FEDERAL UNIVERSITY OF AMAZONAS
INSTITUTE OF COMPUTING
GRADUATE PROGRAM IN COMPUTER SCIENCE

UNDERSTANDING PROGRAMMING BUGS IN ANSI-C SOFTWARE USING BOUNDED MODEL CHECKING COUNTER-EXAMPLES

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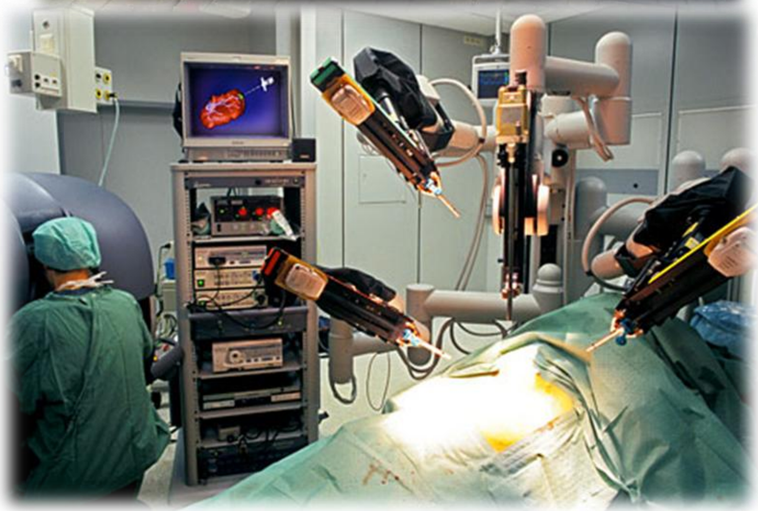
Agenda

1. Introduction
2. Background
3. Proposed Method
4. Experimental Results
5. Related Work
6. Conclusions and Future Work

Software Applications



Model Checking

- ✓ In the last few years, we can observe **a trend towards** the application of formal verification techniques to the **implementation level**;

- ✓ BMCs have gained **popularity** due to their ability to handle the **full semantics** of actual programming languages, and to support the verification of **a rich set of properties**.

And what are we proposing? **The EZProofC Method**

- ✓ To apply a **software bounded model checker**, in this case ESBMC (Efficient SMT-Based Context-Bounded Model Checker);
- ✓ To verify **critical parts of a software** written in the C programming language;
- ✓ To gather **data to show** the evidence that **failures** might happen.

The motivation of this work - **EZProofC**

- ✓ Data collected by verification tools is usually **not trivial** to be understood:
  - **Amount of variables;**
  - **Values involved in the counter-example;**
  - **The lack of a standard output to represent the counter-example;**
- ✓ Our techniques can also be applied to other programming languages like C++ and Java

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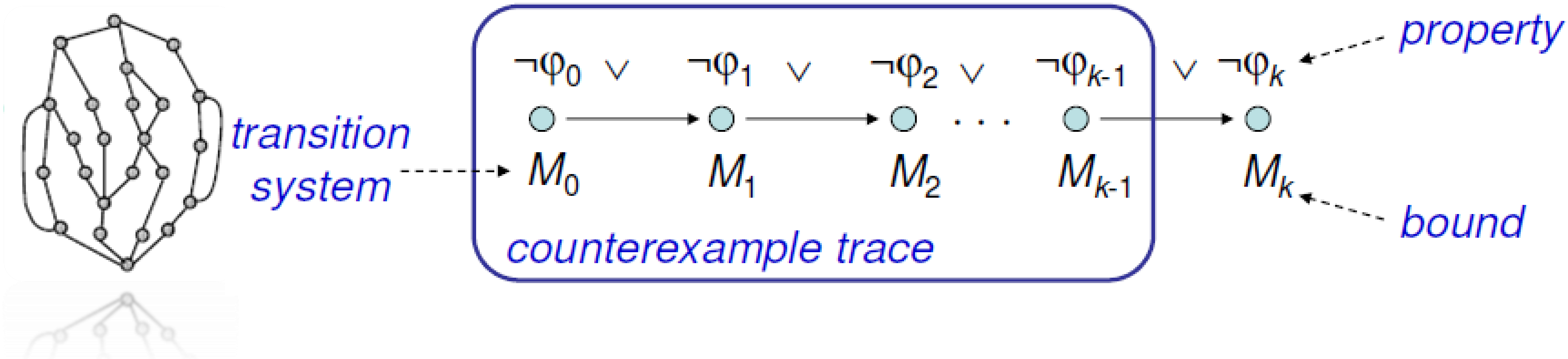
Bounded Model Checking

✓ The basic idea of BMC is to check (**the negation of**) a given property at a given depth.



✓ Transition system M unrolled k times

- for programs: unroll loops, unfold arrays, …

✓ Translated into verification condition $\boldsymbol{\psi}$ such that

- $\boldsymbol{\psi}$ satisfiable iff $\boldsymbol{\varphi}$ has counterexample of max. depth $\boldsymbol{k}$.

