BMCLua: Verification of Lua Programs in Digital TV Interactive Applications

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The Lua Language and its Applications

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- the Lua language is used in many areas, from games to digital TV applications
  - Adobe's Photoshop Lightroom
  - World of Warcraft e Angry Birds
  - Ginga Middleware (Digital TV)

extension language used in other programming languages

- C/C++
- JAVA
- NCL

interpreted, compact, and fast; it is used in **embedded devices**

- Mobile
- Set-Top Box

incorrect implicit conversion of variable types, returning null from functions with multiple values, and arithmetic overflow

Interactive TV applications are widely spread, but their verification becomes more difficult

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- functionality demands increased significantly in digital TV
  - **peer reviewing** and **testing**

```
local counter = 0
local dx, dy = canvas:attrSize()
function handler (evt)
    if evt.class=='ncl' then
        dy = dy + 1
        while dx ~= dy do
            counter = counter + 1
            canvas:drawText(10,10,'Progress: '..counter)
        end
    end
end
event.register(handler)
```

Arithmetic OverFlow

- negative impact on the performance of interactive TV applications (**presentation failures**)

Bounded Model Checking (BMC)

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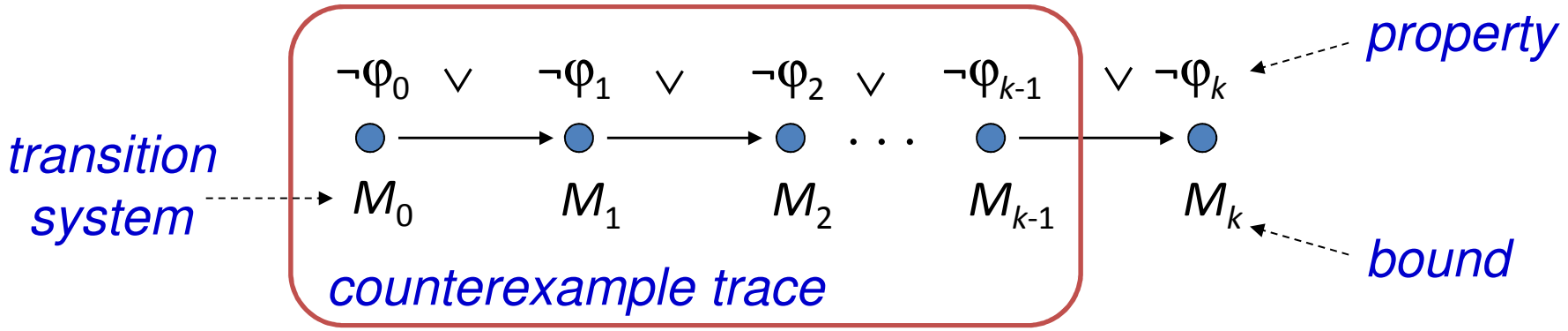
Basic Idea: check negation of given property up to given depth



- transition system *M* unrolled *k* times
  - for programs: unroll loops, unfold arrays, …
- translated into verification condition ψ such that

  ψ satisfiable iff φ has counterexample of max. depth *k*
- has been applied successfully to verify (embedded) software since early 2000's

Objectives of this work

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Apply BMC for Interactive TV software applications based on the Lua programming language

- develop a **verification platform** for Lua programs:
  - translate a Lua program to an intermediate representation
  - check for arithmetic overflow, division by zero, and user-specified assertions
  - interpret the counterexample
- exploit BMC tools to prune the **property and data dependent** search space and to exploit the **bit-accurate representation**
- implement this approach in BMCLua tool and evaluate it using Lua applications
  - consider time and correctness metrics

