Symbion

Interleaving Symbolic with Concrete Execution

***Fabio Gritti**, Lorenzo Fontana, Eric Gustafson, Fabio Pagani, Andrea Continella, Christopher Kruegel, and Giovanni Vigna*

University of California, Santa Barbara

Motivation

- **Symbolically execution of binaries is very useful.**
  - Identify bugs and security vulnerabilities
  - Reverse-engineer closed-source software
  - Formally verify properties
- **Scalability of symbolic execution is an issue**
  - State/path explosion
  - Program behaviors can't always be fully modeled by symbolic execution engines
    - Complex state initializations
    - Filesystem accesses
    - Network requests
    - Interrupts

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    - Network requests
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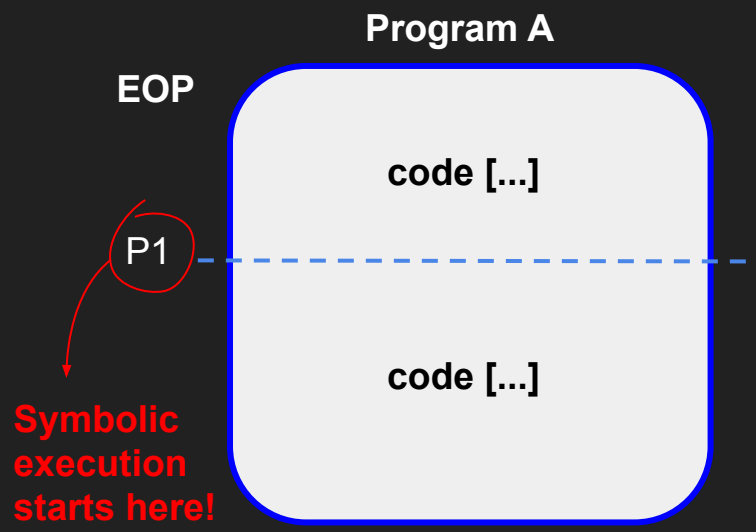
CAN'T EXECUTE THE WHOLE PROGRAM SYMBOLICALLY!

Motivation

- **Idea: why not just focus on a smaller portion of the code?**
  - Also known as **under-constrained symbolic execution.**



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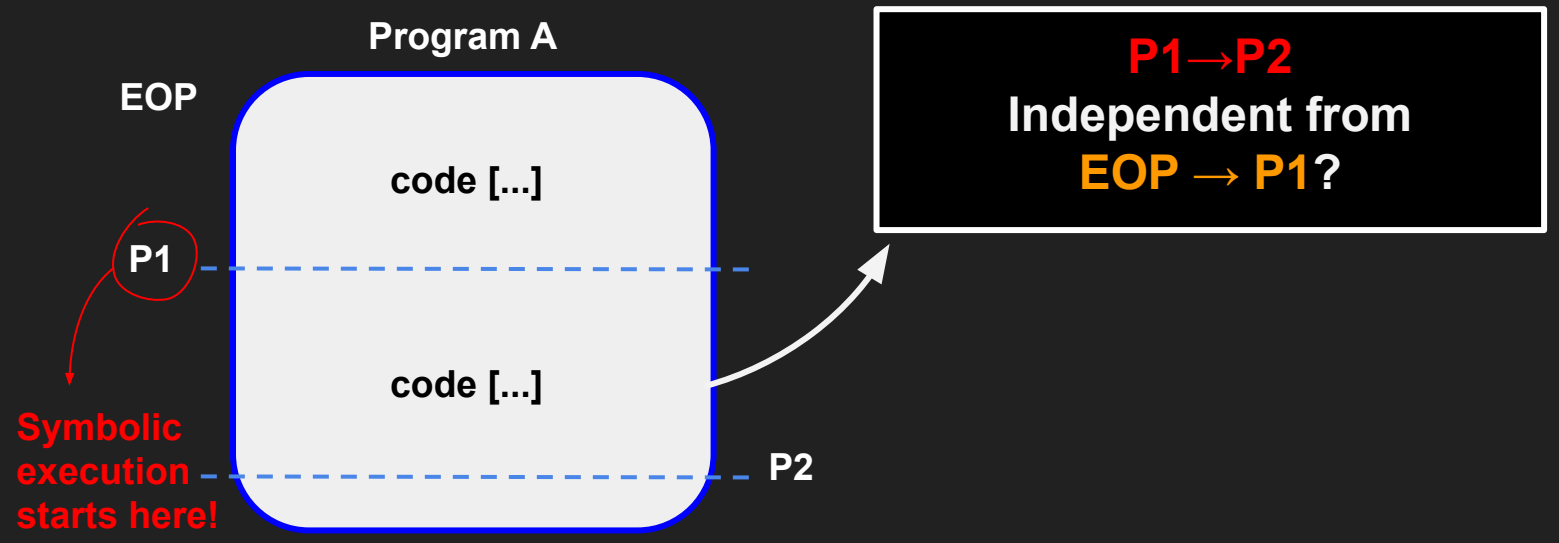

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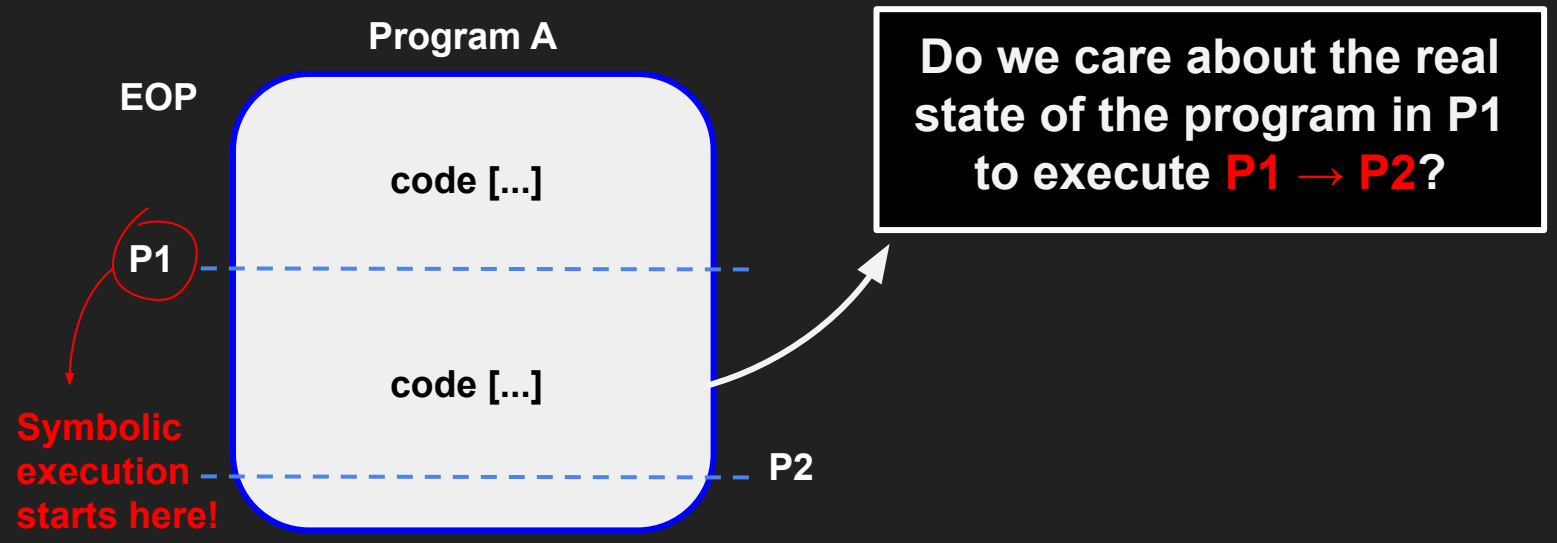

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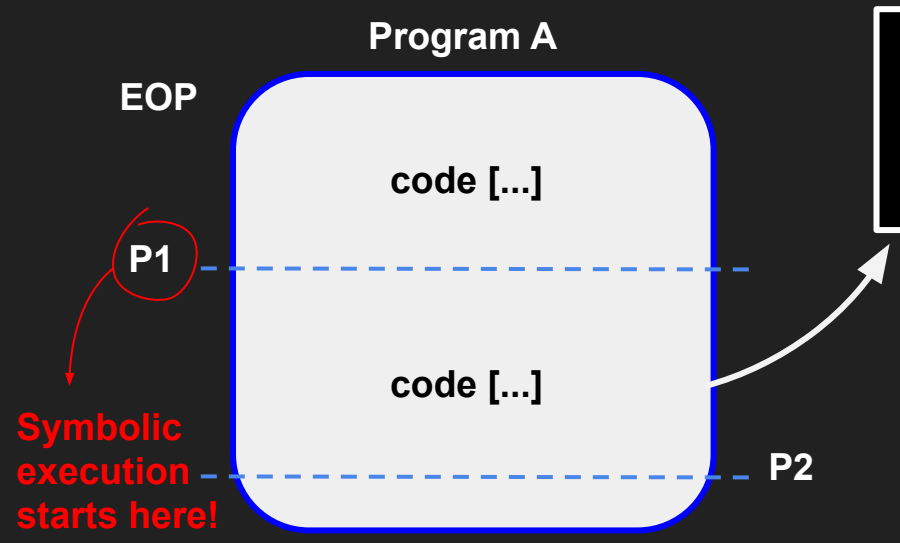
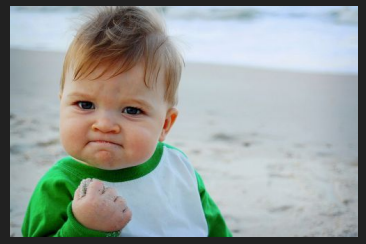


Do we care about the real state of the program in P1 to execute P1 → P2?

NO



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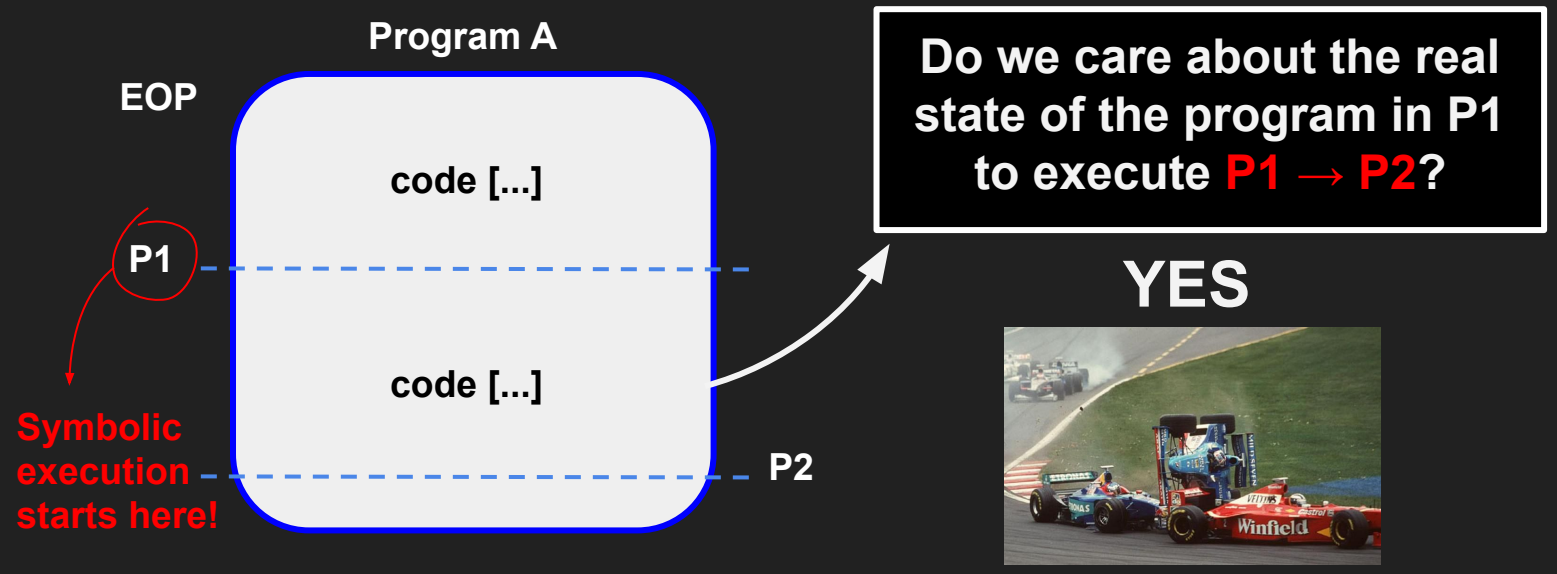

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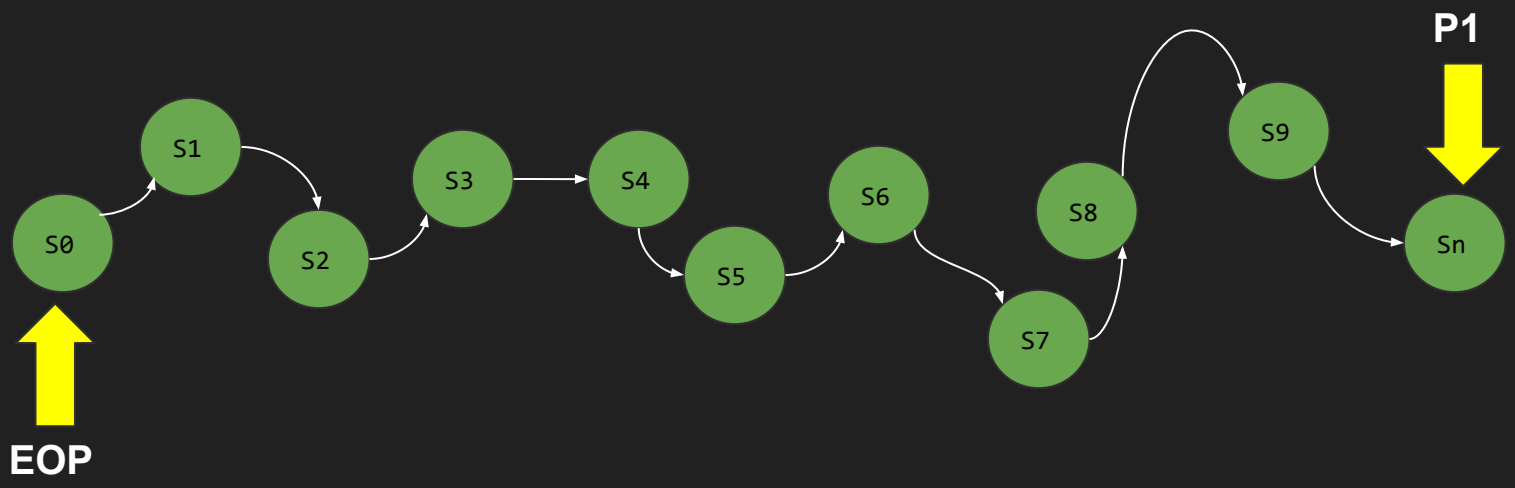
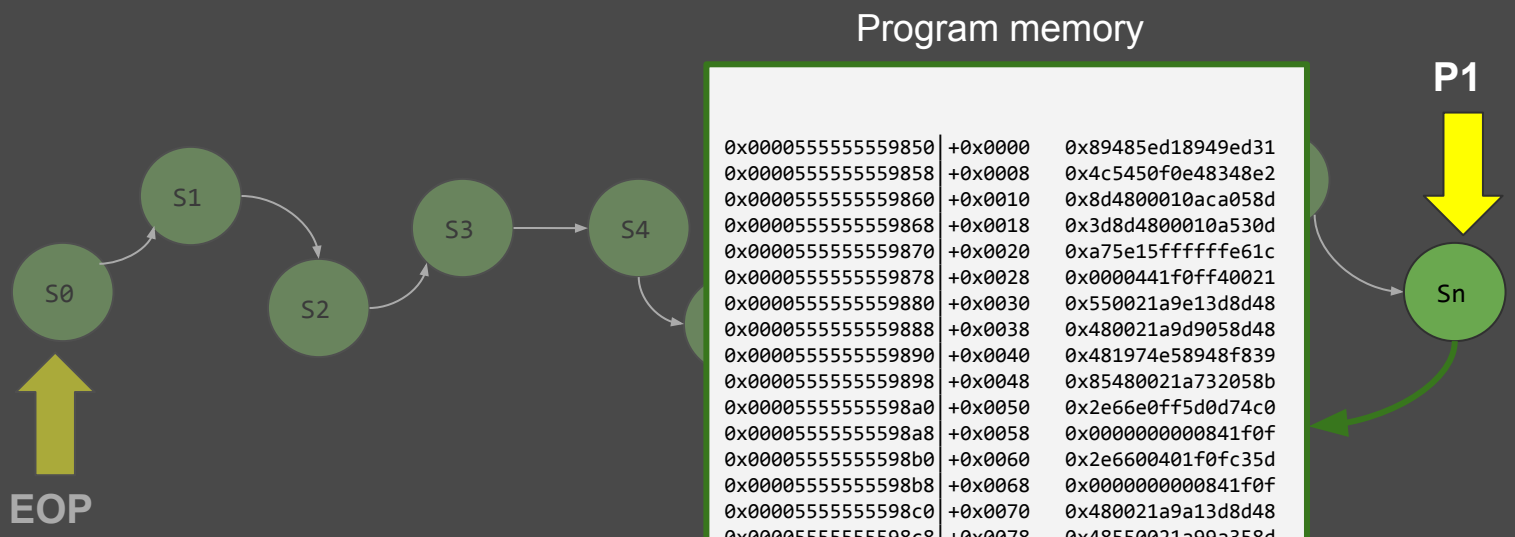


typical concrete execution

Motivation



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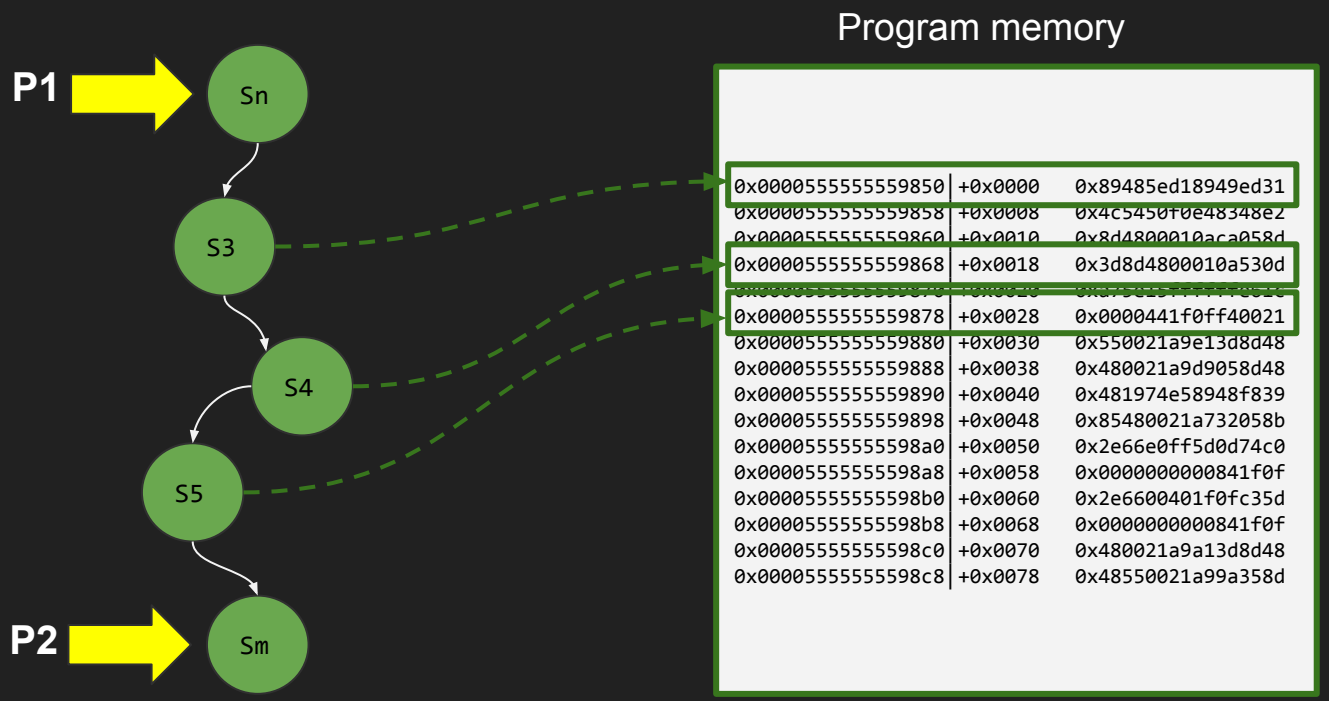

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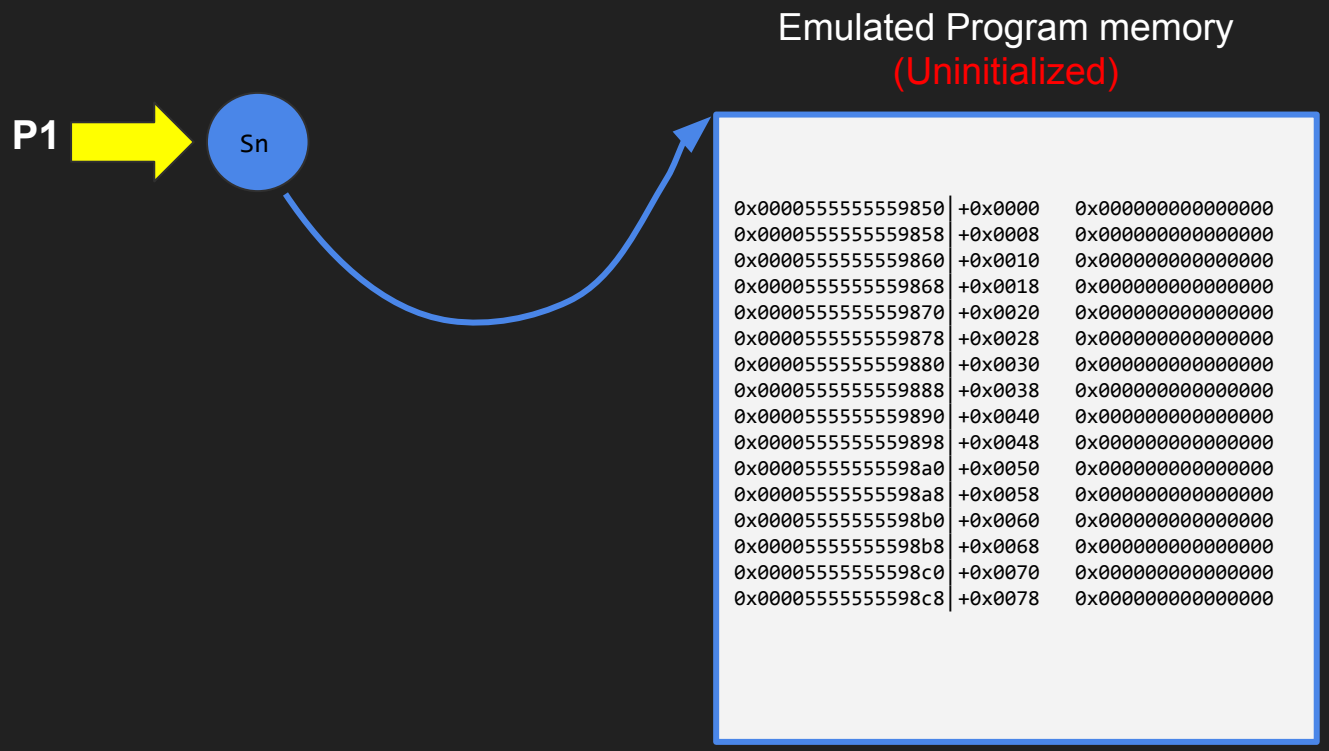

"under-constrained" symbolic execution

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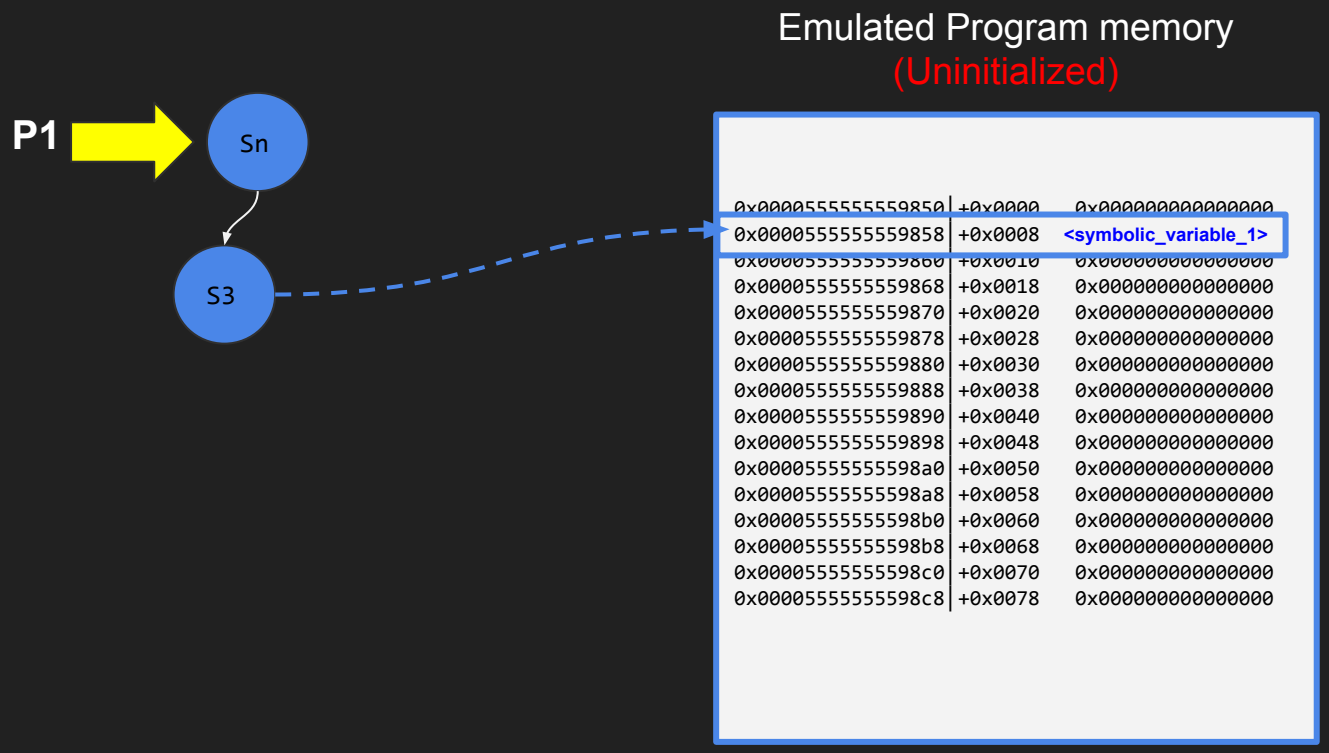

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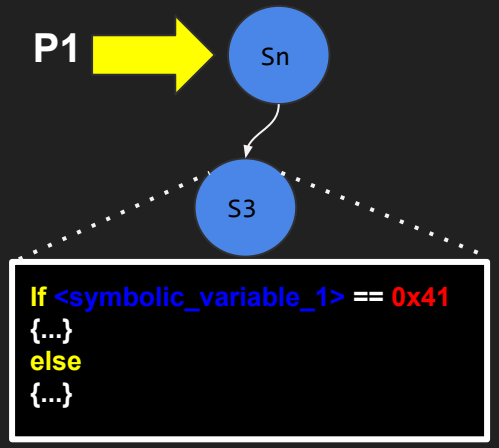

Emulated Program memory
(Uninitialized)

0x0000555555559858	+0x0008	<symbolic_variable_1>
0x0000555555559868	+0x0018	0x0000000000000000
0x0000555555559870	+0x0020	0x0000000000000000
0x0000555555559878	+0x0028	0x0000000000000000
0x0000555555559880	+0x0030	0x0000000000000000
0x0000555555559888	+0x0038	0x0000000000000000
0x0000555555559890	+0x0040	0x0000000000000000
0x0000555555559898	+0x0048	0x0000000000000000
0x00005555555598a0	+0x0050	0x0000000000000000
0x00005555555598a8	+0x0058	0x0000000000000000
0x00005555555598b0	+0x0060	0x0000000000000000
0x00005555555598b8	+0x0068	0x0000000000000000
0x00005555555598c0	+0x0070	0x0000000000000000
0x00005555555598c8	+0x0078	0x0000000000000000

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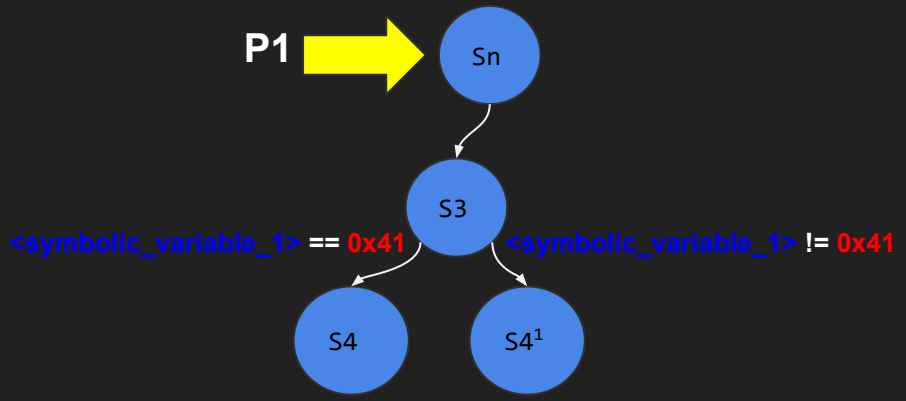

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(Uninitialized)

0x0000555555559858	+0x0008	<symbolic_variable_1>
0x0000555555559868	+0x0018	0x0000000000000000
0x0000555555559870	+0x0020	0x0000000000000000
0x0000555555559878	+0x0028	0x0000000000000000
0x0000555555559880	+0x0030	0x0000000000000000
0x0000555555559888	+0x0038	0x0000000000000000
0x0000555555559890	+0x0040	0x0000000000000000
0x0000555555559898	+0x0048	0x0000000000000000
0x00005555555598a0	+0x0050	0x0000000000000000
0x00005555555598a8	+0x0058	0x0000000000000000
0x00005555555598b0	+0x0060	0x0000000000000000
0x00005555555598b8	+0x0068	0x0000000000000000
0x00005555555598c0	+0x0070	0x0000000000000000
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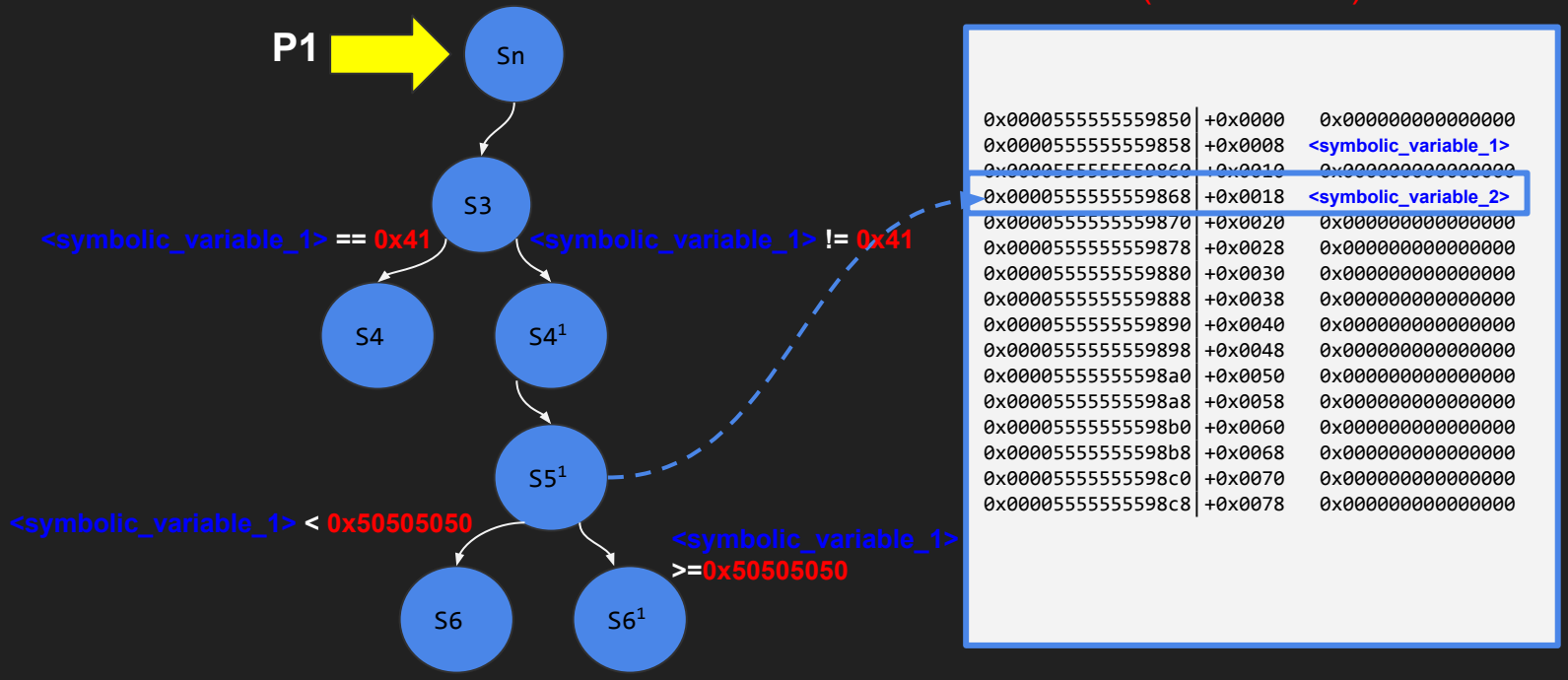

