ESBMC 5.0

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MOTIVATION

Motivation

USS Yorktown

- Battleship built in 1946 and automated in 1996 (27 dual-core 200MHz processors and Windows NT).

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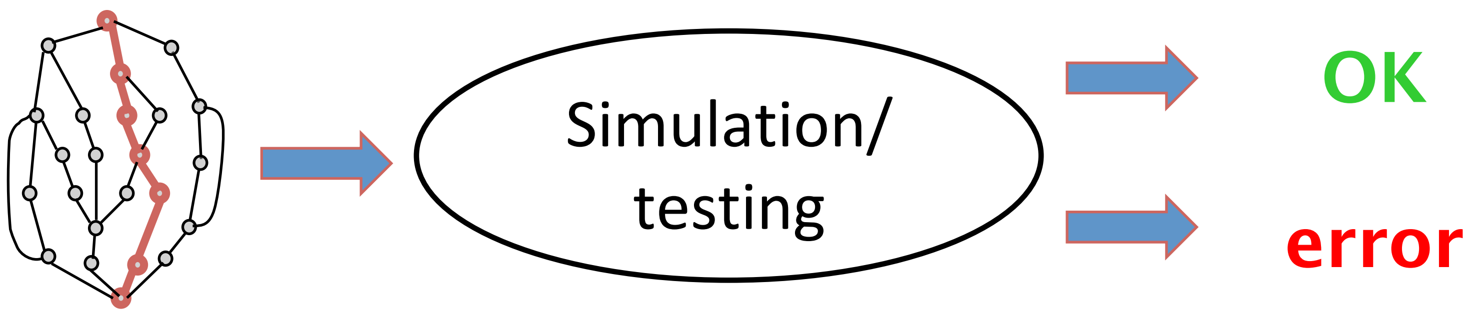
USS Yorktown

- Battleship built in 1946 and automated in 1996 (27 dual-core 200MHz processors and Windows NT).
- **Failure due to a division by zero:** It had to be towed back to its naval base.

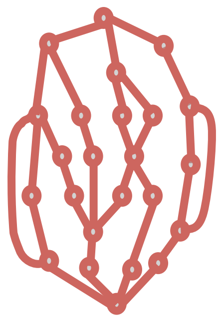
SOFTWARE VERIFICATION TECHNIQUES

Model Checking vs Testing/ Simulation



- Checks only some of the system executions.
- May miss errors.
- Can be less expensive than model checking.

Model Checking vs Testing/ Simulation



Model Checking

OK

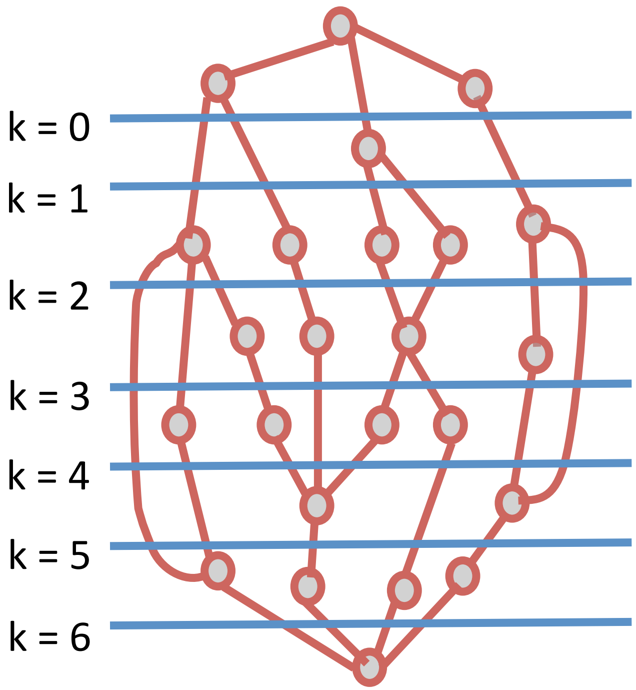
Error trace

```
Line 5: …
Line 12: …
…
Line 41:…
```

Specification (e.g, LTL)

- Exhaustively explores all executions.
  - Can be bounded to limit number of iterations, context-switch, etc.
- Report errors as traces.
- Can be extremely resource-hungry.

Bounded Model checking



- Bounded model checkers “slice” the state space in depth.
- It’s aimed to find bugs and (naïvely) can only prove correctness if all states are reachable within the bound.

ESBMC 5.0

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- ESBMC, the *Efficient SMT-Based Context-Bounded Model Checker* was originally developed at Southampton by Lucas Cordeiro under the supervision of Bernd Fischer.

- Jeremy Morse further developed ESBMC during his PhD.

- Development is now led from Southampton by Mikhail Gadelha.

- Turned 10 years in 2018!

ESBMC 5.0

- SMT-based BMC of single- and multi-threaded C/C++ programs.
- exploits SMT solvers and their background theories:
  - optimized encodings for pointers, bit operations, unions, arithmetic over- and underflow, and floating-points,
  - support for Boolector, Z3, MathSAT, CVC4 and Yices.
- supports verifying multi-threaded software that uses pthreads threading library:
  - *lazy exploration of the reachability tree.*

Supported Properties

- built-in properties:
  - arithmetic under- and overflow,
  - pointer safety,
  - array bounds,
  - division by zero,
  - memory leaks,
  - atomicity and order violations,
  - deadlock,
  - data race.

K-INDUCTION

K-induction: we can sometimes analyse to unbounded depths

- In general, there is no way to deduce depths:
  - halting problem,
  - lots of current work on deducing invariants.
- For simple loops, they can sometimes be guessed.
- Interval analysis often speed up the analysis considerably.