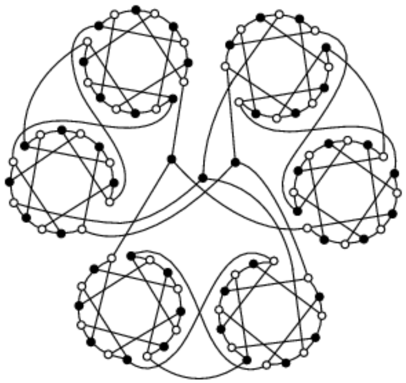
Context-Bounded Model Checking with ESBMC

ESBMC is a bounded model checker for embedded ANSI-C software based on SMT (Satisfiability Modulo Theories) solvers, which allows:

- ✓ Out-of-bounds array indexing;
- ✓ Division by zero;
- ✓ Pointers safety
- ✓ Dynamic memory allocation;
- ✓ Data races;
- ✓ Deadlocks;
- ✓ Underflow e Overflow;

Counter-Example

- ✓ A counter-example **<u>is a trace</u>** that shows that a given property does not hold in the model;



- ✓ Counter-examples allow the user:
  i. to analyze the failure;
  ii. to understand the root of the error;
  iii. to correct either the specification or the model, in this case, from the property and the program that has been analyzed respectively.

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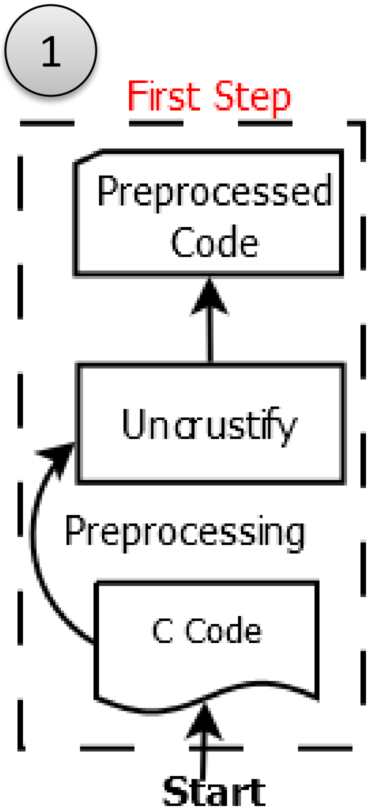
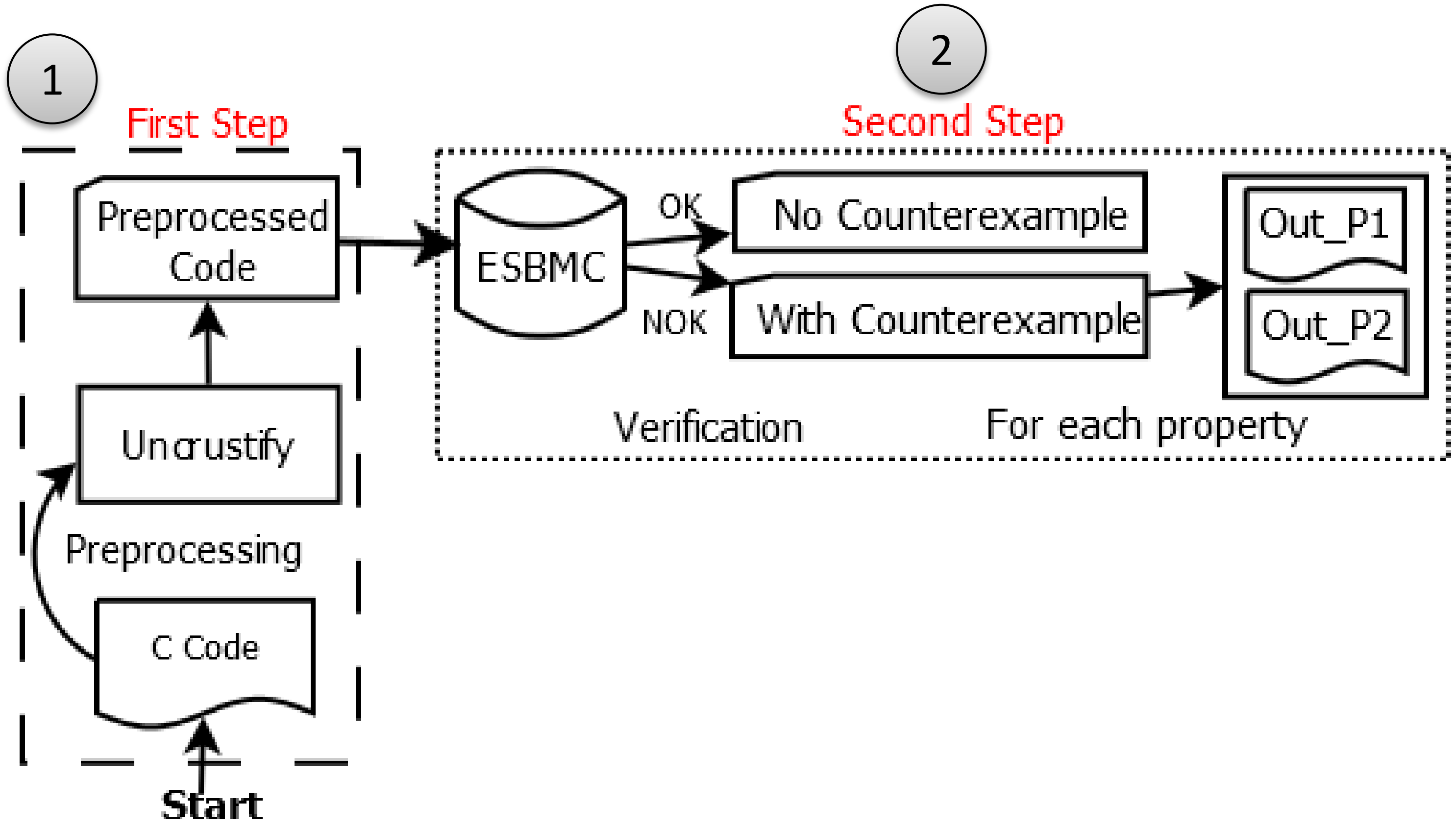
EZProofC