The BMCLua Verification Platform

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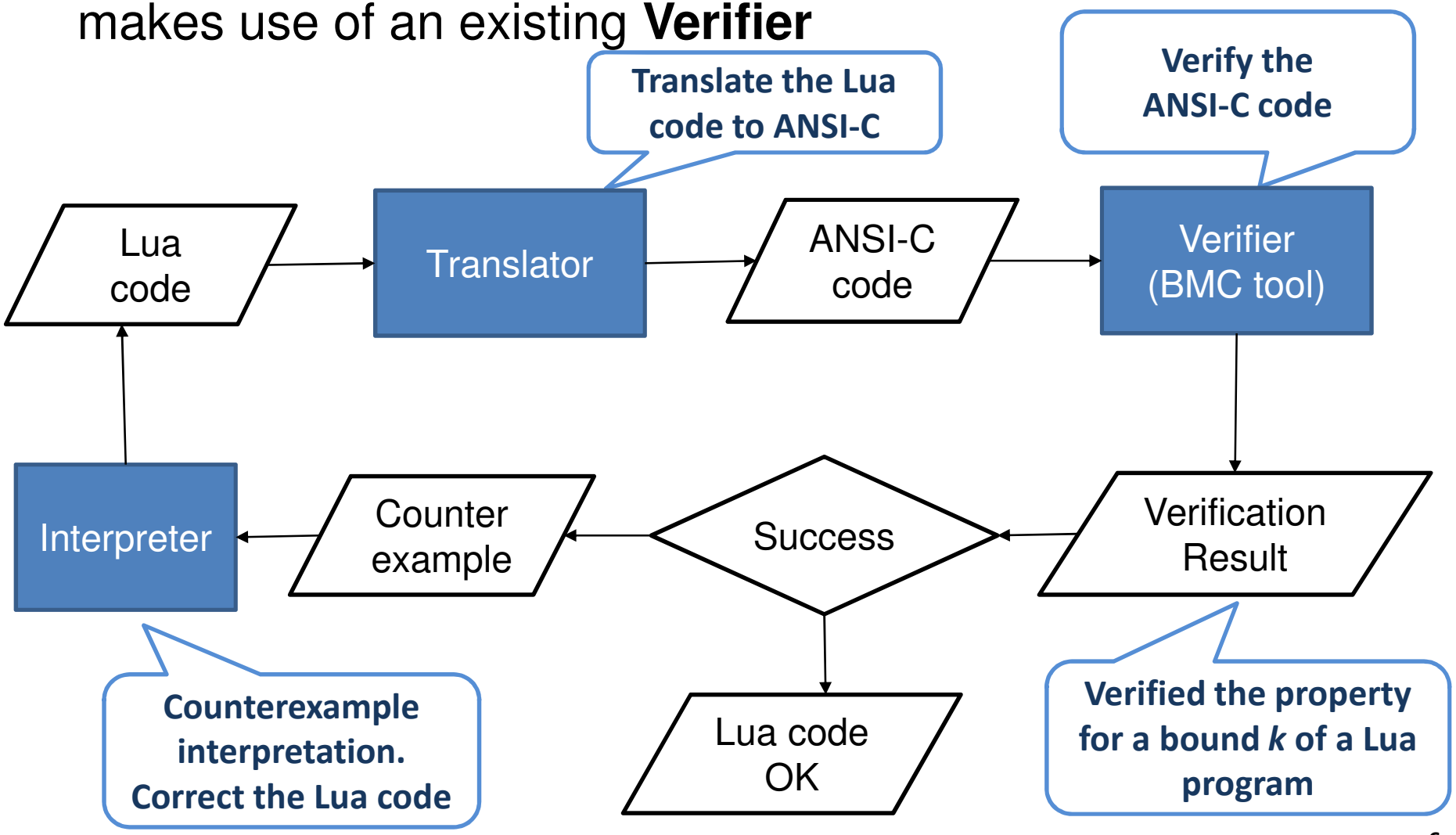
- BMCLua consists of a **Translator** and **Interpreter**, and makes use of an existing **Verifier**



