Local Nontermination Detection for Parallel C++ Programs

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Motivation

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DEMO: DIVINE

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... at the very least, we should not blindly trust safety checking

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- targeting assertion violations, memory corruption, data races
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- not enough for parallel programs

(Non)Termination Checking

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- or checks that certain parts of it terminate
  - critical sections
  - waiting for condition variables, threads...
  - user-defined parts

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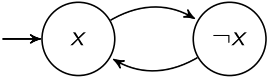
- build on explicit-state model checking → finite-state programs (with possibly infinite behaviour)
- user can specify what to check

```
bool x = true;
while (true) { x = !x; }
```



What is Nontermination?

```
mutex mtx;
void w() { mutex.lock(); x++; mutex.unlock(); }
int main() { thread t0(w), t1(w); t0.join(); t1.join(); }
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Does this program terminate?

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atomic< bool > spin_lock;
void w() {
    while (spin_lock.exchange(true)) { /* wait */ }
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`[t0: spin_lock.exchange(true) → false]`

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but only because `t0` is not allowed to run

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Does every *wait* end?

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([t1:  spin_lock.exchange(true) → true]
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 [t0:  spin_lock = false]
 [t0:  spin_lock.exchange(true) → false])^ω
```

both threads can run

What is Nontermination?

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 [t0:  spin_lock = false]
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- this run requires a scheduler which allows `t1` to run only if `t0` is in the critical section

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$$\Big(\texttt{[t1: spin\_lock.exchange(true)} \to \texttt{true]}$$
$$\texttt{[t0: x++]}$$
$$\texttt{[t0: spin\_lock = false]}$$
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- this run requires a scheduler which allows `t1` to run only if `t0` is in the critical section
- does not happen in reality

