **Propose to remove this ability**
    - (reflection appears to be safe)
- Objects that escape their constructor before final fields are set
  - Base class “registers” object, derived class has final fields
- Doesn't suffice to make strings immutable

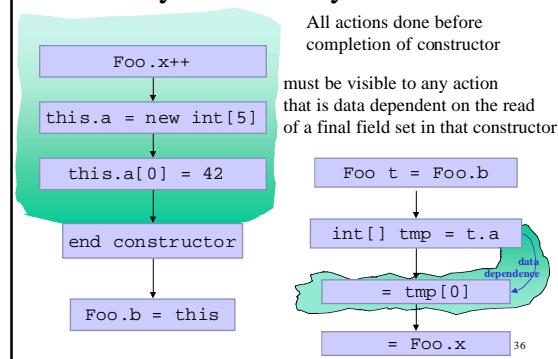
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### Doesn't make Strings immutable

- No way for elements of an array to be final
- For Strings, have to see final values for elements of character array
- So...
  - Read of final field is treated as a weak acquire
    - matching a release done when object is constructed
  - weak in that it only effects things dependent on value read
    - no compiler impact

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### Visibility enforced by final field a



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