FuSeBMC_IA

FuSeBMC_IA : Interval Analysis and Methods for Test-case Generation

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FuSeBMC IA Team

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Motivation

Software testing is one of the most crucial phases in software development. Tests often expose critical bugs in software applications.

Abstract Interpretation

Bounded Model Checking

Fuzzing

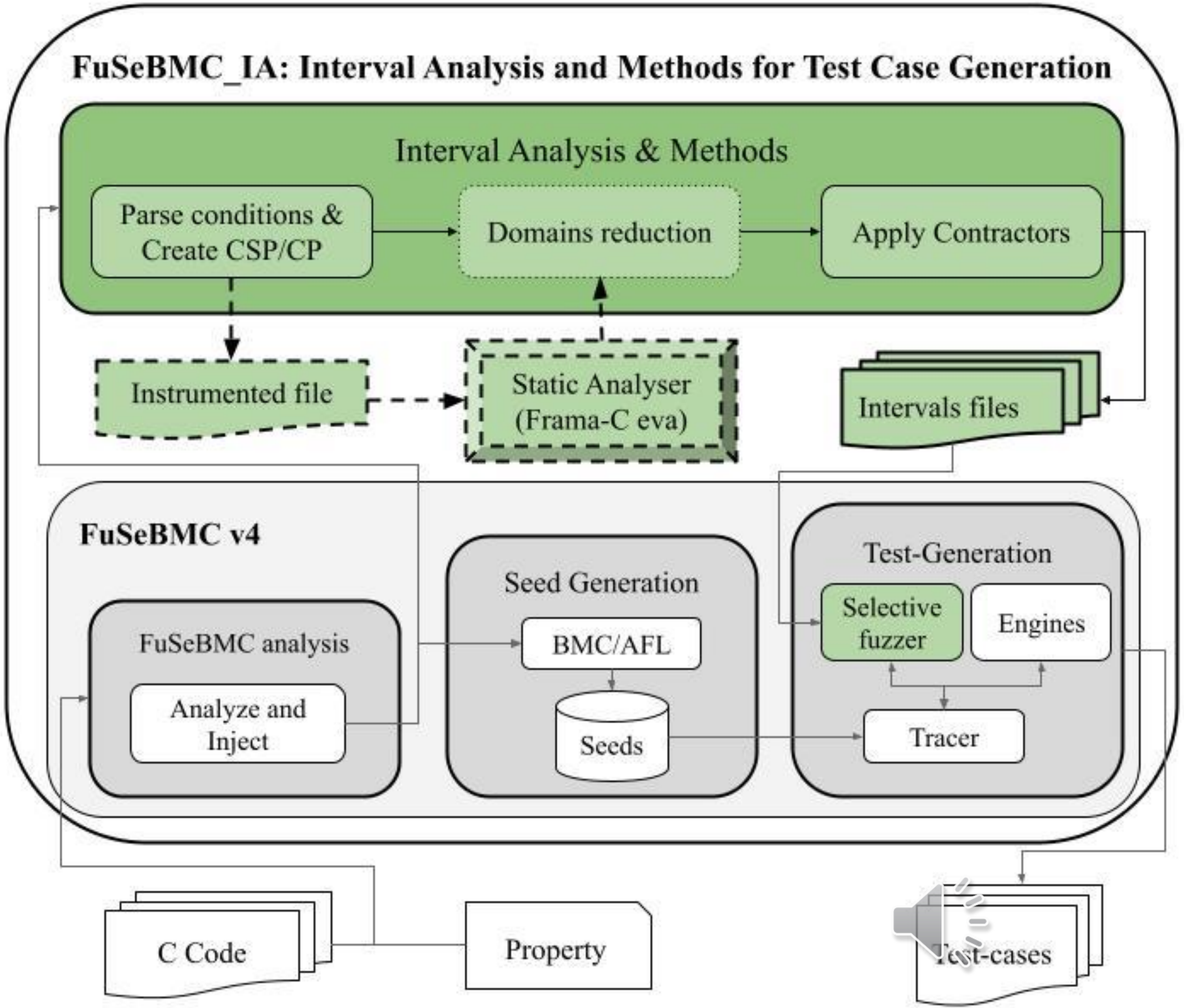
- Combine different techniques to produce various test-cases.
- Desire to optimize the current version of FuSeBMC in terms of time by pruning the search space.

FuSeBMC_IA

We propose FuSeBMC_IA, a test case generator that relies on Abstract Interpretation and Interval Analysis and Methods to improve the selective fuzzer by pruning the search space for the fuzzer.

FuSeBMC_IA Framework

- Built on top of FuSeBMC v4
- Utilizes Abstract interpretation to extract accurate intervals.
- Applies Interval Methods (Contractor) to prune the search space for the Selective fuzzer.



FuSeBMC_IA: Interval Analysis and Methods for Test Case Generation

Interval Analysis & Methods

Parse conditions & Create CSP/CP

Domains reduction

Apply Contractors

Instrumented file

Static Analyser (Frama-C eva)

