Semantics for Transactional Languages

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thoughts inspired by a series of wonderful students

A Simple Idea [Herlihy & Moss '93]

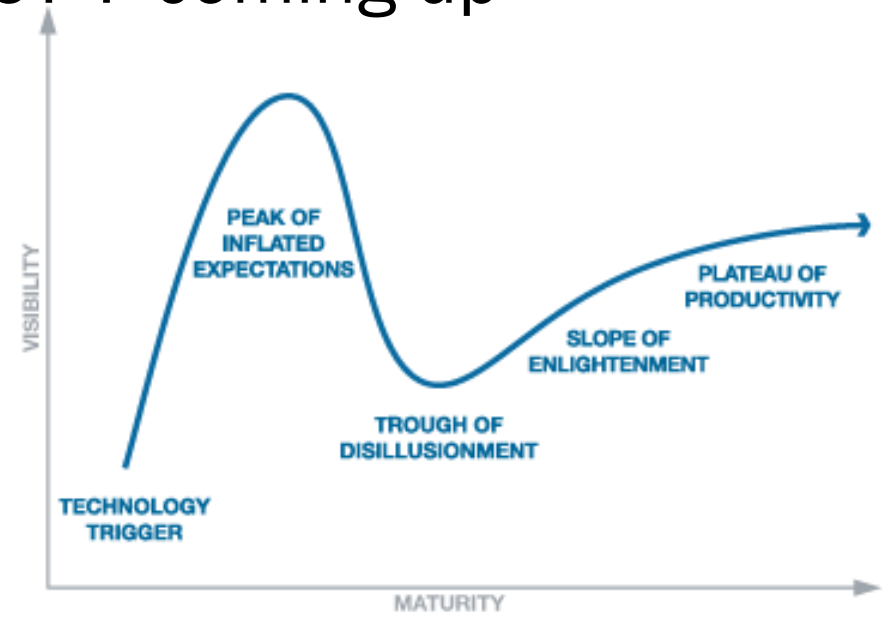
- User labels atomic sections

```
atomic {
        ...
}
```

- Underlying system ensures atomicity; executes in parallel when possible (speculation)
- Motivations
  - » performance (via lock elision)
  - » simplicity: as easy as coarse-grain locks

Since Then

- Surge of interest ~2003, with the multicore revolution and with breakthroughs in HW (UWisc, UIUC) and SW (Sun, Cambridge)
- Scores of papers & systems; at least a dozen active groups; TRANSACT 7 coming up
- Through the trough of disillusionment?



A Fleeting Opportunity

- HTM is coming
  - » Azul, Sun Rock, AMD ASF
  - » IBM has announced for Blue Gene/Q
  - » … ?
- STM for backward compatibility, fallback on HW overflow
- Language support essential
- Narrow window in time to “get the semantics right”

Outline

- Assertions
  - » atomicity is central
  - » speculation is an implementation issue (only)
  - » small transactions are what matter
  - » privatization is essential
    - – necessary for correctness
    - – solves the problem of legacy synchronization
- Open Questions
  - » non-transactional reads and writes
  - » big transactions, integration with system transactions
  - » relationship to “deterministic parallel programming”

Memory Model

- Transactional sequential consistency (TSC)
  - » ideal but expensive: global total order on accesses
    - – consistent w/ program order $<_p$
    - – w/ each transaction contiguous — atomic
- Strict serializability (SS)
  - » txns globally totally ordered wrt one another
  - » also ordered wrt preceding & following accesses of same thread (though those accesses aren't necessarily globally ordered wrt one another)
- Transactional Data-Race Freedom (TDRF)
  - » if all conflicting accesses are ordered by SS
  - » then the program appears to be TSC

Strong Isolation Is a Non-Issue

- Hard to explain to the programmer
  - » what is a memory access?
- Heavy performance penalty in STM
- Only matters in racy programs
  - » constrains the behavior of buggy code
  - » less than you want (TSC); more than you need to build what you want (TSC given TDRF)
  - » may be useful for debugging, but a good race detector is better

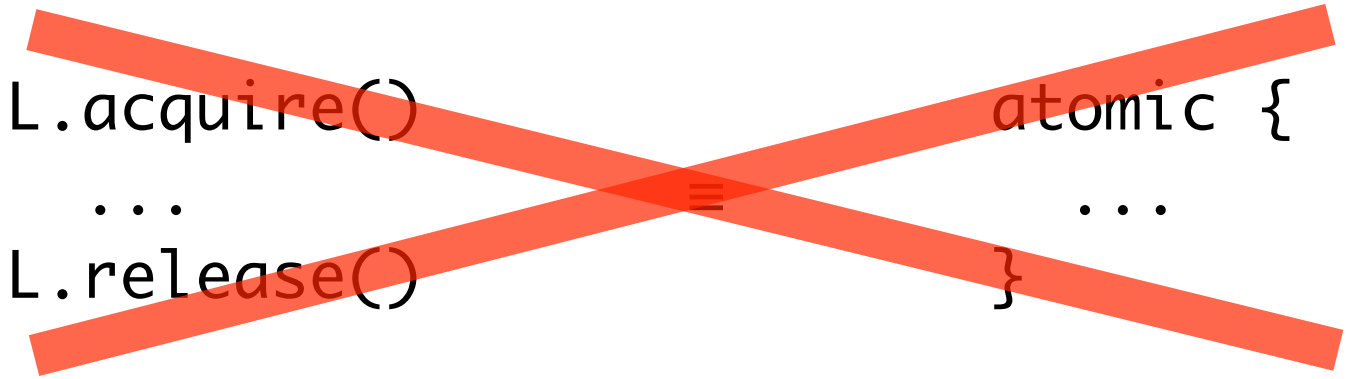
Opacity Is a Semantic Non-Issue

- Aborted transactions do not appear in (language-level) histories
- Opacity is simply one end of the implementation spectrum: validate at every read
- Sandboxing is the other end: validate before every “dangerous” operation (and periodically)
- Some very promising implementations in the middle: delayed/out-of-band validation
  - » ask me later!

Privatization Is Essential

- Definition: transaction T with history prefix P privatizes datum D if
  - » ∃ extensions of P in which a first access to D after P occurs in different threads
  - » ∀ extensions of P+T, the first access to D after P+T occurs in the same one thread
- Crucial for performance with STM
- Solves the problem of legacy synchronization
  - » locking is privatization — `acquire` and `release` are small atomic blocks

Transactions ≠ Critical Sections




```
L.acquire()          ≡      atomic { ... }
  ...                           ...
L.release()                  atomic { ... }
```

Open Questions

Non-transactional Accesses

- Want reads for, e.g., ordered speculation, high-performance hybrid TM
  - » clearly important at the HTM ISA level
  - » not clear whether needed/wanted at language API level
- Want writes out of aborted txns for debugging
  - » again, clearly important at the HTM ISA level
    - – and probably more useful if immediate
  - » probably important at the language level too
    - – not as clear that these need to be immediate
- Immediate writes, and writes in aborted txns, a challenge for the memory model

Atomicity and Determinism

- See our paper at DISC'11
  - » languages/idioms that guarantee all abstract executions will be "equivalent" in some well-defined sense
- Independent split-merge an obvious foundation for language-level determinism
- Atomic commutative [+associative] ops an obvious extension
- Is there anything else?
  - » atomic event handlers, perhaps?

The Bottom Line: Keep It Simple!

- Atomicity is central
- Speculation is an implementation issue (only)
- Small transactions are what matter
- Privatization is essential (and solves the problem of legacy synchronization)

www.cs.rochester.edu/research/synchronization/

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