Compilation using LLVM

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Quarkslab

Last course

- Dynamic Protections
- Profile-Guided Optimization

Today's objective

- Symbolic Execution
- Dynamic Symbolic Execution

Symbolic Execution

Symbolic Execution

Track the values of instructions as expressions from the program input.

Symbolic Execution

It's not possible to create a symbolic expression for every possible computed value. We have to choose an abstract domain (as in dataflow analysis).

- Bit values
- Integer values
- Affine Expressions

Symbolic Execution

Idea:

- Obtain a symbolic representation of the program
- Use an automatic theorem prover to find an input that makes the program reach a certain state

Symbolic Execution

In reverse engineering it is used for:

- Inversing complex computations (e.g. a hash)
- Produce inputs that cover paths that have not been explored by fuzzing

Symbolic Execution - Limitations

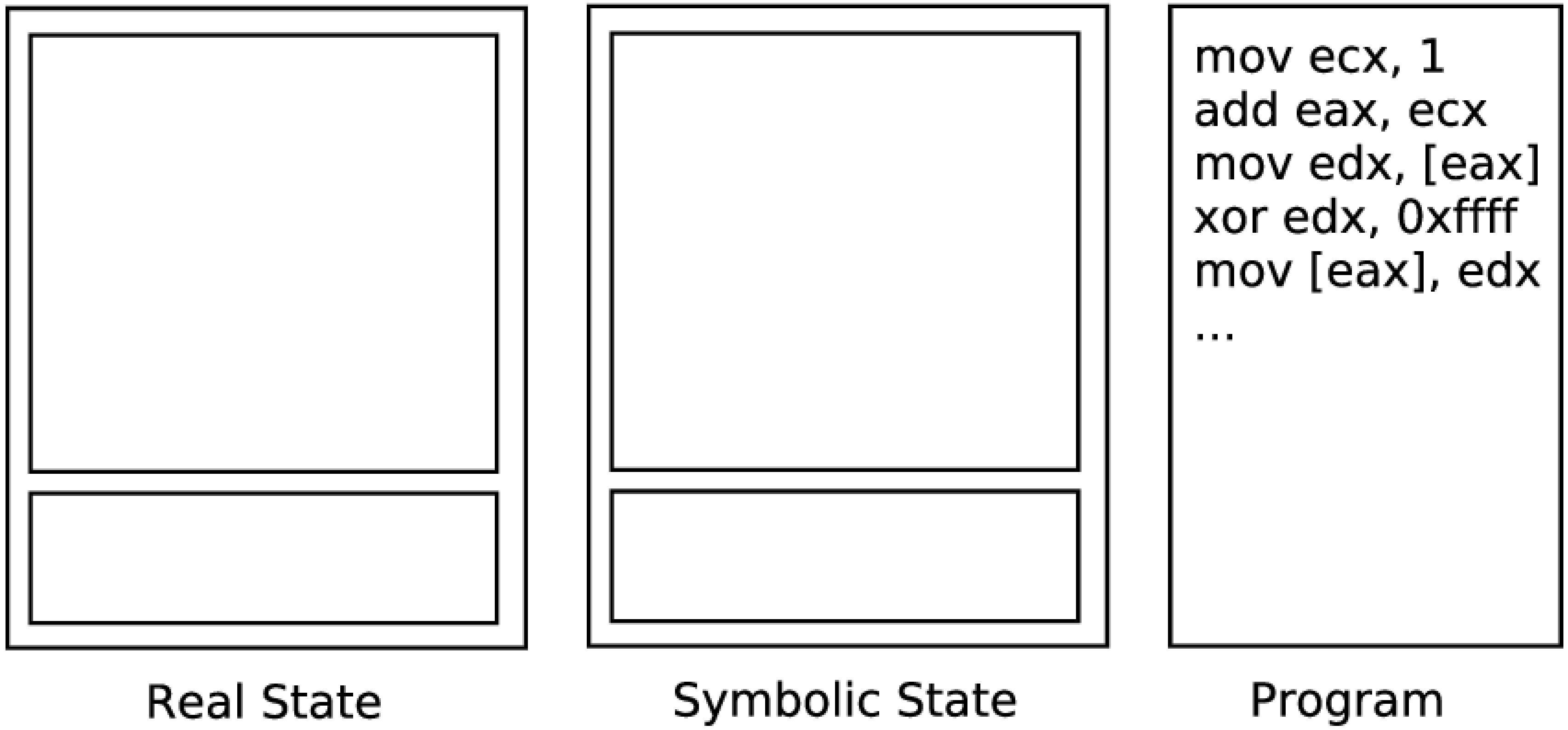
- Modeling Memory: Takes every possible behaviour into account
- Loops and recursion
- Path explosion
- Dealing with complex behaviours: system calls, input/output, concurrency, etc.