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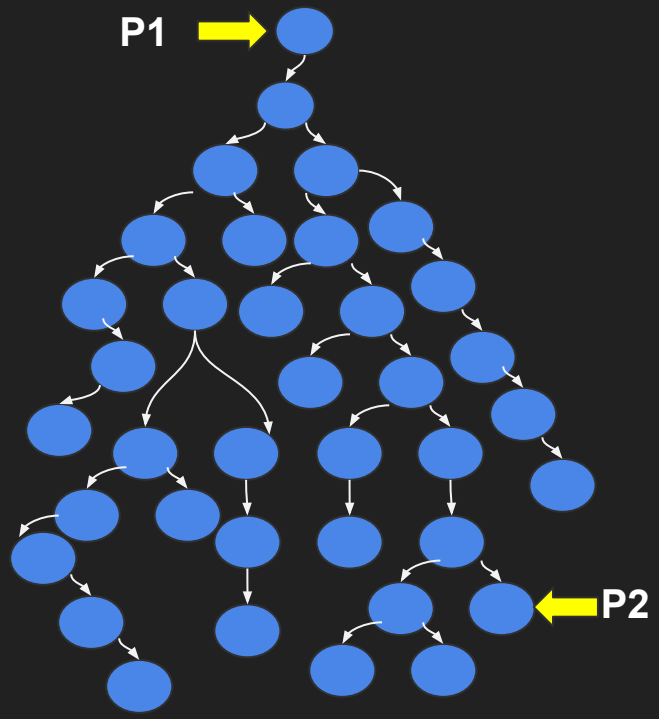

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(Uninitialized)

0x0000555555559850	+0x0000	<symbolic_variable_1>
0x0000555555559858	+0x0008	0x000000000ee0000
0x0000555555559860	+0x0010	0x0000000aaabbc34
0x0000555555559868	+0x0018	<symbolic_variable_2>
0x0000555555559870	+0x0020	0x000000000000000
0x0000555555559878	+0x0028	<symbolic_variable_3>
0x0000555555559880	+0x0030	0x000000000000000
0x0000555555559888	+0x0038	<symbolic_variable_4>
0x0000555555559890	+0x0040	<symbolic_variable_5>
0x0000555555559898	+0x0048	<symbolic_variable_6>
0x00005555555598a0	+0x0050	<symbolic_variable_7>
0x00005555555598a8	+0x0058	<symbolic_variable_8>
0x00005555555598b0	+0x0060	0x000000001231284
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0x00005555555598c0	+0x0070	<symbolic_variable_9>
0x00005555555598c8	+0x0078	<symbolic_variable_a>
0x00005555555598c8	+0x0078	<symbolic_variable_b>
0x00005555555598c8	+0x0078	<symbolic_variable_c>
0x00005555555598c8	+0x0078	<symbolic_variable_d>
0x00005555555598c8	+0x0078	<symbolic_variable_e>
0x00005555555598c8	+0x0078	<symbolic_variable_f>
0x00005555555598c8	+0x0078	<symbolic_variable_10>
0x00005555555598c8	+0x0078	<symbolic_variable_11>

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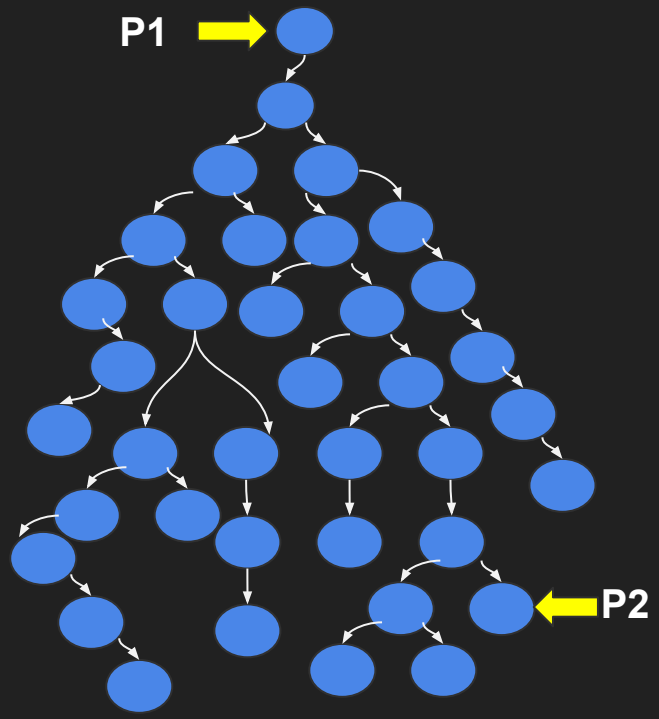

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(Uninitialized)

```
0x0000555555559850 | +0x0000 <symbolic_variable_1>
0x0000555555559858 | +0x0008   0x000000000ee0000
0x0000555555559860 | +0x0010   0x0000000aaabbc34
0x0000555555559868 | +0x0018 <symbolic_variable_2>
```


```
0x00005555555598c8 | +0x0078 <symbolic_variable_e>
0x00005555555598c8 | +0x0078 <symbolic_variable_f>
0x00005555555598c8 | +0x0078 <symbolic_variable_10>
0x00005555555598c8 | +0x0078 <symbolic_variable_11>
```

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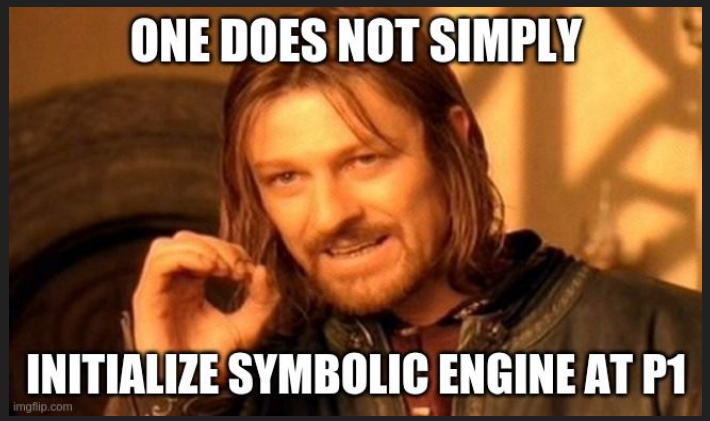

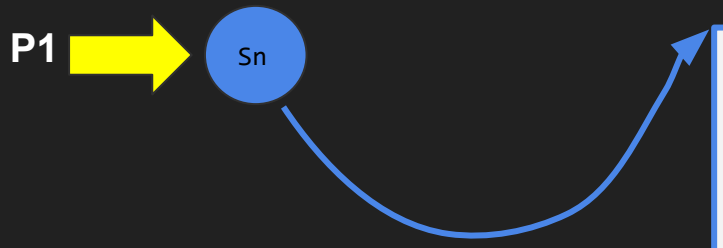

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0x0000555555559868	+0x0018	0x0000000000000000
0x0000555555559870	+0x0020	0x0000000000000000
0x0000555555559878	+0x0028	0x0000000000000000
0x0000555555559880	+0x0030	0x0000000000000000
0x0000555555559888	+0x0038	0x0000000000000000
0x0000555555559890	+0x0040	0x0000000000000000
0x0000555555559898	+0x0048	0x0000000000000000
0x00005555555598a0	+0x0050	0x0000000000000000
0x00005555555598a8	+0x0058	0x0000000000000000
0x00005555555598b0	+0x0060	0x0000000000000000
0x00005555555598b8	+0x0068	0x0000000000000000
0x00005555555598c0	+0x0070	0x0000000000000000
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THIS WAS THE CAUSE!

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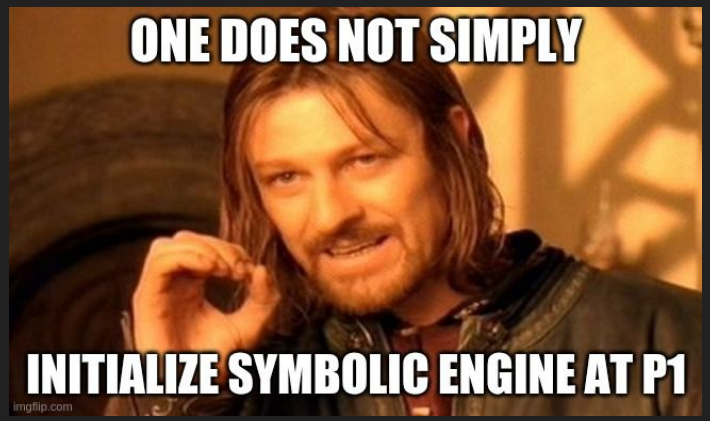

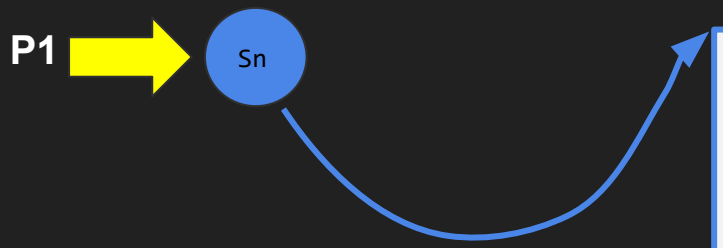

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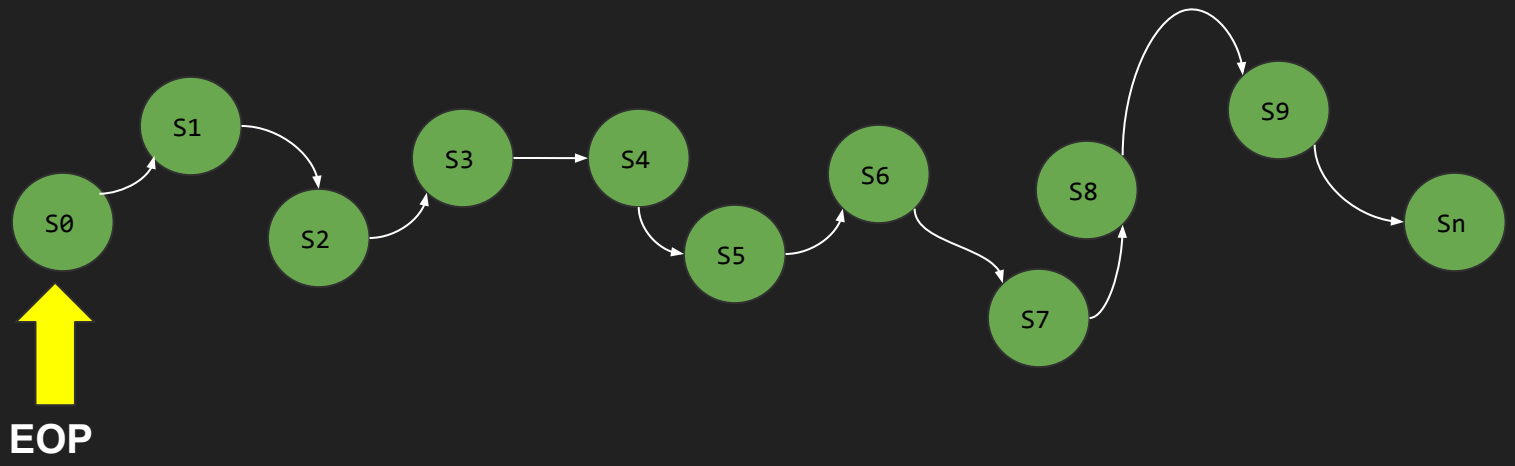
0x0000555555559850	+0x0000	0x89485ed18949ed31
0x0000555555559858	+0x0008	0x4c5450f0e48348e2
0x0000555555559860	+0x0010	0x8d4800010aca058d
0x0000555555559868	+0x0018	0x3d8d4800010a530d
0x0000555555559870	+0x0020	0xa75e15ffffffe61c
0x0000555555559878	+0x0028	0x0000441f0ff40021
0x0000555555559880	+0x0030	0x550021a9e13d8d48
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x481974e58948f839
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
0x00005555555598c8	+0x0078	0x48550021a99a358d

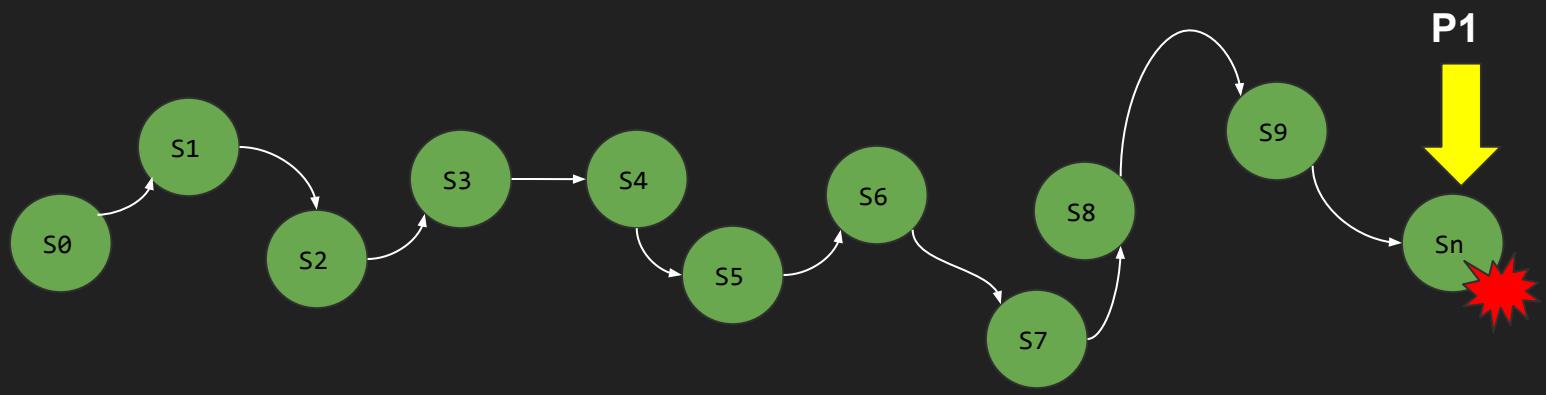
CAN WE HAVE THIS?

Approach



Interleaved symbolic execution

Approach



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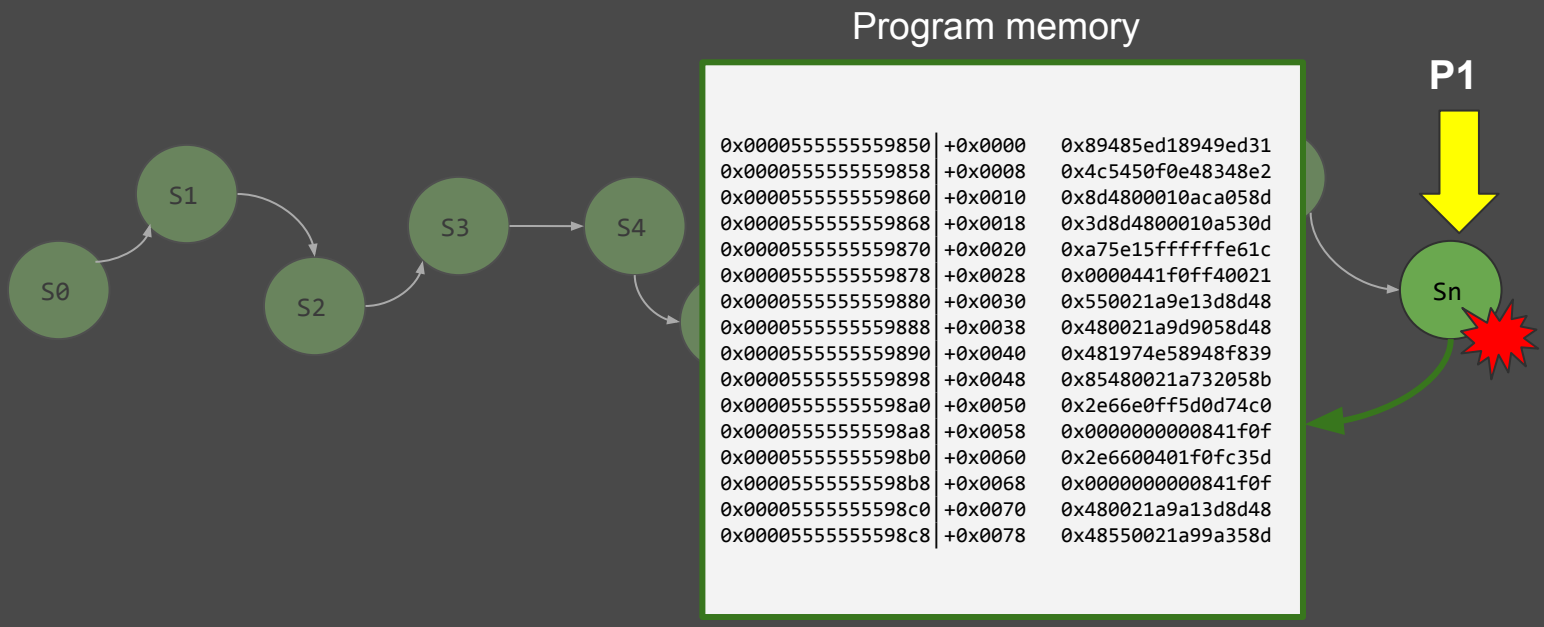

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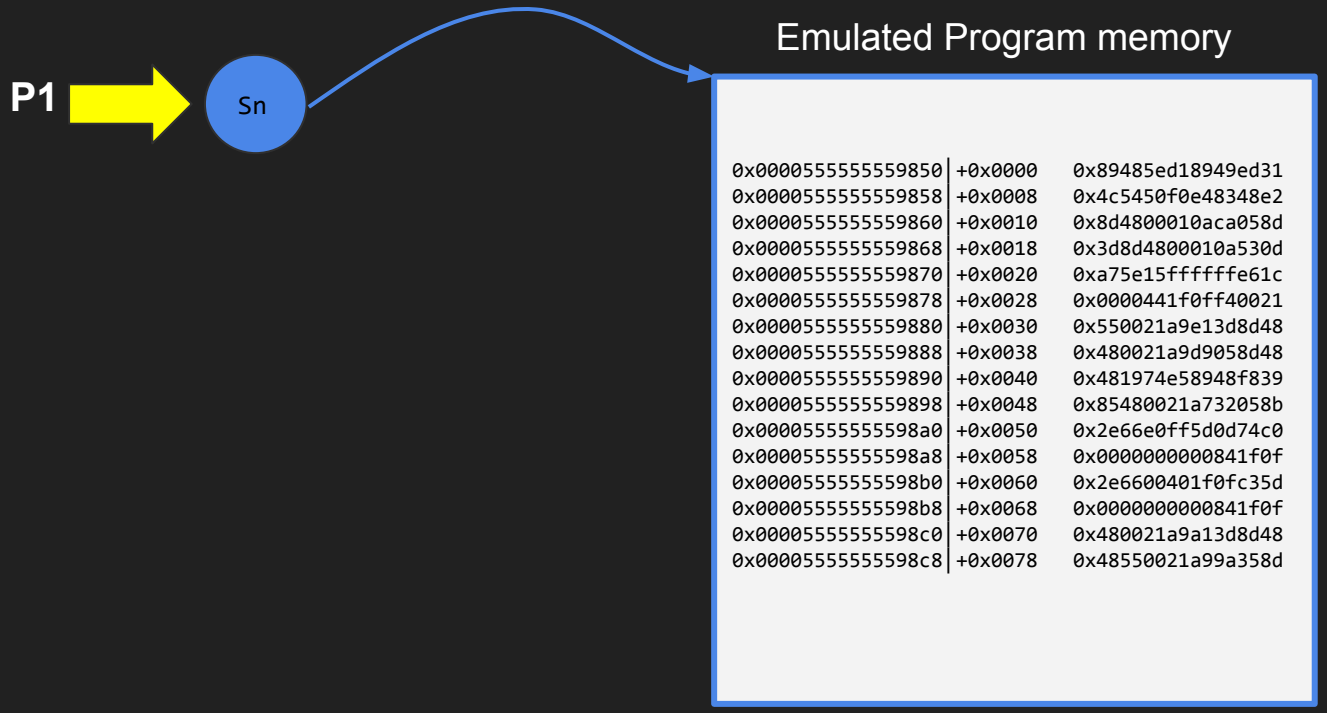

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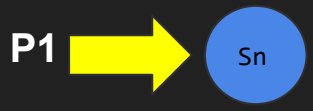


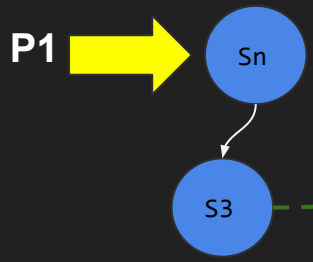
Emulated Program memory

0x0000555555559850	+0x0000	0x89485ed18949ed31
0x0000555555559858	+0x0008	0x4c5450f0e48348e2
0x0000555555559860	+0x0010	0x8d4800010aca058d
0x0000555555559868	+0x0018	<symbolic_variable_1>
0x0000555555559870	+0x0020	0xa75e15ffffffe61c
0x0000555555559878	+0x0028	0x0000441f0ff40021
0x0000555555559880	+0x0030	0x550021a9e13d8d48
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x481974e58948f839
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
0x00005555555598c8	+0x0078	0x48550021a99a358d

User controlled

Interleaved symbolic execution

Approach



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0x0000555555559850	+0x0000	0x89485ed18949ed31
0x0000555555559858	+0x0008	0x4c5450f0e48348e2
0x0000555555559860	+0x0010	0x8d4800010aca058d
0x0000555555559868	+0x0018	<symbolic_variable_1>
0x0000555555559870	+0x0020	0xa75e15ffffffe61c
0x0000555555559878	+0x0028	0x0000441f0ff40021
0x0000555555559880	+0x0030	0x550021a9e13d8d48
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x481974e58948f839
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
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Interleaved symbolic execution

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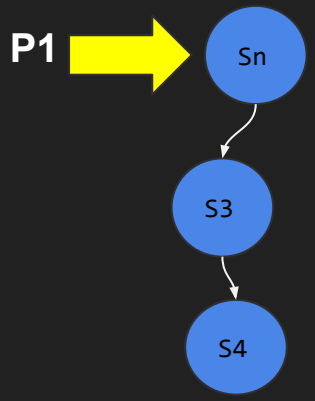

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0x0000555555559858	+0x0008	0x4c5450f0e48348e2
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0x0000555555559868	+0x0018	<symbolic_variable_1>
0x0000555555559870	+0x0020	0xa75e15ffffffe61c
0x0000555555559878	+0x0028	0x0000441f0ff40021
0x0000555555559880	+0x0030	0x550021a9e13d8d48
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x481974e58948f839
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
0x00005555555598c8	+0x0078	0x48550021a99a358d

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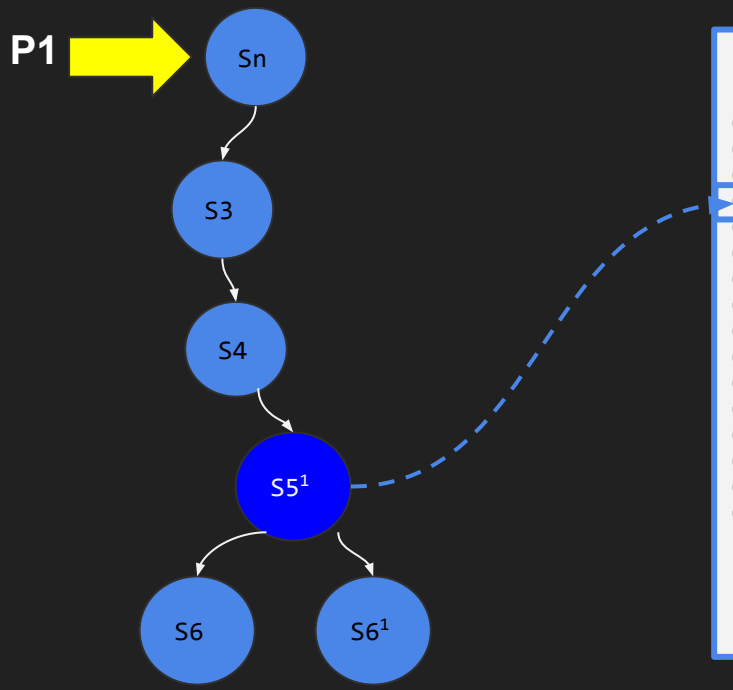

Emulated Program memory

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0x0000555555559858	+0x0008	0x4c5450f0e48348e2
0x0000555555559860	+0x0010	0x8d4800010aca058d
0x0000555555559868	+0x0018	<symbolic_variable_1>
0x0000555555559870	+0x0020	0xa75e15ffffffe61c
0x0000555555559878	+0x0028	0x0000441f0ff40021
0x0000555555559880	+0x0030	0x550021a9e13d8d48
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x481974e58948f839
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
0x00005555555598c8	+0x0078	0x48550021a99a358d

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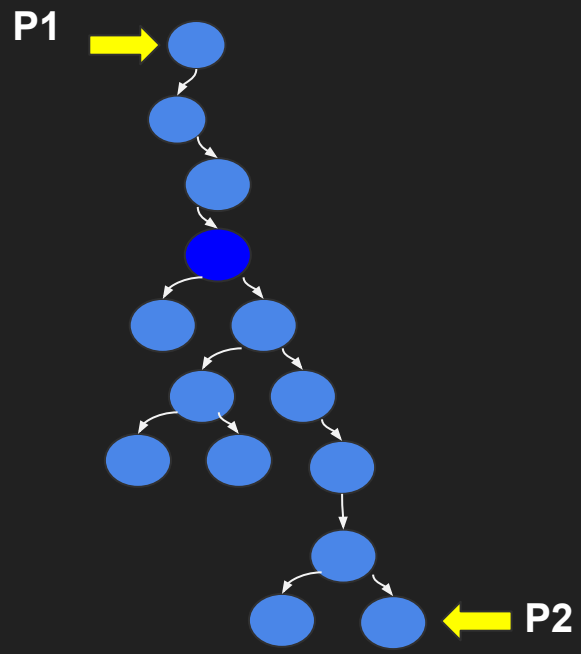
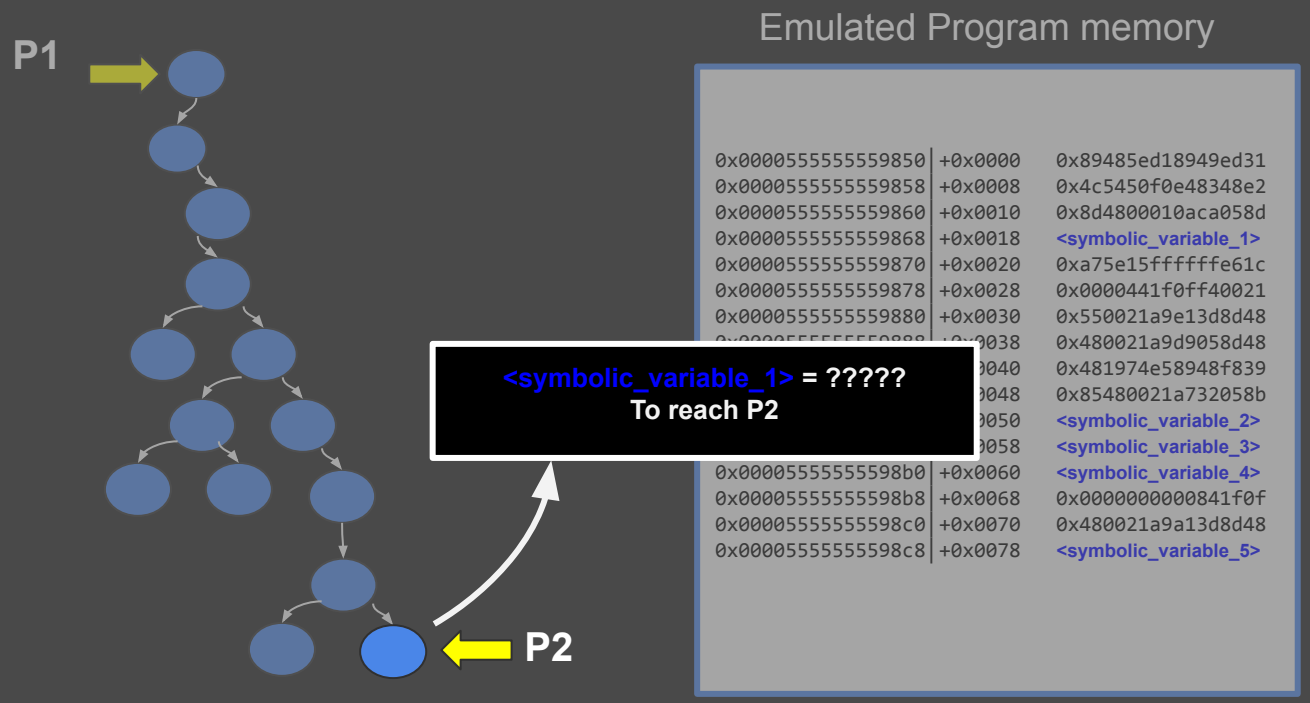


Emulated Program memory

0x0000555555559850	+0x0000	0x89485ed18949ed31
0x0000555555559858	+0x0008	0x4c5450f0e48348e2
0x0000555555559860	+0x0010	0x8d4800010aca058d
0x0000555555559868	+0x0018	<symbolic_variable_1>
0x0000555555559870	+0x0020	0xa75e15ffffffe61c
0x0000555555559878	+0x0028	0x0000441f0ff40021
0x0000555555559880	+0x0030	0x550021a9e13d8d48
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x481974e58948f839
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	<symbolic_variable_2>
0x00005555555598a8	+0x0058	<symbolic_variable_3>
0x00005555555598b0	+0x0060	<symbolic_variable_4>
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
0x00005555555598c8	+0x0078	<symbolic_variable_5>

