All You Ever Wanted to Know About Dynamic Taint Analysis and Forward Symbolic Execution

(but might have been afraid to ask)

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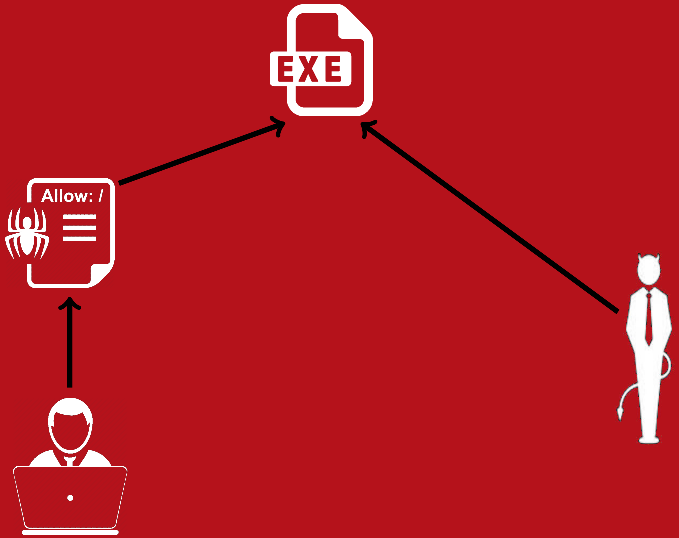
Outline

Of who or what do we trust?



Dynamic Analysis

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1. **Is the final value affected by user input?**
    - **Dynamic Taint Analysis**!
    - Tracks information flow between sources and sinks
2. **What input will make execution reach this line of code?**
    - **Forward Symbolic Execution**
    - Allows us to reason about the behavior of a program on many different inputs

Use cases

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3. **Forward Symbolic Execution**: analyze how information flows through a malware binary

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1. **Unknown Vulnerability Detection**: monitor whether user input is executed
2. **Automatic Input Filter Generation**: detect and remove exploits from the input stream
3. **Forward Symbolic Execution**: analyze how information flows through a malware binary
4. **Test Case Generation**: automatically generate inputs to test programs

SimpIL

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Designed to demonstrate the critical aspects of this analysis.

program	::=	*stmt**
stmt s	::=	*var* := *exp* | store(*exp*, *exp*)
		| goto *exp* | assert *exp*
		| if *exp* then goto *exp*
		else goto *exp*
exp e	::=	load(*exp*) | *exp* $\Diamond_b$ *exp* | $\Diamond_u$ *exp*
		| *var* | get_input(*src*) | *v*
$\Diamond_b$	::=	typical binary operators
$\Diamond_u$	::=	typical unary operators
value v	::=	32-bit unsigned integer

SimpIL Grammar

Dynamic Taint Analysis

```
x := get_input( )
z := 42
y := x + z
goto y
```

Dynamic Taint Analysis

Tainted

```
x := get_input( )
z := 42
y := x + z
goto y
```

x is derived from a tainted source

Dynamic Taint Analysis


```
x := get_input( )
z := 42
y := x + z
goto y
```

Untainted

z is a ”static” constant

Dynamic Taint Analysis

```
x := get_input(
```

```
)
z := 42
y := x + z
goto y
```

Is y taited?

Dynamic Taint Analysis

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```

Is y taited?

It depends on the selected policy

What's a policy?

- A taint policy specifies three properties:
  - **Taint Introduction**
    - specifies how taint is introduced into a system
    - typically distinguishes between different input sources
  - **Taint Propagation**
    - specifies the taint status for data derived from tainted or untainted operands
  - **Taint Checking**
    - is used to determine the runtime behavior of a program
- **Undertainting** vs **Overtainting**

Forward Symbolic Execution

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- Reasoning about the behavior of the program can be reduced to the domain of logic!
- Creating a forward symbolic execution engine is **conceptually** a very simple process

```
x := 2 * get_input(src)
if x - 5 == 14 then goto 3 else goto 4
// line 3: catastrophic failure
// line 4: normal behaviour
```

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// line 3: catastrophic failure
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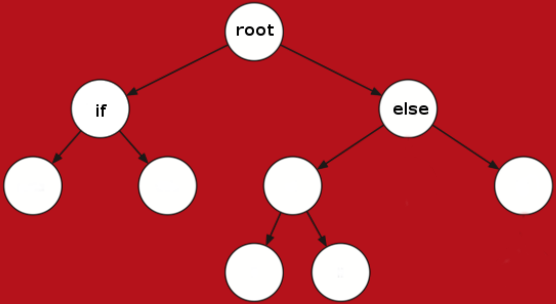
- `get_input(src)` now returns a **symbol** instead of a concrete value
- Expressions involving symbols **cannot** be fully evaluated to a concrete value

Path Selection and Performance

- Every conditional jump we must decide what path to follow first
  - But some path may never terminate
- Exponential Blowup due to branches (running time, number of formulas and formula size)



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    `while` $(3^n + 4^n == 5^n)$ `{n++; ...}`
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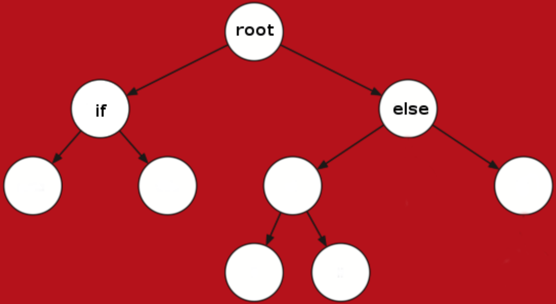

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- Exponential Blowup due to branches (running time, number of formulas and formula size)
- Solutions
  - **Path Selection Heuristic**
    - Concolic Testing
    - Depth-First or Random Search
  - More and faster **hardware**
  - Identify **redundancies** between formulas or **independent subformulas**

Memory Address Problems

What are we supposed to do if a referenced address of an expression is derived from user input?

- **Symbolic Memory Address**
  - The `LOAD` and `STORE` rules evaluate the expression representing the memory address to a **non-negative integer** value
- **Symbolic Jumps**
  - The `GOTO` rule requires the address expression to evaluate to a concrete value

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- Solutions
  - Concolic testing
  - SMT (**S**atisfiability **M**odulo **T**heories) solvers
  - Static and alias analysis

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THANK YOU FOR ALLOWING ME TO TAINT YOUR PRECIOUS TIME!

Questions?

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MATEMATICA