"An easy way to demonstrate and verify errors in C code"



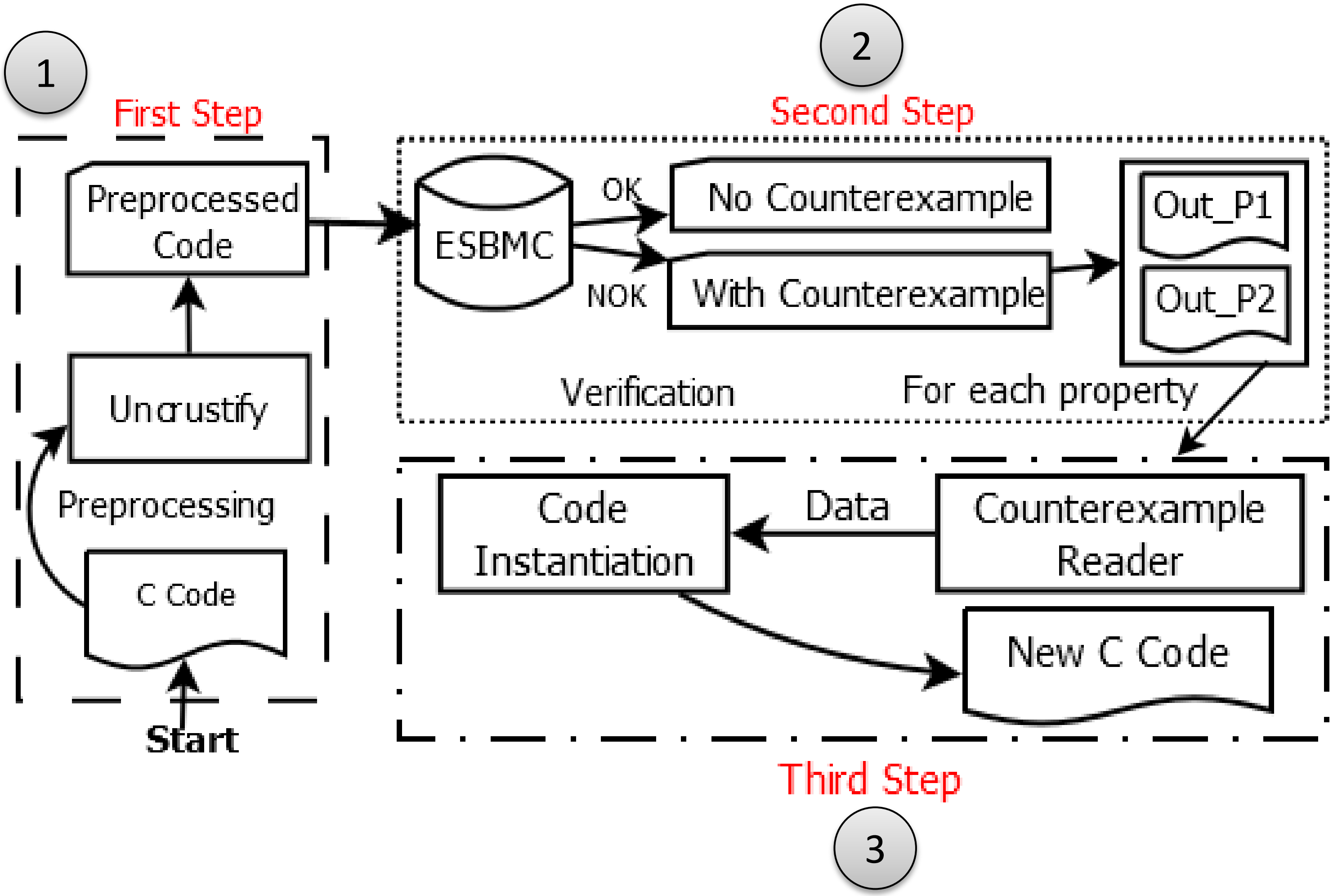
EZProofC

"An easy way to demonstrate and verify errors in C code"