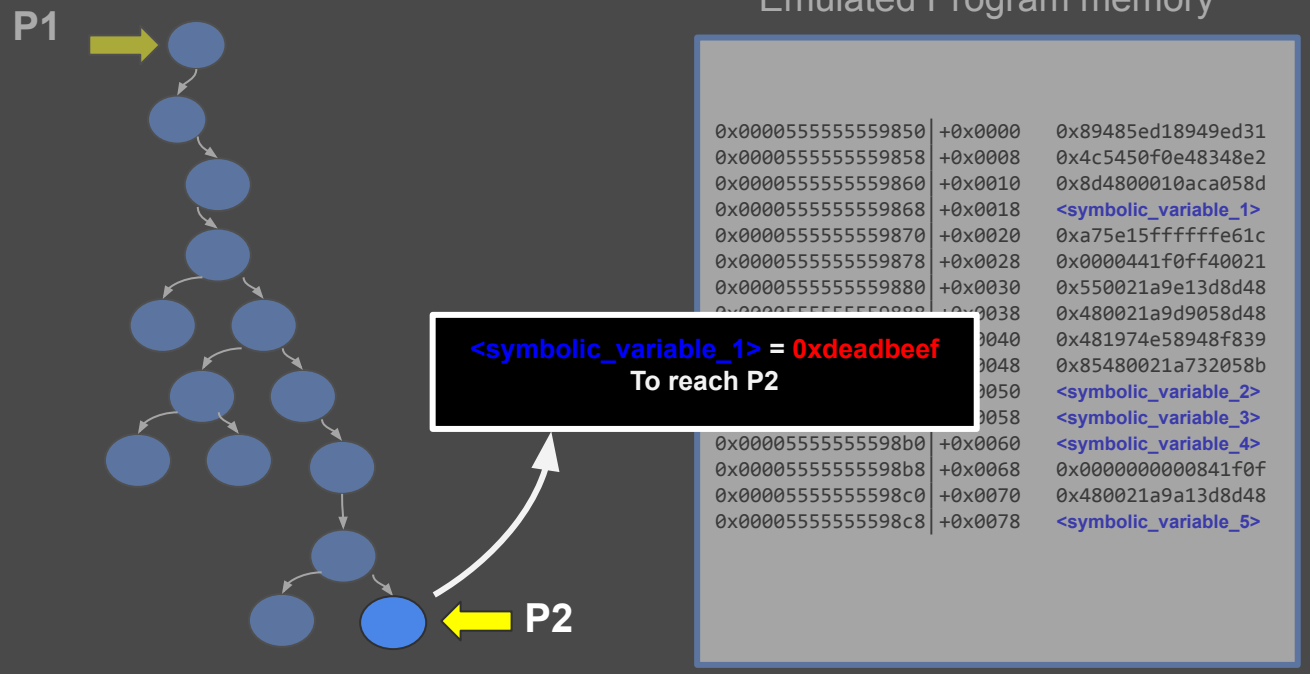
Interleaved symbolic execution

Approach



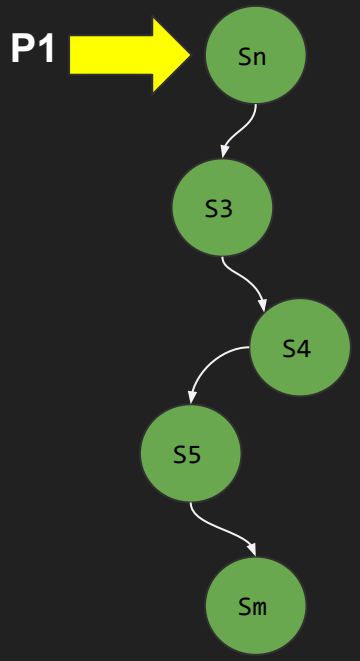
Interleaved symbolic execution

Approach



Interleaved symbolic execution

Approach

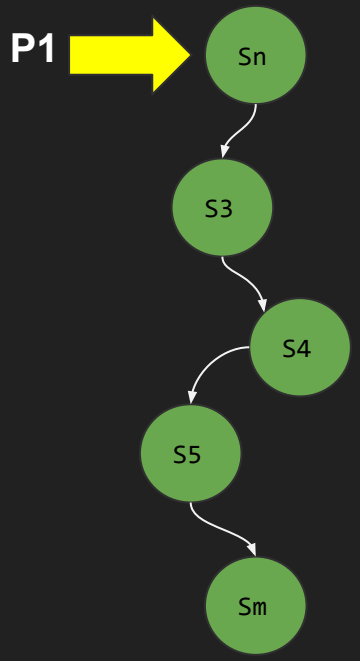


Program memory

0x0000555555559850	+0x0000	0x89485ed18949ed31
0x0000555555559858	+0x0008	0x4c5450f0e48348e2
0x0000555555559860	+0x0010	0x8d4800010aca058d
0x0000555555559868	+0x0018	0x8d4800010aca058d
0x0000555555559870	+0x0020	0xa75e15ffffffe61c
0x0000555555559878	+0x0028	0x0000441f0ff40021
0x0000555555559880	+0x0030	0x550021a9e13d8d48
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x481974e58948f839
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
0x00005555555598c8	+0x0078	0x48550021a99a358d

Interleaved symbolic execution

Approach

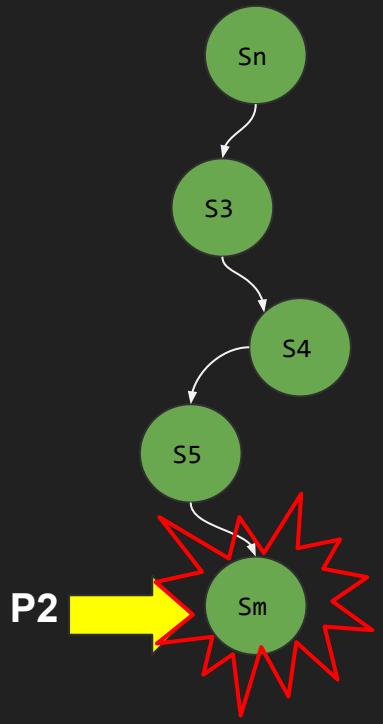


Program memory

0x0000555555559850	+0x0000	0x89485ed18949ed31
0x0000555555559858	+0x0008	0x4c5450f0e48348e2
0x0000555555559860	+0x0010	0x8d4800010aca058d
0x0000555555559868	+0x0018	0x00000000deadbeef
0x0000555555559870	+0x0020	0xa75e15ffffffe61c
0x0000555555559878	+0x0028	0x0000441f0ff40021
0x0000555555559880	+0x0030	0x550021a9e13d8d48
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x481974e58948f839
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
0x00005555555598c8	+0x0078	0x48550021a99a358d

Interleaved symbolic execution

Approach



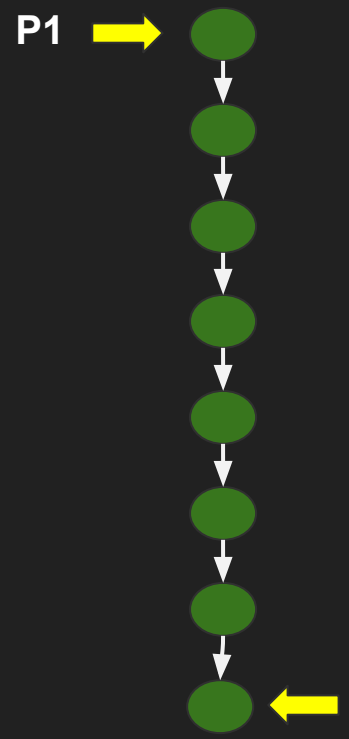
Program memory

0x0000555555559850	+0x0000	0x0000000111111111
0x0000555555559858	+0x0008	0x4c5450f0e48348e2
0x0000555555559860	+0x0010	0x8d4800010aca058d
0x0000555555559868	+0x0018	0x00000000deadbeef
0x0000555555559870	+0x0020	0xa75e15ffffffe61c
0x0000555555559878	+0x0028	0x0000441f0ff40021
0x0000555555559880	+0x0030	0x1123012312310010
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x4141414141414141
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x0000100100000000
0x00005555555598c8	+0x0078	0x48550021a99a358d

Interleaved symbolic execution

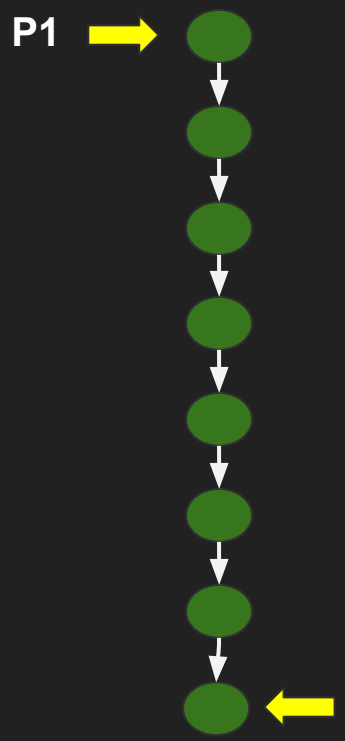
Approach

Approach

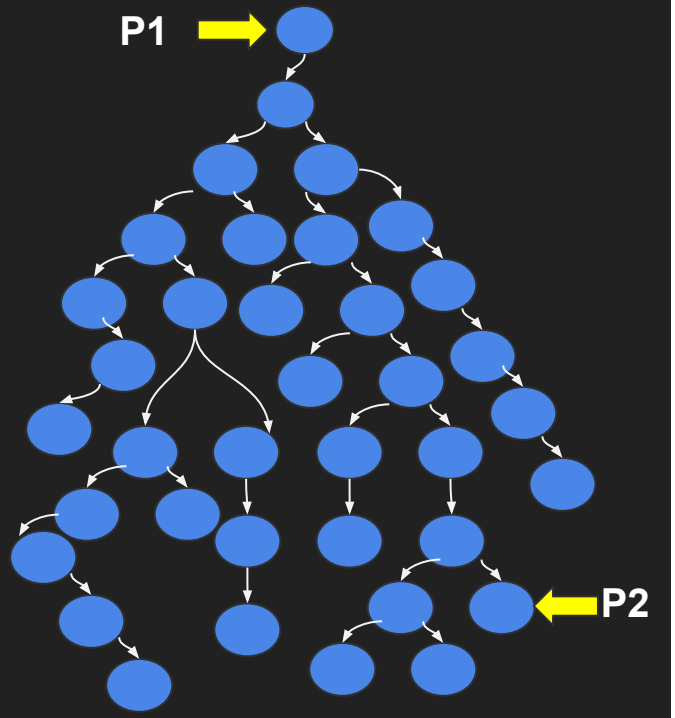


concrete execution

Approach

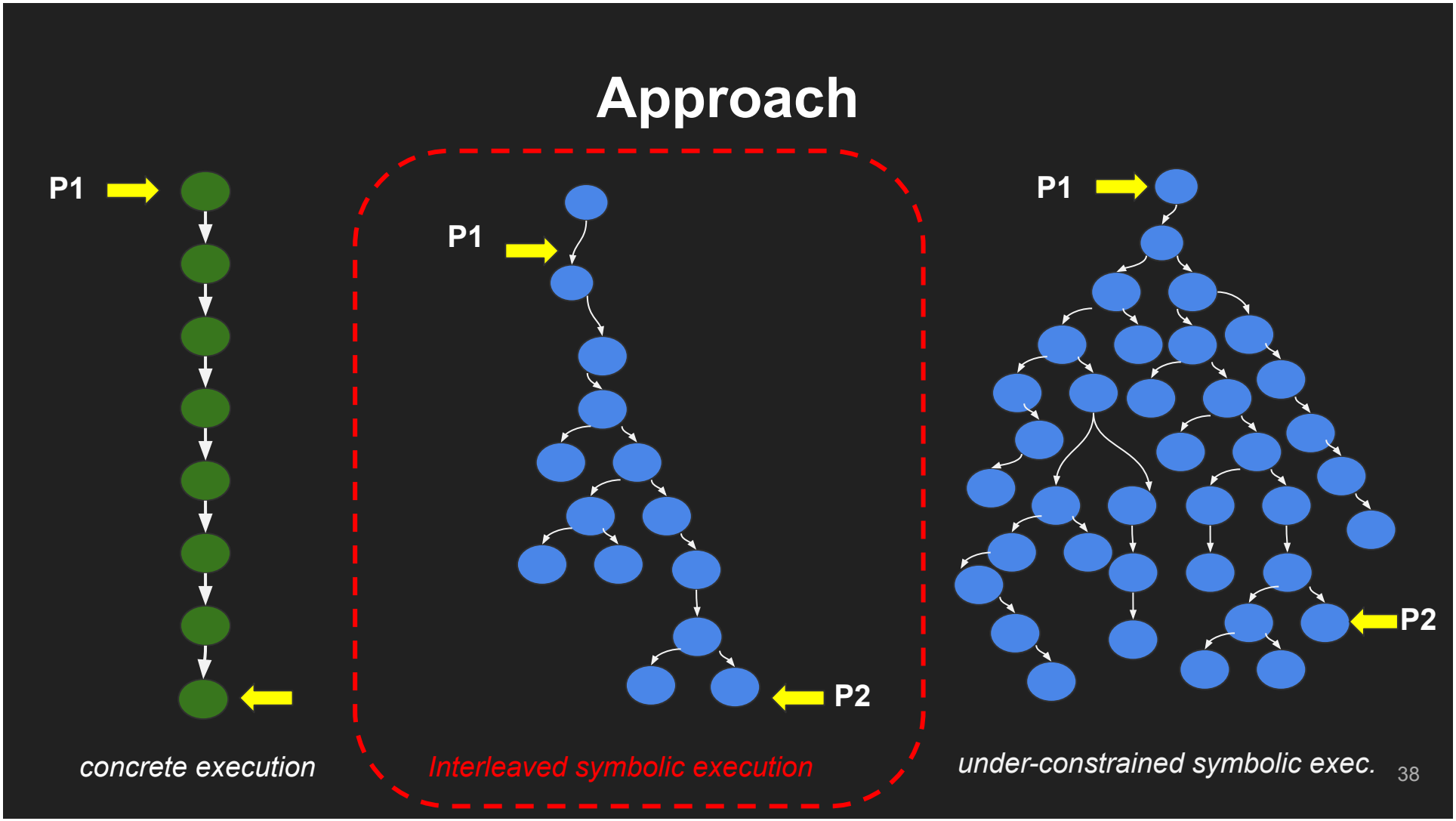


concrete execution

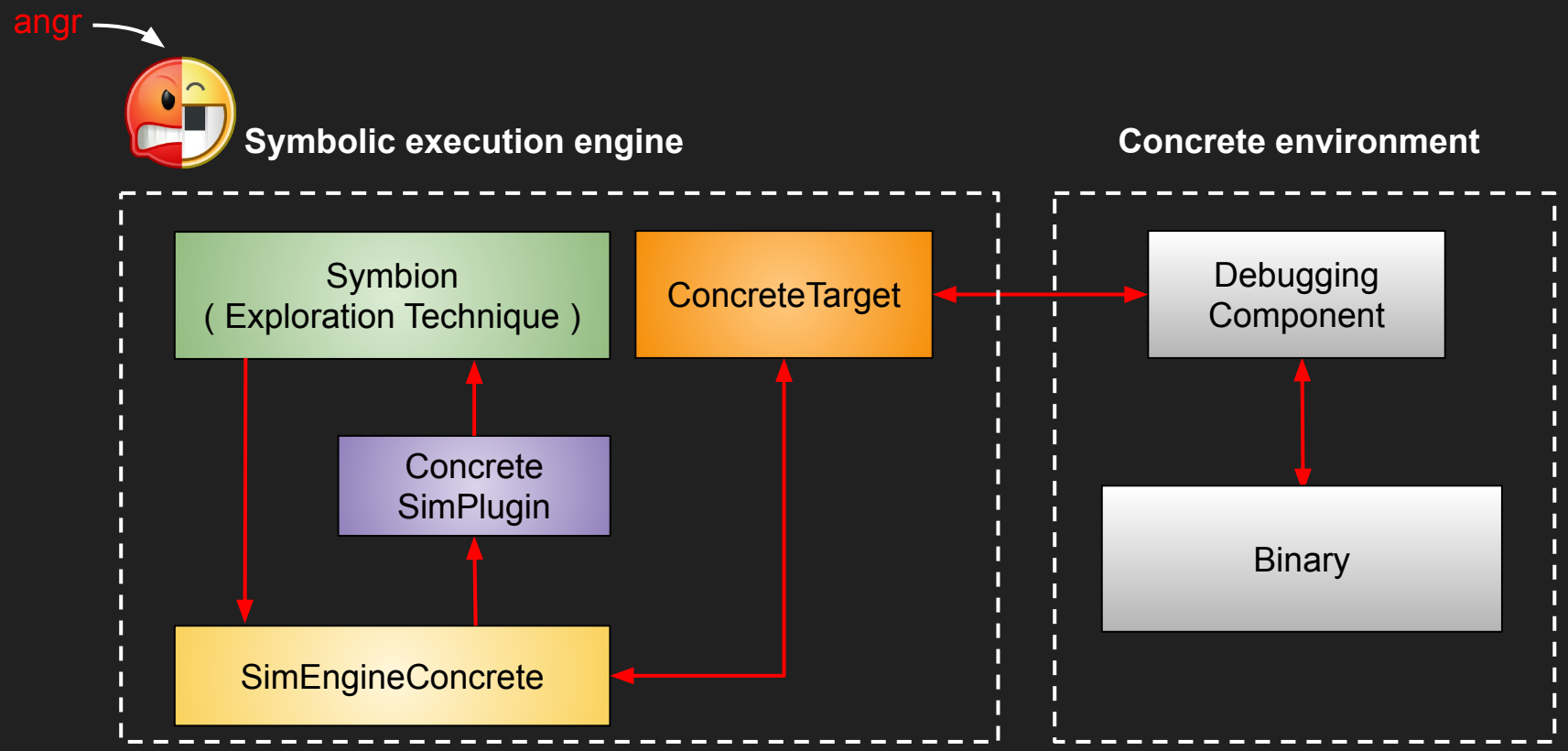


under-constrained symbolic exec.

Approach


P1
P1
P2
P1
P2
concrete execution
Interleaved symbolic execution
under-constrained symbolic exec.

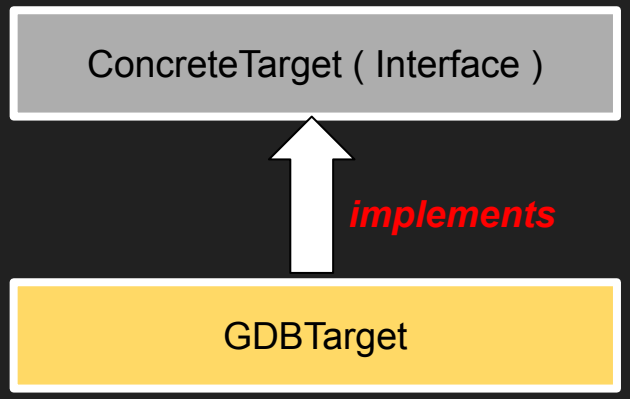
System Overview



ConcreteTarget

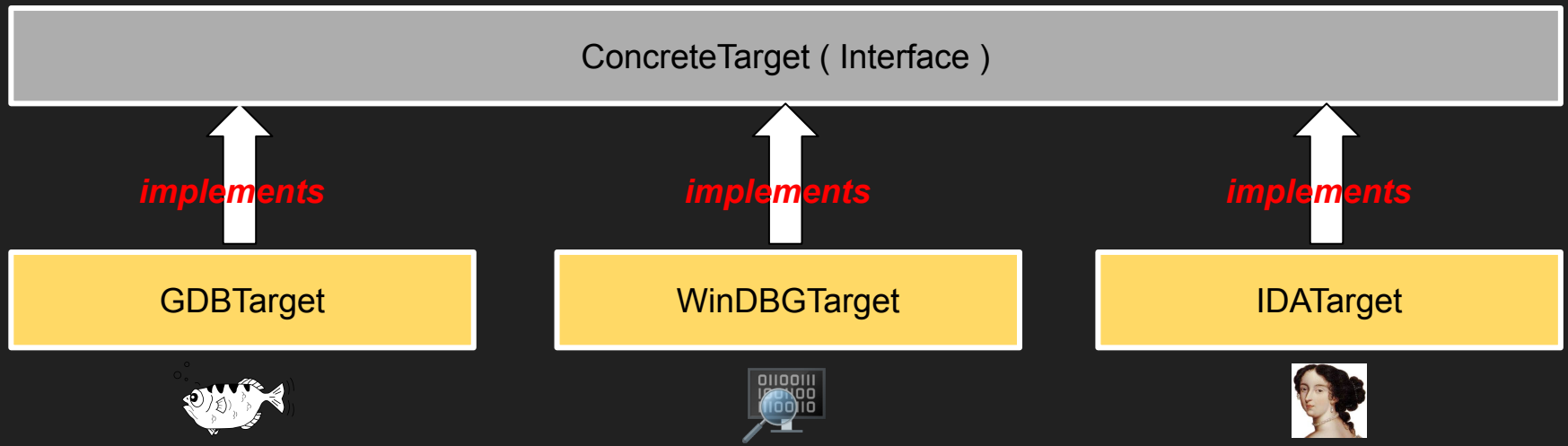
- Interface used to implement objects that will control the program executed inside the concrete analysis environment.

- Exposes the following methods:
  - `def read_memory(self, address, length)`
  - `def write_memory(self, address, data)`
  - `def read_register(self, register)`
  - `def write_register(self, register, value)`
  - `def set_breakpoint(self, address)`
  - `def remove_breakpoint(self, address)`
  - `def set_watchpoint(self, address)`
  - `def remove_watchpoint(self, address)`
  - `def get_mappings(self)`
  - `def run(self)`

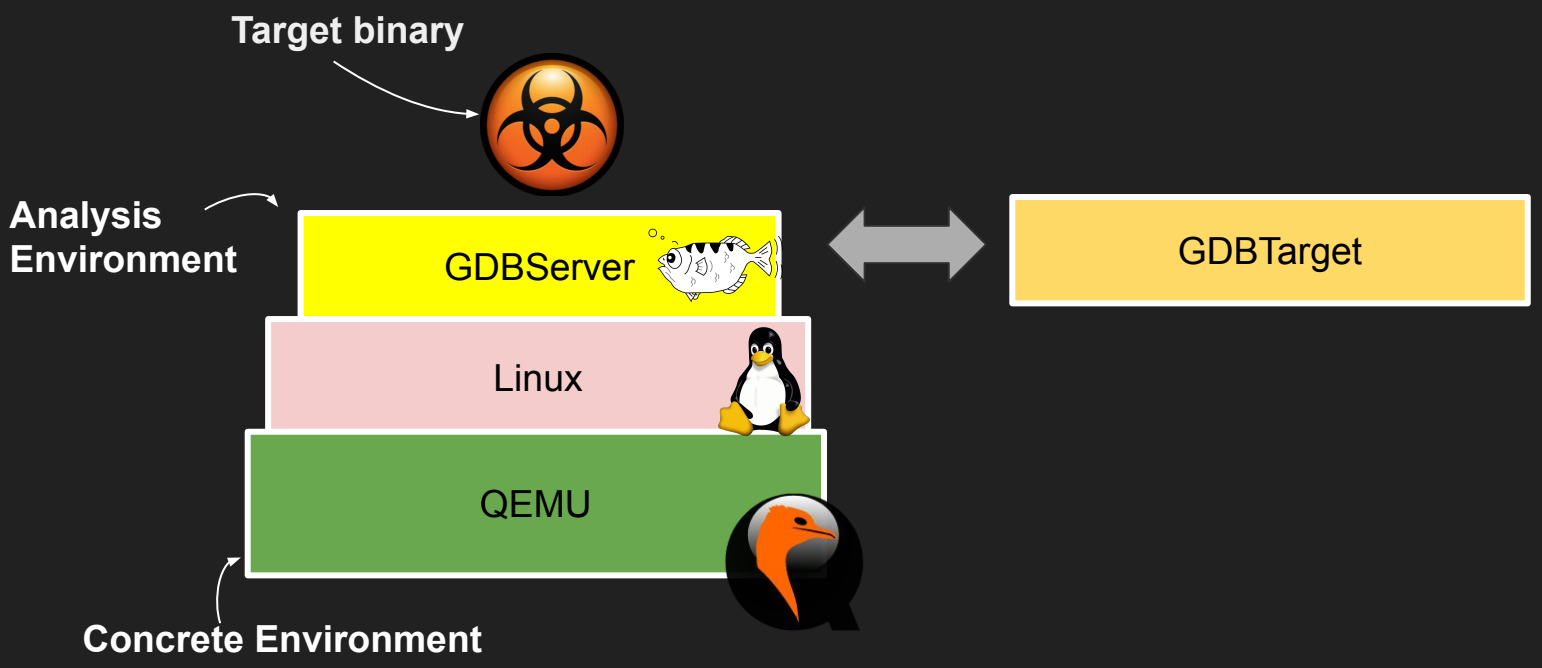


ConcreteTarget

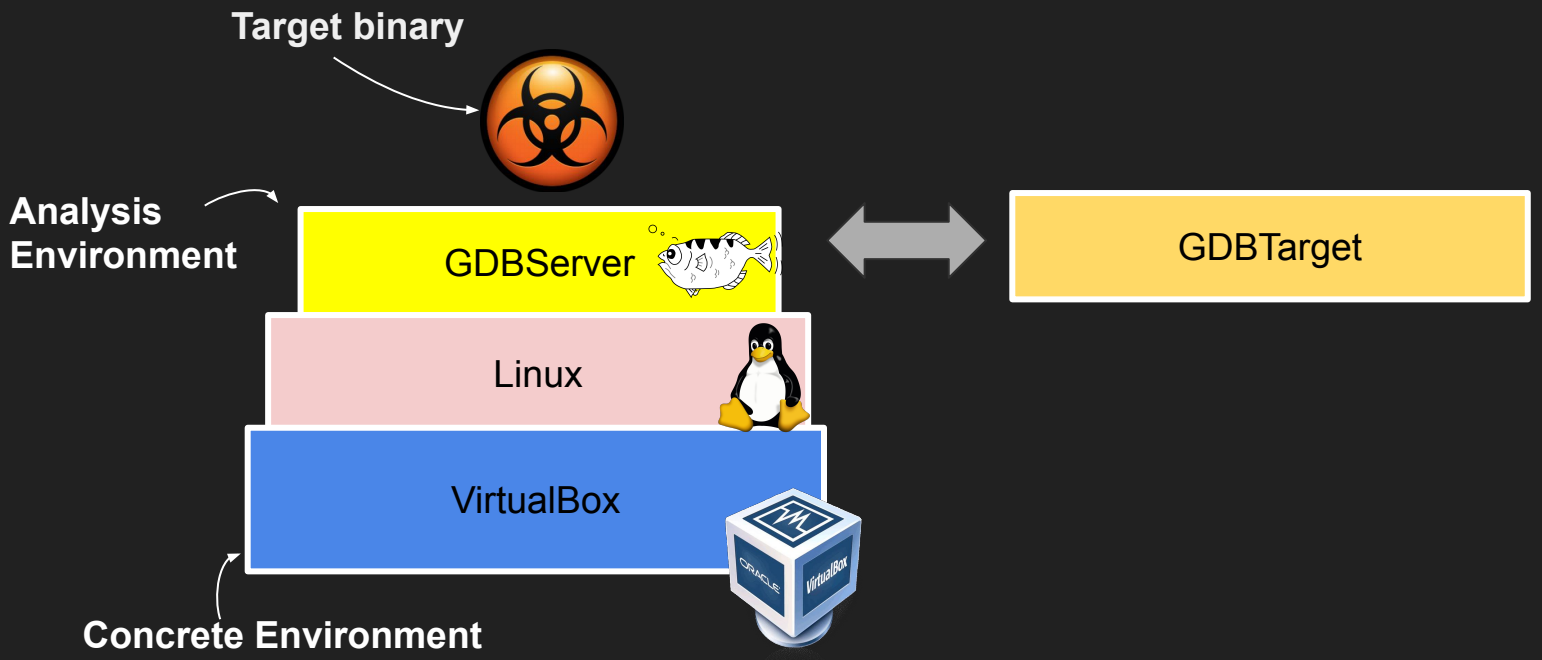
- It can have different interesting implementations!



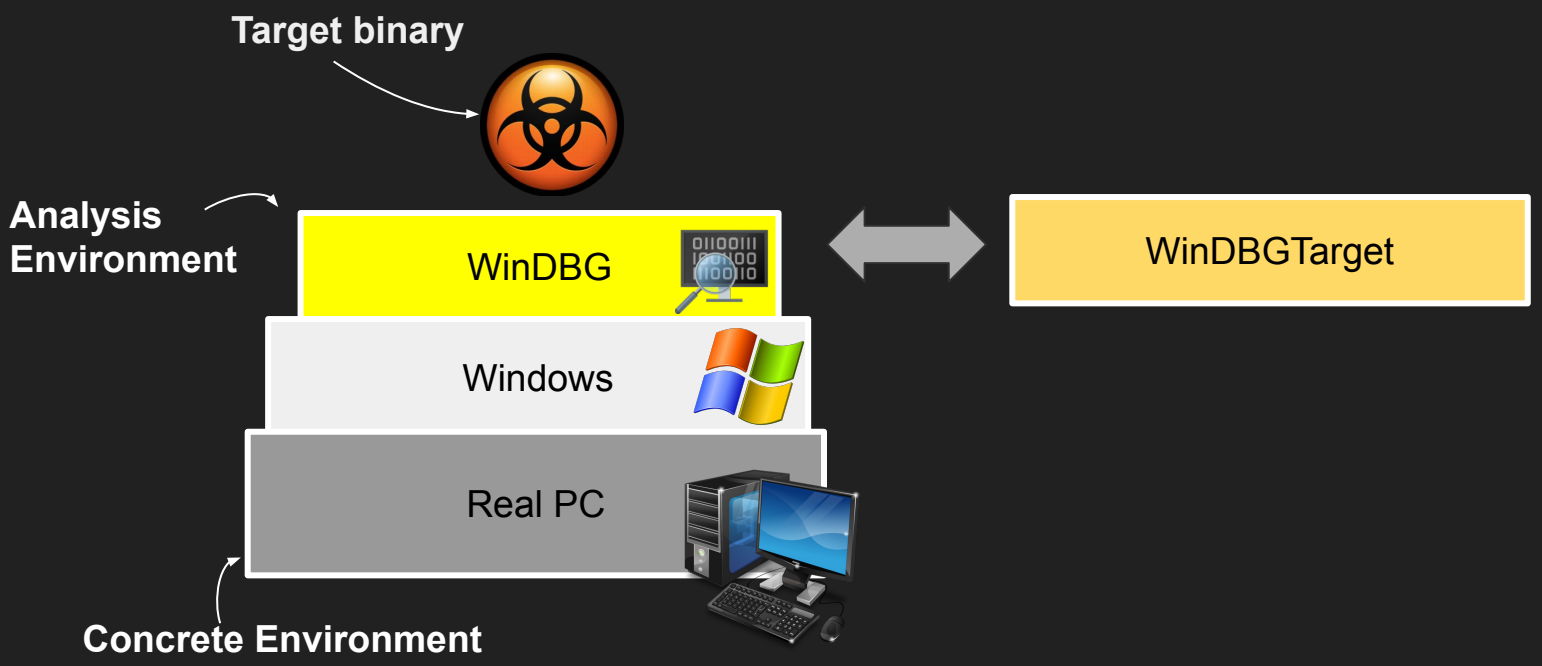
ConcreteTarget



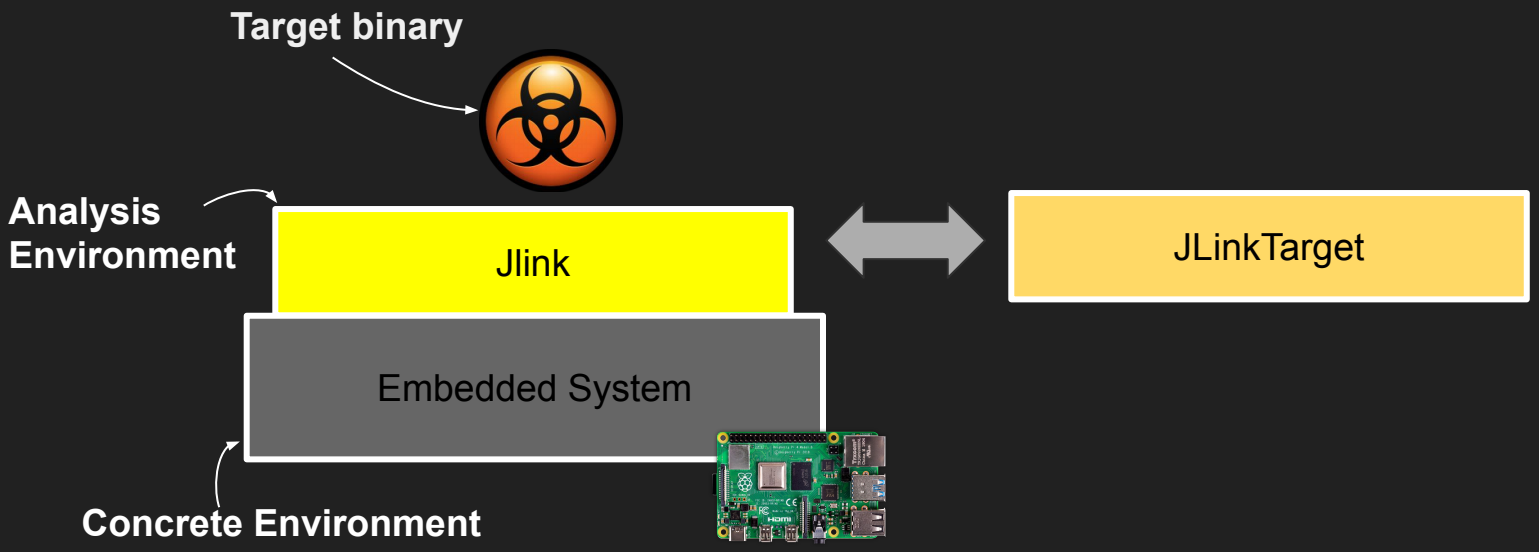
ConcreteTarget



ConcreteTarget



ConcreteTarget



Let’s put all the pieces together

Use Cases
(malware reverse engineering)