Dynamic Symbolic Execution

Overcome the explosion of states of pure symbolic execution

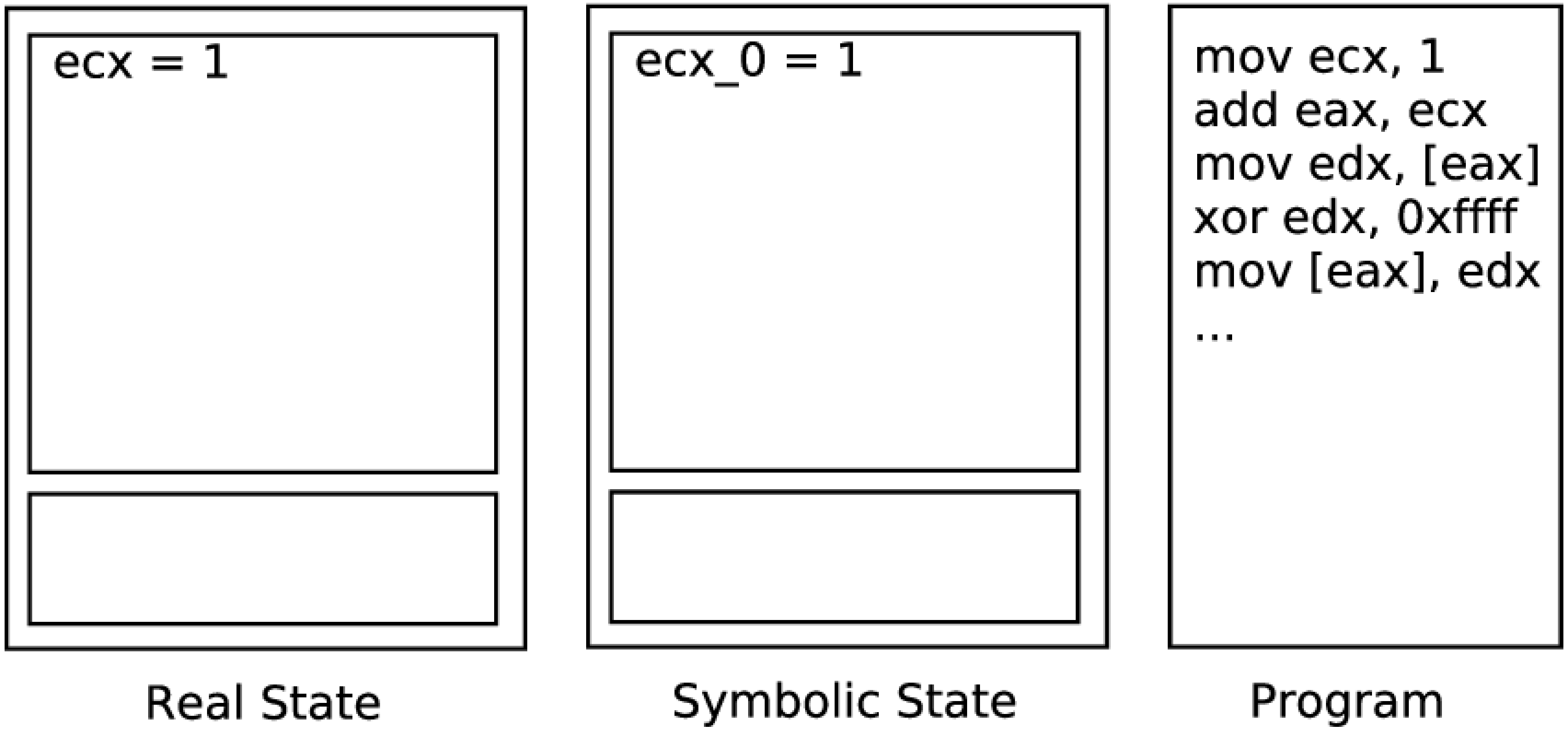
- Only take into account relevant paths
- When in trouble, disambiguate using concret execution