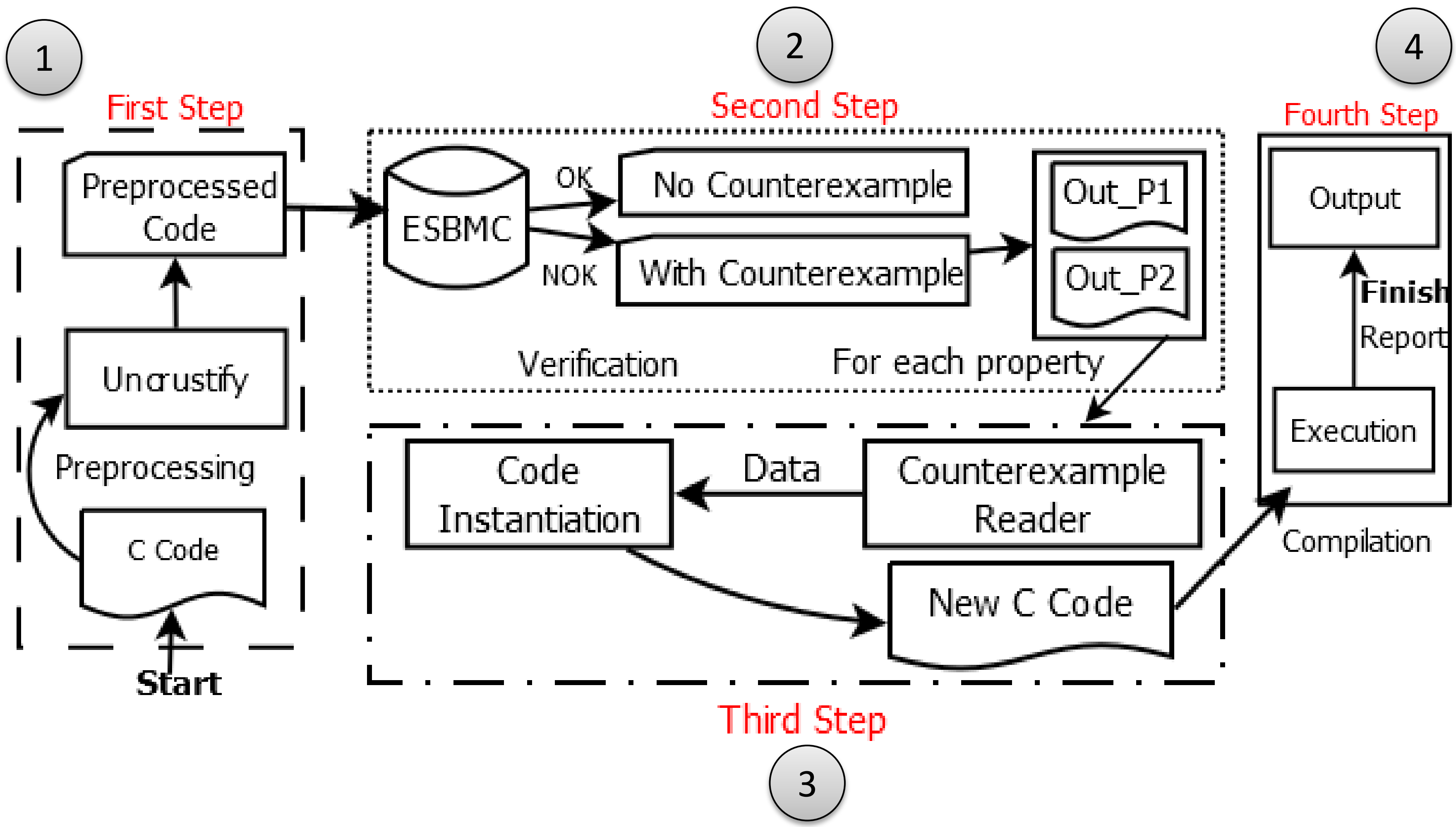
EZProofC

"An easy way to demonstrate and verify errors in C code"



EZProofC

"An easy way to demonstrate and verify errors in C code"



First Step: Code Preprocessing

UNCRUSTIFY

```
#define INSIZE 14
int main (void){
     unsigned char in[INSIZE+1];
     ...
    if (c == `-')
    {
        i=0;
        idx_in++;
        c = in[idx_in];
        while ((`0' <= c) && (c <= `9'))
       {
            j = c - `0';
            i = i * 10 + j;
            idx_in++;
            c = in[idx_in];
        }
    }
}
```

tTflag_arr_two_loops_bad.c
from Verisec benchmark

Second Step: Model Checking with ESBMC

Counterexample:

```
(......)
State 97 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 13 function main thread 0
----------------------------------------------------
  pre_tTflag_arr_two_loops_bad::main::1::i=33 (00000000000000000000000000100001)

State 98 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 14 function main thread 0
----------------------------------------------------
  pre_tTflag_arr_two_loops_bad::main::1::idx_in=15 (00000000000000000000000000001111)

State 93 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 15 function main thread 0
----------------------------------------------------
  pre_tTflag_arr_two_loops_bad::main::1::c=51 (00110011)

Violated property:
  file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 15 function main
  array `in' upper bound
  idx_in < 15

VERIFICATION FAILED
```