The BMCLua Translator

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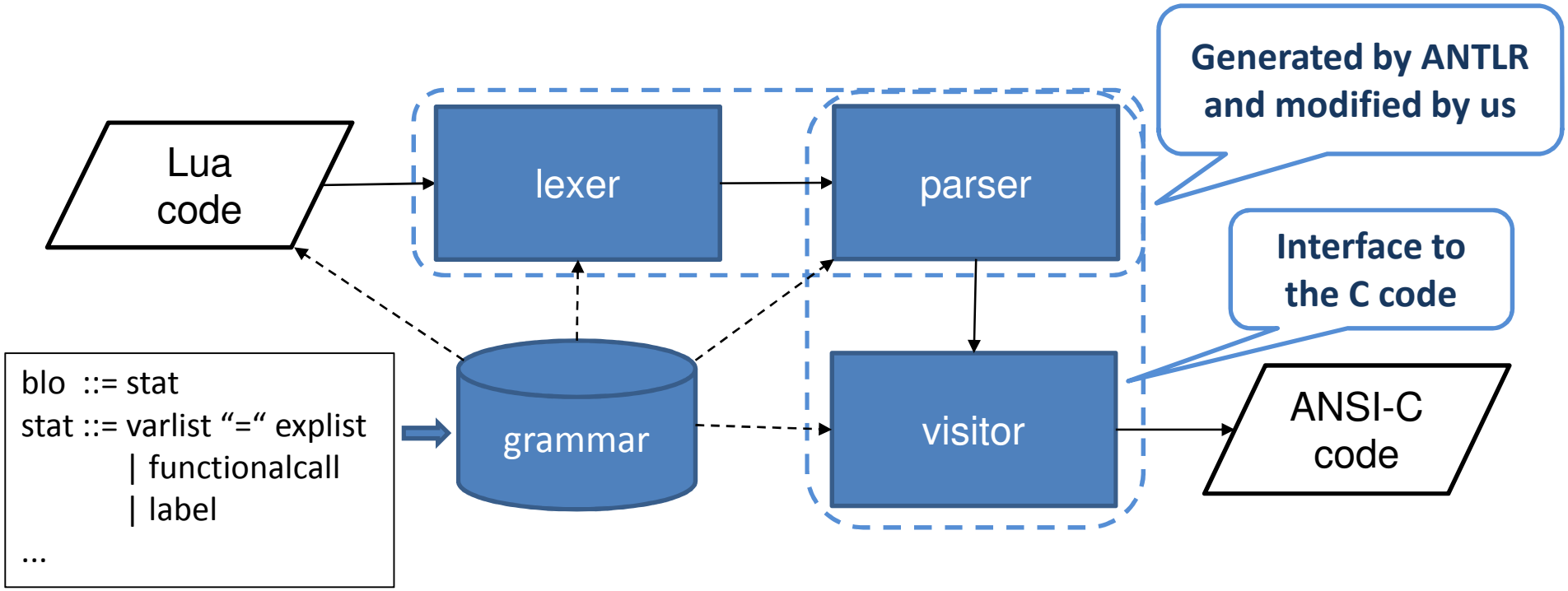
- the translator consists of the language **grammar**, the lexical analyzer (**lexer**), and the syntax analyzer (**parser**)



- the grammar consists of a set of **rules** describing the syntax
- the lexer generates **tokens** from a sequence of characters
- the parser checks the **syntax** of the input characters