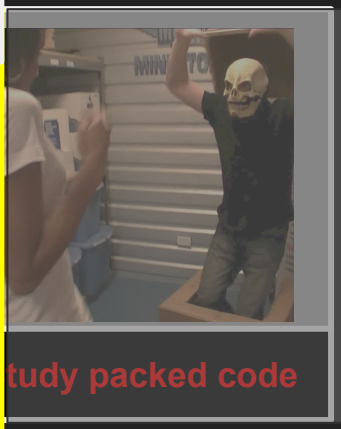
Detect DGA

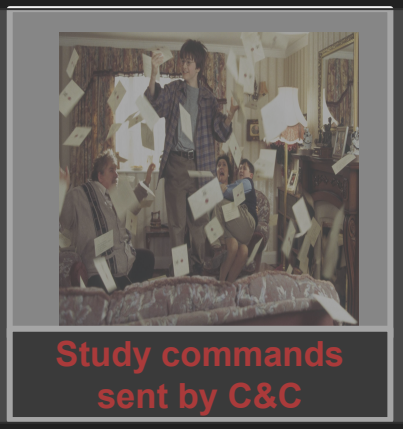
Study packed code

Study evasion techniques

Study commands sent by C&C

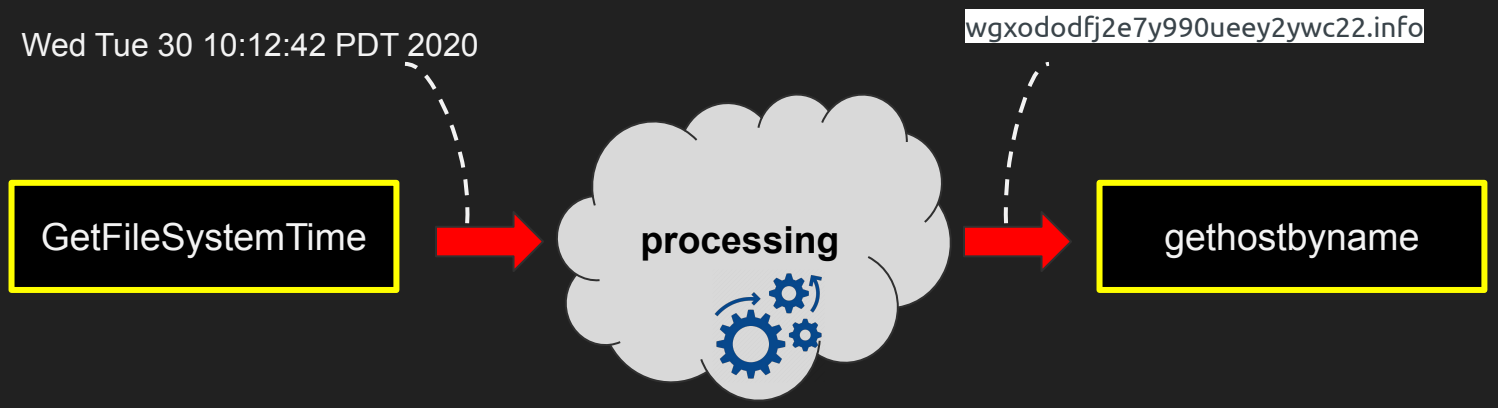
Use Cases
(malware reverse engineering)





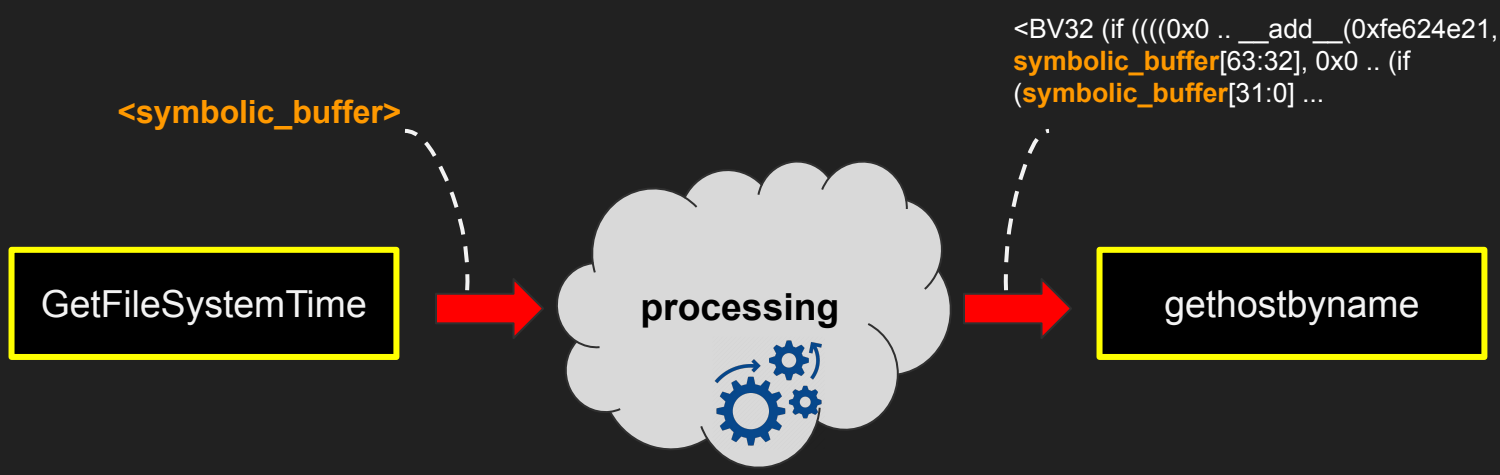
Use Case

- Symmi Trojan
  - Detecting a domain generation algorithm (DGA) inside the binary.



Use Case

- Symmi Trojan
  - Detecting a domain generation algorithm (DGA) inside the binary.

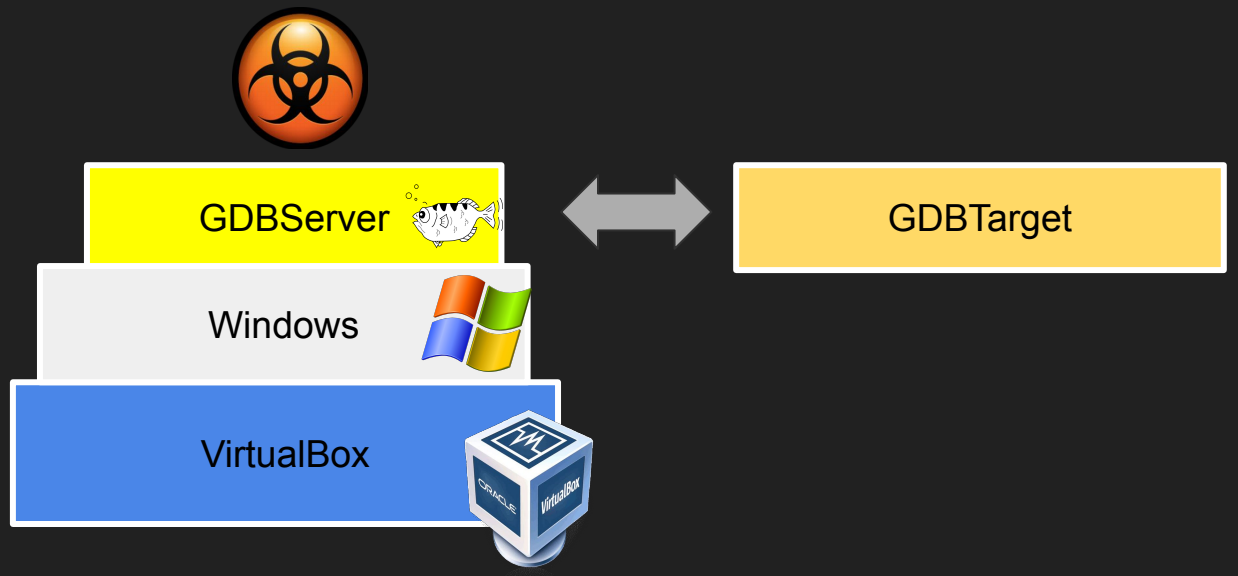


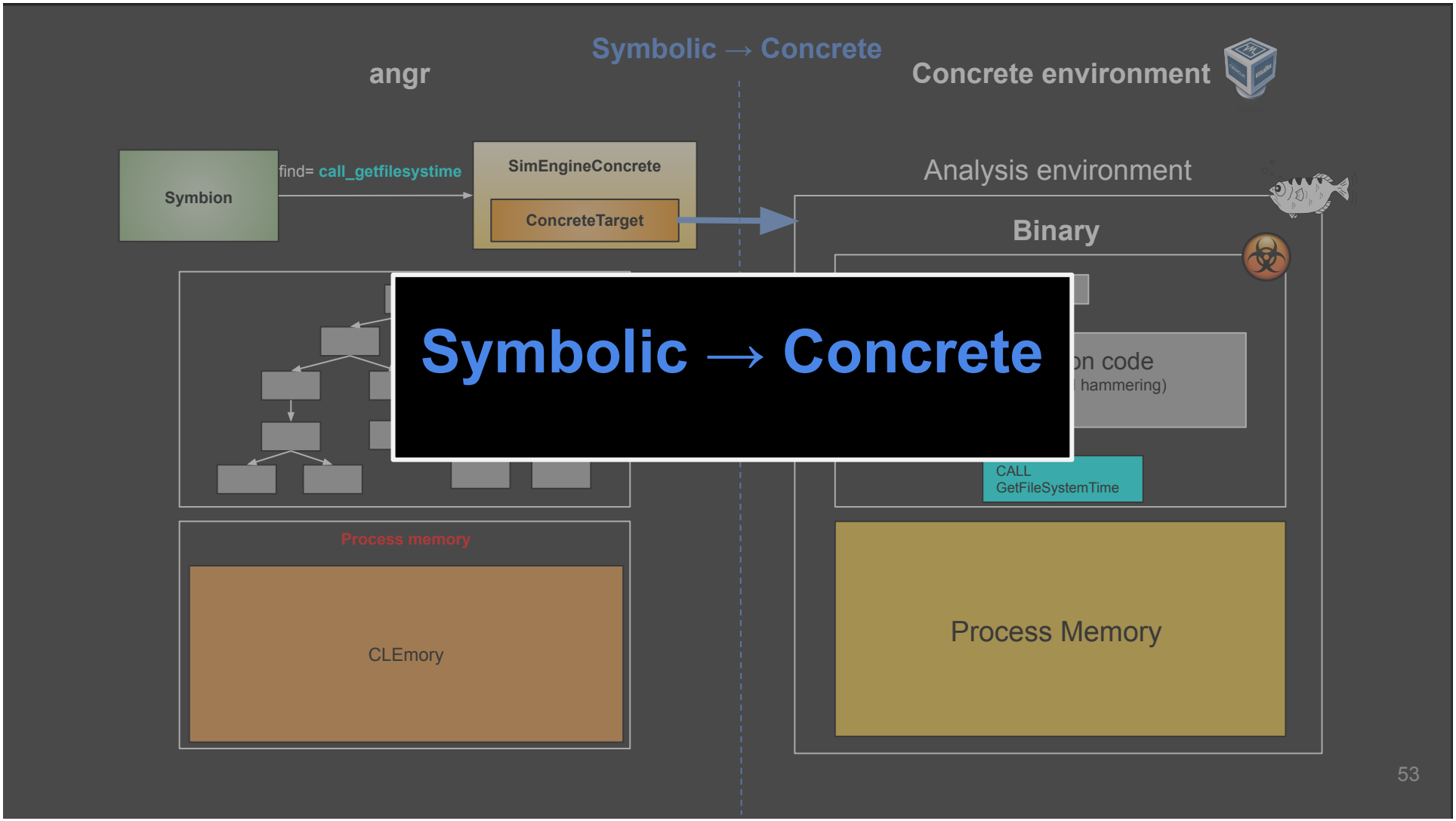
Use Case

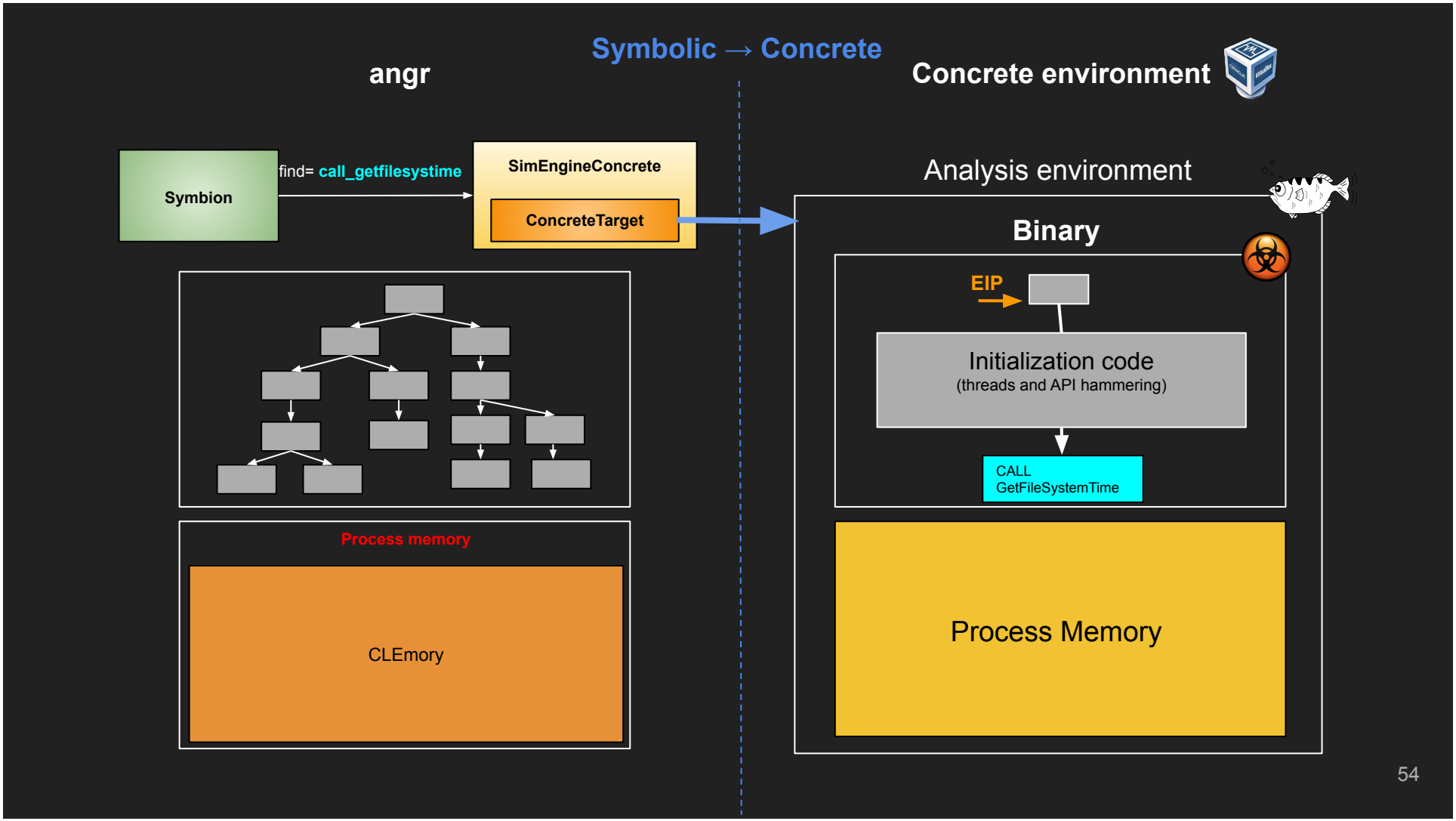
- Symmi Trojan
  - Detecting a domain generation algorithm (DGA) inside the binary.
  - **Challenges**:
    - Malware has noisy initialization code and evasion:
      - “API Hammering”
      - Junk code
      - Self-checks
    - Vanilla symbolic execution or under-constrained symbolic execution won’t work.

Use Case

- Symmi Trojan
  - Detecting a domain generation algorithm (DGA) inside the binary.




Symbolic → Concrete
angr
Concrete environment
Symbion
find= call_getfilesystime
SimEngineConcrete
ConcreteTarget
Analysis environment
Binary
Symbolic → Concrete
n code
hammering)
CALL
GetFileSystemTime
Process memory
CLEmory
Process Memory


Symbolic → Concrete
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Concrete environment
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find= call_getfilesystime
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ConcreteTarget
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EIP
Initialization code
(threads and API hammering)
CALL
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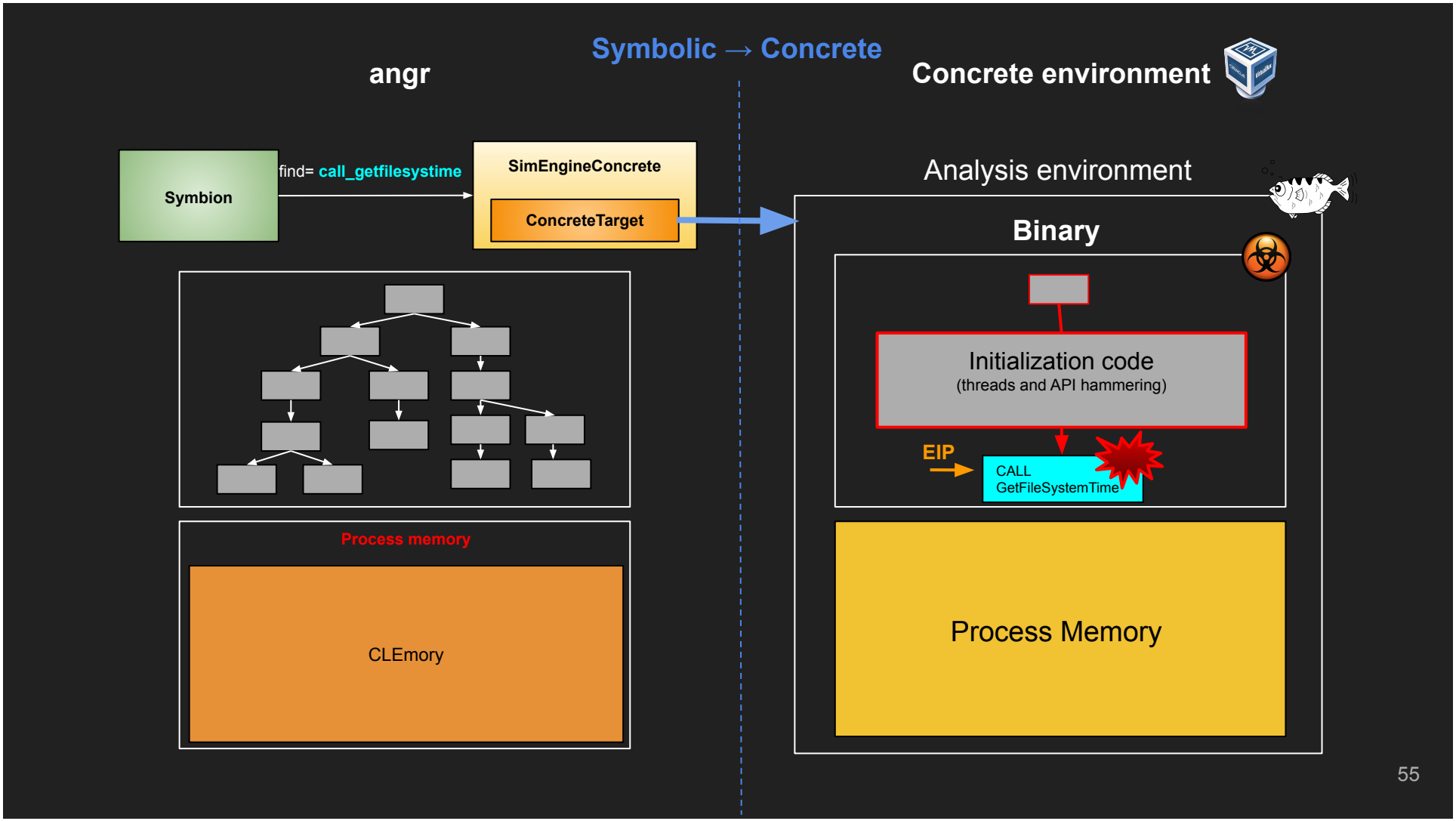
Process Memory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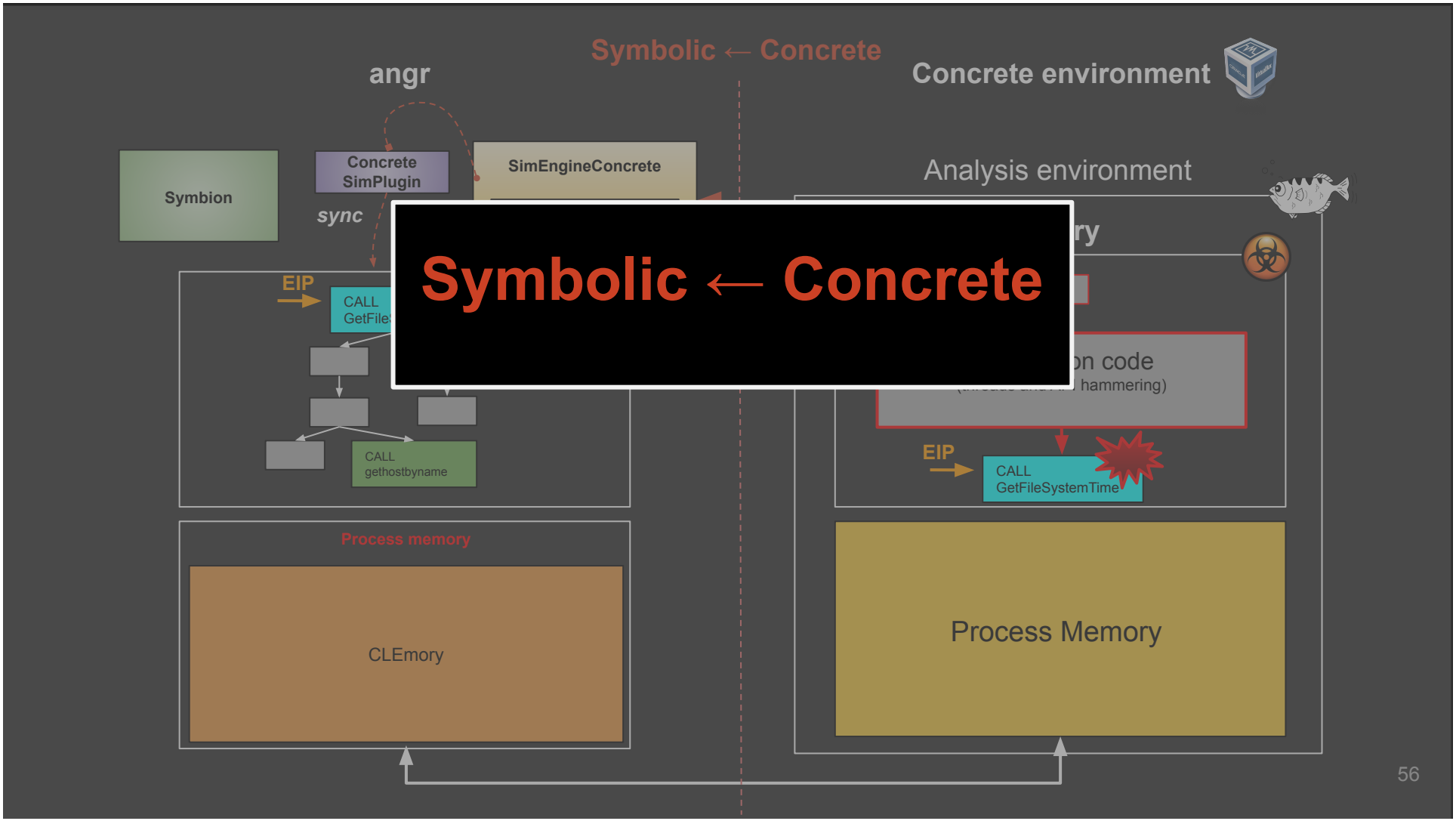
Symbolic ← Concrete
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SimEngineConcrete
sync
Analysis environment
Symbolic ← Concrete
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CALL GetFile
CALL gethostbyname
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CALL GetFileSystemTime
Process memory
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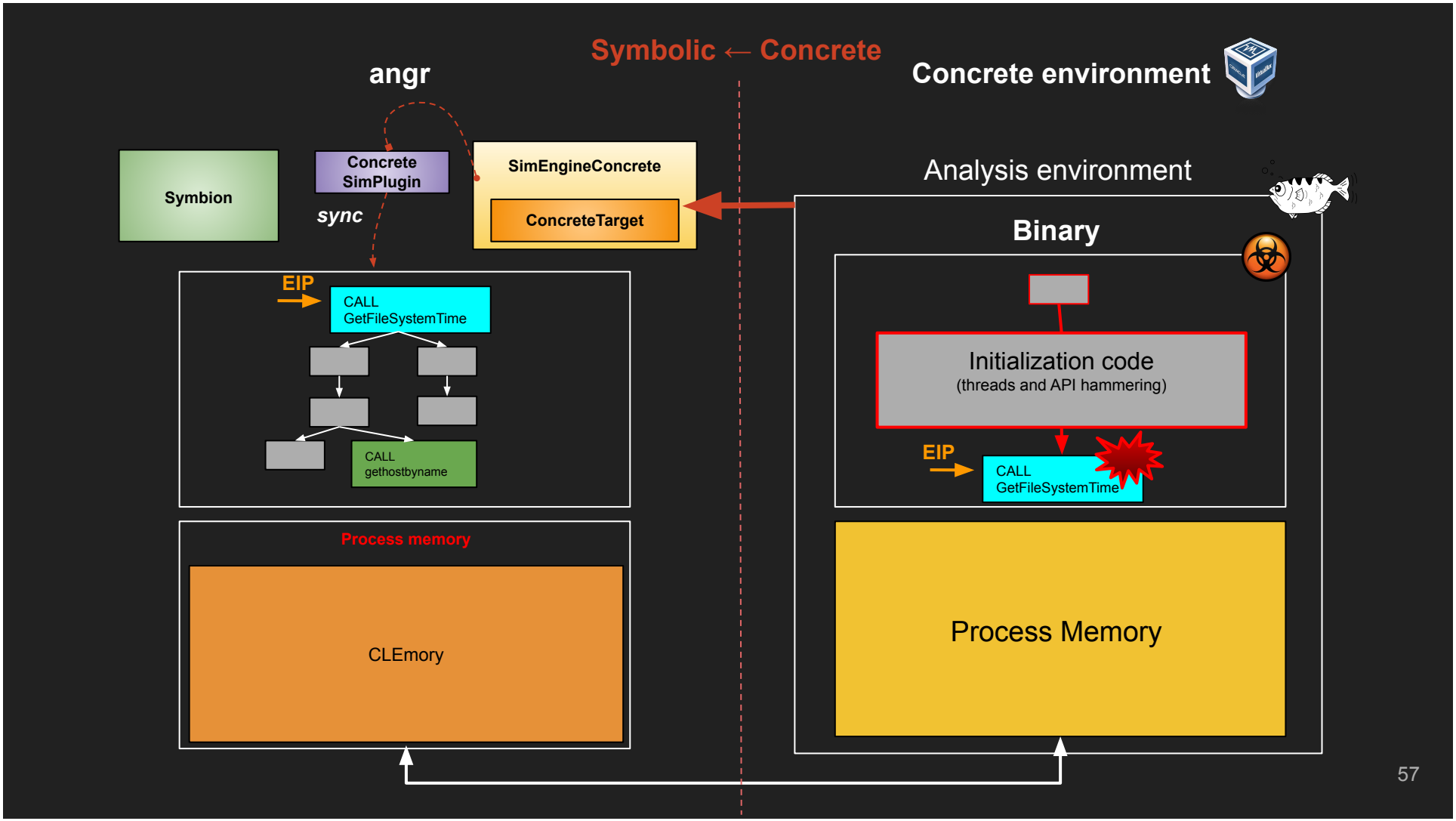
Process Memory