Intervals files

FuSeBMC v4

FuSeBMC analysis

Analyze and Inject

Seed Generation

BMC/AFL

Seeds

Test-Generation

Selective fuzzer

Engines

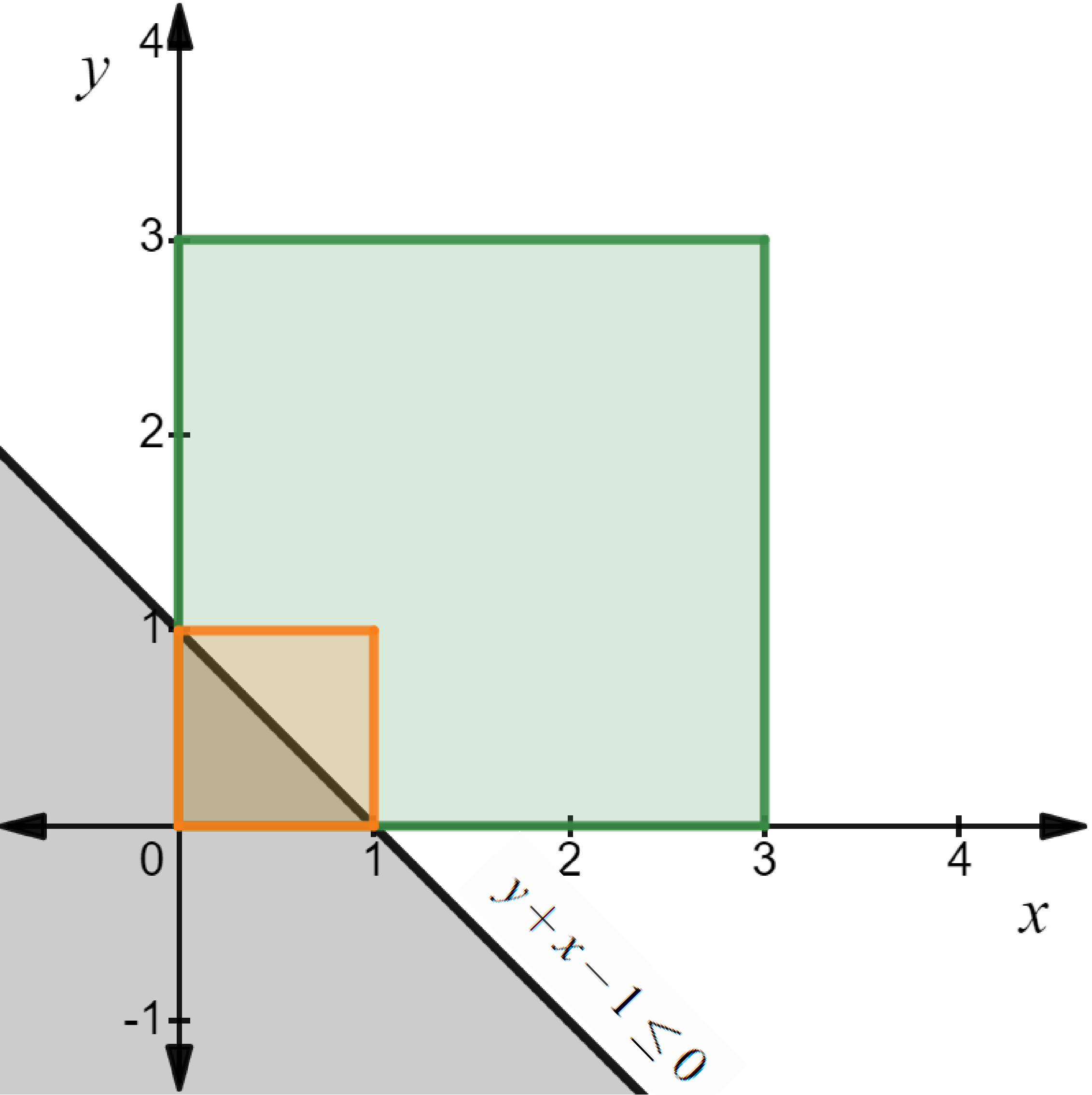
Tracer

C Code

Property

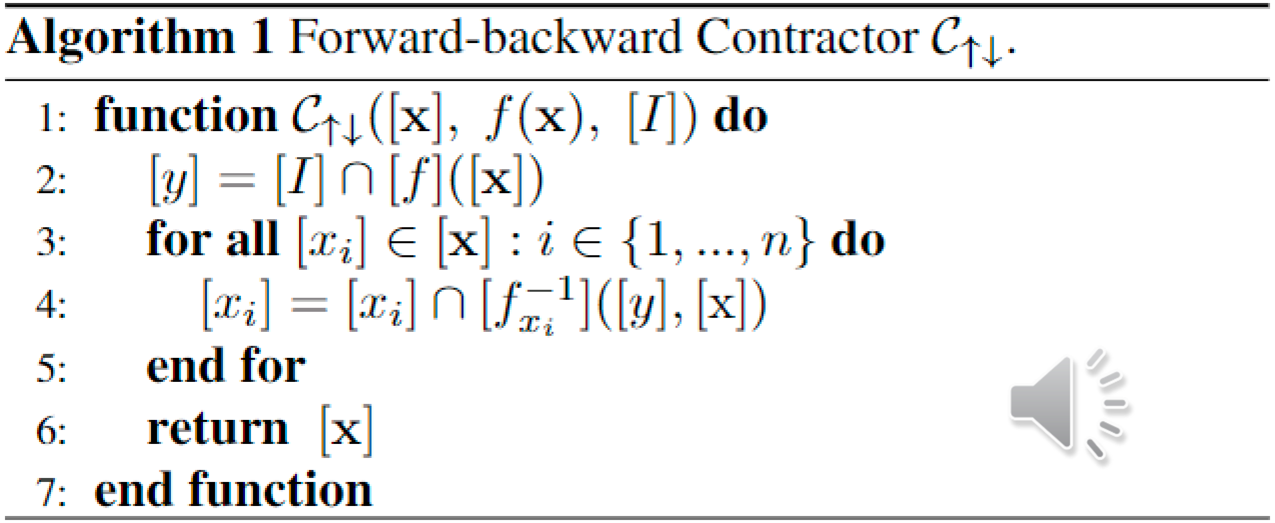
Test-cases

Forward-Backward Contractors



Forward-backward Contractor is an interval method that is applied to a Constraint Satisfaction Problem with one single constraint; it contracts in two steps: forward evaluation and backward propagation.

$$C([X]) \subseteq [X]$$

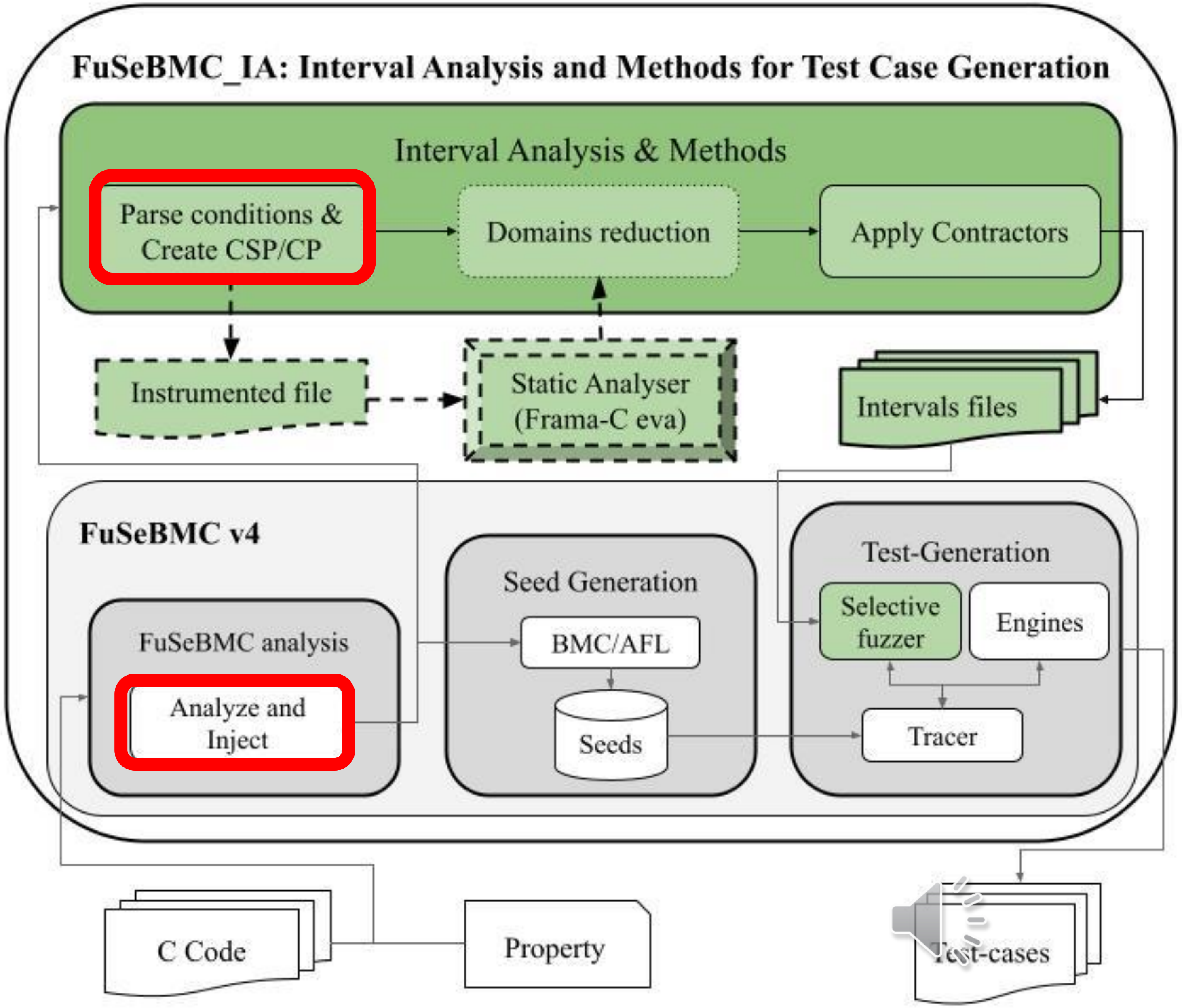


Algorithm 1 Forward-backward Contractor $\mathcal{C}_{\uparrow\downarrow}$.