Second Step: Model Checking with ESBMC

The line number

```
Counterexample:

(......)
State 97 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 13 function main thread 0
------------------------------------------------
  pre_tTflag_arr_two_loops_bad::main::1::i=33 (00000000000000000000000000100001)

State 98 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 14 function main thread 0
------------------------------------------------
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State 93 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 15 function main thread 0
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  pre_tTflag_arr_two_loops_bad::main::1::c=51 (00110011)

Violated property:
  file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 15 function main
  array `in' upper bound
  idx_in < 15

VERIFICATION FAILED
```

Second Step: Model Checking with ESBMC

Counterexample:

The variables involved

The line number

le.pre/pre_tTflag_arr_two_loops_bad.c line **13** functio ain thread 0

\---

pre_tTflag_arr_two_lo _bad::main::1::i=33 (00000000000000 000000000000000100001)

State 98 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line **14** function main thread 0

\---

pre_tTflag_arr_two_loops_bad::main::1::idx_in=15 (00000000000000000000000000001111)

State 93 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line **15** function main thread 0

\---

pre_tTflag_arr_two_loops_bad::main::1::c=51 (00110011)

Violated property:

file ccode.pre/pre_tTflag_arr_two_loops_bad.c line **15** function main
array `in' upper bound
idx_in < 15

VERIFICATION FAILED

Second Step: Model Checking with ESBMC

Counterexample:

The variables involved

The line number

le.pre/pre_tTflag_arr_two_loops_bad.c line **13** functio main thread 0

---

pre_tTflag_arr_two_loo _bad::main::1::i=33 (0000000000000 0000000000000100001)

State 98 file ccode.pre/pre_tTflag arr_two_loops_bad.c line **14** function main thread 0

---

pre_tTflag_arr_two_loops_bad::main::1::idx_in=15 (00000000000000000000000000001111)

State 93 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line

---

pre_tTflag_arr_two_loops_bad::main::1::c=51 (00110011)

The specific value for variable

Violated property:
file ccode.pre/pre_tTflag_arr_two_loops_bad.c line **15** function main
array `in' upper bound
idx_in < 15

VERIFICATION FAILED

Second Step: Model Checking with ESBMC

Counterexample:

The variables involved

The line number

(
S le.pre/pre_tTflag_arr_two_loops_bad.c line **13** functio nain thread 0
- ----------------------------
pre_tTflag_arr_two_loo _bad::main::1::i=33 (0000000000000 0000000000000100001)

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----
pre_tTflag_arr_two_loops_bad::main::1::c=51 (00110011)

The specific value for variable

Violated property:
file ccode.pre/pre_tTflag_arr_two_loops_bad.c line **15** function main
array `in' upper bound
idx_in < 15

Violated Property

VERIFICATION FAILED

Second Step: Model Checking with ESBMC

```
#define INSIZE 14
int main (void){
    unsigned char in[INSIZE+1];
    ...
   if (c == `-')
   {
      i=0;
      idx_in++;
      c = in[idx_in];
      while ((`0' <= c) && (c <= `9'))
     {
        j = c - `0';
        i = i * 10 + j;
        idx_in++;
        c = in[idx_in];
     }
   }
}
```

Property "***idx_in < 15***" that has been violated

Second Step: Model Checking with ESBMC

```
#define INSIZE 14
int main (void){
    unsigned char in[INSIZE+1];
    ...
   if (c == `-')
   {
      i=0;
      idx_in++;
      c = in[idx_in];
      while ((`0' <= c) && (c <= `9'))
     {
         j = c - `0';
         i = i * 10 + j;
         idx_in++;
         c = in[idx_in];
      }
   }
}
```

Define the BOUND
[0 .. 14]

Property "***idx_in < 15***" that has been violated

Second Step: Model Checking with ESBMC

```
#define INSIZE 14
int main (void){
    unsigned char in[INSIZE+1];
    ...
   if (c == `-')
   {
      i=0;
      idx_in++;
      c = in[idx_in];
      while ((`0' <= c) && (c <= `9'))
     {
         j = c - `0';
         i = i * 10 + j;
         idx_in++;
         c = in[idx_in];
      }
   }
}
```

Define the BOUND [0 .. 14]

Loop doesn't control the value of the variable

Property "***idx_in < 15***" that has been violated

Third Step: Code Instantiation

```
Input: Code, CE_Out
Output: New_instanced_code.c

BEGIN
  Analysis The counter-example (CE_Out) and C program to collect several
      pieces of information
  FOREACH line from the C program
          IF the line number identified (counter-example) is equal to the line
             number of the C program
             IF the violated property is in a set of specific cases
                    Apply a Trigger for a specific case
                    Generate and write a new line using variable values from
                    counter-example
             ELSE Generate and write a new line using variable values from
             counter-example
          ELSE Write the line from the C program
END
```