Translation, Verification, and Interpretation

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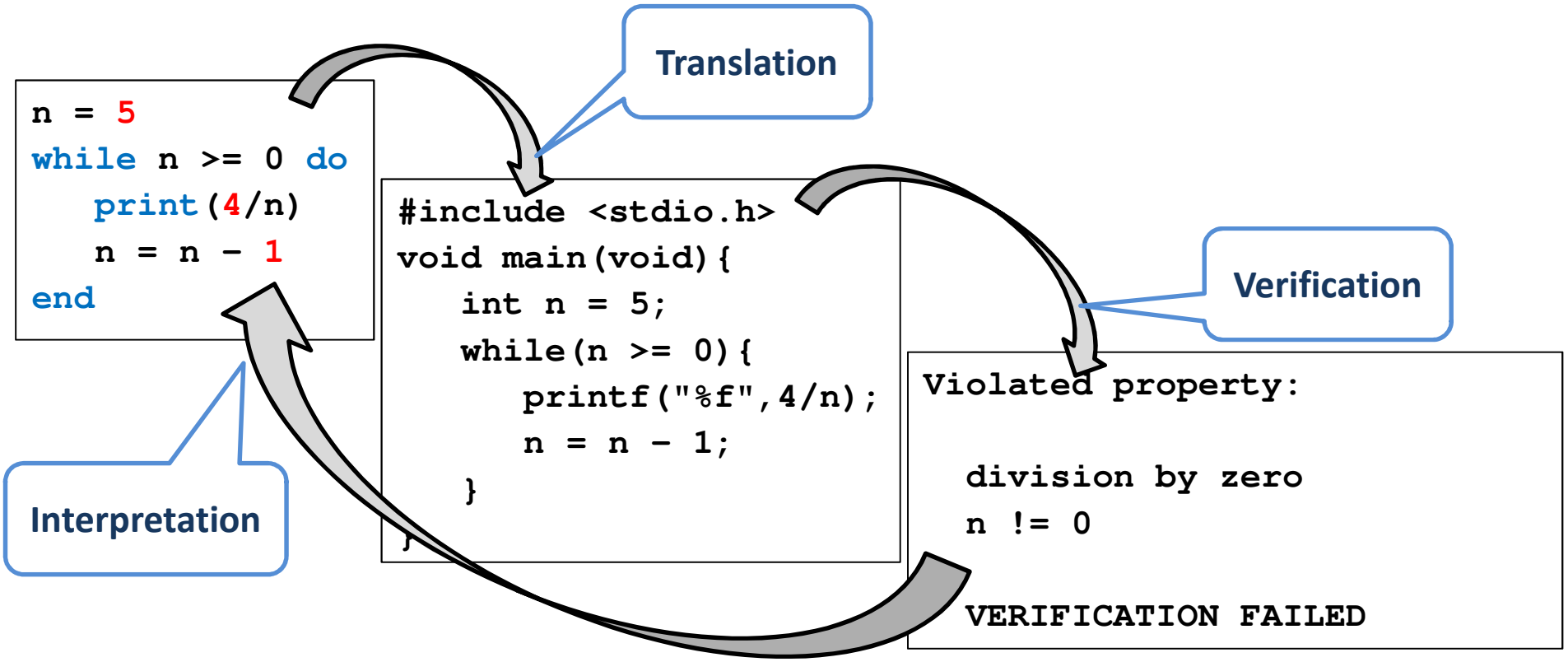
- translates to an ANSI-C code (adds more code lines)
  - supports most primitive data types, relational and logical operators, decision and loops structures, and functions