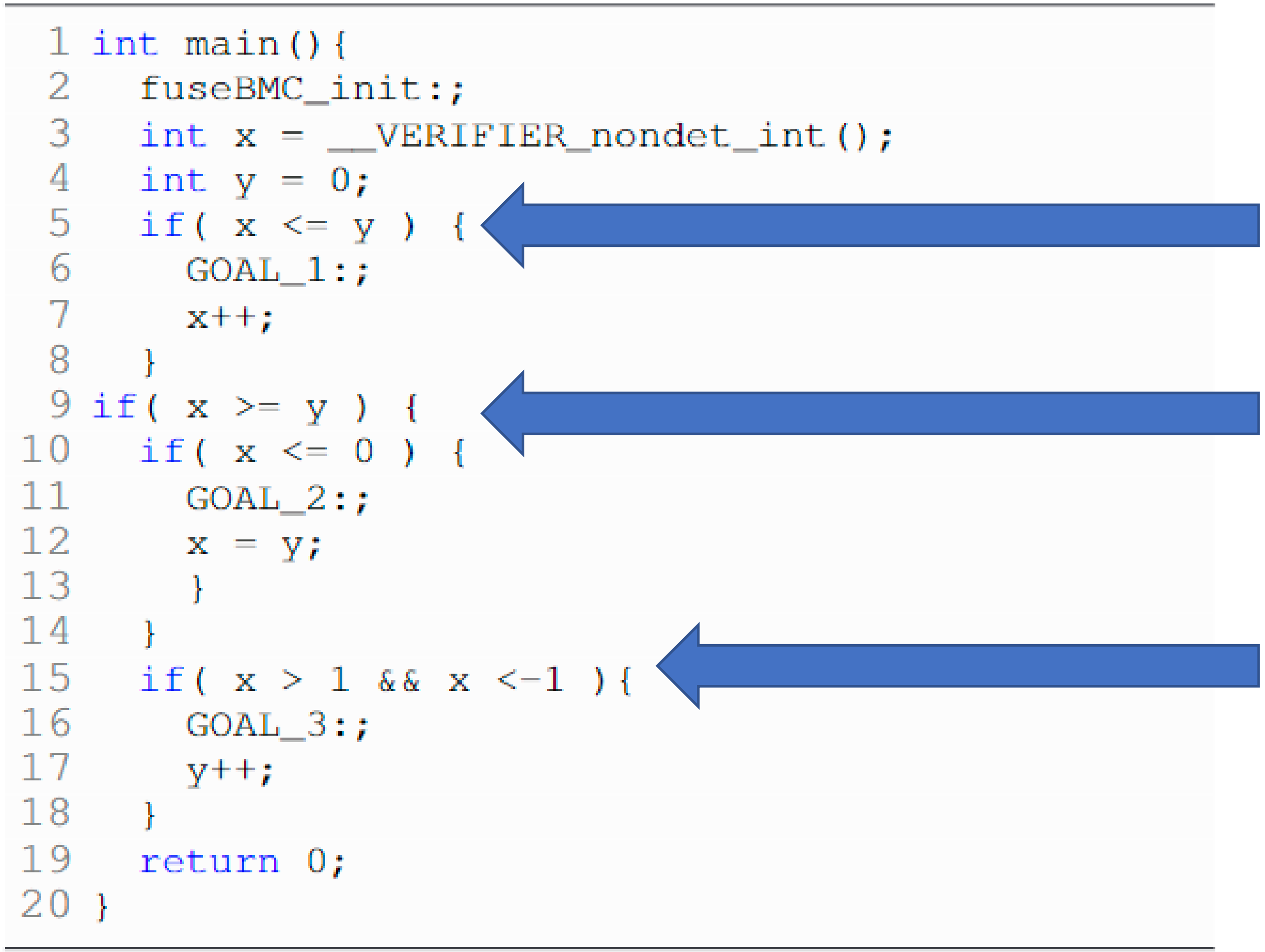
```
function $\mathcal{C}_{\uparrow\downarrow}([\mathrm{x}],\ f(\mathrm{x}),\ [I])$ do
    $[y] = [I] \cap [f]([\mathrm{x}])$
    for all $[x_i] \in [\mathrm{x}] : i \in \{1, ..., n\}$ do
        $[x_i] = [x_i] \cap [f_{x_i}^{-1}]([y], [\mathrm{x}])$
    end for
    return $[\mathrm{x}]$
end function
```

FuSeBMC_IA Framework

- Starting with FuSeBMC analysis. (Goals Instrumented)
- We parse the conditions leading to each goal to create a Constraint Satisfaction Problem.
- Produce an instrumented file to Frama-C



Creating Contractors



```
int main(){
  fuseBMC_init:;
  int x = __VERIFIER_nondet_int();
  int y = 0;
  if( x <= y ) {
    GOAL_1:;
    x++;
  }
if( x >= y ) {
  if( x <= 0 ) {
    GOAL_2:;
    x = y;
    }
  }
  if( x > 1 && x <-1 ){
    GOAL_3:;
    y++;
  }
  return 0;
}
```

File Instrumented by FuSeBMC analysis

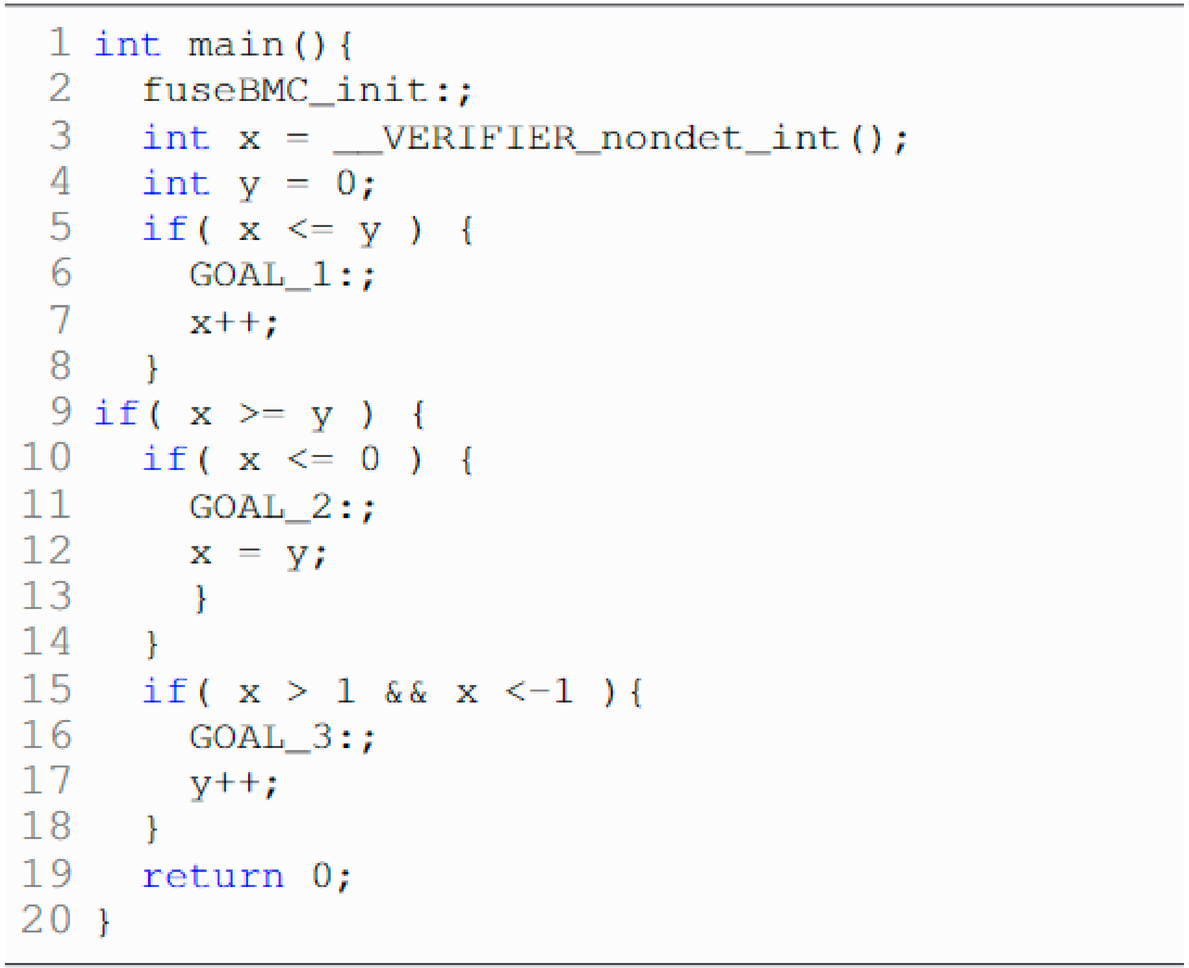
$X$is an interval vector or a box

$C_1(X)$constraint is $x - y \leq 0$

$C_2(X)$ is a composition of two contractors:
$C_{2.1}(X)$ with constraint $y - x < 0$
$C_{2.2}(X)$ with constraint $x \leq 0$
$C_2(X) = C_{2.1}(X) \cap C_{2.2}(X)$

