Simple thread semantics require race detection

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Why data race detectors?

- Debugging
  - Code with data races is
    - Suspect.
      - VERY hard to analyze correctness (stay tuned).
    - Probably wrong.
    - Definitely wrong in many environments (*e.g.* C++0x, C1x, Ada, C + Posix)
    - Hard to debug at point of failure.
  - But you knew that already.

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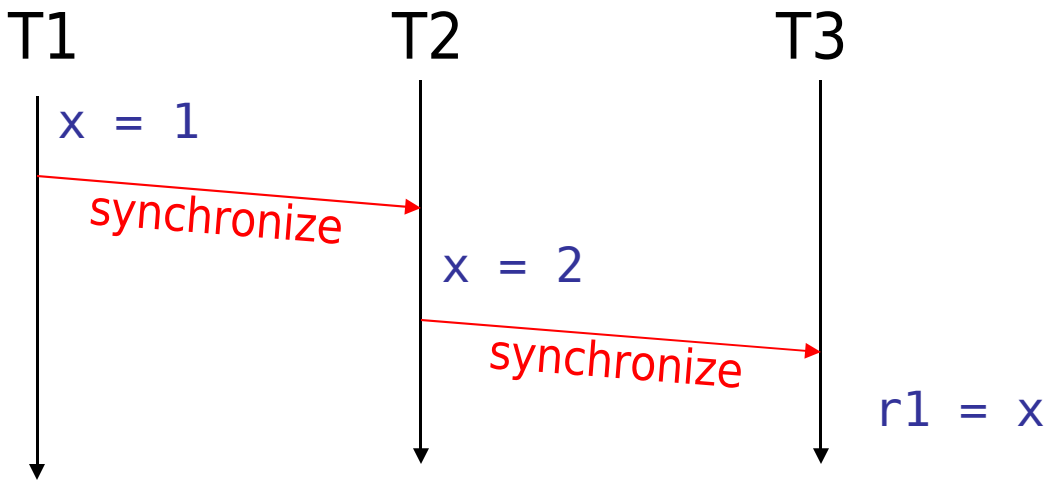
Why else data race detectors?

- Easy to specify semantics of programs without data races (cf. work by S. Adve).
  - Conflicting accesses must be ordered by synchronization (happens before).
  - Each load “sees” the unique store that
    - happens before the load, and
    - happens after all other such stores to that location.



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What about programs with data races?

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Interesting data race outcome 1

`x` initially zero

Thread 1:

```
x = 100000;
```

Thread 2:

```
x = 40000;
```

Outcome: `x = 105536`

(But Java has a hack …)

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Interesting data race outcome?

`x, y` initially null,

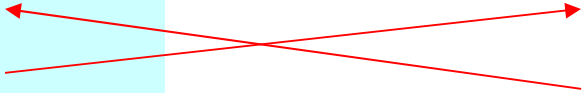
Loads may or may not see racing stores?

Thread 1:

```
r1 = x;
y = r1;
```

Thread 2:

```
r2 = y;
x = r2;
```



Outcome: `x = y = r1 = r2 =`
“<your bank password here>”

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Standard solutions

- Undefined semantics for data races
  - Ada, Posix, C++0x, C1x
  - Doesn’t address security issues
  - Unacceptable for Java
- Statically prevent data races
  - generality vs. type system complexity
  - sometimes appropriate, but not widely used
- Java causality treatment

The Java Solution

Quotation from 17.4.8, Java Language Specification, 3rd edition, omitted, to avoid possible copyright questions. The important point is that this is a rather complex mathematical specification.

...

Complicated, but nice properties?

- Manson, Pugh, Adve: The Java Memory Model, POPL 05

Quotation from section 9.1.2 of above paper omitted, to avoid possible copyright questions. This asserts (Theorem 1) that non-conflicting operations may be reordered by a compiler.

Much nicer than prior attempts, but:

- Aspinall, Sevcik, “Java Memory Model Examples: Good, Bad, and Ugly”, VAMP 2007 (also ECOOP 2008 paper)

Quotation from above paper omitted, to avoid possible copyright questions. This ends in the statement:

“This falsifies Theorem 1 of [paper from previous slide].”

Note 1: This does not necessarily mean implementations are broken, or that we know how to do better. It does suggest this is too complicated.

Note 2: The underlying observation is due to Pietro Cenciarelli.

Another way out

- Accurate data-race detectors allow us to avoid the issue, e.g.:
  - Goldilocks (Elmas et al, PLDI ‘07), or
  - FastTrack (Flanagan and Freund, PLDI ’09)
- All loads either
  - See a store that “happens before” it, or
  - Raise an exception.
- Causal cycles can’t arise.
- Independence from access granularity.
- No security issues.

What about cost?

- Definitely still an issue ☹
  - No sampling allowed!
- No need to detect write-after-read races, the most expensive kind ☺
- We don’t have to detect exactly data races (e.g. Ceze et al, HotPar 09) …

- Neither clearly solvable, nor clearly a show-stopper?

Questions?

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