How it works?



```
mov ecx, 1
add eax, ecx
mov edx, [eax]
xor edx, 0xffff
mov [eax], edx
...
```

How it works?



ecx = 1

ecx_0 = 1

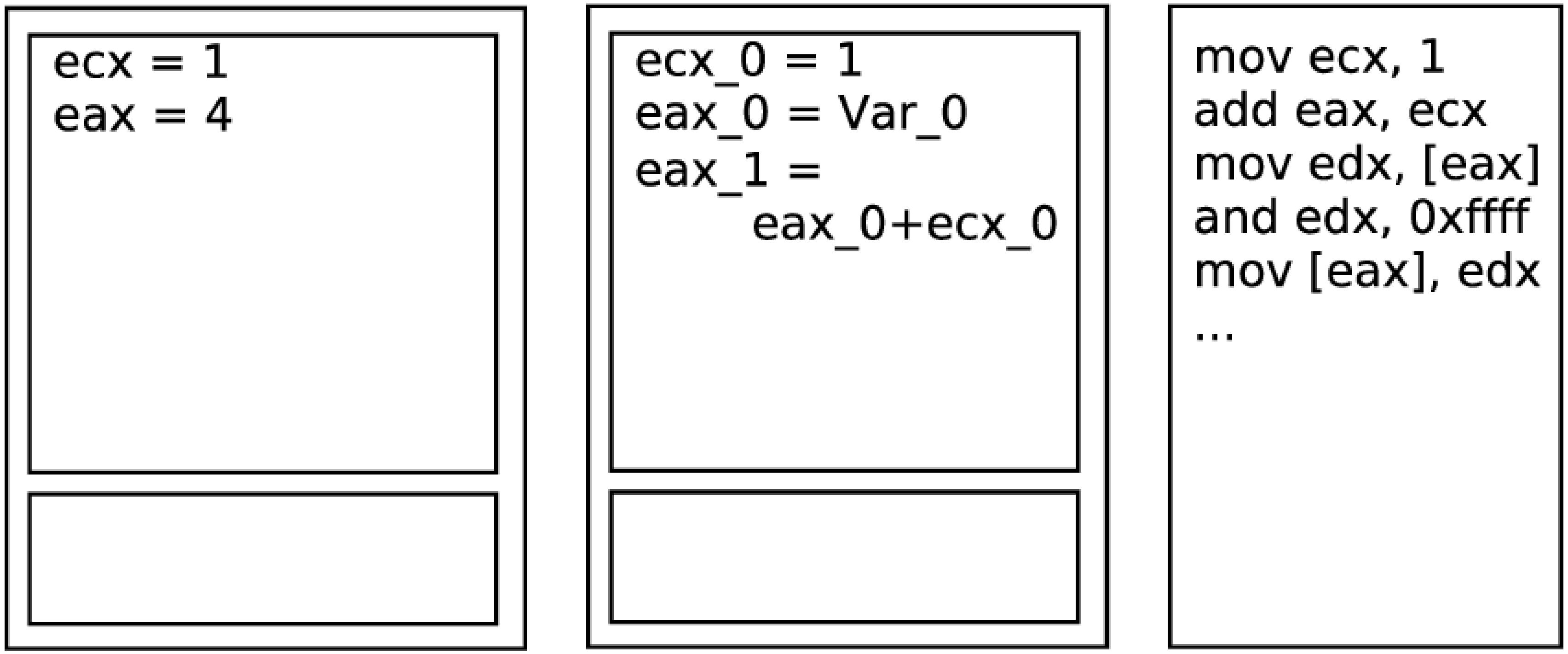
```
mov ecx, 1
add eax, ecx
mov edx, [eax]
xor edx, 0xffff
mov [eax], edx
...
```

Real State

Symbolic State

Program

How it works?