The runtime complexity is $O(n + m)$

Third Step: Code Instantiation

FIRST PHASE: Collect several pieces of information

Input: Code, CE_Out
Output: New_instanced_code.c

BEGIN
Analysis The counter-example (CE_Out) and C program to collect several pieces of information
FOREACH line from the C program
    IF the line number identified (cou[illegible]xample) is equal to the line number of the C program
        IF the violated property is in a [illegible]
            Apply a Trigger for a specific case
            Generate and write a new line using variable values from counter-example
        ELSE Generate and write a new line using variable values from counter-example
    ELSE Write the line from the C program
END

line = 14, var =idx_in and value = 15

Third Step: Code Instantiation

SECOND PHASE: Generate a new instanced code

```
Input: Code, CE_Out
Output: New_instanced_code.c

BEGIN
  Analysis The counter-example (CE_Out) and C program to collect several
      pieces of information
  FOREACH line from the C program
        IF the line number identified (counter-example) is equal to the line
            number of the C program
            IF the violated property is in a set of specific cases
                  Apply a Trigger for a specific case
                  Generate and write a new line using variable values from
                  counter-example
             ELSE Generate and write a new line using variable values from
             counter-example
        ELSE Write the line from the C program
END
```

Third Step: Code Instantiation

It makes a copy and replaces variables assignments

Input: Code, CE_Out
Output: New_instanced_code.c

BEGIN
  Analysis The counter-example (CE_O...) and C program to collect several pieces of information
  FOREACH line from the C program
    IF the line number identified (counter-example) is equal to the line number of the C program
      IF the vio...
        App...
        Generate ... a new line using variable values from counter-example
      ELSE Generate and write a new line using variable values from counter-example
    ELSE Write the line from the C program
END

CE: line = 14, var =idx_in and value = 15
New Line: idx_in = 15;

Third Step: Code Instantiation

```
Input: Code, CE_Out
Output: New_instanced_code.c

BEGIN
    Analysis The counter-example (CE_Out) and C program to collect several
        pieces of information
    FOREACH line from the C program
            IF the line number identified (counter-example) is equal to the line
               number of the C program
               IF the violated property is in a set of specific cases
                    Apply a Trigger for a specific case
                    Generate and write a new line using variable values from
                    counter-example
                ELSE Generate and write a new line using variable values from
                counter-example
            ELSE Write the line from the C program
END
```

UPPER BOUND

Assert(idx_in < 15);

Third Step: Code Instantiation

```
#define INSIZE 14
int main (void){
    unsigned char in[INSIZE+1];
    ...
    if (c == `-')
    {
        i=0;
        idx_in= 9 ; //<- by EZProofC
        c =48 ; //<- by EZProofC
        while ((`0' <= c) && (c <= `9'))
        {
            j =3 ; //<- by EZProofC
            i =33 ; //<- by EZProofC
            idx_in= 15 ; //<- by EZProofC
            assert(idx_in<15); //<- by EZProofC
            c =51 ; //<- by EZProofC
        }
    }
}
```

Directly from the counter-example

Fourth Step: Code execution and confirmation of errors

Module	Result of the Execution
newz_tTflag_arr_two_loops_bad.c	Line:15:main:Assertion & ‘idx in<15’ failed. Aborted

```
Counterexample:

(......)
State 97 file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 13 function main thread 0
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  pre_tTflag_arr_two_loops_bad::main::1::i=33 (00000000000000000000000000100001)

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  pre_tTflag_arr_two_loops_bad::main::1::c=51 (00110011)

Violated property:
  file ccode.pre/pre_tTflag_arr_two_loops_bad.c line 15 function main
  array `in' upper bound
  idx_in < 15

VERIFICATION FAILED
```

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4. **Experimental Results**
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Planning and Design the Experiments

In order to evaluate the proposed method:

- ✓ We considered **211** ANSI-C programs
- ✓ Six different ANSI-C programs benchmarks:
  EUREKA, SNU, WCET, NEC, Siemens (SIR) and CBMC (C bounded model checker) tutorial.

During this empirical evaluation:

(1) Application of the EZProofC method;

