C/C++ Causal Cycles Confound Compositionality

Mike Dodds
University of York

Mark Batty
University of Cambridge

Alexey Gotsman
IMDEA Software Institute

ABSTRACT

In response to the rise of multicore processors, mainstream languages have begun to offer primitives for concurrent programming. To avoid the cost of inter-core synchronisation, the new C/C++ standard, C11 [2], offers weakly consistent *relaxed* operations, alongside traditional reads, writes and mutexes. When using relaxed operations, different threads may see different, apparently contradictory orders of events.

C11 permits a particularly surprising kind of relaxed behaviour: *cycles in causality*. Two conditional guards on different threads can be satisfied by writes down the other branch. Both branches execute, even though each appears to depend on the other.

```
          x = 0; y = 0;
if (x == 42)  ||  if (y == 23)
  y = 23;     ||    x = 42;
```

Such behaviour could potentially be produced by hardware speculation or compiler optimisations, but it is unclear whether it occurs in current implementations. Causal cycles are known to be problematic: the Java standard tried to rule them out, but inadvertently forbade several widely-used optimisations [3]. C11 heavily deprecates cycles, but falls short of banning them outright.

A property is *compositional* if each program sub-component can be analysed separately while assuming its surrounding context is well-behaved. By allowing programs to be decomposed, compositionality aids documentation, testing and verification. In most languages, safety properties (e.g., absence of memory faults) are compositional, because a given fault must originate in the sub-component or its context, but not both. Causal cycles in C11 allow two faults to cause each other, which violates this assumption and breaks compositionality [1].

Fixing compositionality in C11 requires a condition for ruling out cycles which avoids Java's problems. This remains a difficult open problem.

BODY

C/C++ permit seemingly-impossible cycles in causality. This breaks compositionality: two apparently safe programs may fault when composed.

REFERENCES

[1] M. Batty, M. Dodds, and A. Gotsman. Library abstraction for C/C++ concurrency. In *Principles of Programming Languages*, 2013.

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[3] J. Sevcik. *Program Transformations in Weak Memory Models*. PhD thesis, University of Edinburgh, 2008.

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