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 [t0:  spin_lock = false]
 [t0:  spin_lock.exchange(true) → false])^ω
```

- this run requires a scheduler which allows `t1` to run only if `t0` is in the critical section
- does not happen in reality
- for realistic schedulers an infinite run does not imply nontermination

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Nontermation

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Local Nontermation

- a resource section does not terminate if the program can reach a point *in the resource section* from which it cannot reach *the corresponding resource section end*

Detecting Nontermination

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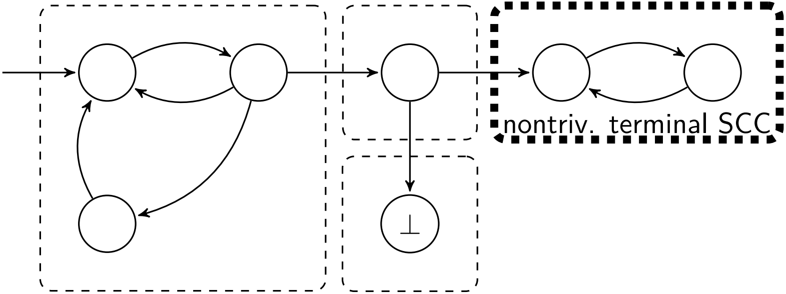
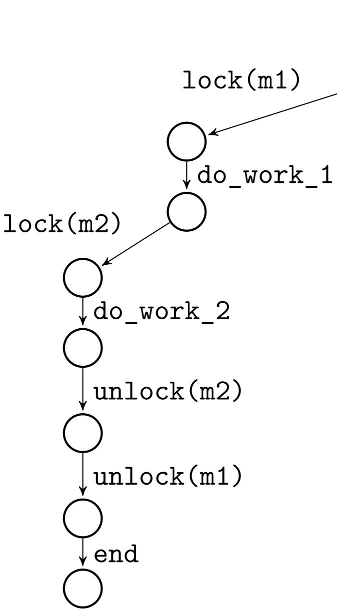
Detecting Nontermination

- a program does not terminate if it can reach a point from which it cannot reach its end
- detect nontrivial terminal strongly connected components



Going **Local**: Active Resource Section Instances



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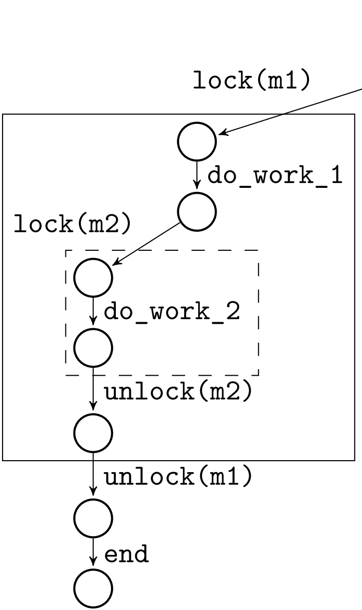

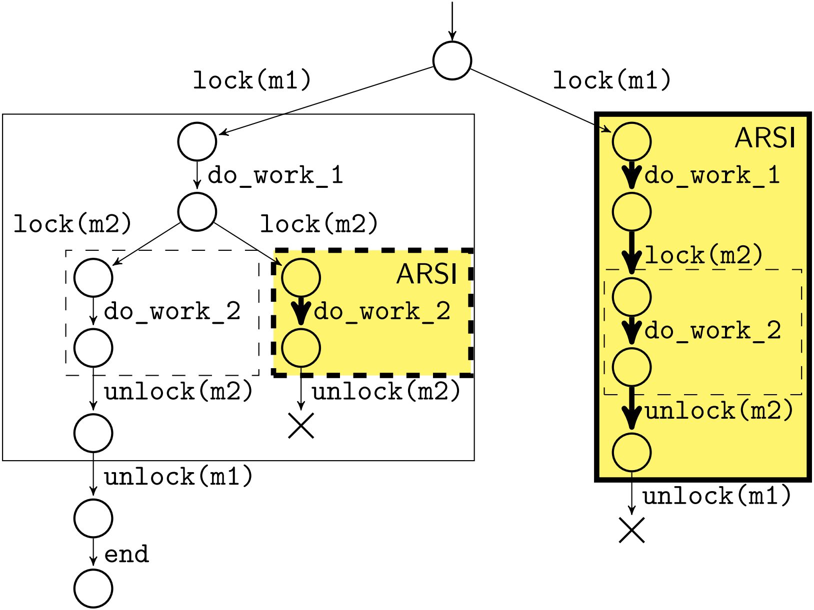
lock(m1)
lock(m1)
ARSI
do_work_1
do_work_1
lock(m2)
lock(m2)
lock(m2)
ARSI
do_work_2
do_work_2
do_work_2
unlock(m2)
unlock(m2)
unlock(m2)
unlock(m1)
unlock(m1)
end

Detecting **Local** Nontermination

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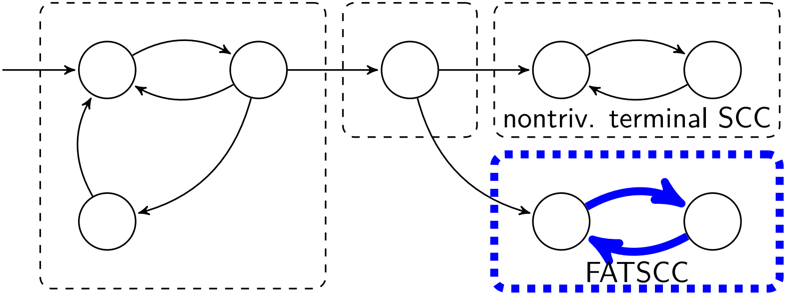
- a resource section does not terminate if the program can reach a point in the section from which it cannot reach the corresponding resource section end
- mark edges in ARSIs as **accepting**
- detect **fully accepting** terminal strongly connected components (**FATSCC**)



Detection Algorithm

- modified Tarjan's algorithm for SCC decomposition: $\mathcal{O}(|G|)$
- global nontermination has no overhead
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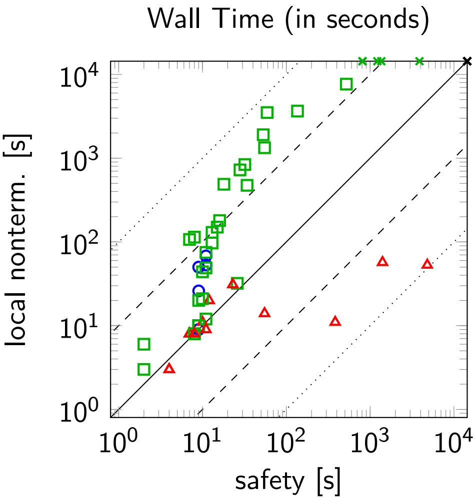

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- either built-in (mutexes, condition variables, thread joining, . . .)
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- works also on programs which do not terminate
- open-source implementation
- performance is underwhelming, but it can detect new class of bugs
- `https://divine.fi.muni.cz/2019/lnterm/`