Symbolic ← Concrete
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Concrete SimPlugin
sync
SimEngineConcrete
ConcreteTarget
Analysis environment
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CALL GetFileSystemTime
CALL gethostbyname
Initialization code
(threads and API hammering)
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CALL GetFileSystemTime
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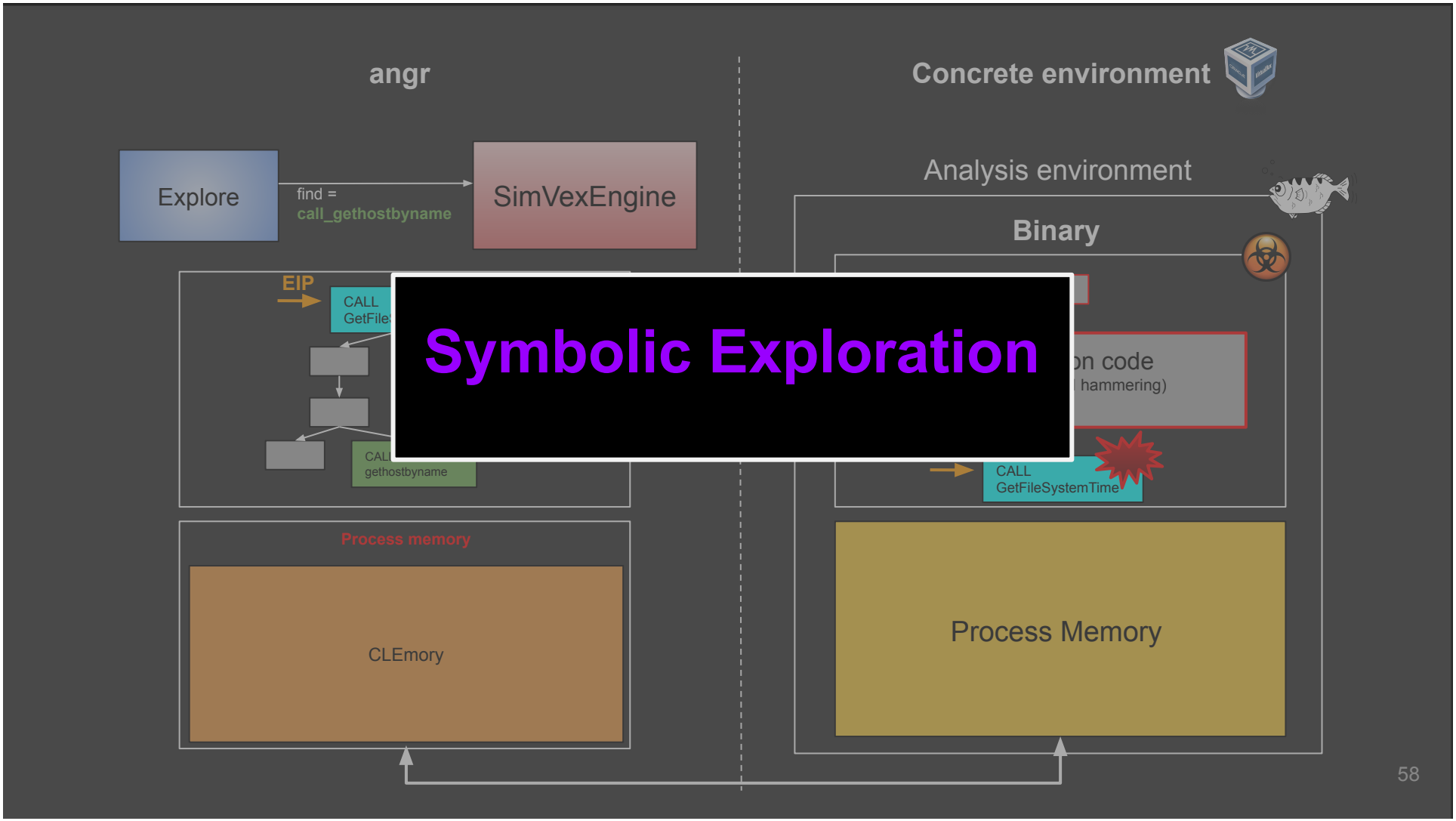
Process Memory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GetFileSystemTime
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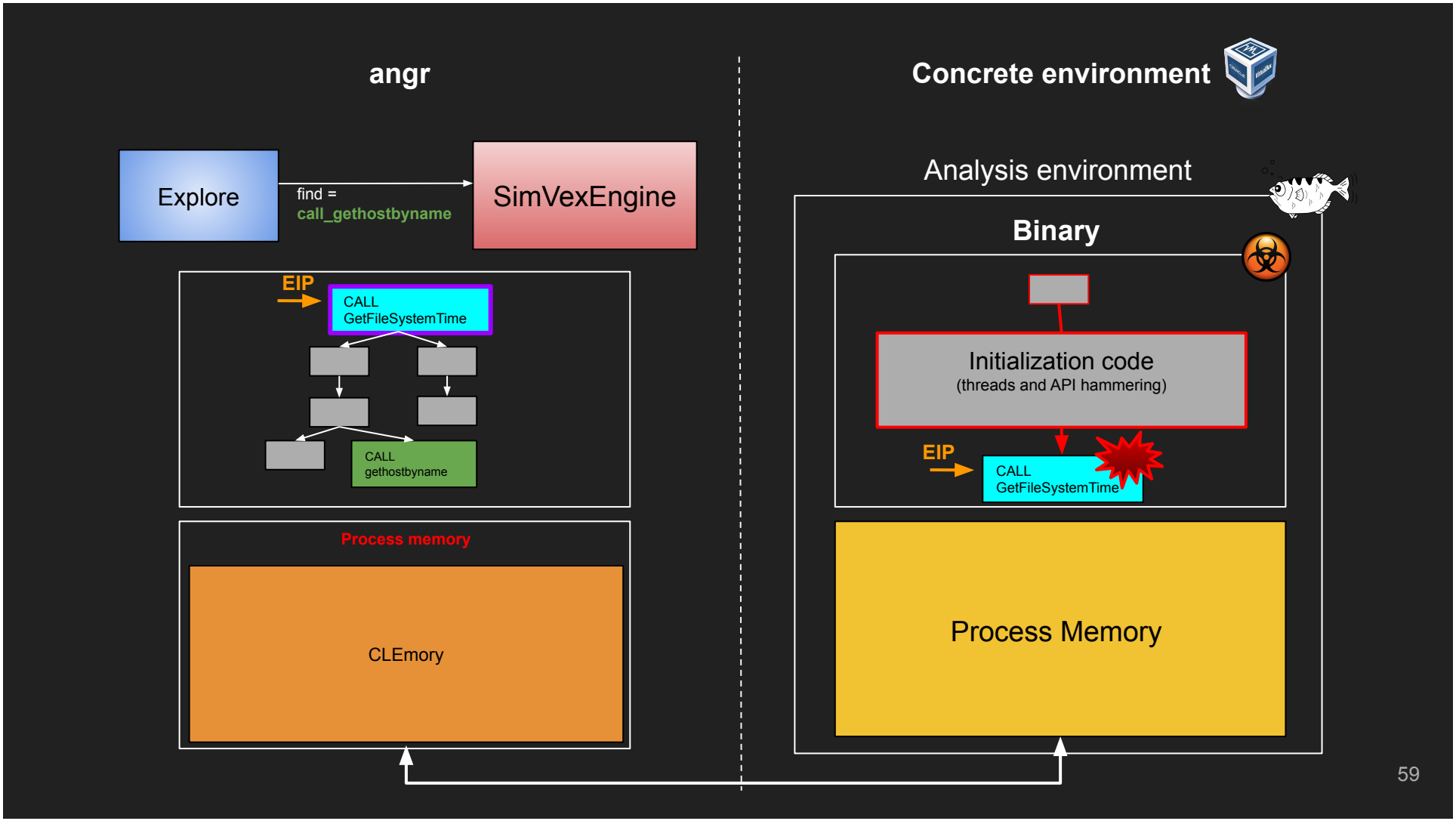
Process Memory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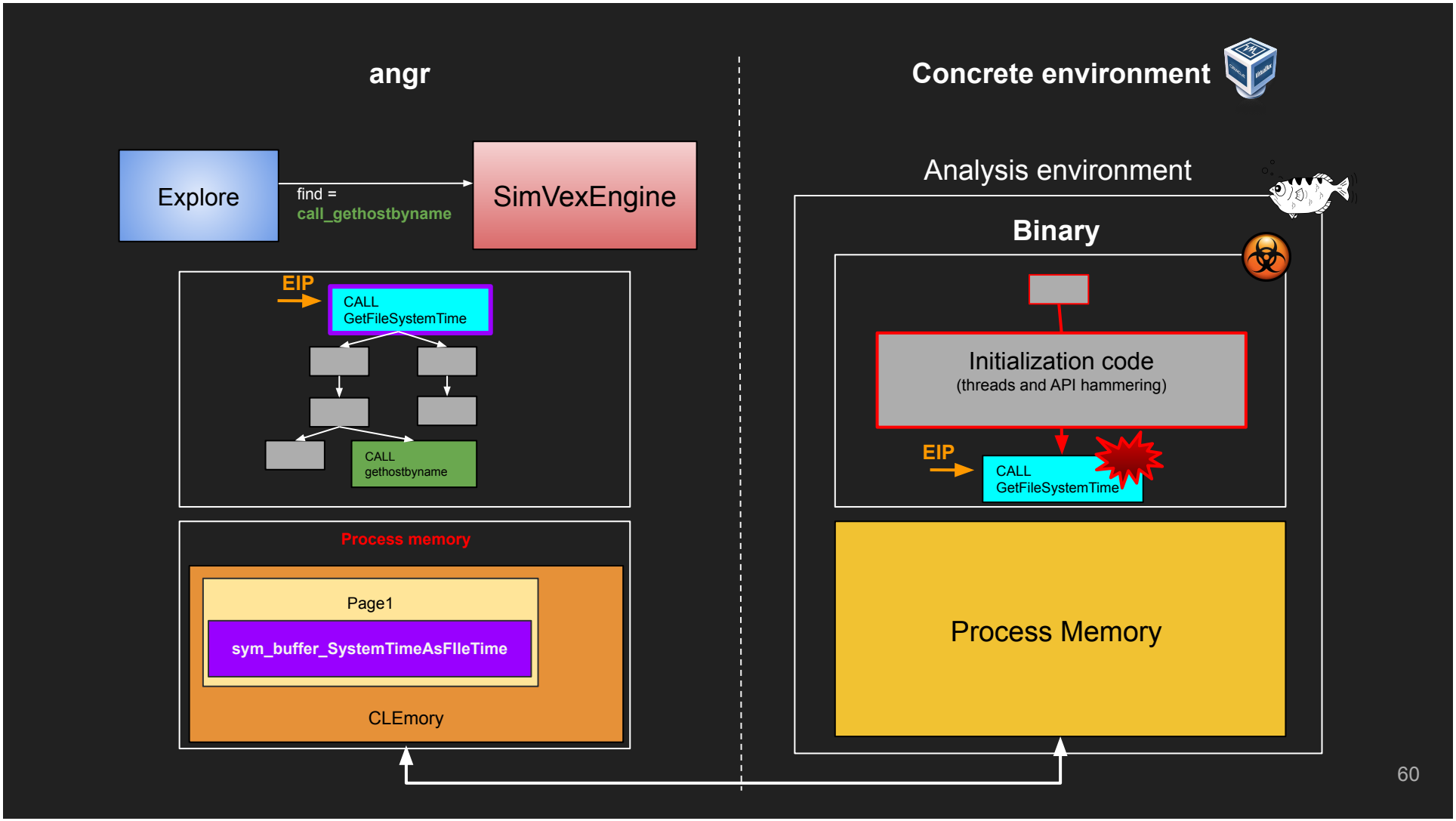
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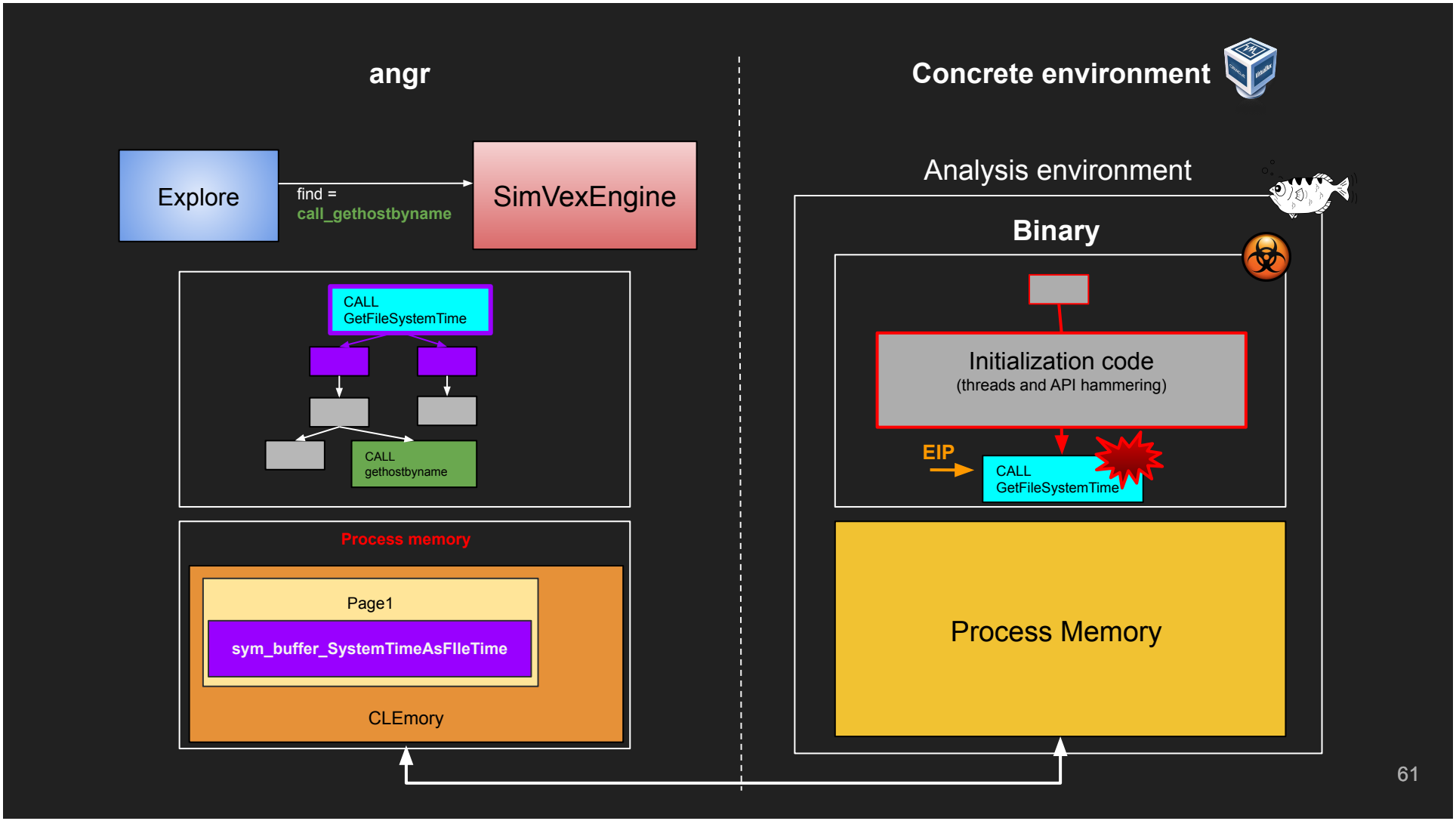
Concrete environment
Explore
find =
call_gethostbyname
SimVexEngine
EIP
CALL
GetFileSystemTime
CALL
gethostbyname
Process memory
Page1
sym_buffer_SystemTimeAsFIleTime
CLEmory
Analysis environment
Binary
Initialization code
(threads and API hammering)
EIP
CALL
GetFileSystemTime
Process Memory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find =
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SimVexEngine
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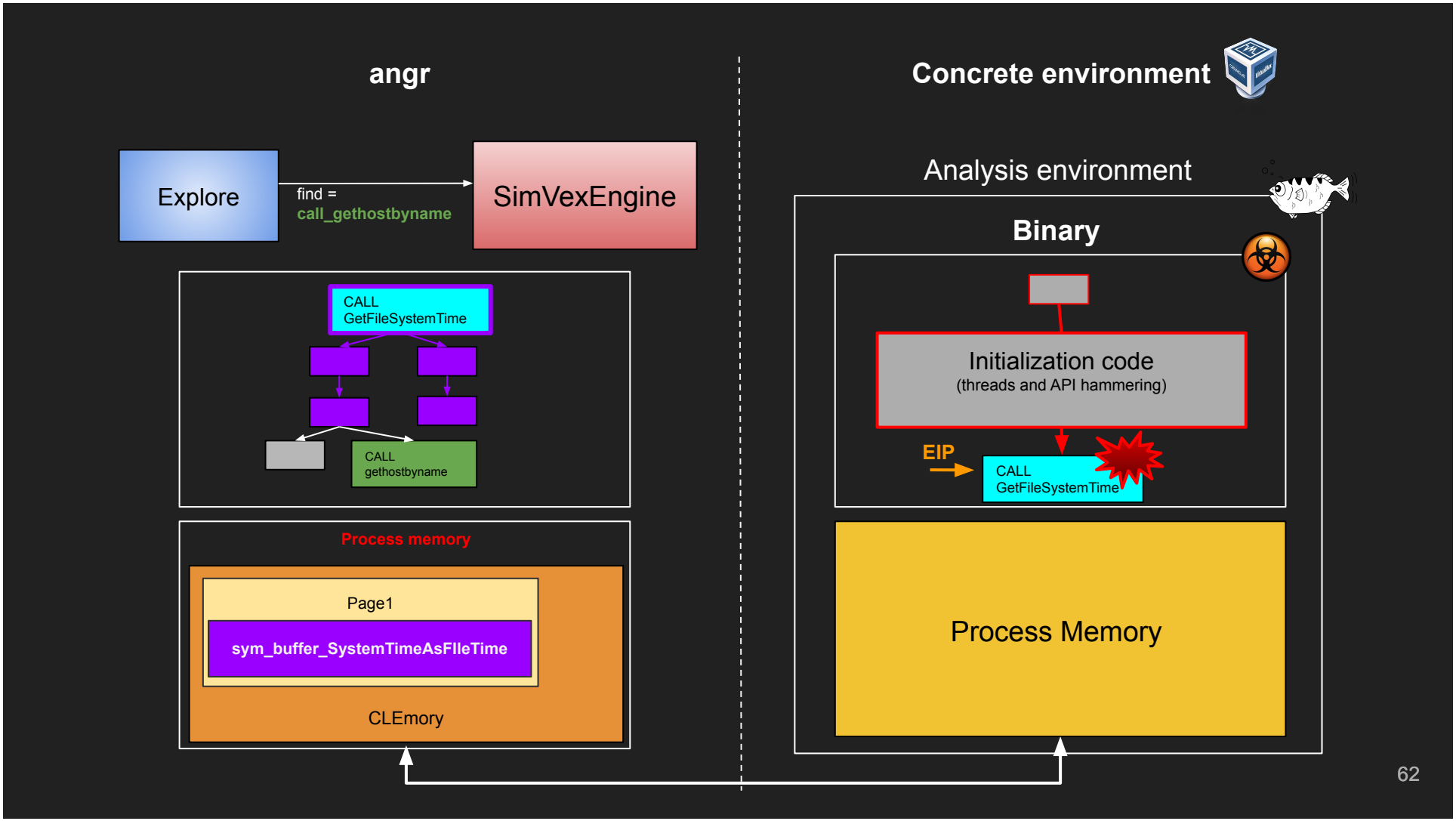
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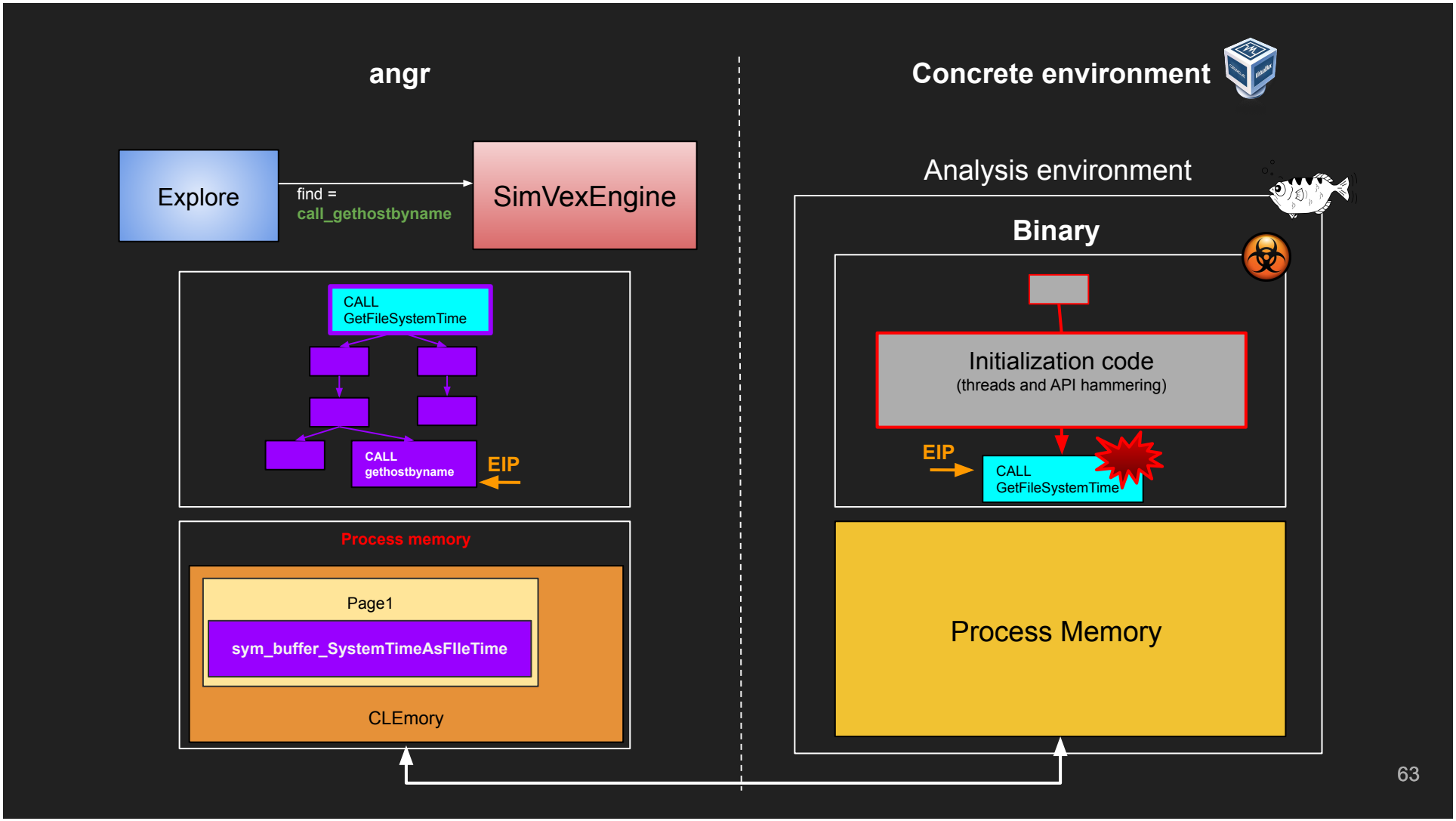
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GetFileSystemTime
CALL
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EIP
Process memory
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sym_buffer_SystemTimeAsFIleTime
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Analysis environment
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Initialization code
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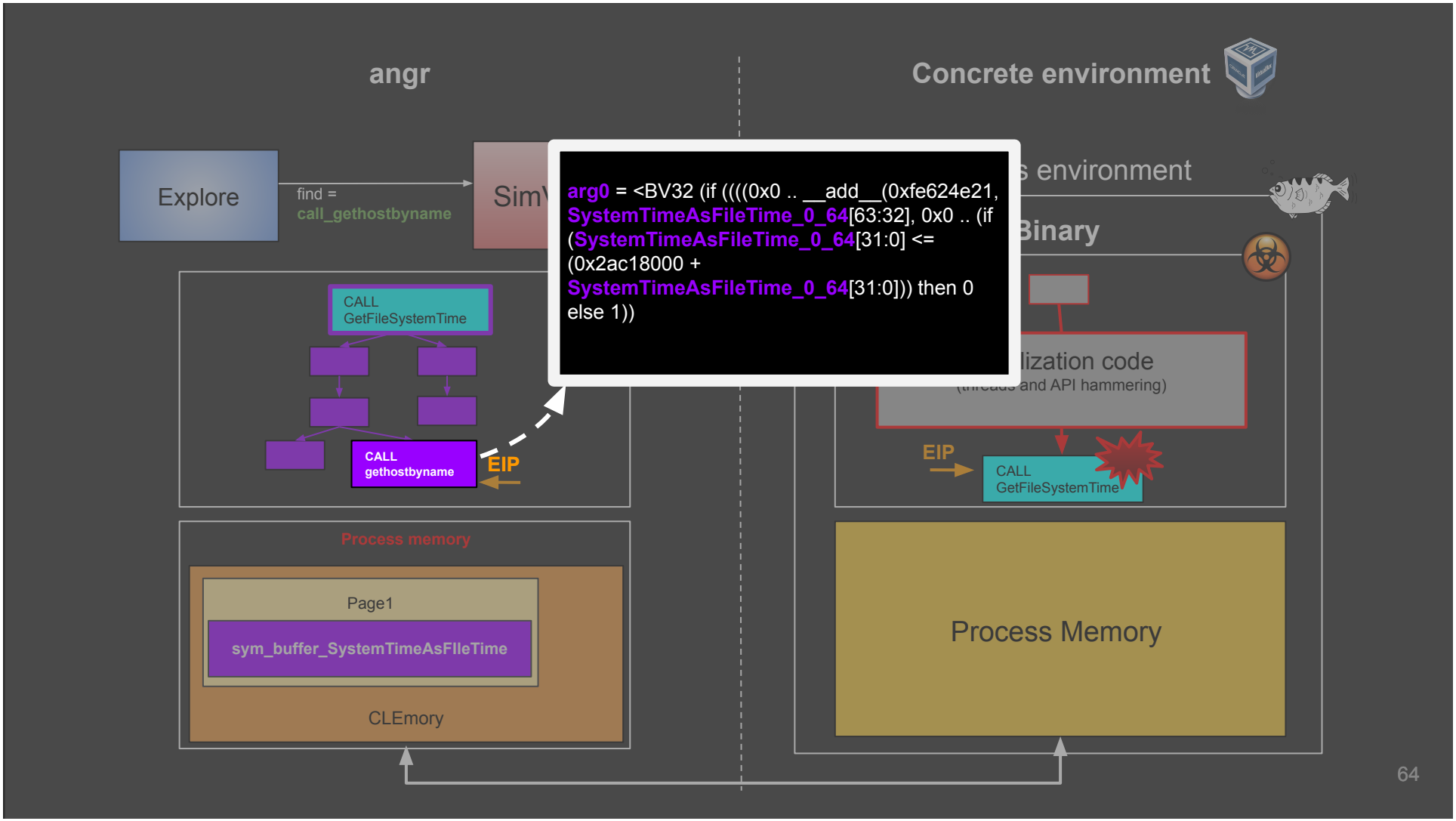
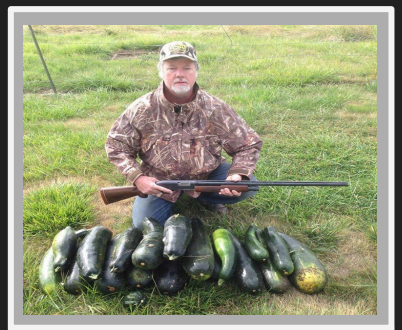
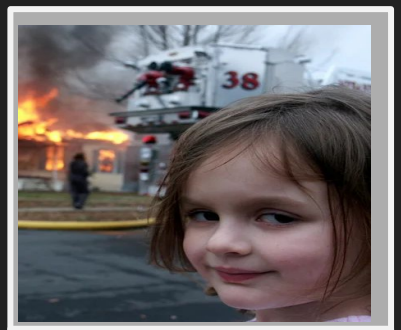

angr
Concrete environment
Explore
find =
call_gethostbyname
arg0 = <BV32 (if ((((0x0 .. __add__(0xfe624e21, SystemTimeAsFileTime_0_64[63:32], 0x0 .. (if (SystemTimeAsFileTime_0_64[31:0] <= (0x2ac18000 + SystemTimeAsFileTime_0_64[31:0])) then 0 else 1))
s environment
Binary
lization code
and API hammering)
CALL
GetFileSystemTime
CALL
gethostbyname
EIP
EIP
CALL
GetFileSystemTime
Process memory
Page1
sym_buffer_SystemTimeAsFIleTime
CLEmory
Process Memory

(More) Use Cases



Vulnerabilities Hunting



Exploit Writing/Generation

More!

Comparison

- Question prediction: Why isn’t this just “Concolic Execution?”

Comparison

- Question prediction: Why isn't this just "Concolic Execution?"
- **Concolic execution** has the goal of improving code coverage of vanilla symbolic execution.
- The techniques are orthogonal and can be chained together

Comparison

- Other similar tools have been developed in the past:
  - Avatar2
  - Triton
  - S2E
  - Mayhem (not freely available to the community)
- None was really making available this kind of technique in a customizable, general purpose and easy to use/programmatic way

Limitations

- Program execution correctness not guaranteed by default
  - Users could force executions that are not feasible
  - Solutions to mitigate this can be implemented on top of the technique
- Desynchronized environment interactions
  - Only registers and memory are synchronized
  - States of other objects (socket,file,stdin/stdout) are not sync with the symbolic engine
- Targets support
  - Limited amount of Concrete Targets
  - “Lazy developing” (as needed)

Takeaways

1. Symbion is a building block that can empower different new analyses applied to many scenarios

2. Supporting symbolic execution at real-world-program scale is essential

3. Symbion provides a compromise between the power of symbolic execution and the ability to operate on real-world programs

Support

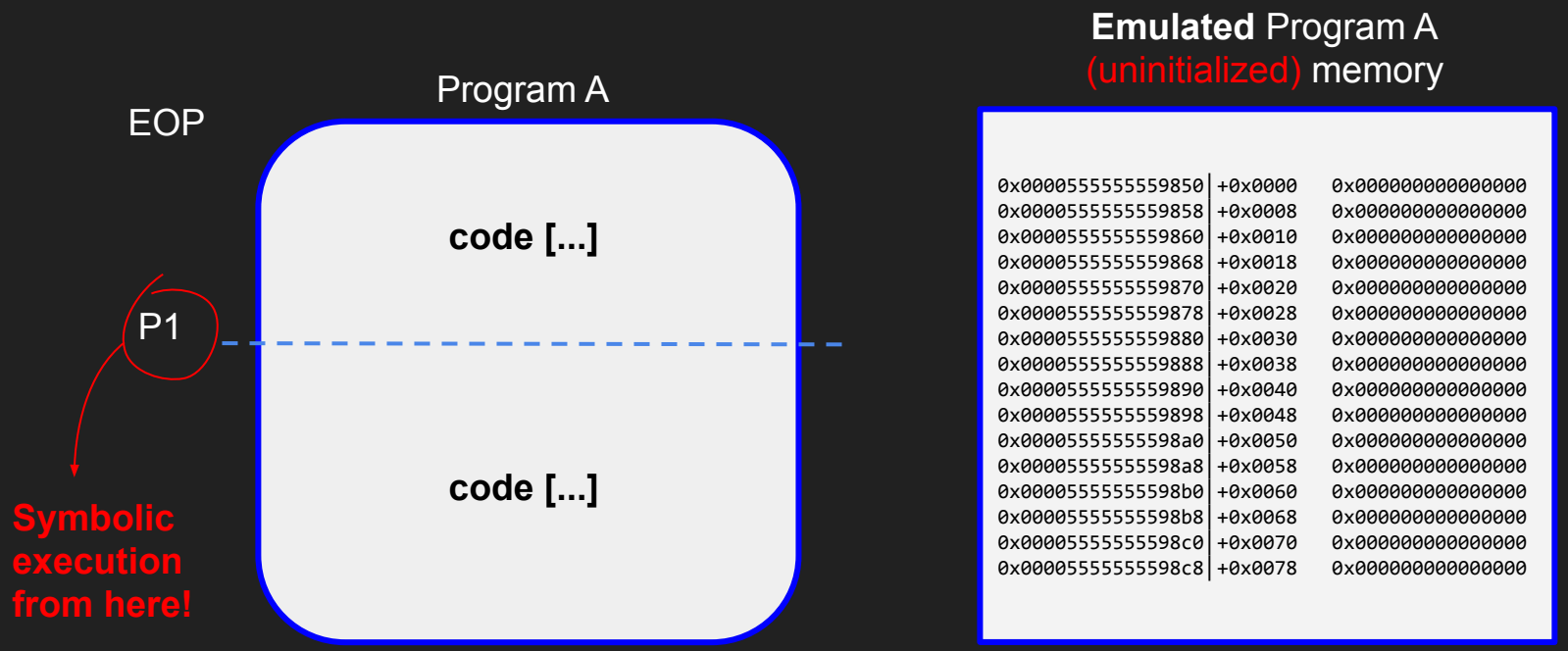
- Open source
  - https://github.com/angr/angr
  - https://github.com/degrigis/symbion-use-cases
  - https://github.com/angr/angr-targets
- Docs & Tutorials
  - https://angr.io/blog/angr_symbion/
  - https://docs.angr.io/advanced-topics/symbion
- Support
  - https://angr.io/invite/
  - Just yell in #help or directly ping me @degrigis

Thanks!