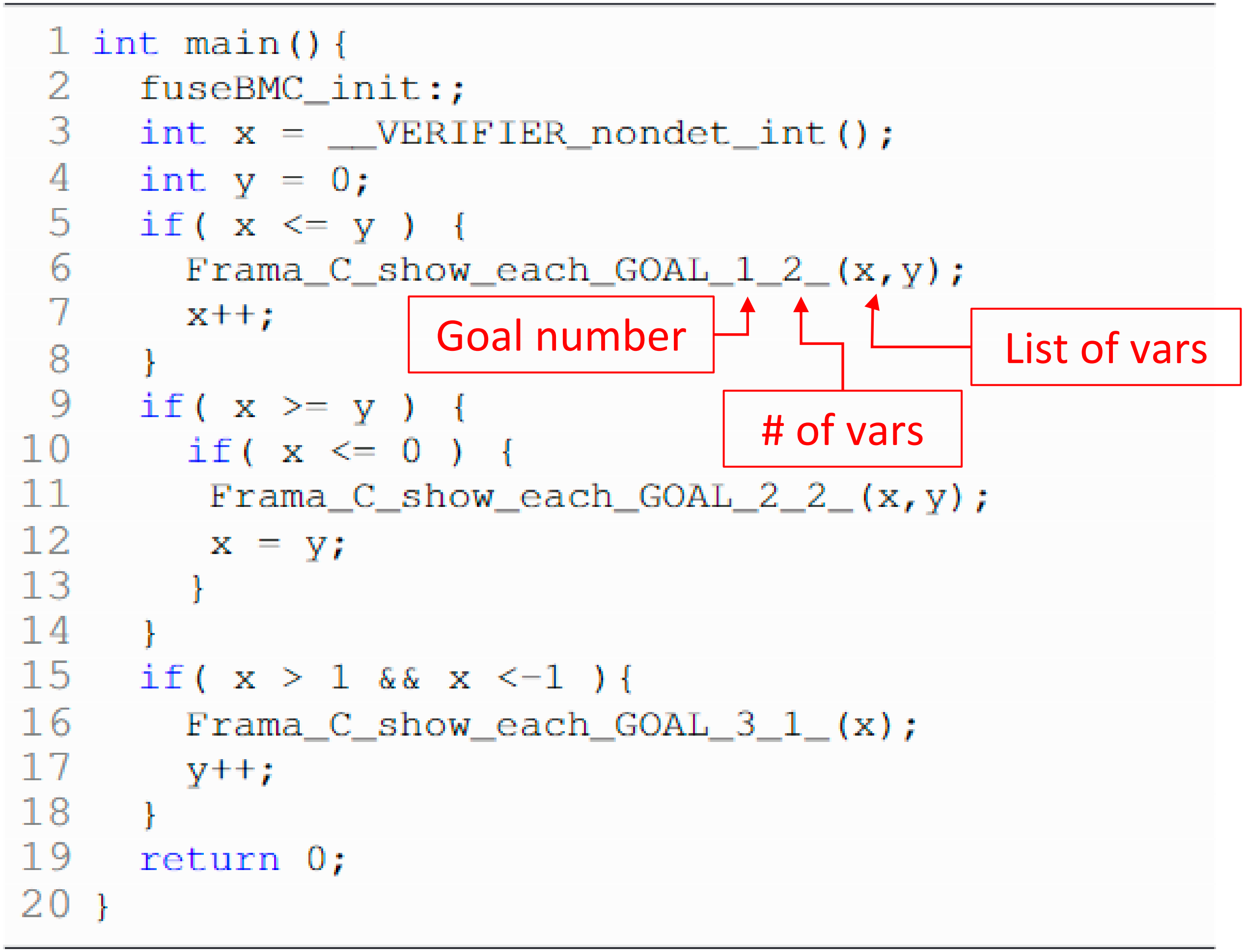
$C_3(X)$ is also a composition of two contractors:
$C_{3.1}(X)$ with constraint $1 - x \leq 0$
$C_{3.2}(X)$ with constraint $x + 1 < 0$
$C_3(X) = C_{3.1}(X) \cap C_{3.2}(X)$

Frama-C instrumentation



```
int main(){
  fuseBMC_init:;
  int x = __VERIFIER_nondet_int();
  int y = 0;
  if( x <= y ) {
    GOAL_1:;
    x++;
  }
if( x >= y ) {
  if( x <= 0 ) {
    GOAL_2:;
    x = y;
    }
  }
  if( x > 1 && x <-1 ){
    GOAL_3:;
    y++;
  }
  return 0;
}
```

File Instrumented by FuSeBMC analysis

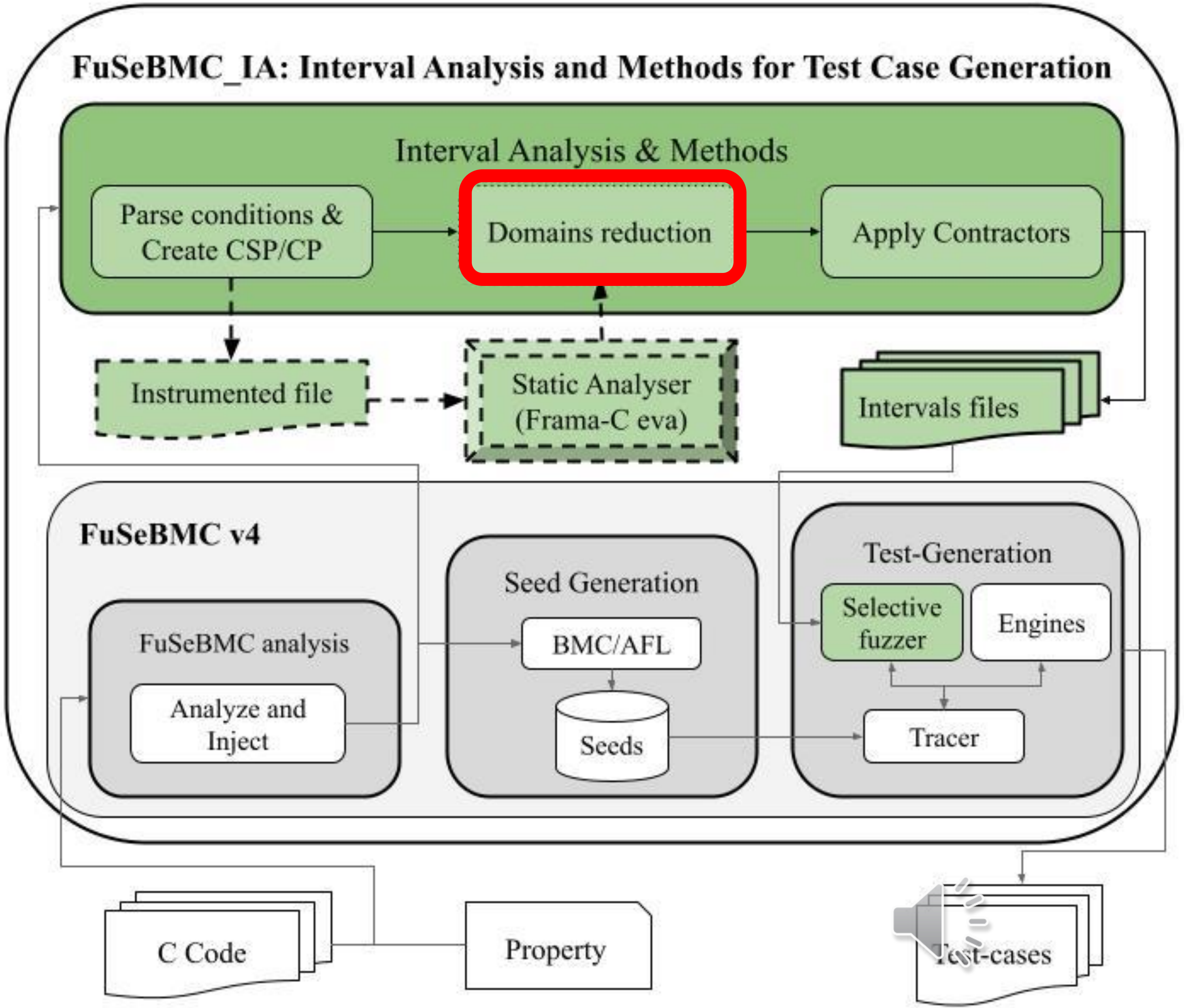


```
int main(){
  fuseBMC_init:;
  int x = __VERIFIER_nondet_int();
  int y = 0;
  if( x <= y ) {
    Frama_C_show_each_GOAL_1_2_(x,y);
    x++;
  }
  if( x >= y ) {
    if( x <= 0 ) {
     Frama_C_show_each_GOAL_2_2_(x,y);
     x = y;
    }
  }
  if( x > 1 && x <-1 ){
    Frama_C_show_each_GOAL_3_1_(x);
    y++;
  }
  return 0;
}
```