ecx = 1
eax = 4

Real State

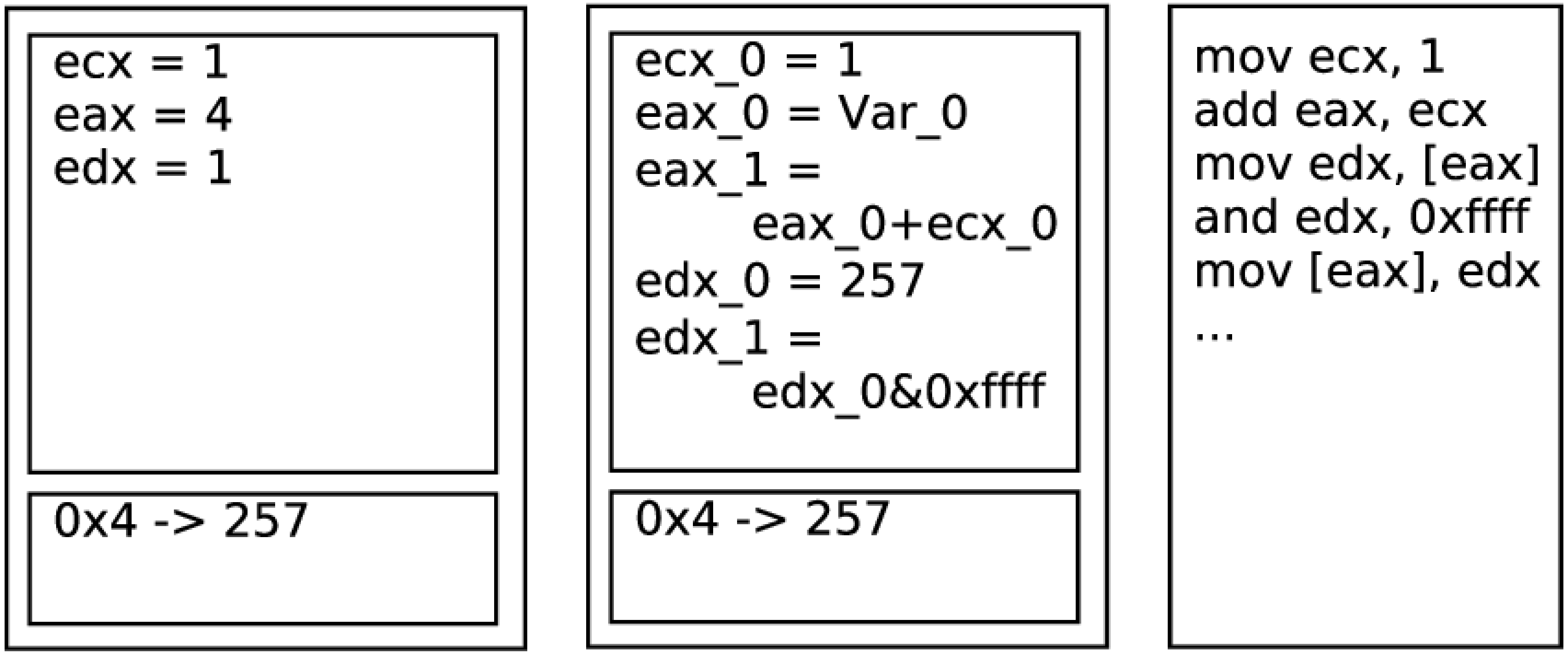
ecx_0 = 1
eax_0 = Var_0
eax_1 =
    eax_0+ecx_0

Symbolic State

```
mov ecx, 1
add eax, ecx
mov edx, [eax]
and edx, 0xffff
mov [eax], edx
...
```