degrigis@cs.ucsb.edu

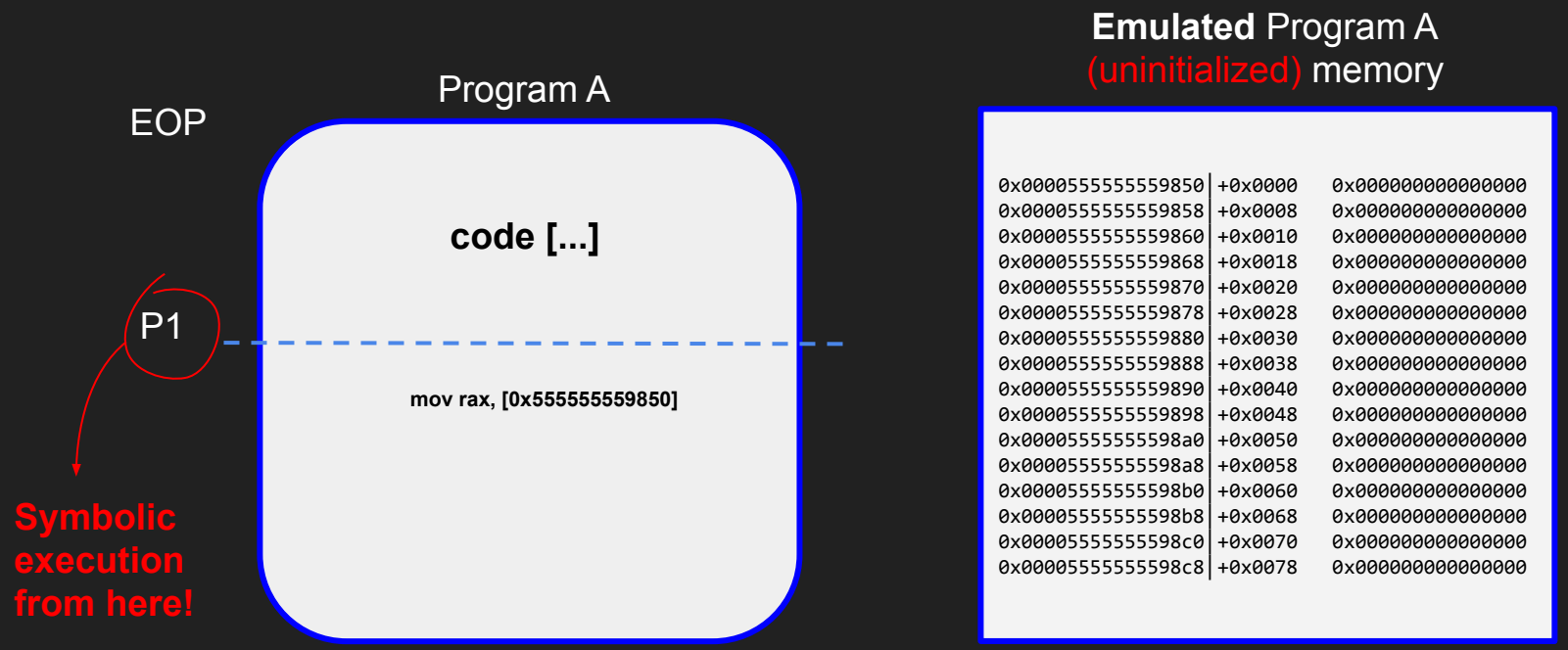
@degrigis

Motivation



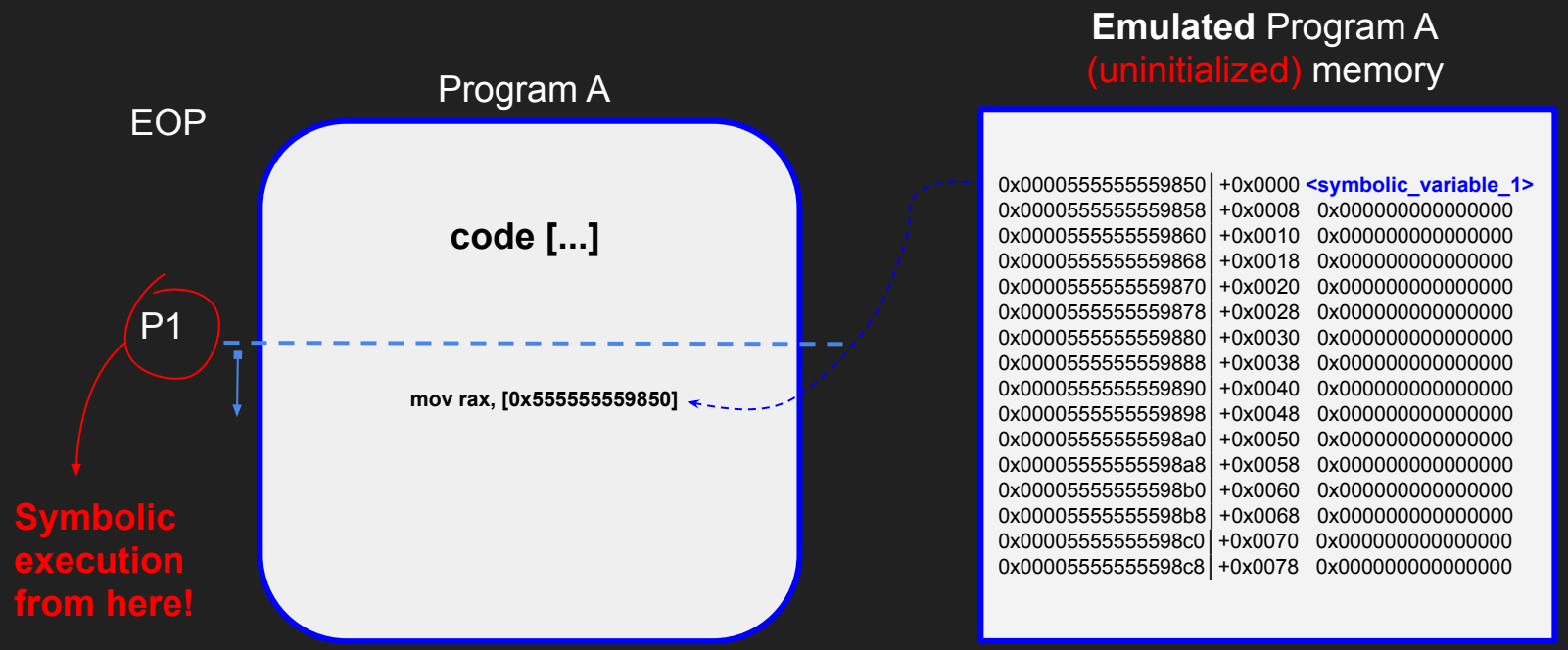
"under-constrained" symbolic execution

Motivation



"under-constrained" symbolic execution

Motivation



"under-constrained" symbolic execution

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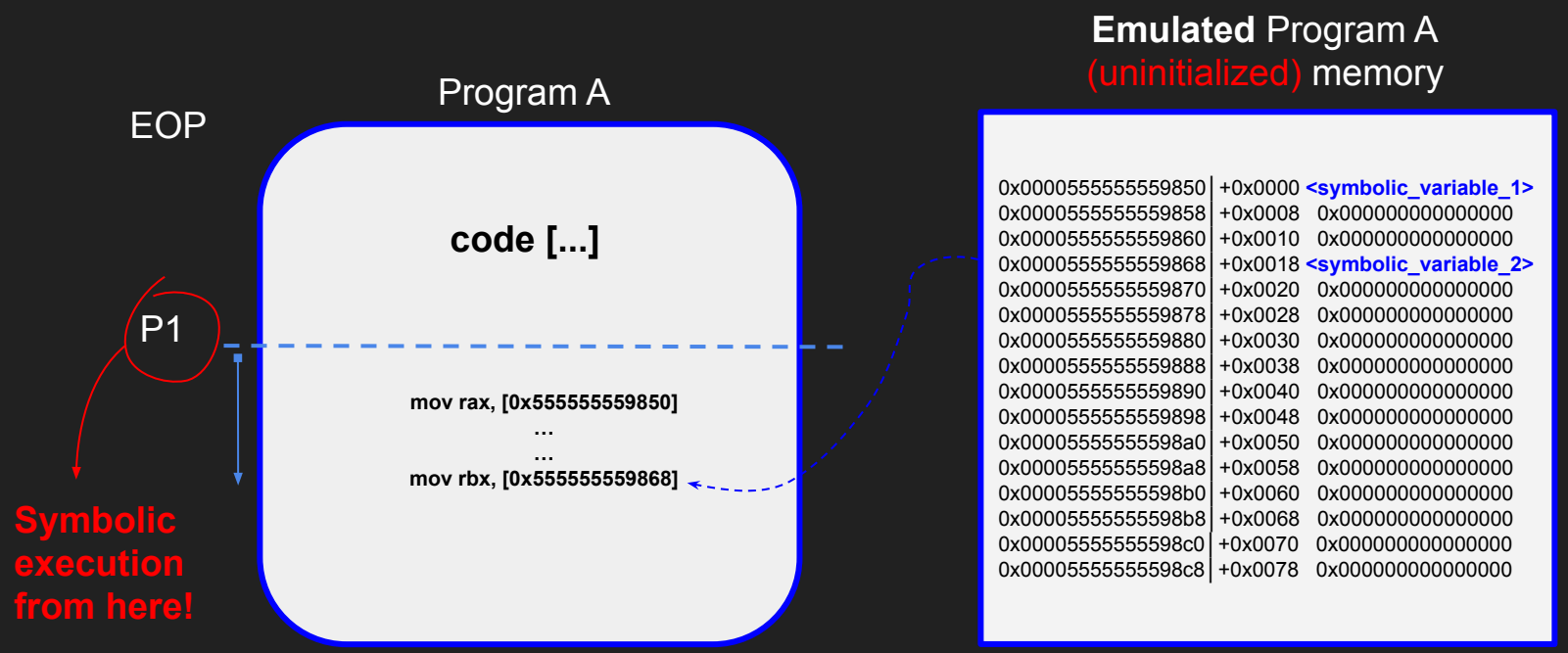
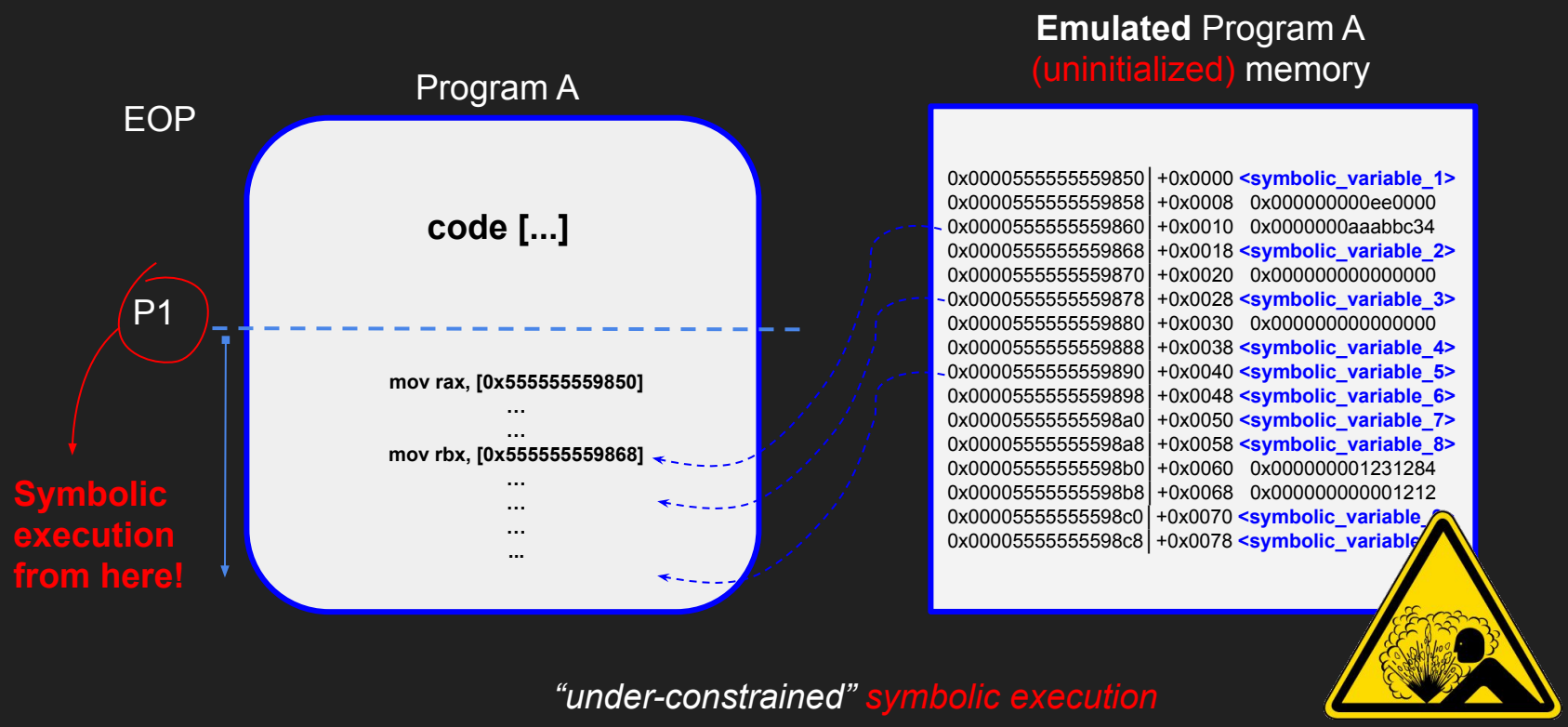


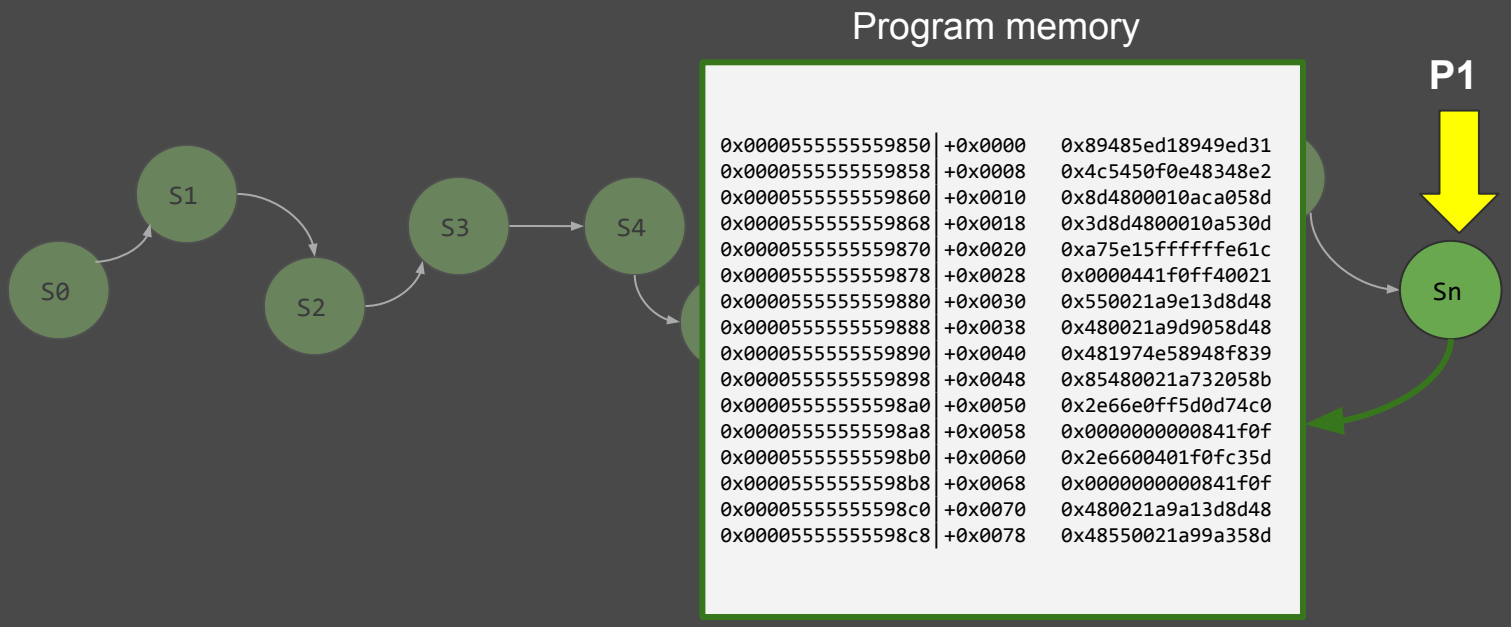
"under-constrained" symbolic execution

Motivation



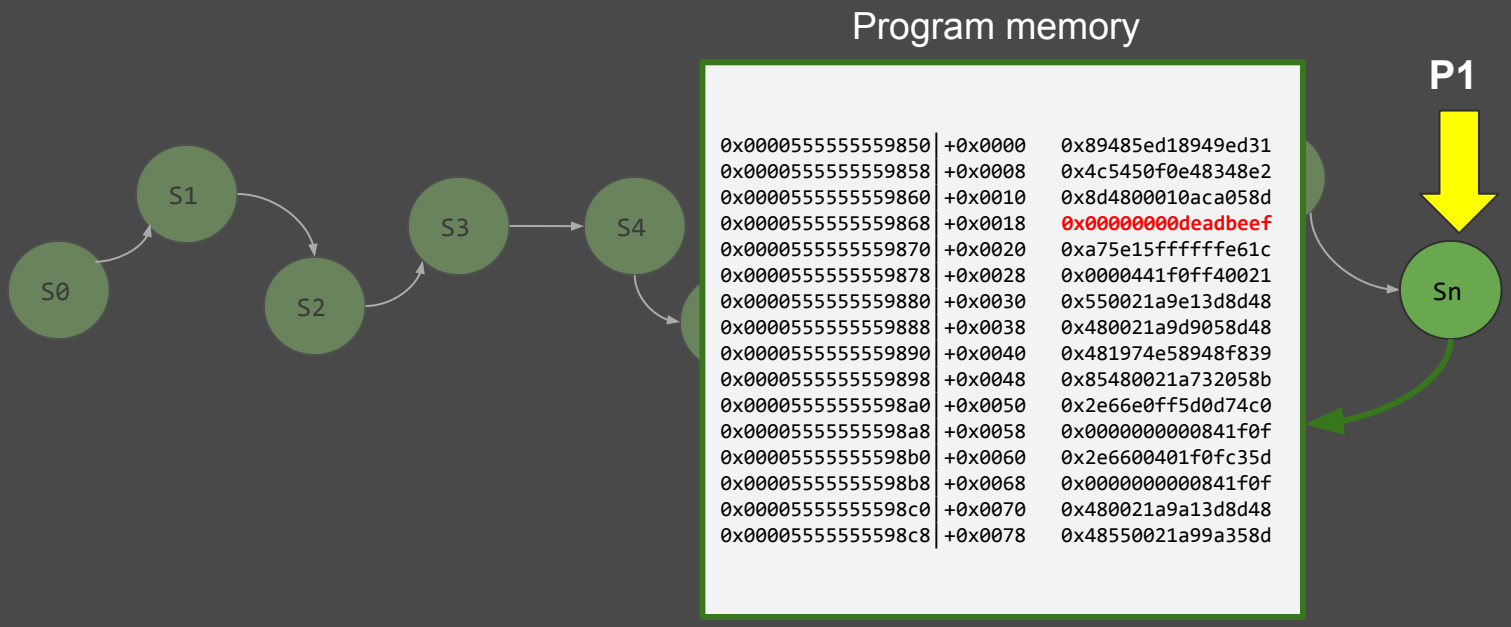
"under-constrained" symbolic execution

Approach



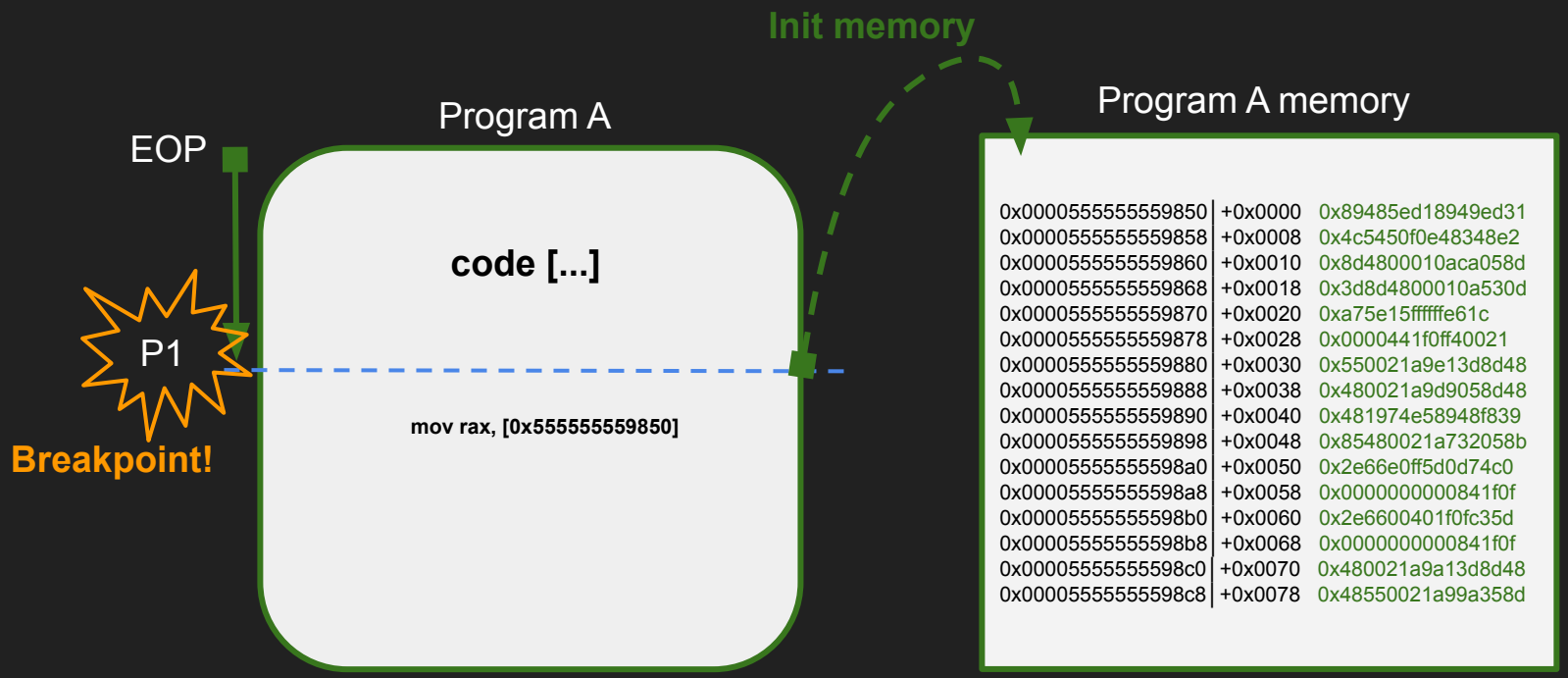
Interleaved symbolic execution

Approach



Interleaved symbolic execution

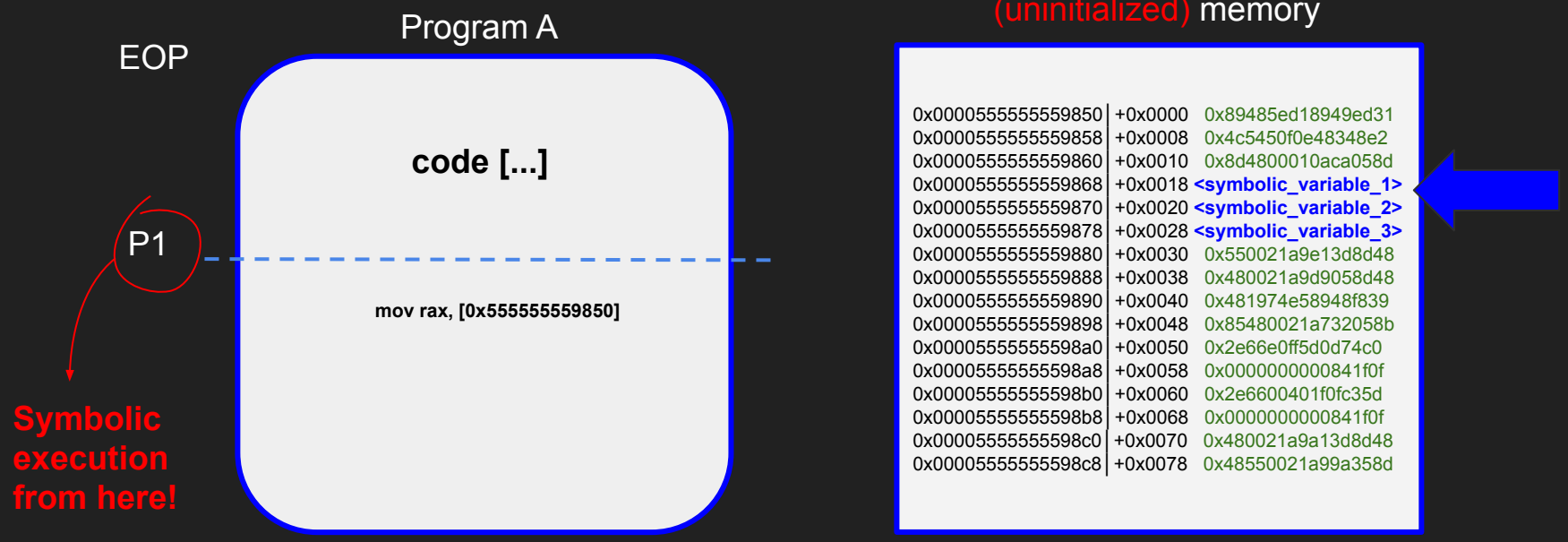
Approach



Interleaved symbolic execution

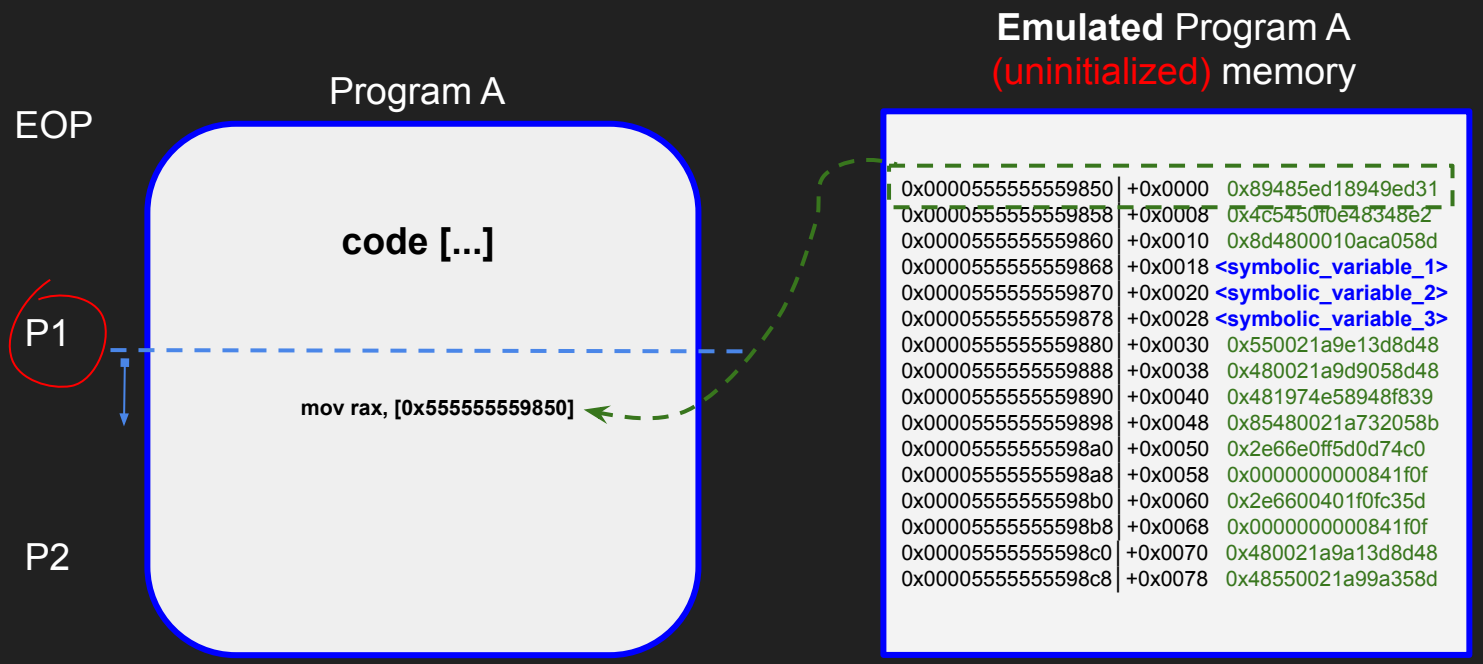
(Phase 1: concrete execution to P1)

Approach



Interleaved symbolic execution
(Phase 2: setup symbolic data)

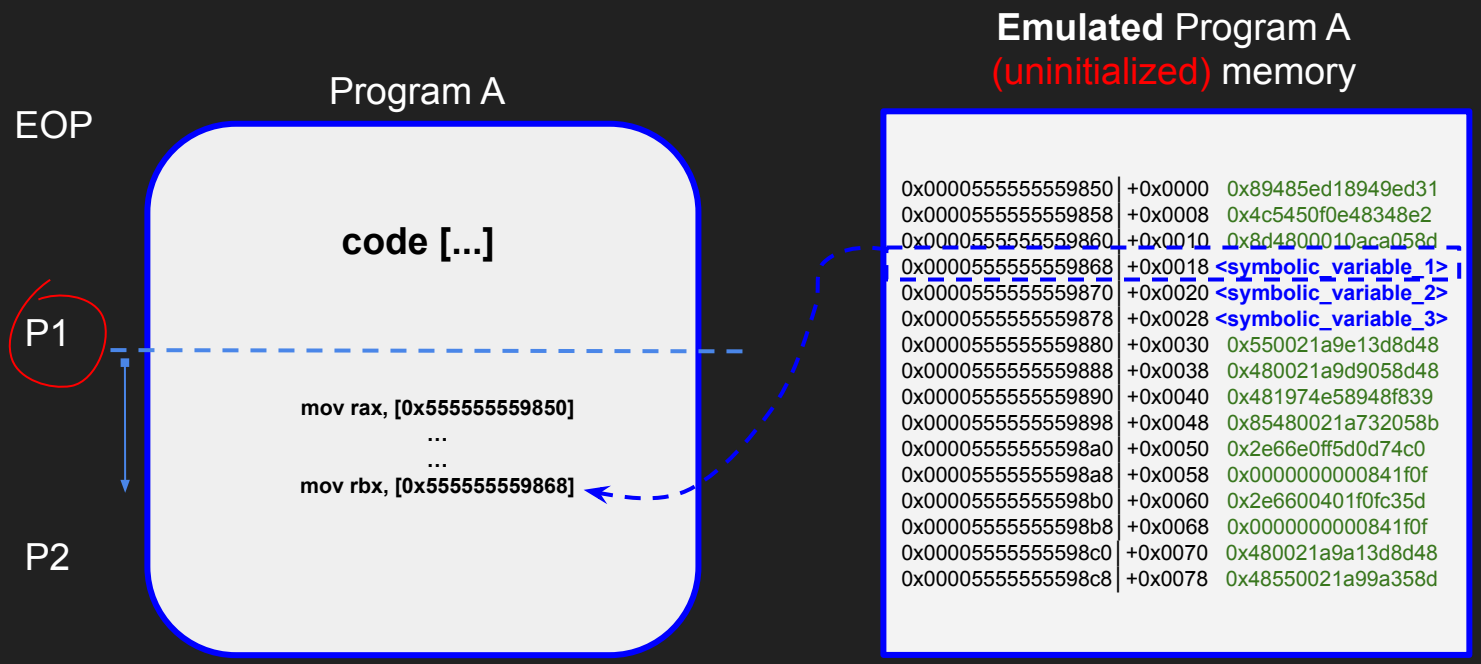
Approach



Interleaved symbolic execution

(Phase 3: symbolic execution)

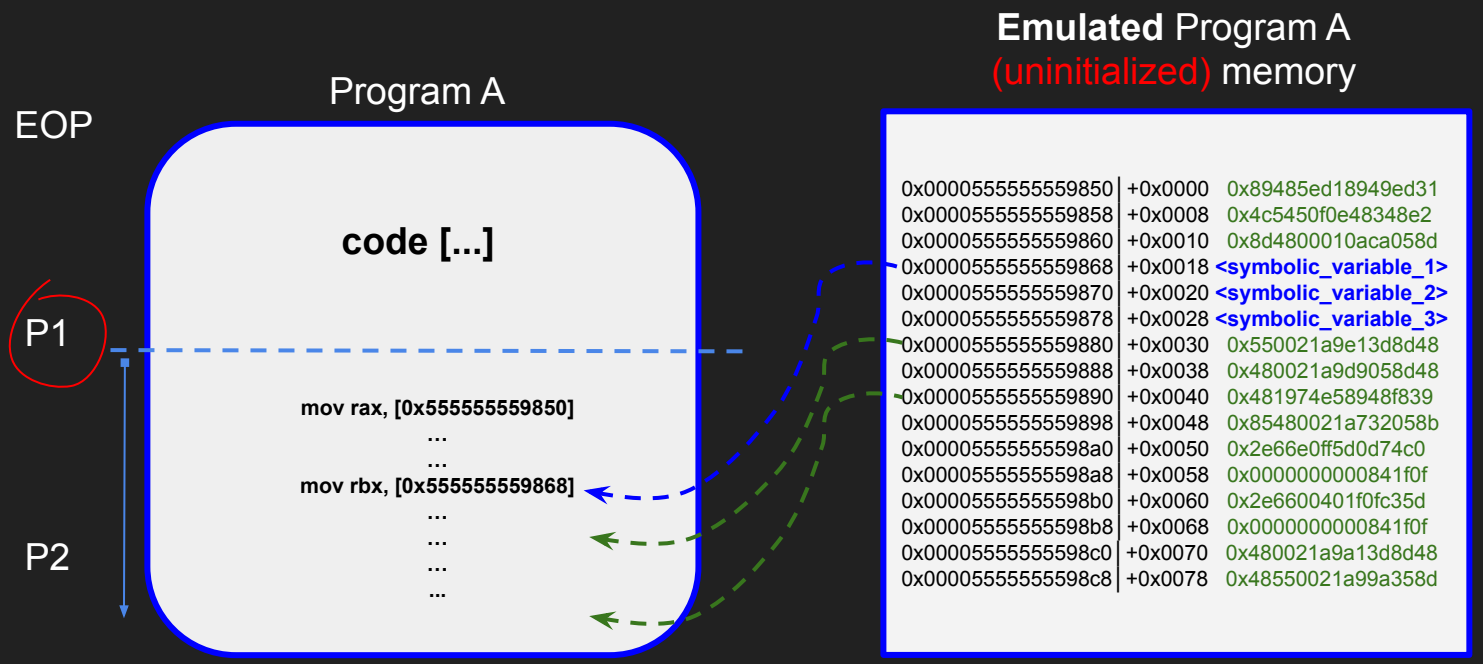
Approach



Interleaved symbolic execution

(Phase 3: symbolic execution)