- counterexample informs the code line and the violation

Experimental Evaluation

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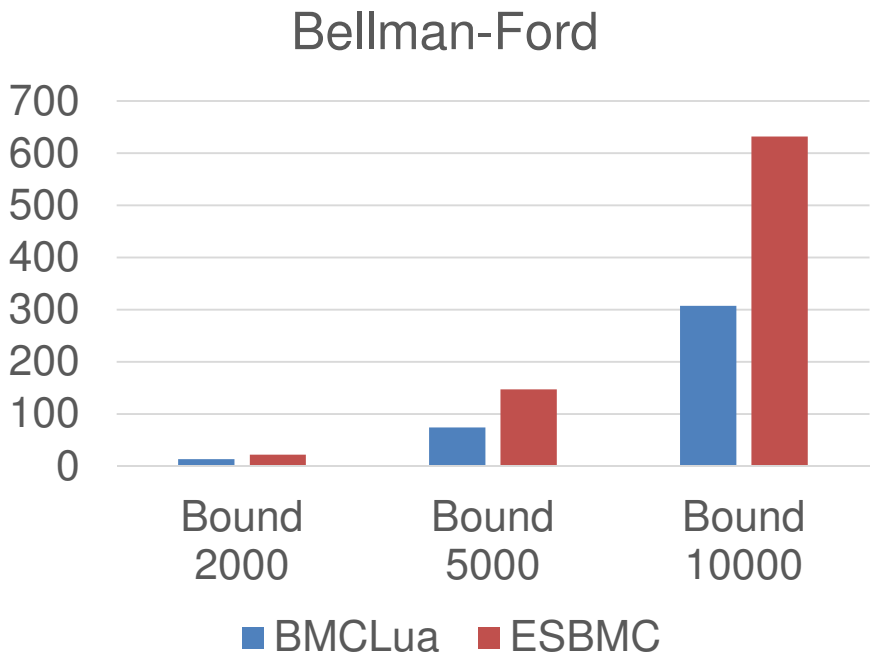
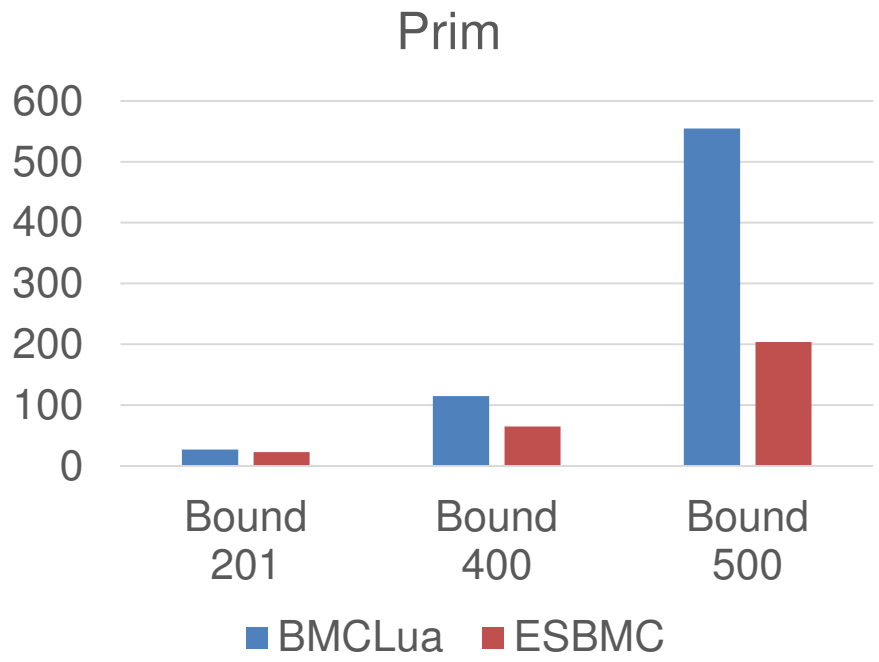
- Goal: evaluate the **performance** and **correctness** of BMCLua using standard benchmarks with a single user-specified property
  - compare to the verification time of ESBMC as a reference

- Experimental setup:
  - Intel Core i3 2.5 GHz with 2 GB of RAM running on Linux Ubuntu 32-bits
  - ESBMC v1.21 with SMT solver Z3 v3.2

Experimental Evaluation (Cont.)

- the **verification time** reported by BMCLua and ESBMC are **comparable** to each other for **smaller bounds**
  - the **translation time** is typically less than **one second**





no false-positive / false-negative

Experimental Evaluation (Cont.)