Program

How it works?



```
ecx = 1
eax = 4
edx = 1

0x4 -> 257
```

Real State

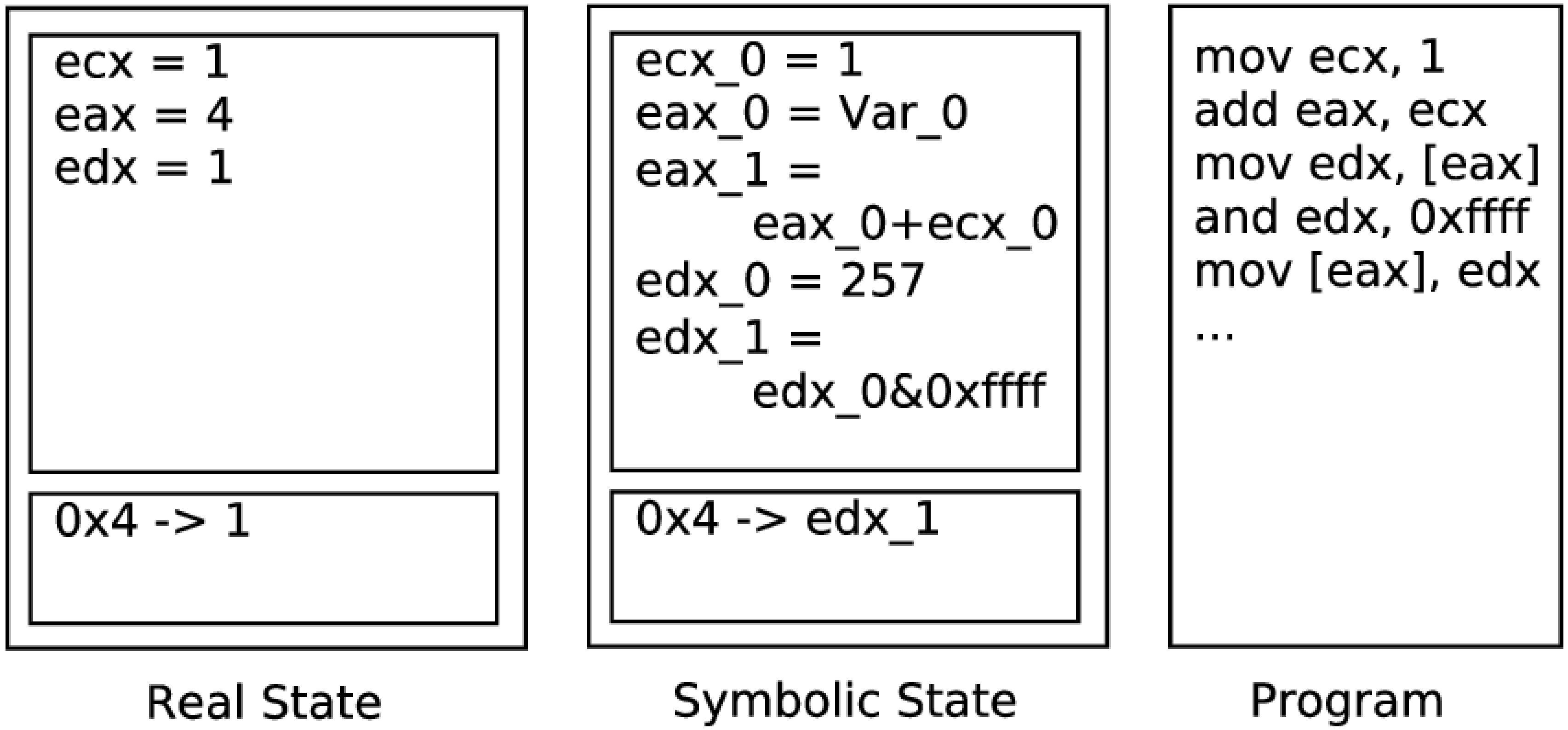
```
ecx_0 = 1
eax_0 = Var_0
eax_1 =
      eax_0+ecx_0
edx_0 = 257
edx_1 =
      edx_0&0xffff

0x4 -> 257
```

Symbolic State

```
mov ecx, 1
add eax, ecx
mov edx, [eax]
and edx, 0xffff
mov [eax], edx
...
```

Program

How it works?



ecx = 1
eax = 4
edx = 1

0x4 -> 1

Real State

ecx_0 = 1
eax_0 = Var_0
eax_1 =
  eax_0+ecx_0
edx_0 = 257
edx_1 =
  edx_0&0xffff

0x4 -> edx_1

Symbolic State

```
mov ecx, 1
add eax, ecx
mov edx, [eax]
and edx, 0xffff
mov [eax], edx
...
```

Program

Dynamic Symbolic Execution - Limitations

Altough the concrete execution helps reducing the scope of the symbolic execution, the problems remain

- Modeling Memory: Aproximation
- Loops and recursion
- Path explosion
- Dealing with complex behaviours: system calls, input/output, concurrency, etc.

Conclusions

- Symbolic Execution considers every possible execution in the code and, build a formula that represents them
- Dynamic Symbolic Execution considers a subset of executions, and builds a formula that represents them
- They all exhibit flaws from relying on a SMT solver