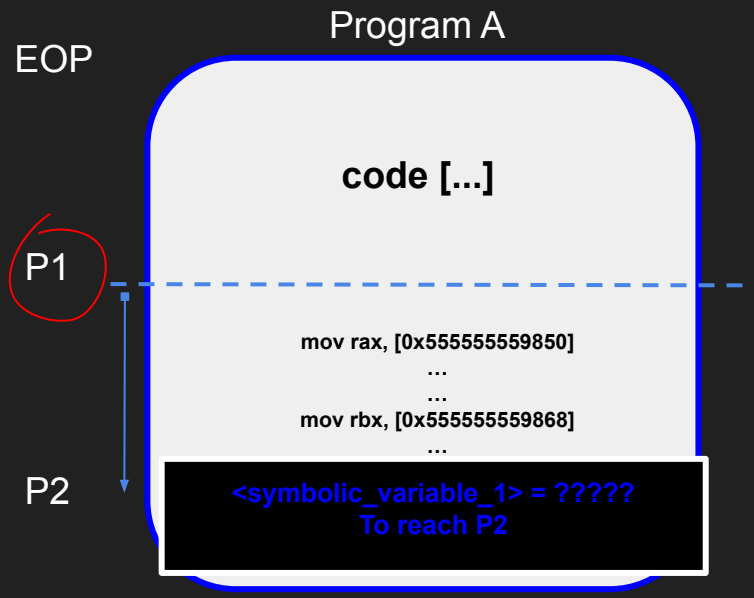
Approach



Interleaved symbolic execution

(Phase 3: symbolic execution)

Approach

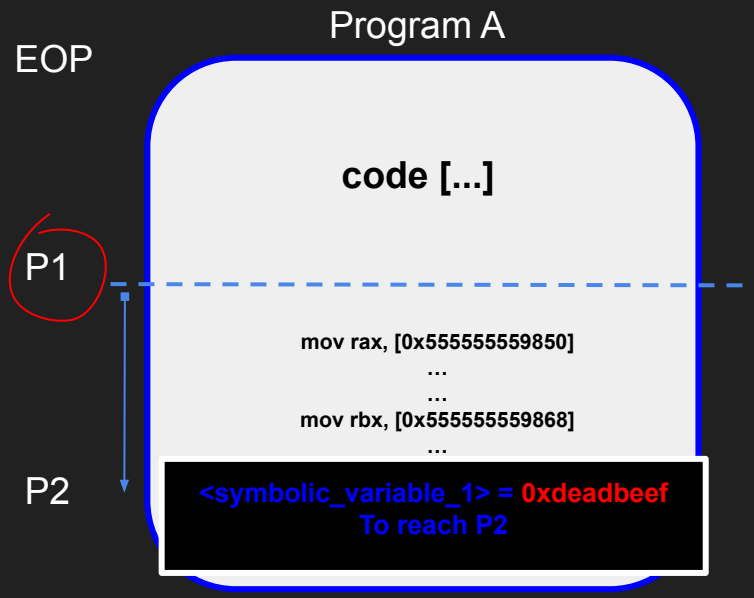


Emulated Program A
(uninitialized) memory

0x0000555555559850	+0x0000	0x89485ed18949ed31
0x0000555555559858	+0x0008	0x4c5450f0e48348e2
0x0000555555559860	+0x0010	0x8d4800010aca058d
0x0000555555559868	+0x0018	<symbolic_variable_1>
0x0000555555559870	+0x0020	<symbolic_variable_2>
0x0000555555559878	+0x0028	<symbolic_variable_3>
0x0000555555559880	+0x0030	0x550021a9e13d8d48
0x0000555555559888	+0x0038	0x480021a9d9058d48
0x0000555555559890	+0x0040	0x481974e58948f839
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
0x00005555555598c8	+0x0078	0x48550021a99a358d

Interleaved symbolic execution
(Phase 3: symbolic execution)

Approach



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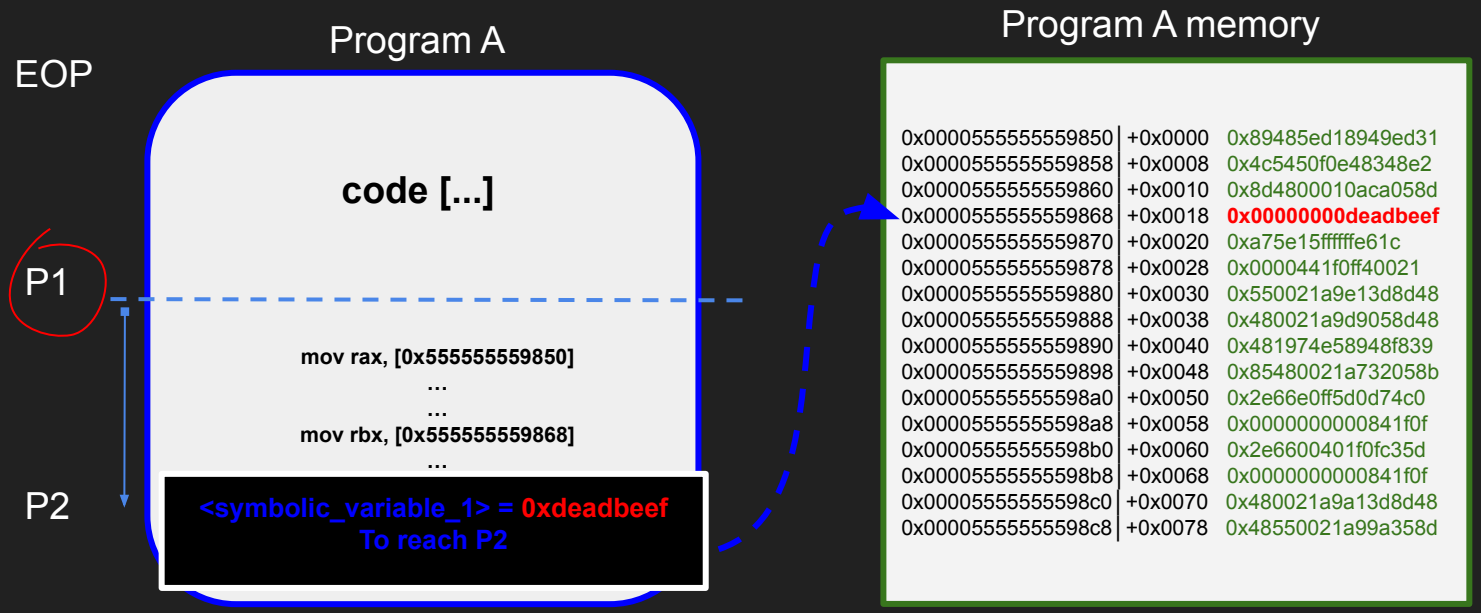
0x0000555555559898	+0x0048	0x85480021a732058b
0x00005555555598a0	+0x0050	0x2e66e0ff5d0d74c0
0x00005555555598a8	+0x0058	0x0000000000841f0f
0x00005555555598b0	+0x0060	0x2e6600401f0fc35d
0x00005555555598b8	+0x0068	0x0000000000841f0f
0x00005555555598c0	+0x0070	0x480021a9a13d8d48
0x00005555555598c8	+0x0078	0x48550021a99a358d

Interleaved symbolic execution
(Phase 3: symbolic execution)

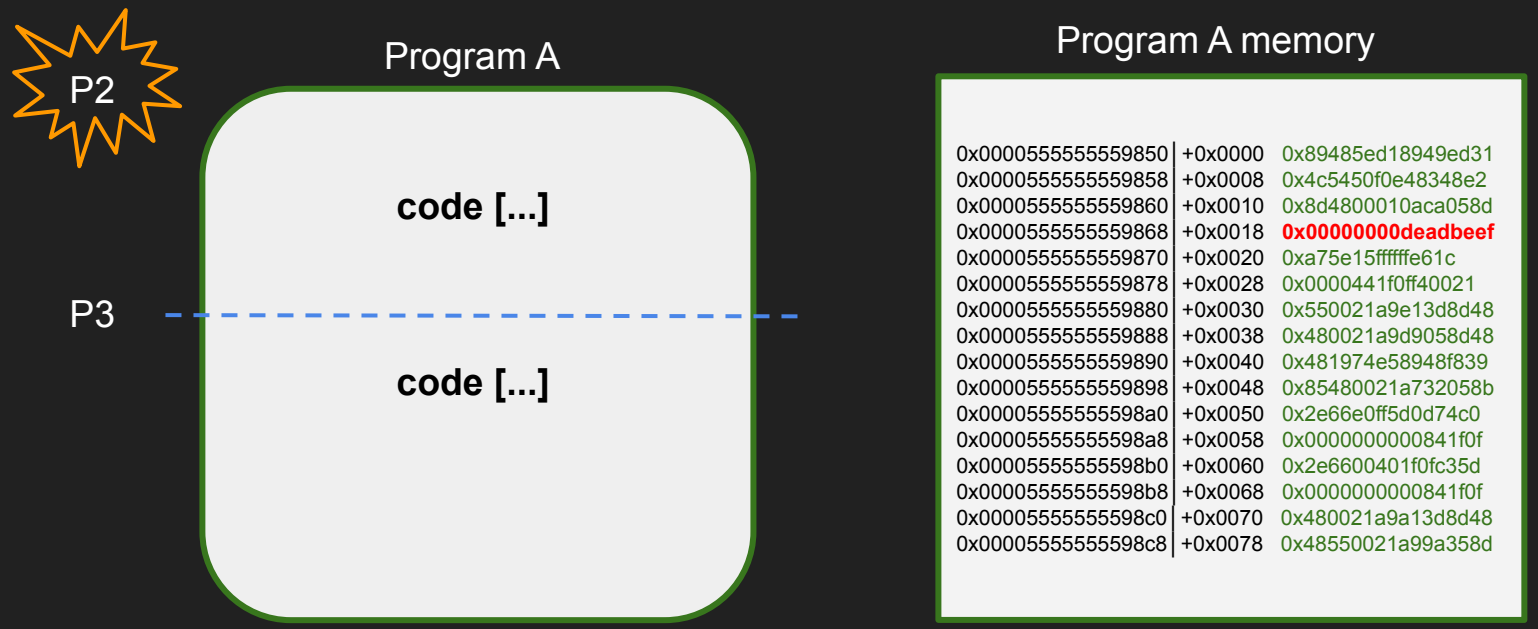
Approach



Interleaved symbolic execution

(Phase 4: Edit program A concrete memory)

Approach



Interleaved symbolic execution

(Phase 5: Resume concrete execution)

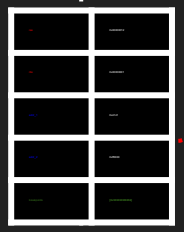
Symbion - Exploration Technique

- API provided to the users in order to control the *concrete execution* of the binary inside the *concrete environment*

System Overview

Symbolic execution engine

Concrete environment



Symbion
(Exploration Technique)

ConcreteTarget

Debugging
Component

Concrete
SimPlugin

Binary

SimEngineConcrete

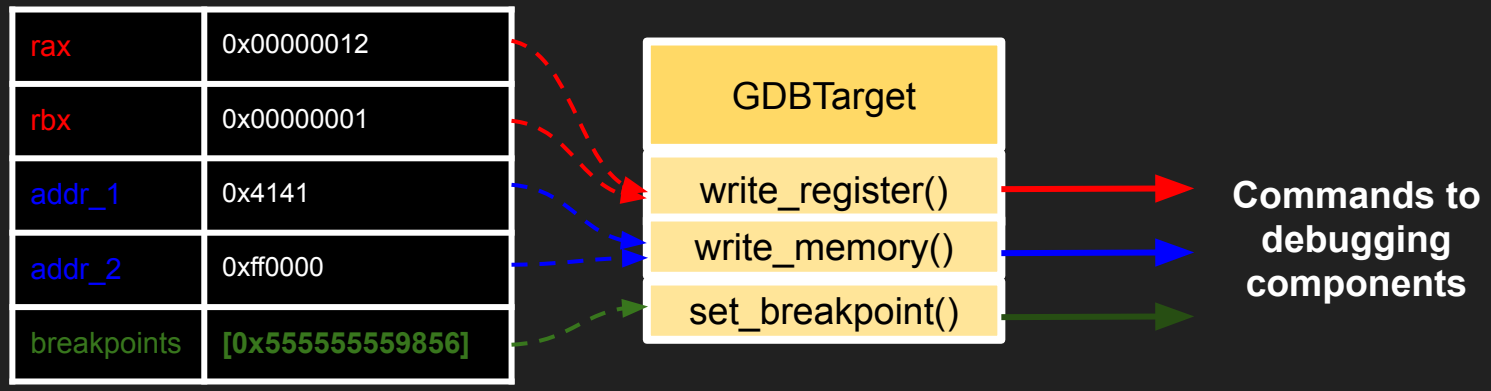
SimEngineConcrete

- Engine used by the **Symbion Exploration Technique** in order to step the *concrete execution* of the binary in the analysis environment.

- Consists of two main parts:
  - **to_engine**( )
    - Handle the “jump” **inside** the concrete world!
  - **from_engine**( )
    - Handle the “jump” **outside** the concrete world leveraging the **Concrete SimPlugin**.

SimEngineConcrete

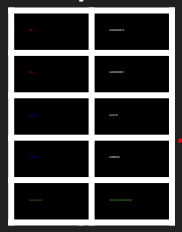
- **to_engine( ):**
  - Leverages the **ConcreteTarget** object to:
    - Set breakpoints on the concrete execution instance of the program.
    - Modify the concrete memory.
    - Resume the concrete execution by exploiting.



System Overview

Symbolic execution engine

Concrete environment



Symbion
(Exploration Technique)

ConcreteTarget

Debugging
Component

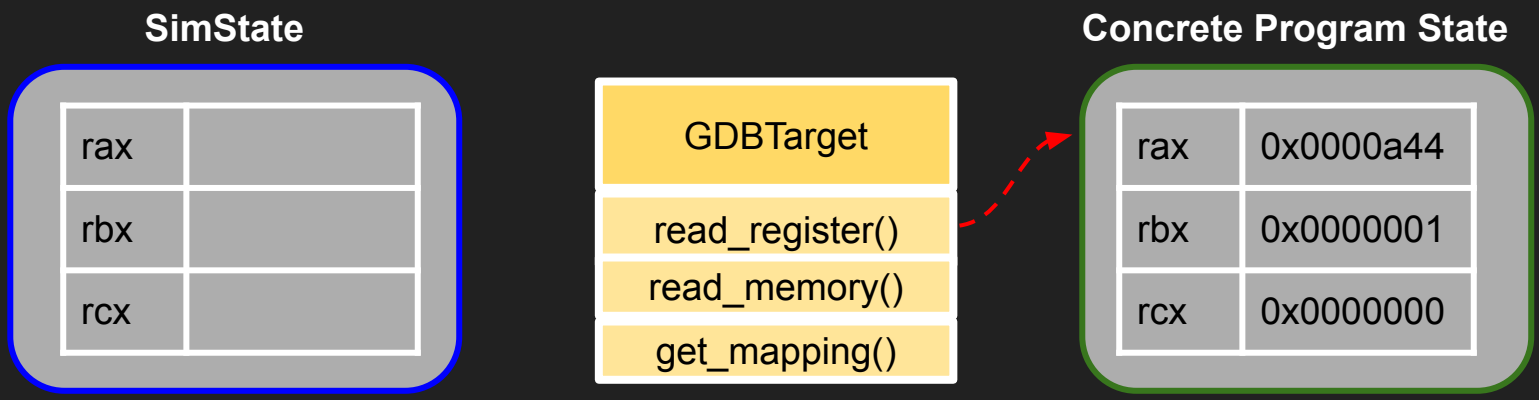
Concrete
SimPlugin

Binary

SimEngineConcrete

SimConcrete Plugin

- Synchronize the concrete process with **angr** and returns a a new SimState.
  - Copy values of ALL registers.



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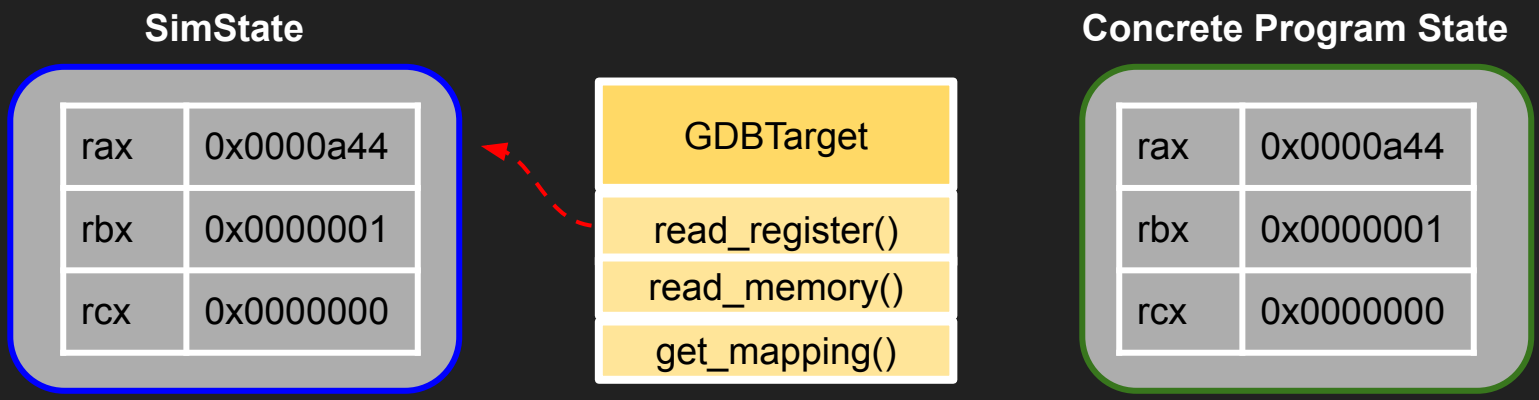
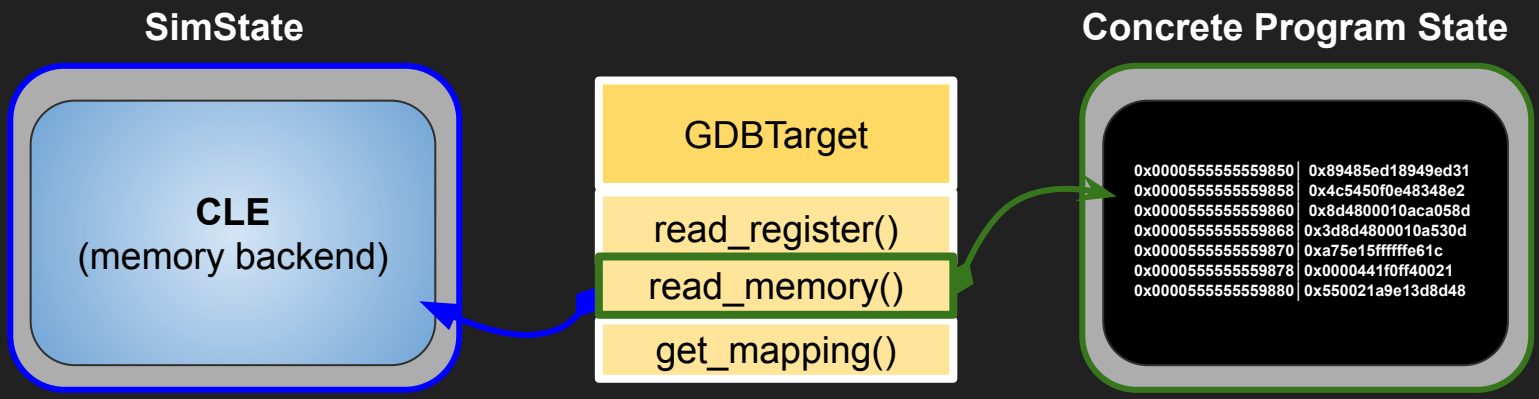


SimConcrete Plugin

- Synchronize the concrete process with **angr** and returns a a new SimState.
  - Copy values of ALL registers.
  - Hook new SimState memory backend to redirect reads to concrete process.



SimConcrete Plugin

- Synchronize the concrete process with **angr** and returns a a new SimState.
  - Copy values of ALL registers.
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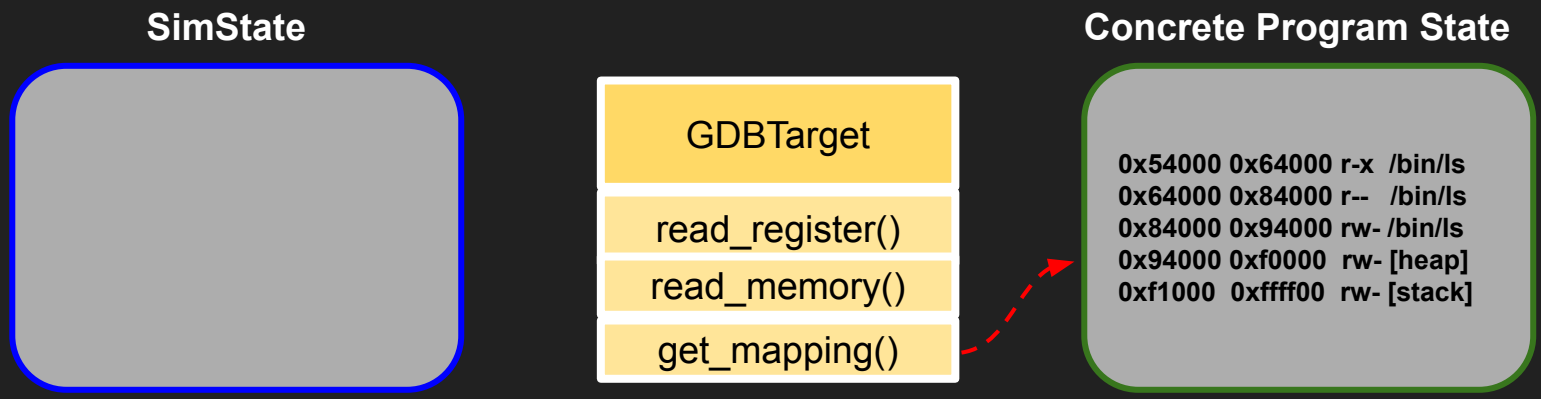
  - Updates memory mapping information.



SimConcrete Plugin

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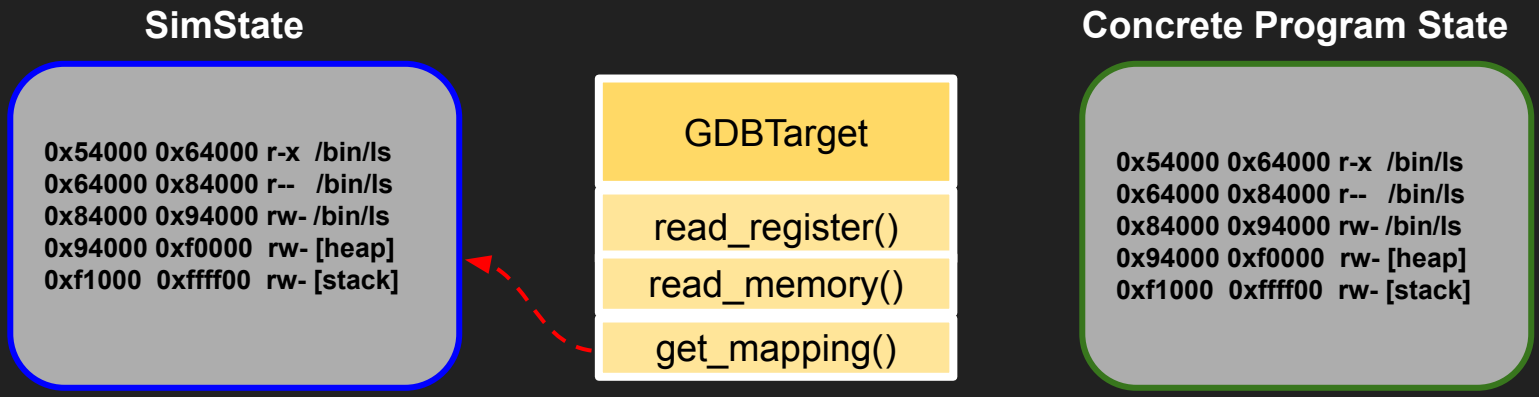
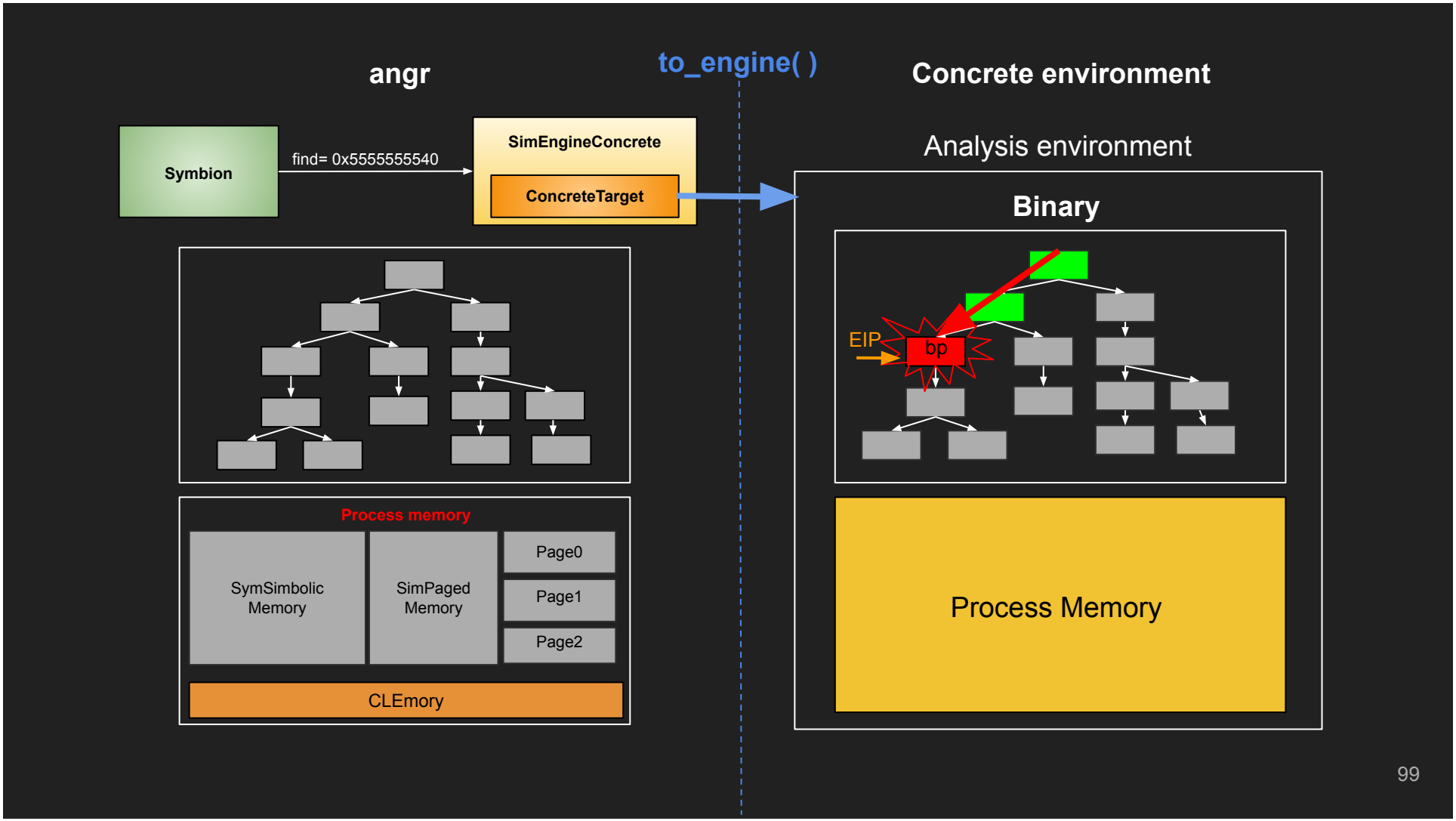
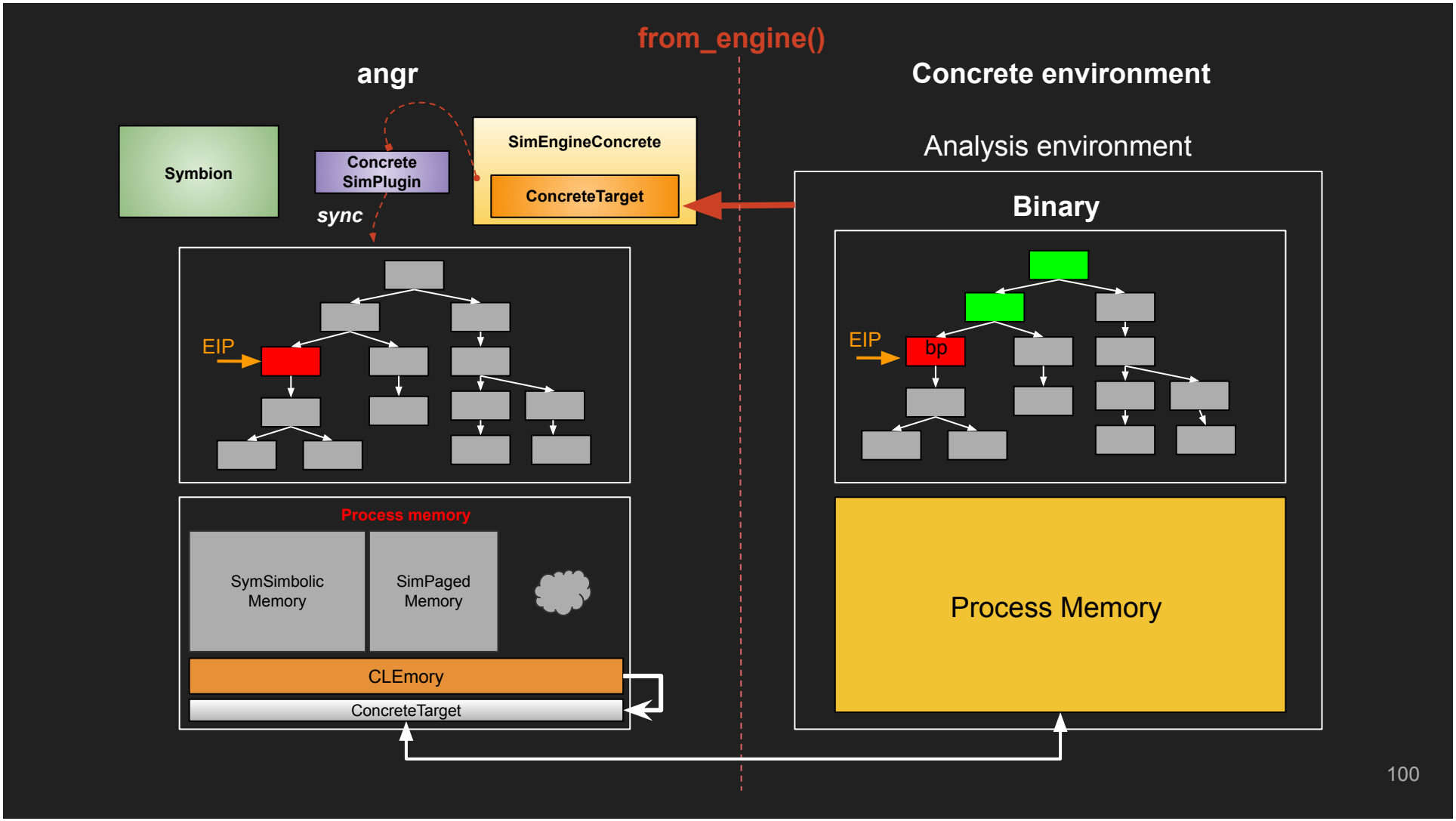