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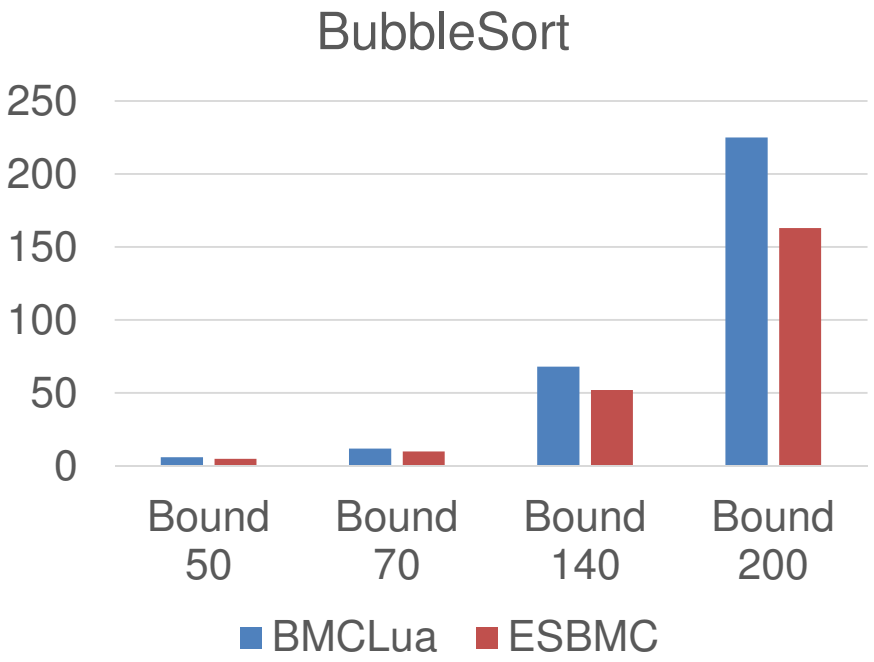
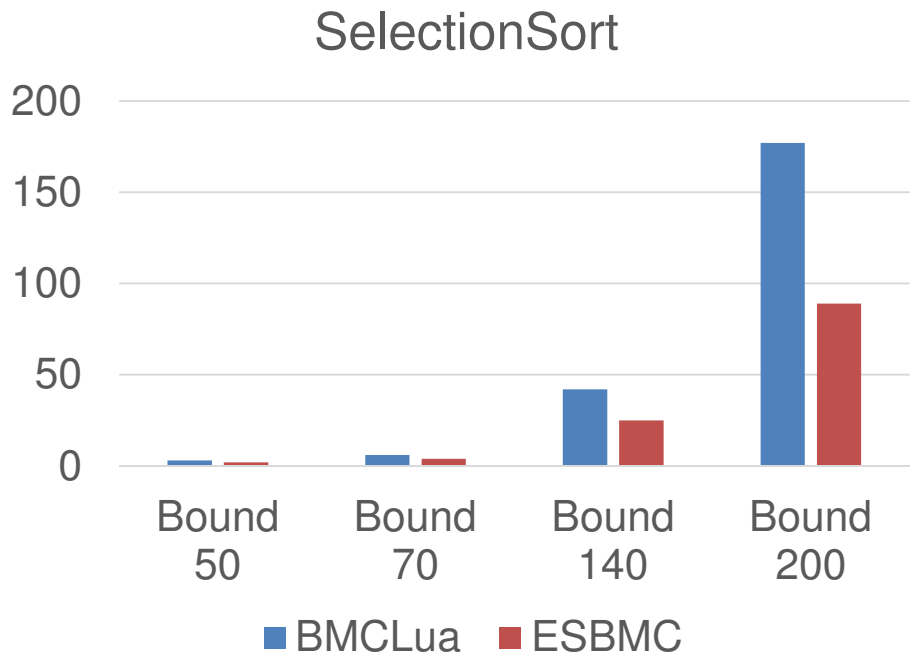
- the BMCLua **verification time** is **higher** due to the increase of **code lines** when translating into ANSI-C code
  - common subexpression elimination and constant propagation





no false-positive / false-negative

Conclusions

- proposed **first application** of BMC to Lua programs
- BMCLua checks for **arithmetic overflow**, **division by zero** and **user-specified assertions**
- the **verification time** of BMCLua is **comparable** to ESBMC
  - only 21% of the benchmarks present higher verification time
- BMCLua did not report **false-positive** or **false-negative**

Future Work

- support the remaining **Lua constructs** (typecasts, functional call, NCLua, and Lua library)
- convert Lua programs to **SMT formulas**
- integrate BMCLua into the **Eclipse** and **Ginga middleware**