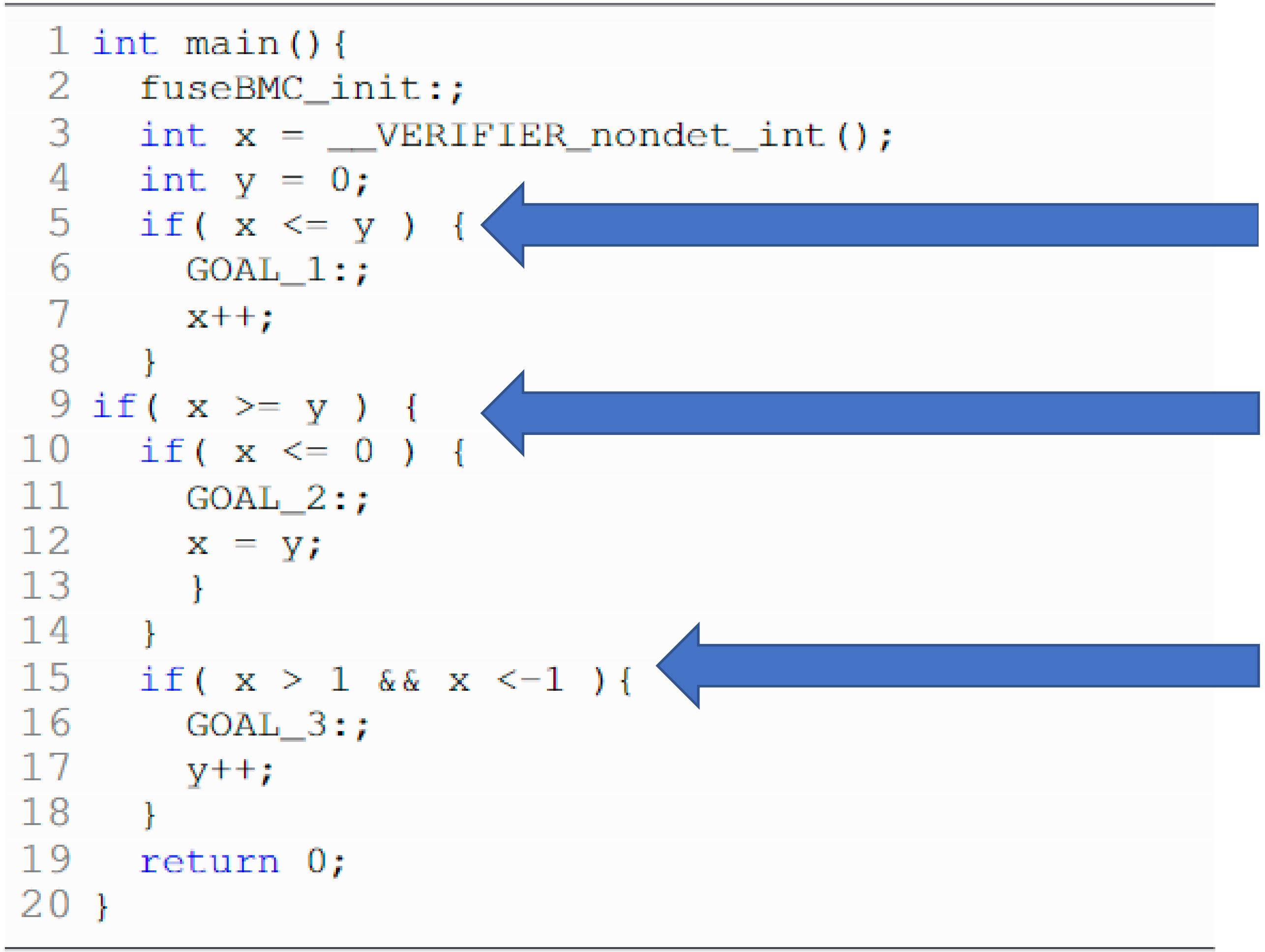
File Instrumented to be run in Frama-C

FuSeBMC_IA Framework

- Run Frama-C with the instrumented file
- Parse the output of Frama-C and update intervals