(2) Application of the tool Frama-C with value analysis plug-in

frama-c -val <file.c>

(3) Application of the tool Frama-C with the plug-in Jessie

frama-c -jessie -jessie-atp=z3 <file.c>

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	
1	bf5_20.c	49	6	<1s	33	<1s	<60s	0	-	0
2	bubble_sort1_13.c	51	2	<1s	25	<1s	<15s	0	-	0
3	fibonacci1_13.c	25	1	<1s	1	<1s	<1s	0	-	0
4	init_sel_sort1_13.c	54	2	<1s	25	<1s	<15s	0	-	0
5	minmax1_13.c	19	6	<1s	9	<1s	<3s	0	-	0
6	n_k_gray_codes1_13.c	45	36	<1s	22	<1s	<120s	0	-	11
7	prim4_8.c	79	12	<1s	30	<1s	<60s	0	-	3
8	selection_sort1_13.c	54	2	<1s	25	<1s	<15s	0	-	0
9	crc_det.c	125	1	<1s	15	<1s	≈840s	0	-	1
10	cnt_nondet.c	139	0	<1s	16	<1s	<60s	0	-	0
11	minmax_unsafe1_13.c	19	6	<1s	9	<1s	<4s	1	16	0
12	no_init_bubble_sort_safe1_13.c	25	2	<1s	14	<1s	<7s	1	32	1
13	no_init_sel_sort1_13.c	41	5	<1s	25	<1s	<15s	12	144	3
14	no_init_sel_sort_safe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
15	no_init_sel_sort_unsafe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
16	strcmp1_13.c	15	4	<1s	6	<1s	≈14400s	3	80	0
17	sum1_13.c	21	1	<1s	1	<1s	<1s	1	48	0
18	sum_array1_13.c	11	1	<1s	7	<1s	<3s	1	8	0
19	D_CBMC_assert_unsafy.c	15	4	<1s	1	<1s	<1s	1	24	0
20	D_CBMC_bound_array.c	16	2	<1s	10	<1s	<10s	1	30	1
21	D_CBMC_division_by_zero.c	32	3	<1s	1	<1s	<1s	1	24	1
22	ex26.c	29	4	<1s	8	<1s	≈420s	2	1236	1
23	select_det.c	122	3	<1s	39	<1s	≈14400s	3	40	1
24	Siemens_print_tokens2.c	508	90	<1s	51	<1s	≈18000s	1	3344	34

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	

C Program name

LOC

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	

Number of Warnings

Execution time of Frama-C with Value Analysis plug-in

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	

#P: Number of Properties

TC: Time - Properties Identification

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	

Time spent by ESBMC

Counterexample LOC

Violated Properties

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	

Claims in common between EZProofC and Frama-C

EZProofC tool are available at :
https://sites.google.com/site/ezproofc/

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	
1	bf5_20.c	49	6	<1s	33	<1s	<60s	0	-	0
2	bubble_sort1_13.c	51	2	<1s	25	<1s	<15s	0	-	0
3	fibonacci1_13.c	25	1	<1s	1	<1s	<1s	0	-	0
4	init_sel_sort1_13.c	54	2	<1s	25	<1s	<15s	0	-	0
5	minmax1_13.c	19	6	<1s	9	<1s	<3s	0	-	0
6	n_k_gray_codes1_13.c	45	36	<1s	22	<1s	<120s	0	-	11
7	prim4_8.c	79	12	<1s	30	<1s	<60s	0	-	3
8	selection_sort1_13.c	54	2	<1s	25	<1s	<15s	0	-	0
9	crc_det.c	125	1	<1s	15	<1s	≈840s	0	-	1
10	cnt_nondet.c	139	0	<1s	16	<1s	<60s	0	-	0

EZProofC did not find any violated property

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	
11	minmax_unsafe1_13.c	19	6	<1s	9	<1s	<4s	1	16	0
12	no_init_bubble_sort_safe1_13.c	25	2	<1s	14	<1s	<7s	1	32	1
13	no_init_sel_sort1_13.c	41	5	<1s	25	<1s	<15s	12	144	3
14	no_init_sel_sort_safe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
15	no_init_sel_sort_unsafe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
16	strcmp1_13.c	15	4	<1s	6	<1s	≈14400s	3	80	0
17	sum1_13.c	21	1	<1s	1	<1s	<1s	1	48	0
18	sum_array1_13.c	11	1	<1s	7	<1s	<3s	1	8	0
19	D_CBMC_assert_unsafy.c	15	4	<1s	1	<1s	<1s	1	24	0
20	D_CBMC_bound_array.c	16	2	<1s	10	<1s	<10s	1	30	1
21	D_CBMC_division_by_zero.c	32	3	<1s	1	<1s	<1s	1	24	1
22	ex26.c	29	4	<1s	8	<1s	≈420s	2	1236	1
23	select_det.c	122	3	<1s	39	<1s	≈14400s	3	40	1
24	Siemens_print_tokens2.c	508	90	<1s	51	<1s	≈18000s	1	3344	34

All possible scenarios in terms of LOC???

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	
11	minmax_unsafe1_13.c	19	6	<1s	9	<1s	<4s	1	16	0
12	no_init_bubble_sort_safe1_13.c	25	2	<1s	14	<1s	<7s	1	32	1
13	no_init_sel_sort1_13.c	41	5	<1s	25	<1s	<15s	12	144	3
14	no_init_sel_sort_safe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
15	no_init_sel_sort_unsafe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
16	strcmp1_13.c	15	4	<1s	6	<1s	≈14400s	3	80	0
17	sum1_13.c	21	1	<1s	1	<1s	<1s	1	48	0
18	sum_array1_13.c	11	1	<1s	7	<1s	<3s	1	8	0
19	D_CBMC_assert_unsafy.c	15	4	<1s	1	<1s	<1s	1	24	0
20	D_CBMC_bound_array.c	16	2	<1s	10	<1s	<10s	1	30	1
21	D_CBMC_division_by_zero.c	32	3	<1s	1	<1s	<1s	1	24	1
22	ex26.c	29	4	<1s	8	<1s	≈420s	2	1236	1
23	select_det.c	122	3	<1s	39	<1s	≈14400s	3	40	1
24	Siemens_print_tokens2.c	508	90	<1s	51	<1s	≈18000s	1	3344	34

