UNIVERSITÄT ZU LÜBECK
INSTITUTE FOR SOFTWARE ENGINEERING
AND PROGRAMMING LANGUAGES

isp

Optimizing Trans-Compilers in Runtime Verification makes Sense – Sometimes

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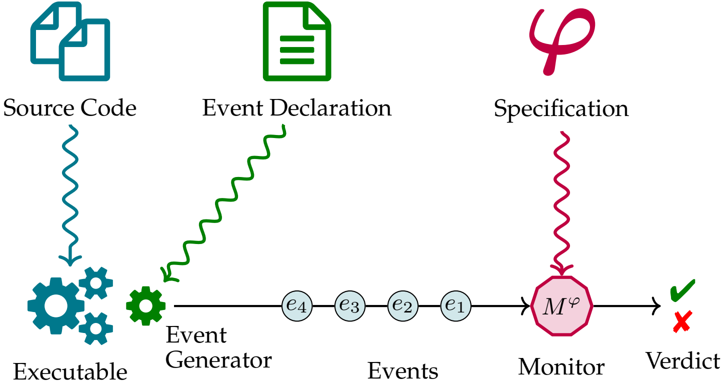
16th International Symposium on Theoretical Aspects of Software Engineering, July 2022

Runtime Verification: General idea



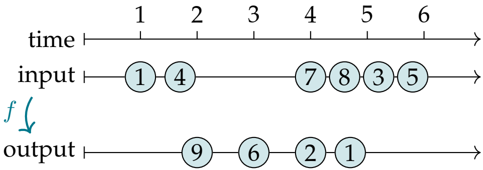
Stream Runtime Verification

Idea: Use dataflow-oriented languages (similar to Lustre, Lucid, Esterell...) to describe system properties and generate monitors.

Basic concept: Input streams are combined with operators to generate output streams.

Popular SRV languages:

- LOLA
- Striver
- **TeSSLa**

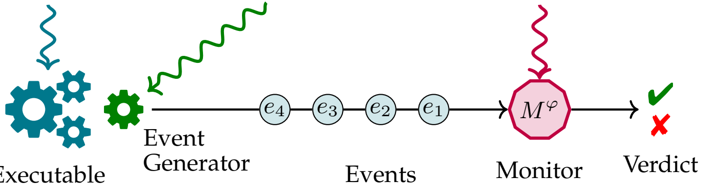


Stream Runtime Verification with TeSSLa

```c
int main() {
  while (1) {
    lock();
    critical();
    unlock();
  }
}
```

```
@InstFunctionCall("lock")
    in lock: Events[Unit]
@InstFunctionCall("unlock")
    in unlock: Events[Unit]
@InstFunctionCall("critical")
    in crit: Events[Unit]

    out on(crit, count(lock) -
                 count(unlock) == 1)
    as verdict
```



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- Every TeSSLa specification can be described by 6 core stream operators + function definitions (TeSSLa Core)
- TeSSLa offers possibility to define own stream operators as macros and offers Stdlib of common functions

Monitor generation from a TeSSLa specification

TeSSLa specification

```
in x: Events[Int]
def o = count(x)
```

TeSSLa Core (schema)

```
def v0: Int = 1
def setDefault = [...]
def addOne = (i: strict Option[Int]) => {
  def v1: Int = getSome(i)
  def v2: Int = add(v1, v0)
  def v3: Option[Int] = Some(v2)
  v3
}

in x: Events[Int]
def v4: Events[Int] = last(o, x)
def v5: Events[Int] = lift(v4, addOne)
def v6: Events[Int] = unit
def o: Events[Int] = lift(v5, v6, setDefault)
```

Monitor generation from a TeSSLa specification

Generated Scala Code (schema)

```
//Var declarations for non−stream constants
var v0: Int = 0
var setDefault: (Option[Int], Option[()]) => Option[Int] = null
var addOne: (Option[Int]) => Option[Int] = null

//Initialization of non−stream constants
v0 = 1
setDefault = [...]
addOne = [...]

//Variables for the state of each stream (5 streams)
var x_changed: Bool = false
var x_hasLast: Bool = false
var x_curr: Int = 0
var x_last: Int = 0
[...]

//Evaluation function
def calculate(ts: Int) = {

  //def v4: Events[Int] = last(o, x)
  if (x_changed && o_hasLast) {
    v4_last = v4_curr
    v4_curr = o_last
    [...]
  }
  [...]

}
```

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- Inefficient code (lots of variable declarations, complex code)

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Compiler optimizations

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2. Avoidance of dummy initialization and usage of **val** keyword where possible

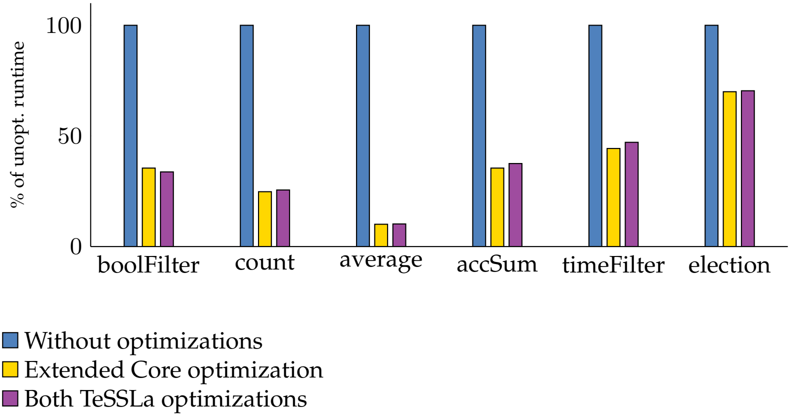
   ⇒ Simple loop analysis to detect dependency cycles.

Compiler optimizations

Generated Scala Code with optimization (schema)

```
//Var declarations for non−stream constants
val v0: Int = 0
val setDefault: (Option[Int], Option[()]) => Option[Int] = [...]
val addOne: (Option[Int]) => Option[Int] = [...]

//Variables for the state of each stream (2 streams)
var x_changed: Bool = false
var x_hasLast: Bool = false
var x_curr: Int = 0
var x_last: Int = 0
[...]

//Evaluation function
def calculate(ts: Int) = {

  //def o: Events[Int] = count(x)
  if (x_changed) {
    o_last = o_curr
    o_curr = o_curr + 1
    o_changed = true
    o_hasLast = true
  }

}
```

Evaluation



100
50
0
% of unopt. runtime
boolFilter
count
average
accSum
timeFilter
election
Without optimizations
Extended Core optimization
Both TeSSLa optimizations

Conclusion

- For monitor generation TeSSLa is compiled to TeSSLa Core and then to Scala code
- Straight-forward strategy produces inefficient code
- Introducing new core operators led to higher monitor performance
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Insight: While small optimizations do often not lead to performance gains in trans-compilers, optimizations affecting significantly the structure of the code may improve the overall performance.

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- For monitor generation TeSSLa is compiled to TeSSLa Core and then to Scala code
- Straight-forward strategy produces inefficient code
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Insight: While small optimizations do often not lead to performance gains in trans-compilers, optimizations affecting significantly the structure of the code may improve the overall performance.

$\Rightarrow$ **Optimizing Trans-Compilers in Runtime Verification makes Sense – Sometimes**