Frama-C instrumentation



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int main(){
  fuseBMC_init:;
  int x = __VERIFIER_nondet_int();
  int y = 0;
  if( x <= y ) {
    GOAL_1:;
    x++;
  }
if( x >= y ) {
  if( x <= 0 ) {
    GOAL_2:;
    x = y;
    }
  }
  if( x > 1 && x <-1 ){
    GOAL_3:;
    y++;
  }
  return 0;
}
```

File Instrumented by FuSeBMC analysis

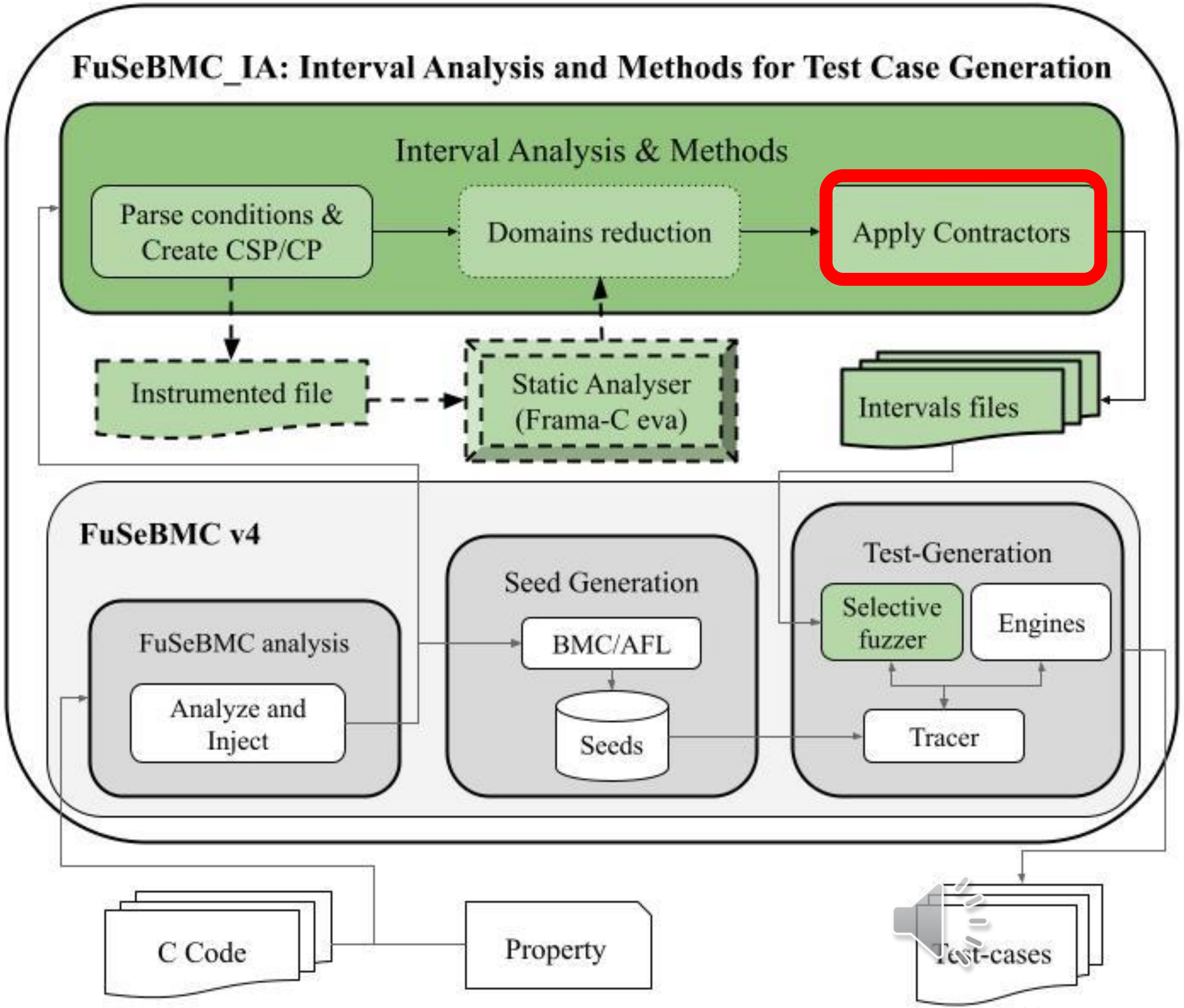
$[x] = (-\infty, \infty)$ reduced to $[-2147483648, 2147483647]$
$[y] = (-\infty, \infty)$ reduced to $[0, 0]$

$[x] = (-\infty, \infty)$ reduced to $[-2147483648, 2147483647]$
$[y] = (-\infty, \infty)$ reduced to $[0, 0]$

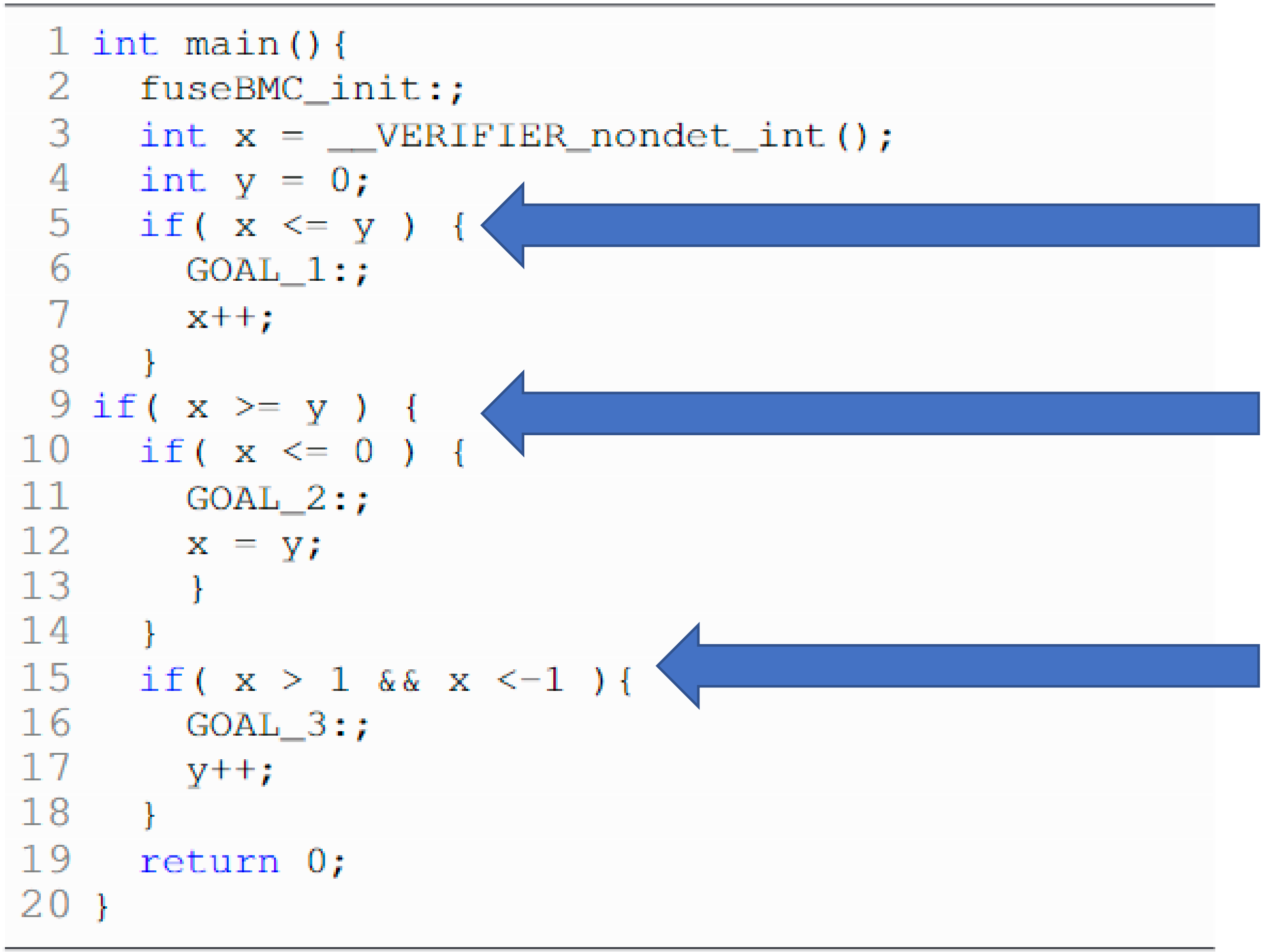
$[x] = (-\infty, \infty)$ reduced to $[-2147483648, 2147483647]$

FuSeBMC_IA Framework

- Apply Contractors for each goal.
- Produce a file with each goal and variables intervals



Apply Contractor



```
int main(){
  fuseBMC_init:;
  int x = __VERIFIER_nondet_int();
  int y = 0;
  if( x <= y ) {
    GOAL_1:;
    x++;
  }
if( x >= y ) {
  if( x <= 0 ) {
    GOAL_2:;
    x = y;
    }
  }
  if( x > 1 && x <-1 ){
    GOAL_3:;
    y++;
  }
  return 0;
}
```

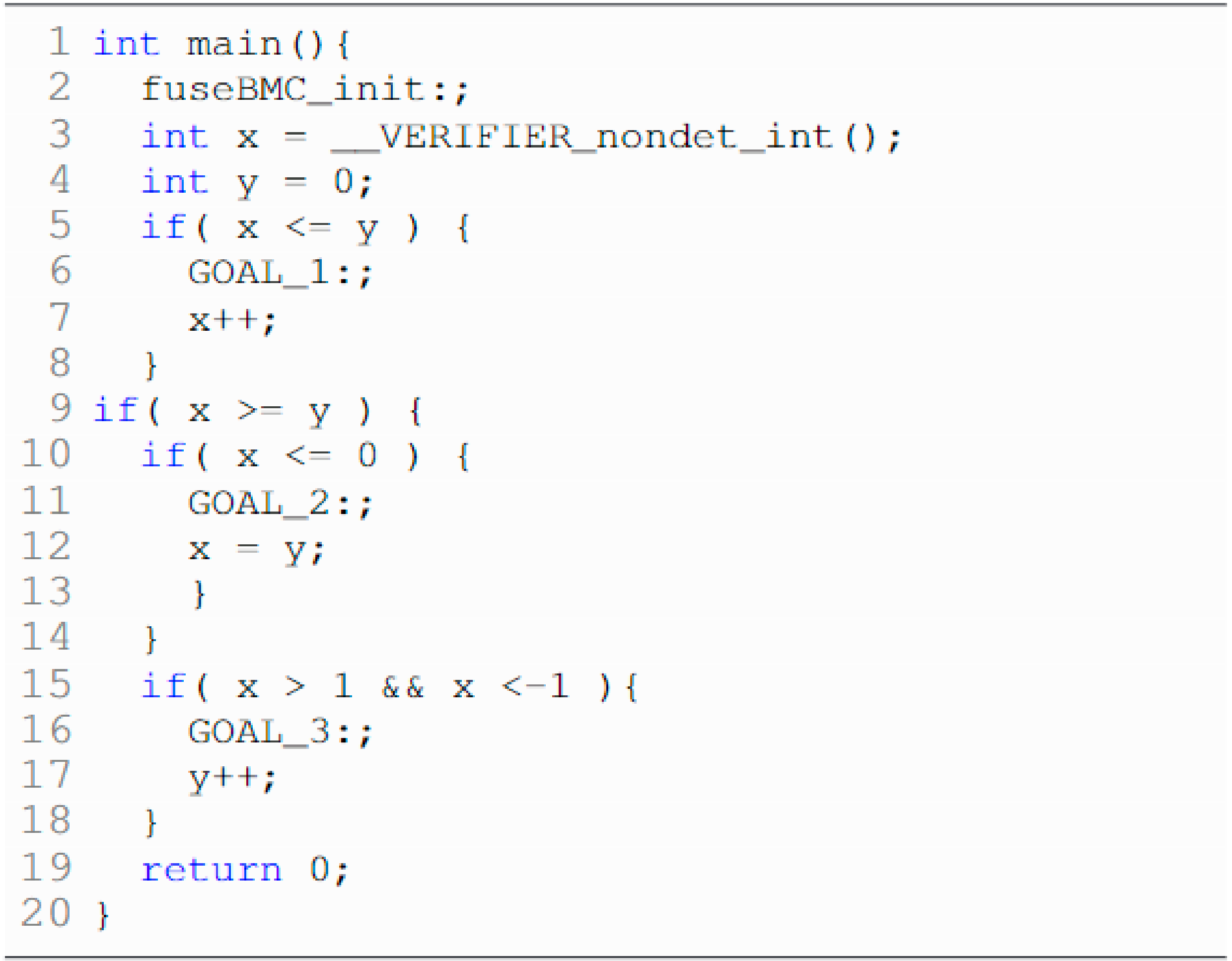
File Instrumented by FuSeBMC analysis

$$[X] = [[-2147483648, 2147483647], [0,0]]$$
$$C_1(X) = [[-2147483648, 0], [0,0]]$$

$$[X] = [[-2147483648, 2147483647], [0,0]]$$
$$C_2(X) = [[0,0], [0,0]]$$

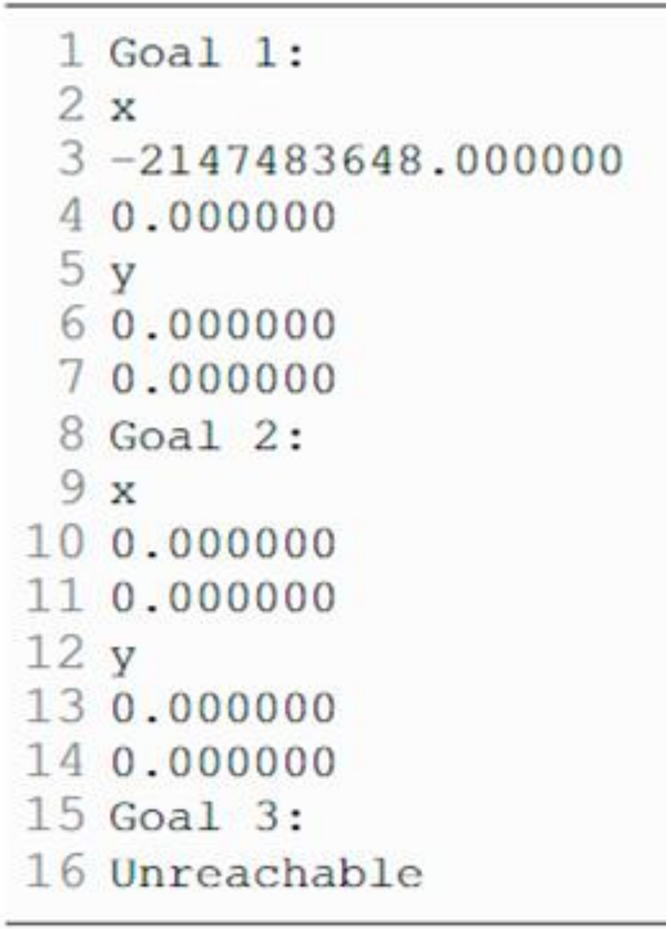
$$[X] = [-2147483648, 2147483647]$$
$$C_3(X) = \phi$$

Produced File