Frama-C X EZProofC

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	
11	minmax_unsafe1_13.c	19	6	<1s	9	<1s	<4s	1	16	0
12	no_init_bubble_sort_safe1_13.c	25	2	<1s	14	<1s	<7s	1	32	1
13	no_init_sel_sort1_13.c	41	5	<1s	25	<1s	<15s	12	144	3
14	no_init_sel_sort_safe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
15	no_init_sel_sort_unsafe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
16	strcmp1_13.c	15	4	<1s	6	<1s	≈14400s	3	80	0
17	sum1_13.c	21	1	<1s	1	<1s	<1s	1	48	0
18	sum_array1_13.c	11	1	<1s	7	<1s	<3s	1	8	0
19	D_CBMC_assert_unsafy.c	15	4	<1s	1	<1s	<1s	1	24	0
20	D_CBMC_bound_array.c	16	2	<1s	10	<1s	<10s	1	30	1
21	D_CBMC_division_by_zero.c	32	3	<1s	1	<1s	<1s	1	24	1
22	ex26.c	29	4	<1s	8	<1s	≈420s	2	1236	1
23	select_det.c	122	3	<1s	39	<1s	≈14400s	3	40	1
24	Siemens_print_tokens2.c	508	90	<1s	51	<1s	≈18000s	1	3344	34

Frama-C X EZProofC

Why??
Values Analysis plug-in

Experiment's Execution and Results Analysis

ID	Module	#L	Frama-C		EZProofC/ESBMC					SC and SW
			#W	TW	#P	TC	TV	#V	CE	
11	minmax_unsafe1_13.c	19	6	<1s	9	<1s	<4s	1	16	0
12	no_init_bubble_sort_safe1_13.c	25	2	<1s	14	<1s	<7s	1	32	1
13	no_init_sel_sort1_13.c	41	5	<1s	25	<1s	<15s	12	144	3
14	no_init_sel_sort_safe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
15	no_init_sel_sort_unsafe1_13.c	28	5	<1s	14	<1s	<7s	1	32	3
16	strcmp1_13.c	15	4	<1s	6	<1s	≈14400s	3	80	0
17	sum1_13.c	21	1	<1s	1	<1s	<1s	1	48	0
18	sum_array1_13.c	11	1	<1s	7	<1s	<3s	1	8	0
19	D_CBMC_assert_unsafy.c	15	4	<1s	1	<1s	<1s	1	24	0
20	D_CBMC_bound_array.c	16	2	<1s	10	<1s	<10s	1	30	1
21	D_CBMC_division_by_zero.c	32	3	<1s	1	<1s	<1s	1	24	1
22	ex26.c	29	4	<1s	8	<1s	≈420s	2	1236	1
23	select_det.c	122	3	<1s	39	<1s	≈14400s	3	40	1
24	Siemens_print_tokens2.c	508	90	<1s	51	<1s	≈18000s	1	3344	34

Jessie plug-in??

Frama-C X EZProofC

Why??
Values Analysis plug-in

Agenda

1. Introduction
2. Background
3. Proposed Method
4. Experimental Results
5. Related Work
6. Conclusions and Future Work

Related Work

- ✓ Ji et al.: **Design and Implementation of Retargetable Software Debugger Based on GDB**. In: Intl. Conf. on Convergence and Hybrid Information Technology (CHIT). 2008.
  - Fixed entry values X Tests exhautively

- ✓ Taghdiri, M.: **Inferring Specifications to Detect Errors in Code**. In: Intl. Conf. on Automated Software Engineering (ASE). 2004.
  - SAT solver X SMT solver
  - Drawback: Solving only structural properties (constrain configuration)

Related Work

- ✓ Cousot et al.: **The ASTRÉE analyzer**. In: Programming Languages and Systems (PLS). 2005.
  - Analyzes structured C programs, **BUT without** dynamic memory allocation and recursion
  - EZProofC provides support for structures **not supported** by Astrée

Agenda

1. Introduction
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Conclusions and Future Work

Proposed Method

- ✓ To help developers **not familiar** with formal verification techniques (find failures);
- ✓ EZProofC is a completely automatic method that **does not need to write specifications**;
- ✓ The experimental results have shown to be very effective over publicly available benchmarks;

Conclusions and Future Work

Future Work

- ✓ Verification with simplifications in the model (e.g. **function-by-function verification**);
- ✓ We intend to extend our experiments to **evaluate the usability** of the proposed method;
- ✓ We also plan to adapt the proposed method to use **other model checkers** (Blast and Java PathFinder) that rely on other abstraction techniques.

Questions ??

Thank you for your attention!

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