K-induction: the proof falls into three parts

1. Base case: naïve BMC, tries to find bugs.

2. Forward condition: checks the completeness threshold (if all loops were completely unrolled).

3. Inductive step: over-approximate loops so all states can be checked without unrolling them completely (sometime it helps to unroll a few times to strengthen invariants).

FLOATING-POINTS

Floating-points: can it fail?

```
int main()
{
  float x;
  float y = x;
  assert (x == y);
  return 0;
}
```

Floating-points: can it fail?

```
int main()
{
   float x = NaN;
   float y = x;
   assert (x == y);
   return 0;
}
```

Floating-point Encoding

- ESBMC encodes floating-point arithmetic using:
  - **bitvectors**, which extends the floating-point arithmetic support to all solvers that are currently integrated.
  - the **SMT theory of floating-points**, available only in Z3 and MathSAT.

PYTHON API

Python API

- ESBMC now includes a **Python API** that reduces the difficulty of prototyping new features and makes the tool internals accessible to a wider audience.

- The verification process can be intercepted and modified: we currently use the process to call Matlab and generate the transfer functions of digital systems.

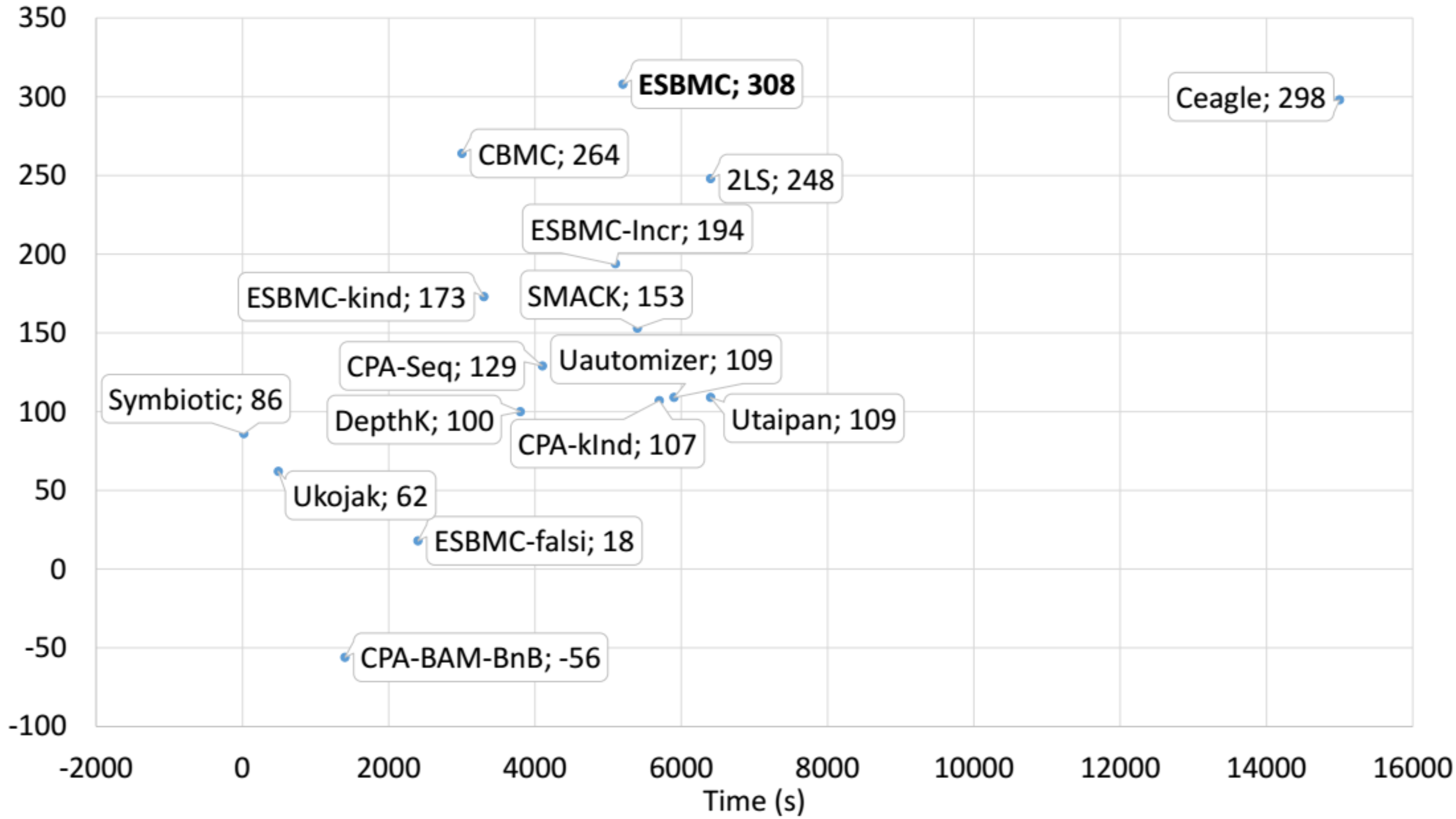
Experimental Evaluation

- Our evaluation consists of 9523 benchmarks from SV-COMP'18, checking a range of properties:
  - Reachability in single- and multi-threaded programs,
  - Memory safety,
  - Overflow,
  - Termination.

Experimental Evaluation

- ESBMC ranked third in the overall category, with a 5476 score.
- The k-induction algorithm reported 4301 correct results, the best result among tools that used *k*-induction in the competition.
- 92% of witnesses being correctly validated.

Experimental Evaluation (floating-points)



Thank you

www.esbmc.org

https://github.com/esbmc/esbmc

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