```
int main(){
  fuseBMC_init:;
  int x = __VERIFIER_nondet_int();
  int y = 0;
  if( x <= y ) {
    GOAL_1:;
    x++;
  }
if( x >= y ) {
  if( x <= 0 ) {
    GOAL_2:;
    x = y;
    }
  }
  if( x > 1 && x <-1 ){
    GOAL_3:;
    y++;
  }
  return 0;
}
```

File Instrumented by FuSeBMC analysis

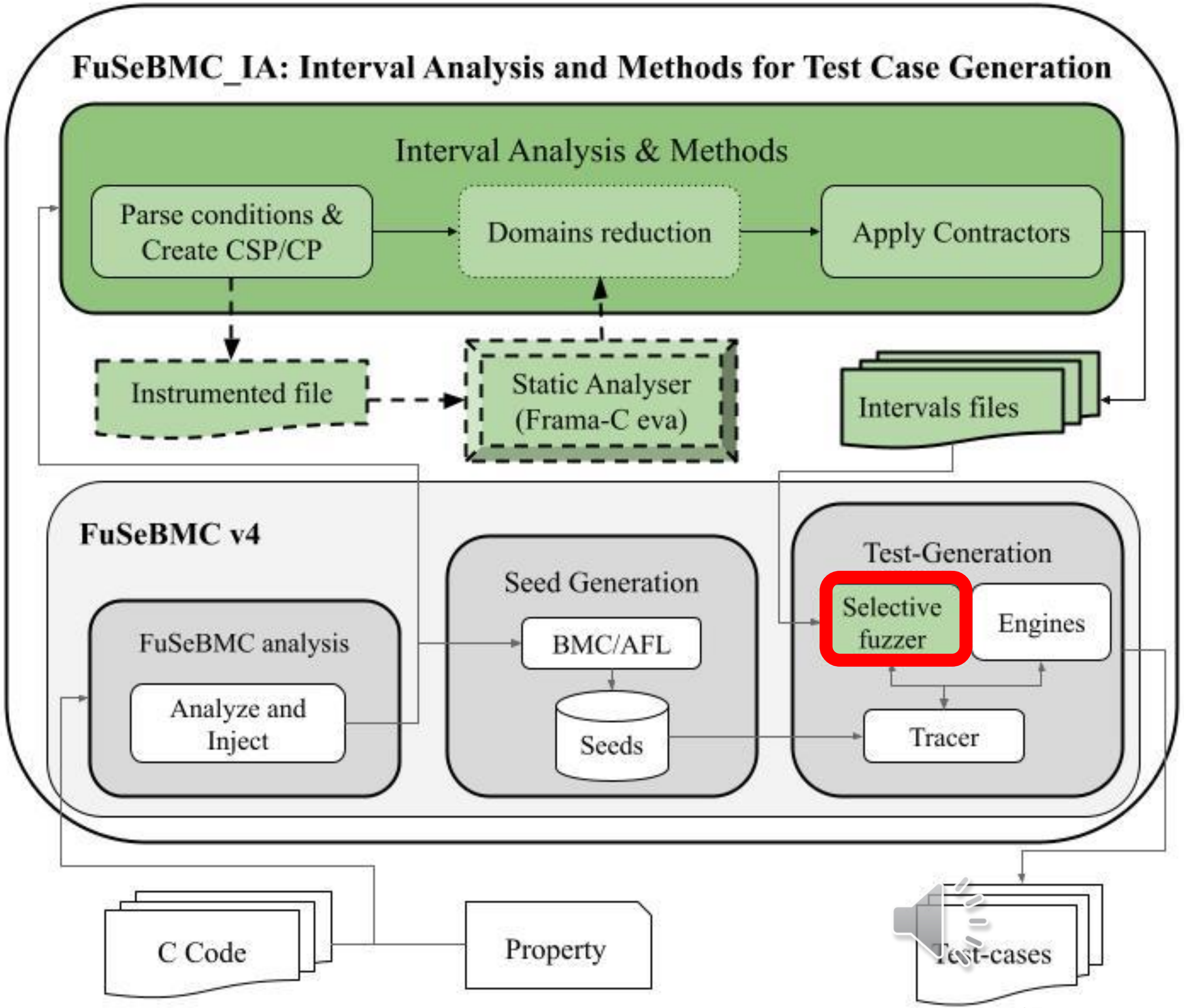


