ESBMC 1.22
(Competition Contribution)

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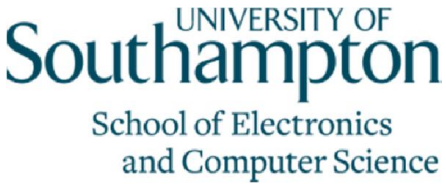


ESBMC: SMT-based BMC of single- and multi-threaded software

- exploits SMT solvers and their background theories:
  - optimized encodings for pointers, bit operations, unions and arithmetic over- and underflow
  - efficient search methods (non-chronological backtracking, conflict clauses learning)
- supports verifying multi-threaded software that uses pthreads threading library
  - interleaves only at “visible” instructions
  - *lazy exploration* of the reachability tree
  - optional context-bound
- derived from CBMC (v2.9) and has inherited its object-based memory model

ESBMC verification support

- built-in properties:
  - arithmetic under- and overflow
  - pointer safety
  - array bounds
  - division by zero
  - memory leaks
  - atomicity and order violations
  - deadlocks
  - data races
- user-specified assertions *(__ESBMC_assume, __ESBMC_assert)*
- built-in scheduling functions *(__ESBMC_atomic_begin, __ESBMC_atomic_end, __ESBMC_yield)*

Differences to ESBMC 1.20

- ESBMC 1.22 is largely a **bugfixing release**:
  - memory handling
  - replaced CBMC's string-based accessor functions
    → increased ESBMC's speed by 2*x*
- improved **memory model** for precision, performance, and stability
- produces a **smaller number of false results**
  - more errors detected (+109),
    fewer unexpected (-15) and missed (-157) errors

ESBMC's memory model

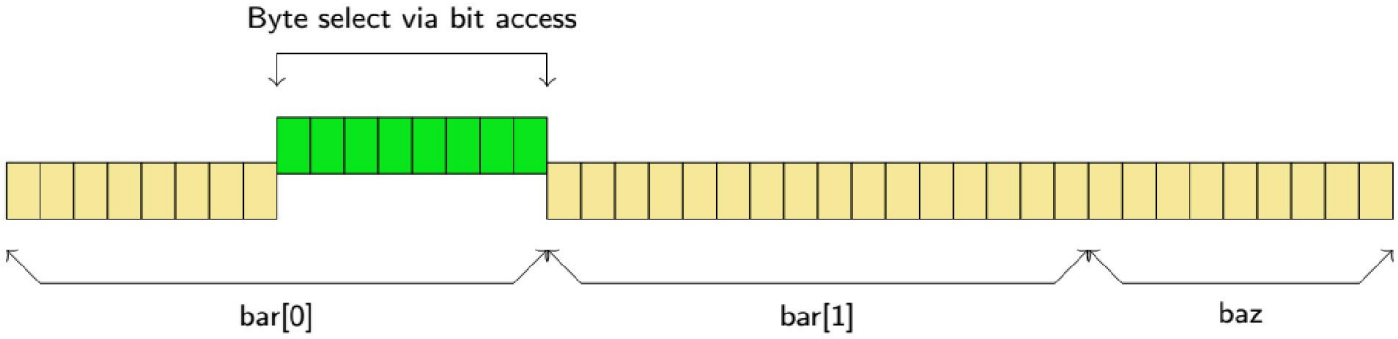
- statically tracks possible pointer variable targets (objects)
  - dereferencing a pointer leads to the construction of **guarded references** to each **potential target**
- C is very **liberal** about **permitted dereferences**

```
struct foo {
  uint16_t bar[2];
  uint8_t baz;
};
```

```
struct foo qux;
char *quux = &qux;
quux++;
*quux;
```

pointer and object types do not match

- **SAT: immediate access** to bit-level representation



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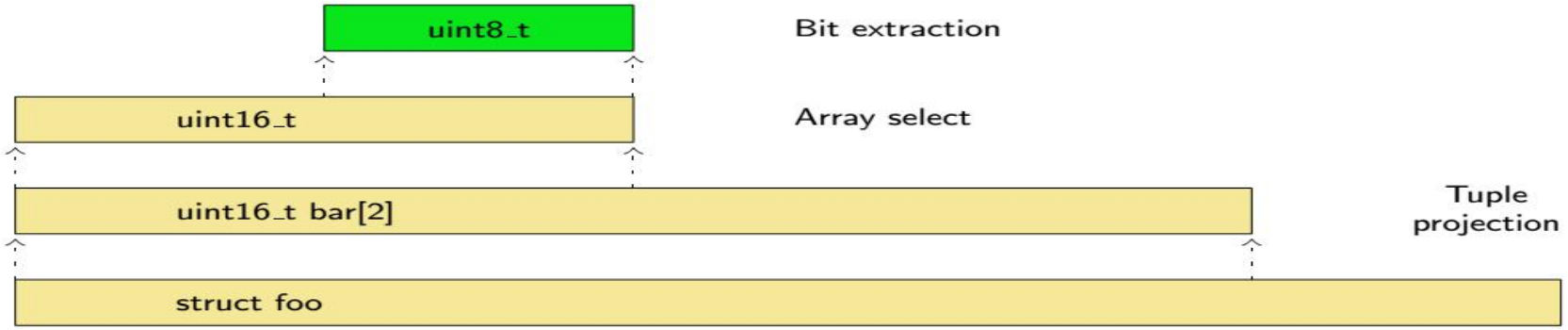
- **SMT:** sorts must be **repeatedly unwrapped**



Byte-level data extraction in SMT

- access to underlying data bytes is complicated
  - requires manipulation of arrays / tuples
- problem is magnified by nondeterministic offsets

```
uint16_t *fuzz;
if (nondet_bool()) {
   fuzz = &qux.bar[0];
 } else {
   fuzz = &qux.baz;
 }
```

  - chooses accessed field nondeterministically
  - requires a *byte_extract* expression
  - handles the *tuple* that encoded the *struct*

- supporting **all legal behaviors** at SMT layer **difficult**
  - extract (unaligned) 16bit integer from *fuzz
- experiments showed significantly increased **memory consumption**

“Aligned” Memory Model

- framework cannot easily be changed to SMT-level byte representation (a la LLBMC)
- push unwrapping of SMT data structures to dereference
- **enforce C alignment rules**
  - static analysis of pointer alignment eliminates need to encode unaligned data accesses
    → reduces number of behaviors that must be modeled
  - add alignment assertions (if static analysis not conclusive)
  - extracting 16-bit integer from *fuzz:
    - offset = 0: project `bar[0]` out of foo
    - offset = 1: **“unaligned memory access” failure**
    - offset = 2: project `bar[1]` out of foo
    - offset = 3: **“unaligned memory access” failure**
    - offset = 4: “access to object out of bounds” failure

Strengths:

- robust context-bounded model checker for C programs
- improved memory model to handle pointer arithmetic
  - greater accuracy and faster verification

Weaknesses:

- all unexpected results are caused by
  - bounding the programs (**Recursive**)
  - differences in the memory models (**MemorySafety**)
    → ESBMC detects an unchecked dereference of a pointer to a freshly allocated memory chunk