angr
to_engine( )
Concrete environment
Symbion
find= 0x5555555540
SimEngineConcrete
ConcreteTarget
Analysis environment
Binary
EIP
bp
Process memory
SymSimbolic Memory
SimPaged Memory
Page0
Page1
Page2
CLEmory
Process Memory


from_engine()
angr
Concrete environment
Symbion
Concrete SimPlugin
SimEngineConcrete
ConcreteTarget
sync
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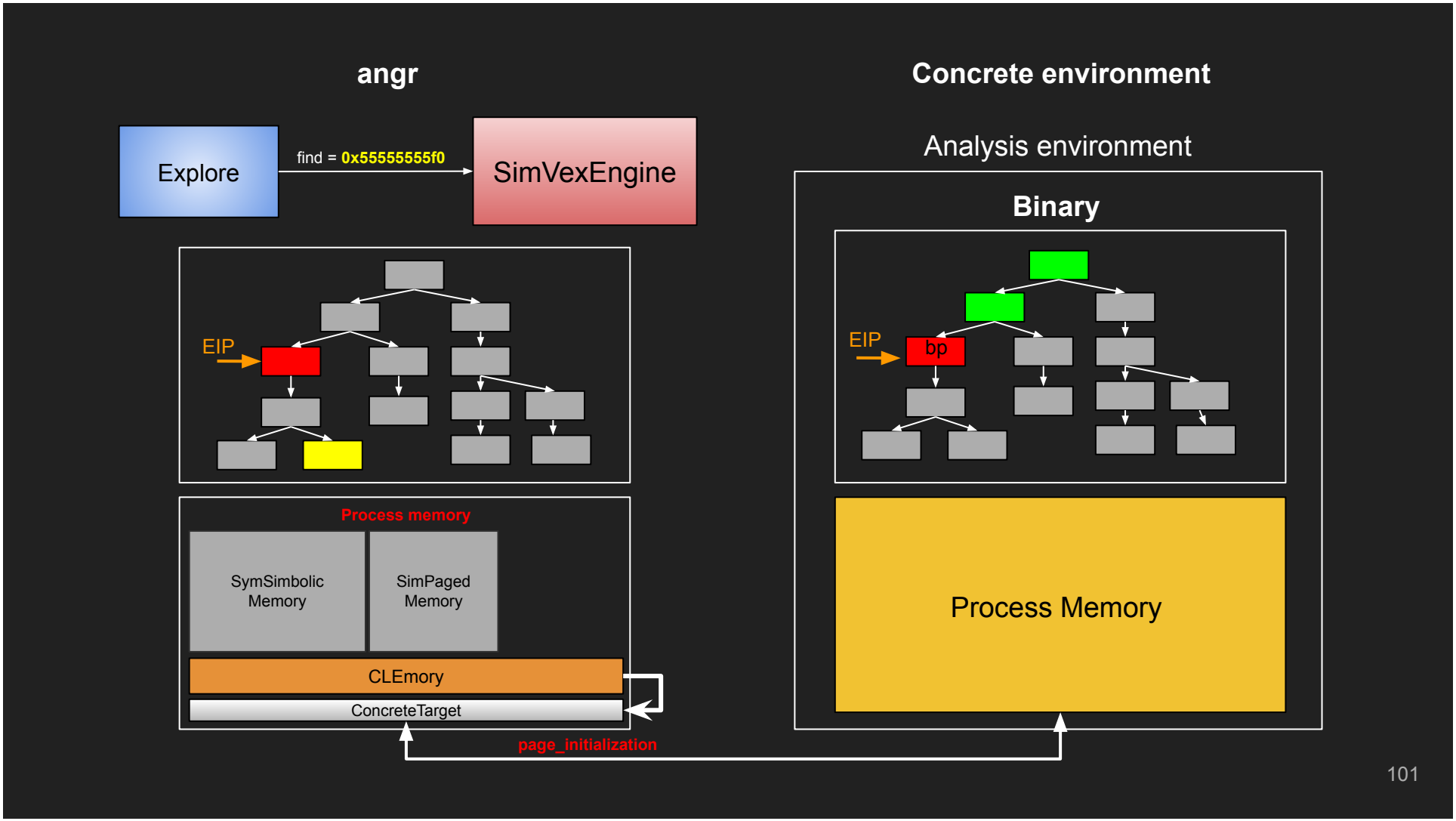
angr
Explore
find = 0x55555555f0
SimVexEngine
EIP
Process memory
SymSimbolic Memory
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CLEmory
ConcreteTarget
page_initialization
Concrete environment
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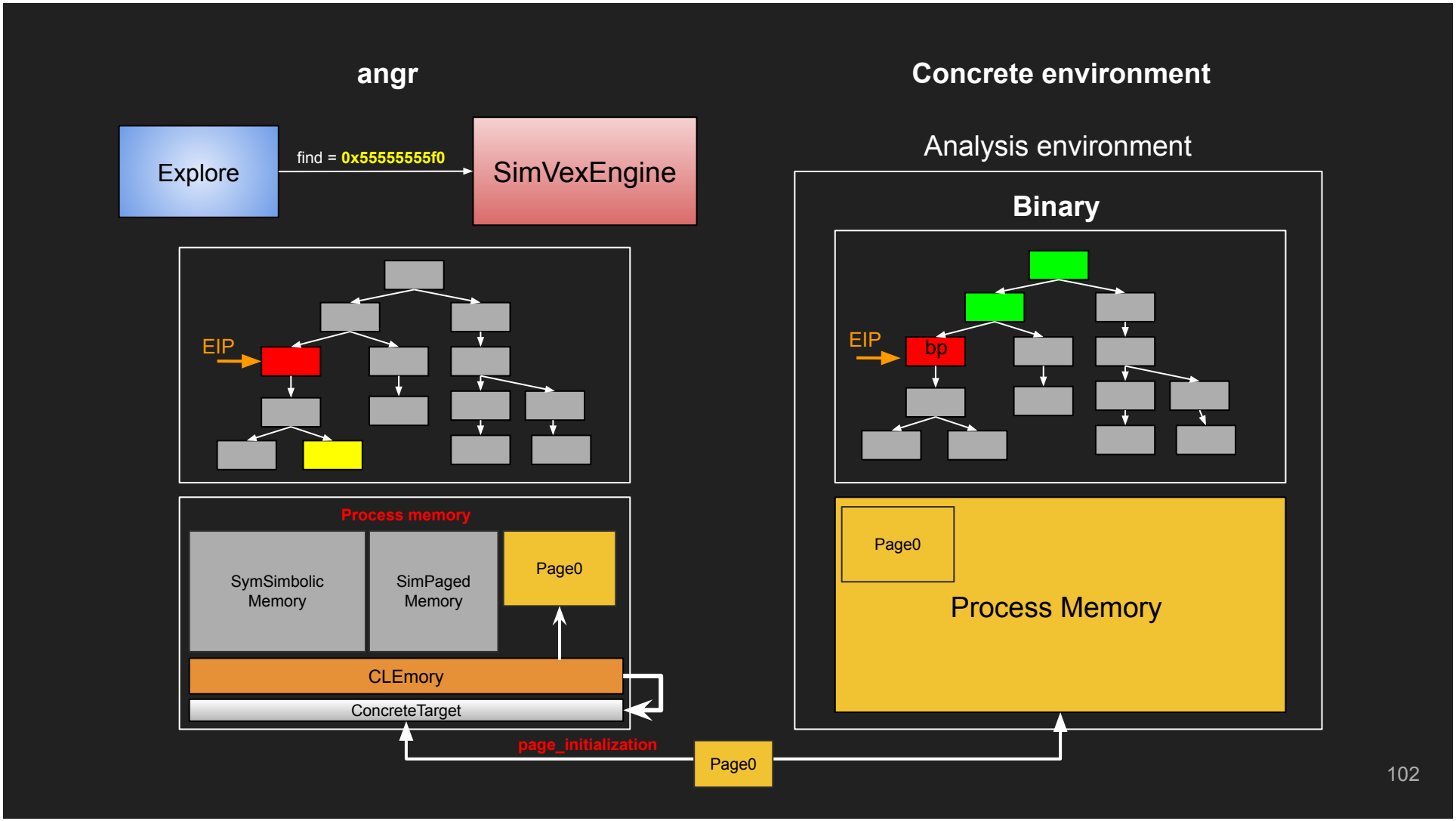
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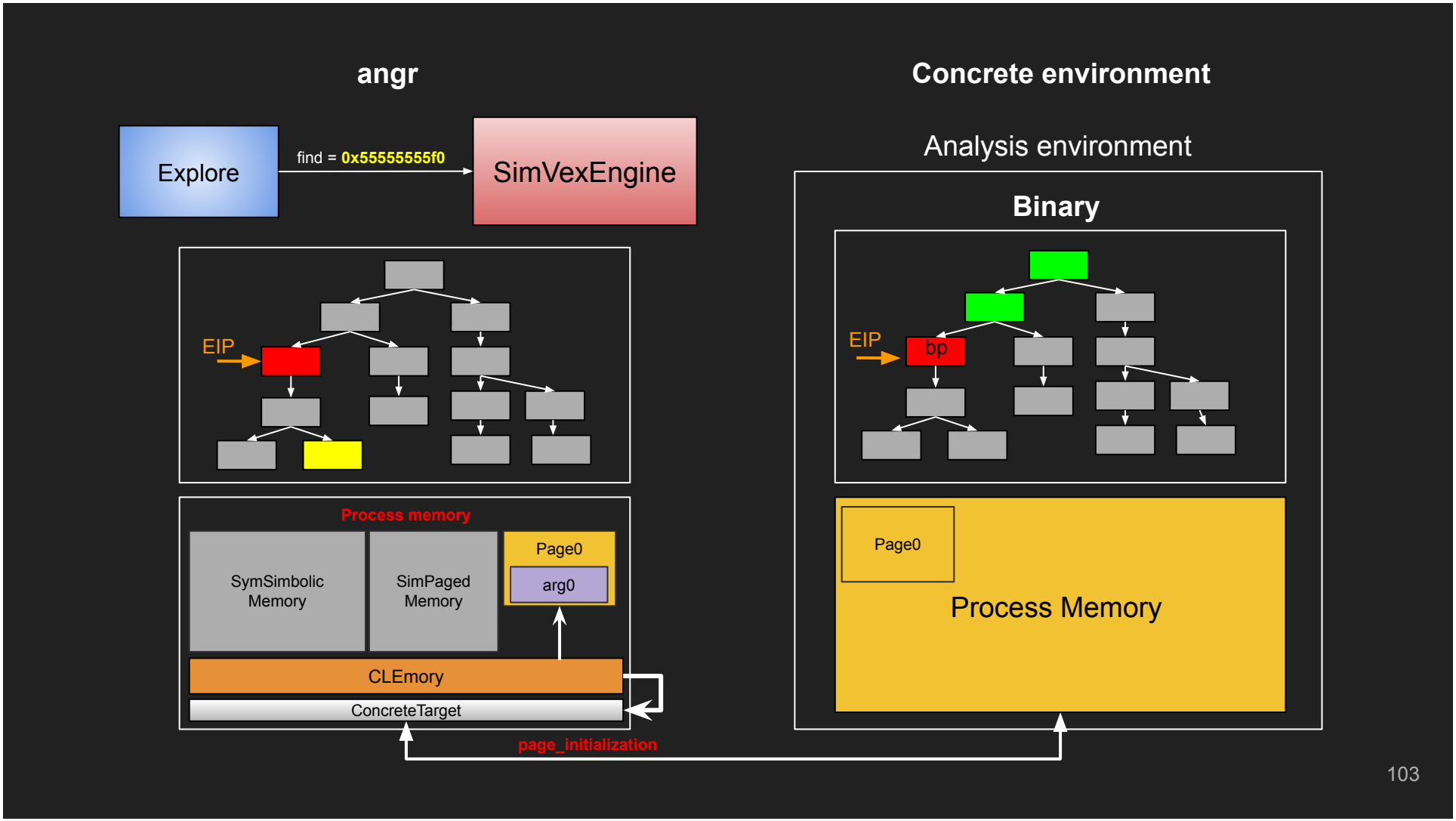
Process Memory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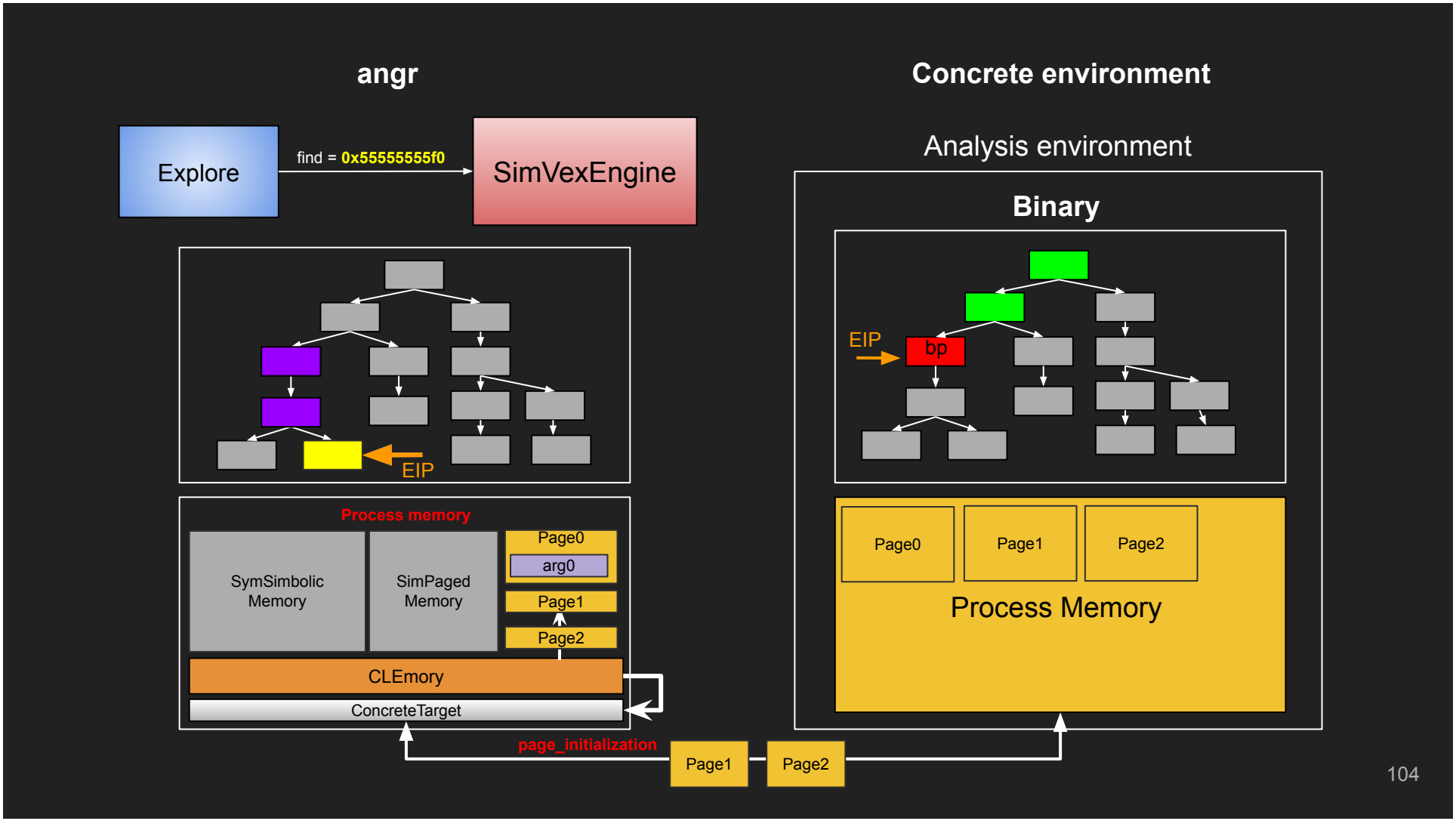
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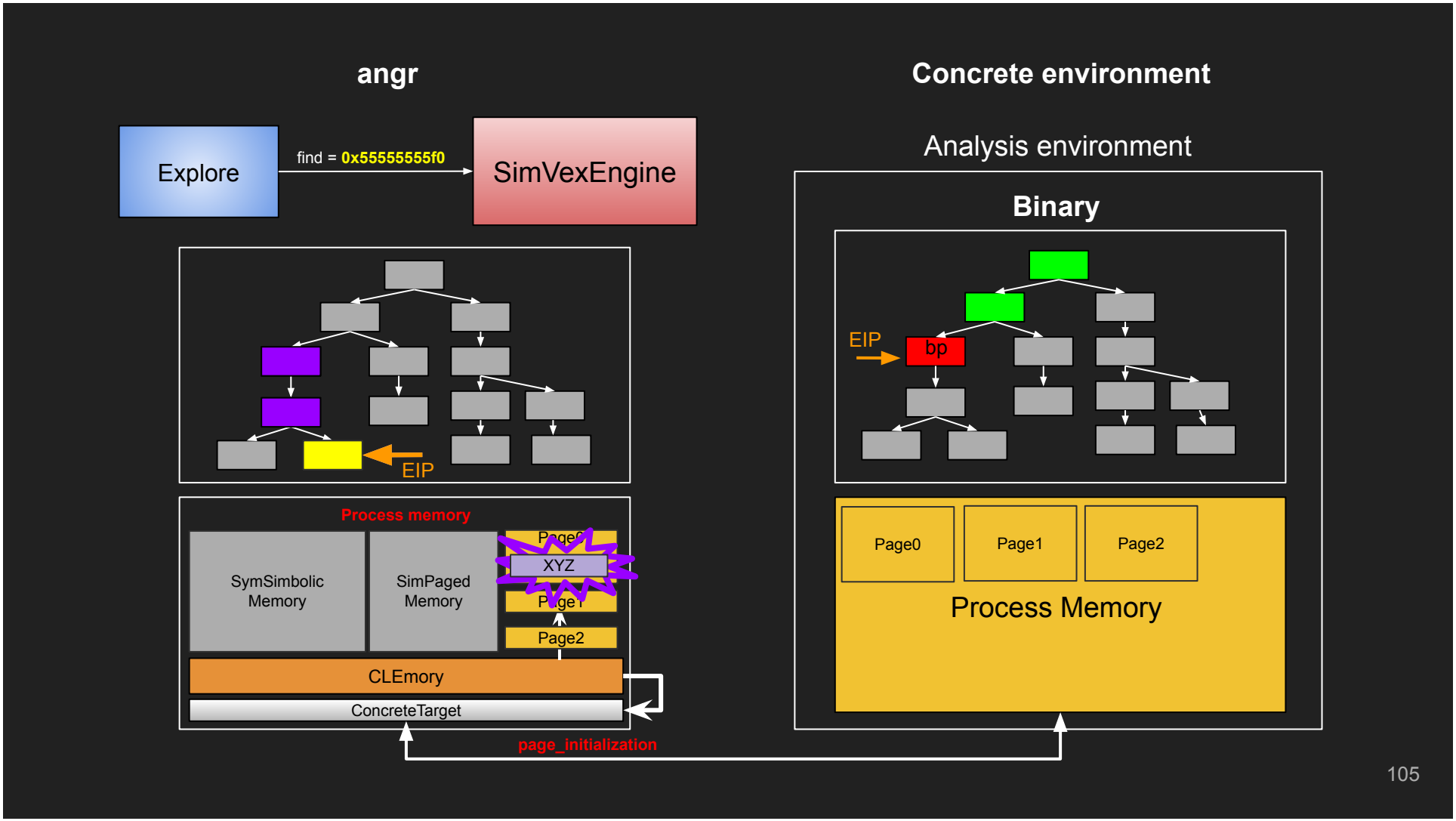
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SimVexEngine
EIP
Process memory
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page_initialization
Concrete environment
Analysis environment
Binary
EIP
bp
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Page1
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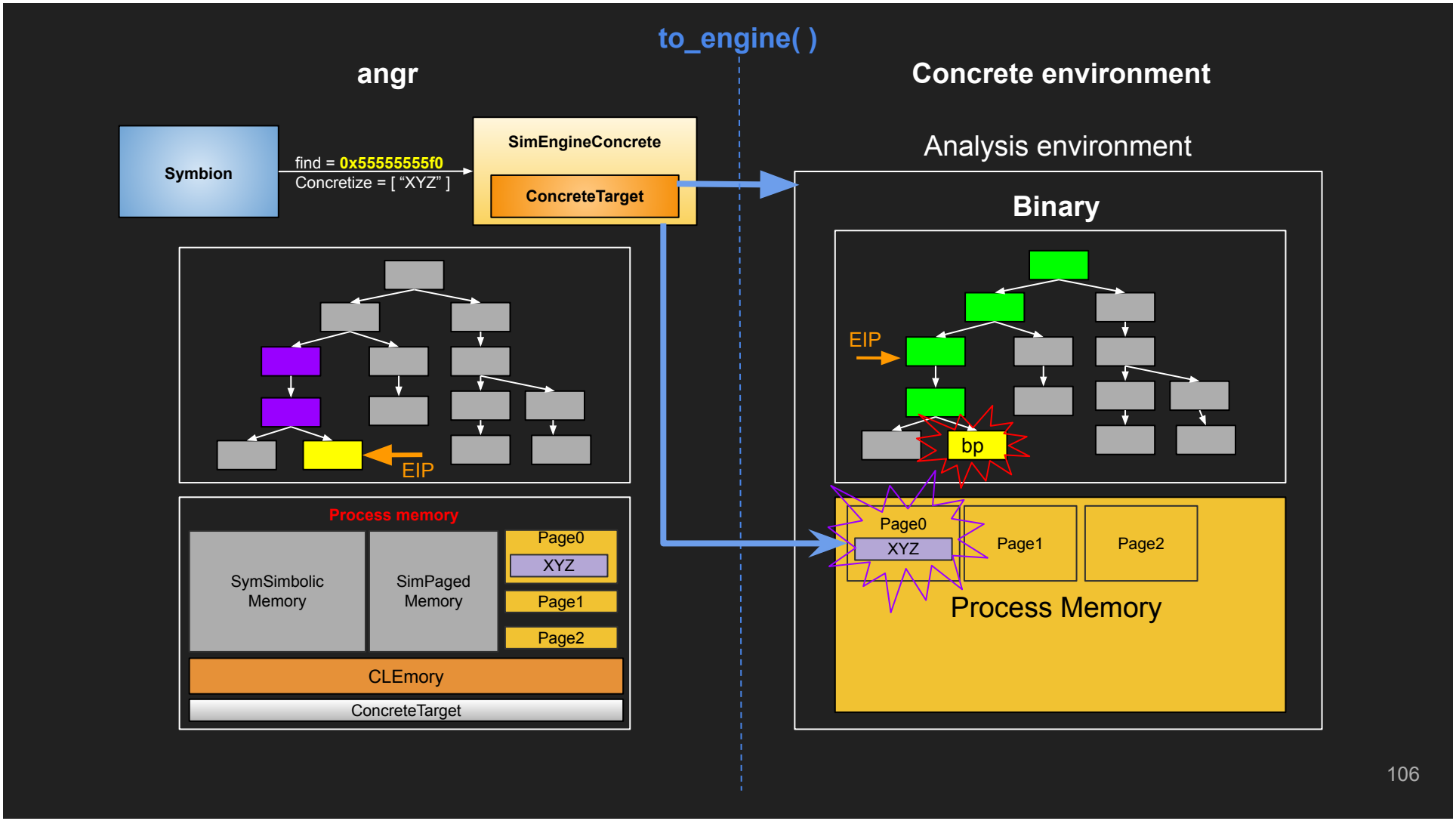
Process Memory


to_engine( )
angr
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Symbion
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EIP
Process memory
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Page0
XYZ
Page1
Page2
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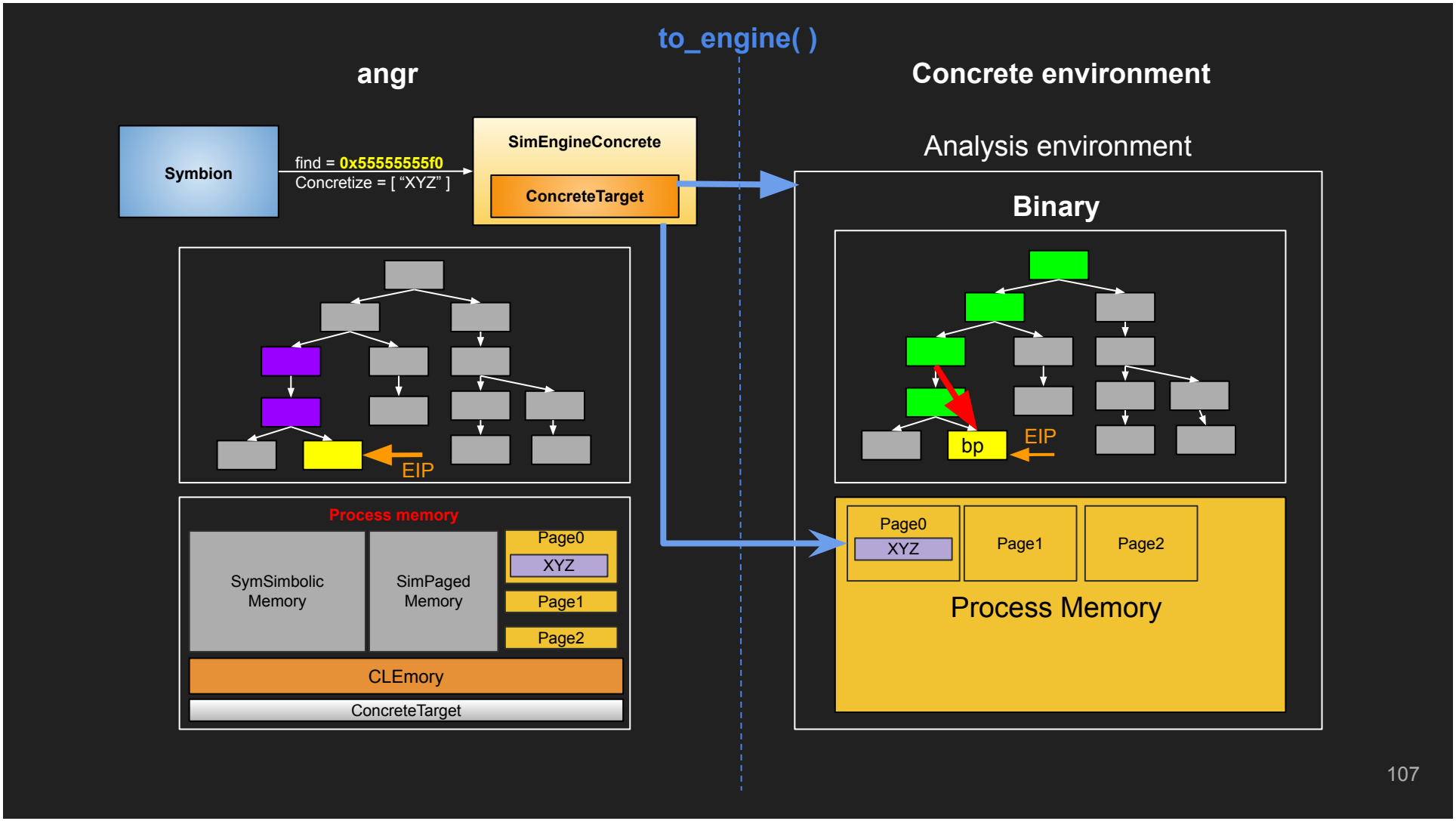
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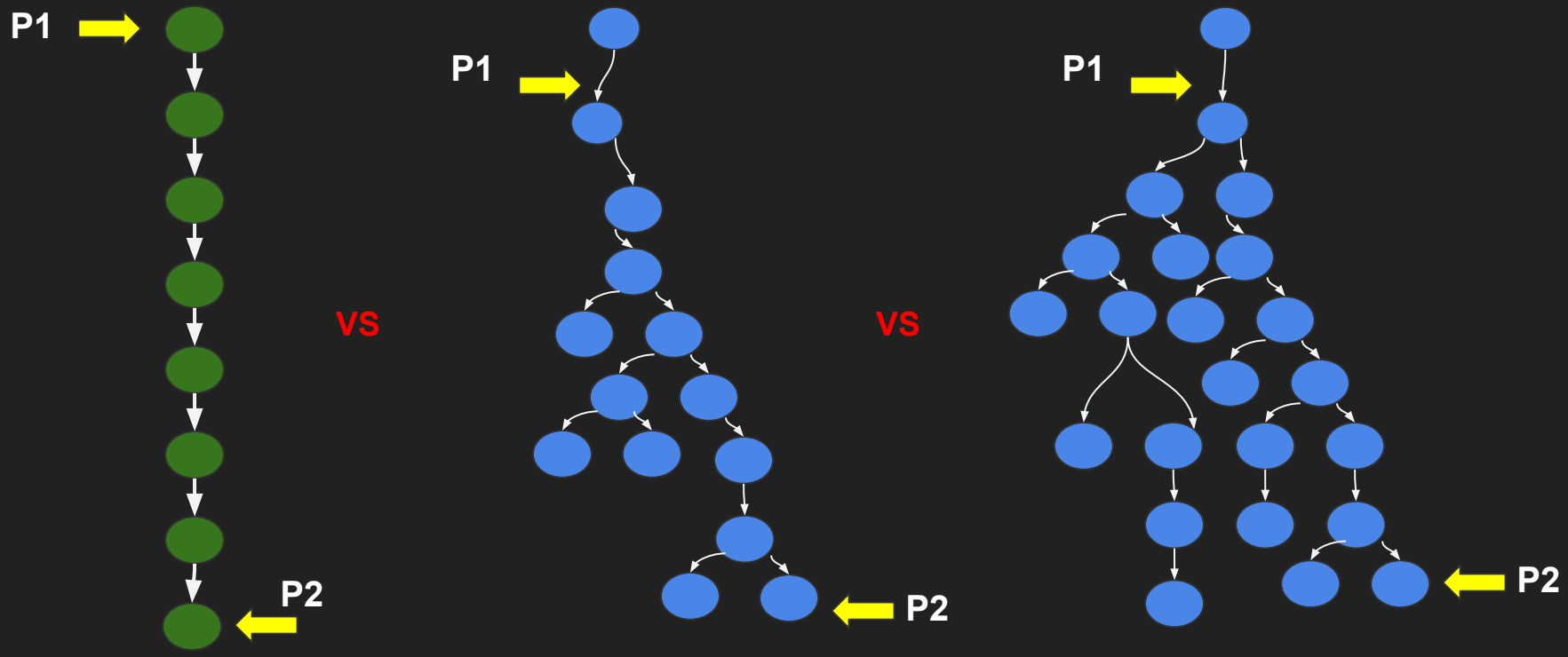
Approach



concrete execution *Interleaved symbolic execution* *under-constrained symbolic exec.*

Approach

- Idea: **Interleaving symbolic and concrete execution**
  - Concrete execute EOP → P1

Approach

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  - Synchronize state at P1 inside symbolic engine

Approach

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  - User defines symbolic variables for analysis

Symbolic execution

Concrete execution

Approach

- Idea: **Interleaving symbolic and concrete execution**
  - Concrete execute EOP → P1
  - Synchronize state at P1 inside symbolic engine
  - User defines symbolic variables for analysis
  - Symbolically execute P1 → P2

Symbolic execution

Concrete execution

Approach

- Idea: **Interleaving symbolic and concrete execution**
  - Concrete execute EOP → P1
  - Synchronize state at P1 inside symbolic engine
  - User defines symbolic variables for analysis
  - Symbolically execute P1 → P2
  - Ask constraints solver for solutions

Symbolic execution

Concrete execution

Approach

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  - Concrete execute EOP → P1
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  - User defines symbolic variables for analysis
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  - Overwrite solutions inside program's real memory

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  - Symbolically execute P1 → P2
  - Ask constraints solver for solutions
  - Overwrite solutions inside program's real memory
  - Concrete execute P1 → P2
  - Repeat!