Local Nontermination Detection for Parallel C++ Programs

Vladimír Štill Jiří Barnat

ParaDiSe
Parallel & Distributed Systems Laboratory

Masaryk University

Brno, Czech Republic

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Motivation

"Would you trust a program which was verified, but not tested?"

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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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- 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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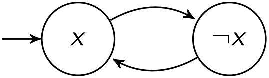
- should be useful for analysis of services/servers

- builds on explicit-state model checking $\rightarrow$ 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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```

both threads can run

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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
- for realistic schedulers an infinite run does not imply nontermination

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Local Nontermination

- 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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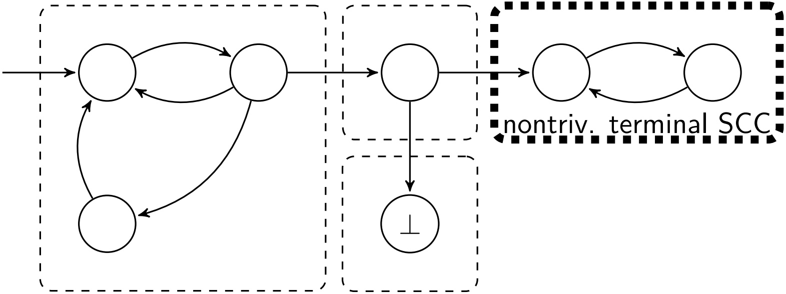
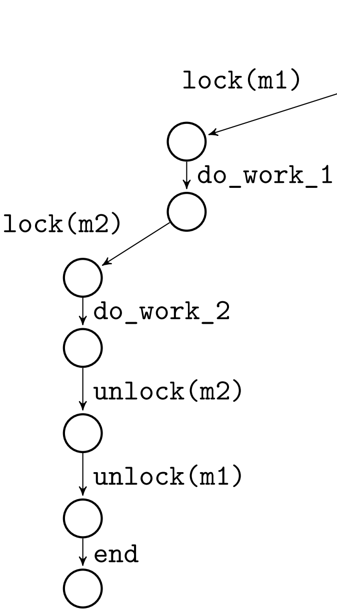
Detecting Nontermination

- 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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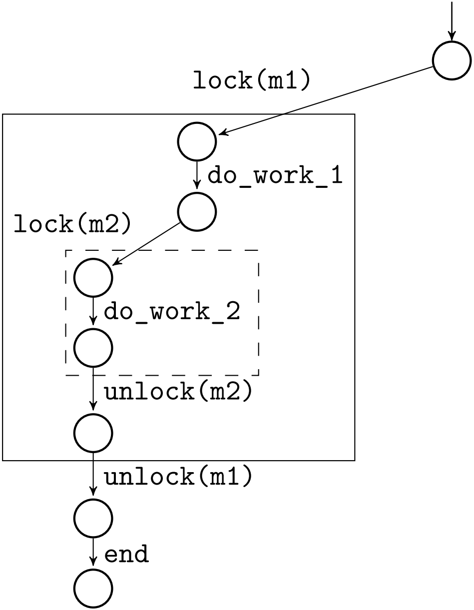

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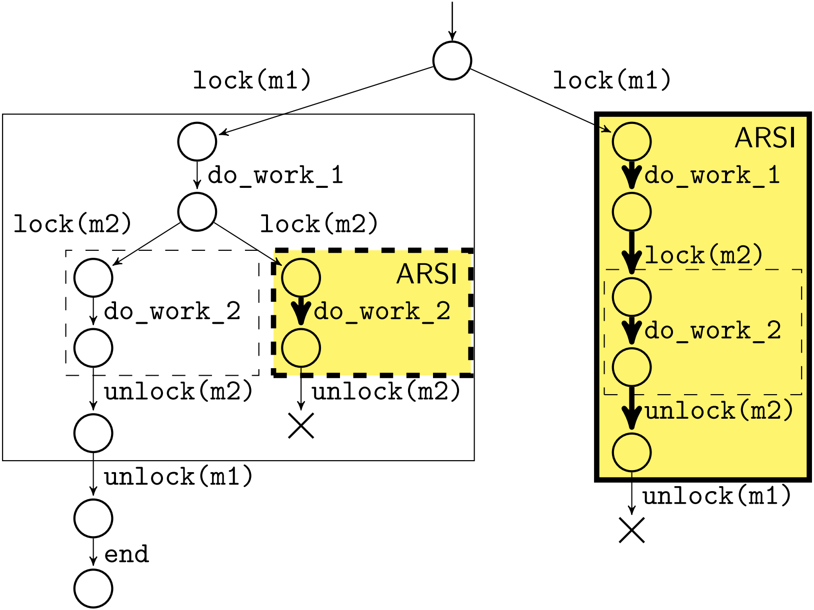

Detecting **Local** Nontermination

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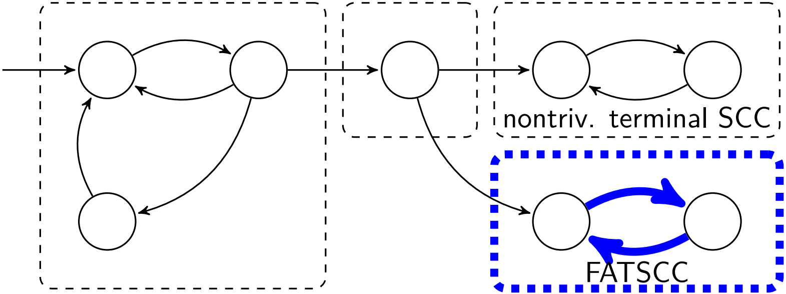
Detecting **Local** Nontermination

- 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
- for local nontermination the graph can get bigger

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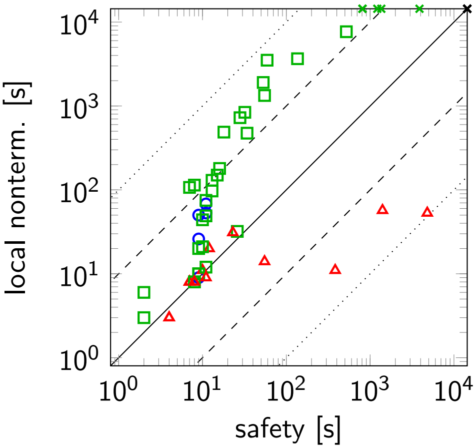
Wall Time (in seconds)



Source of resource sections

- either built-in (mutexes, condition variables, thread joining, . . .)
- or user-provided (in source code; block of code, function end, . . .)

Resource Sections & Conclusions

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- built on explicit-state model checking → finite state space required
- 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/`