```
Goal 1:
x
-2147483648.000000
0.000000
y
0.000000
0.000000
Goal 2:
x
0.000000
0.000000
y
0.000000
0.000000
Goal 3:
Unreachable
```

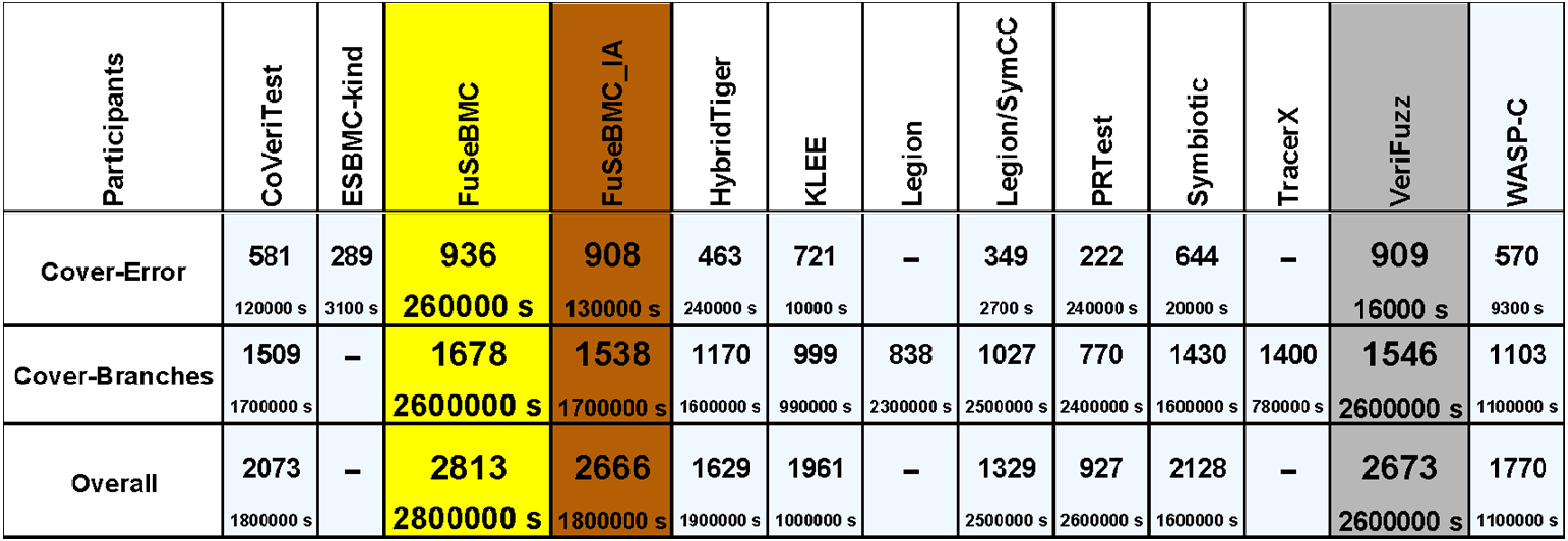
Produced Interval file

FuSeBMC_IA Framework

- With the intervals file as input, we fuzz the PUT with given intervals.
- If a goal is unreachable, we lower the priority for fuzzing it.



Evaluation of FuSeBMC_IA in Test-Comp 2023



Participants	CoVeriTest	ESBMC-kind	FuSeBMC	FuSeBMC_IA	HybridTiger	KLEE	Legion	Legion/SymCC	PRTest	Symbiotic	TracerX	VeriFuzz	WASP-C
Cover-Error	581 120000 s	289 3100 s	936 260000 s	908 130000 s	463 240000 s	721 10000 s	–	349 2700 s	222 240000 s	644 20000 s	–	909 16000 s	570 9300 s
Cover-Branches	1509 1700000 s	–	1678 2600000 s	1538 1700000 s	1170 1600000 s	999 990000 s	838 2300000 s	1027 2500000 s	770 2400000 s	1430 1600000 s	1400 780000 s	1546 2600000 s	1103 1100000 s
Overall	2073 1800000 s	–	2813 2800000 s	2666 1800000 s	1629 1900000 s	1961 1000000 s	–	1329 2500000 s	927 2600000 s	2128 1600000 s	–	2673 2600000 s	1770 1100000 s

The improvement achieved by FuSeBMC_IA in comparison to FuSeBMC v4 in terms of time

Participants	FuSeBMC	FuSeBMC_IA	Points decrease Time decrease
Cover-Error	936 260000	908 130000	-3% -50%
Cover-Branches	1678 2600000	1538 1700000	-8% -35%
Overall	2813 2800000	2666 1800000	-5% -36%
Points per minute	0.060278571	0.088866667	47% increase

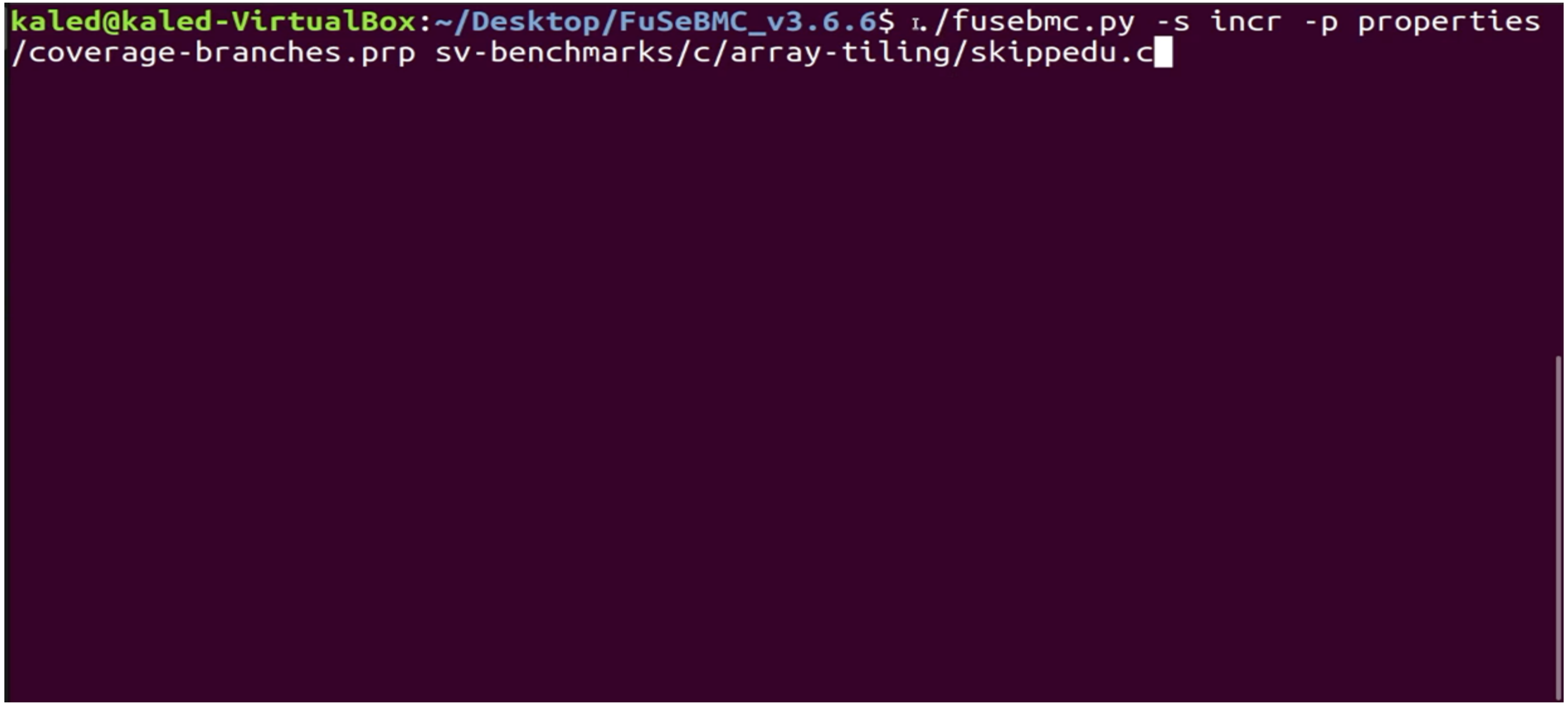
Awards

FuSeBMC_IA received three significant awards from the 5th International Competition on Software Testing (Test-Comp 2023) organized by the European Joint Conferences on Theory and Practice of Software (ETAPS).

- FuSeBMC_IA got third place in the most critical category of Test-Comp: **Cover-Error** (find a test that covers a bug).
- FuSeBMC_IA got third place in the category of Test-Comp: **Cover-Branches** (find a test that covers a branch).
- FuSeBMC_IA earned third place in Test-Comp's overall category.

Software Project

FuSeBMC_IA source code is written in C++ and Python; it is available for download on GitHub. Also, the instructions for using the tool FuSeBMC_IA are given in the file README.



```
kaled@kaled-VirtualBox:~/Desktop/FuSeBMC_v3.6.6$ ./fusebmc.py -s incr -p properties
/coverage-branches.prp sv-benchmarks/c/array-tiling/skippedu.c
```

Want to Try it?

Find out more about FuSeBMC_IA at :
https://github.com/Mohannad-aldughaim/FuSeBMC_IA

FuSeBMC_IA

Test-Comp’23 paper: “FuSeBMC_IA: Interval Analysis and Methods for Test Case Generation (Competition Contribution)”

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Thank you…