All You Ever Wanted to Know About Dynamic Taint Analysis and Forward Symbolic Execution
(but might have been afraid to ask)

Matteo Di Pirro

BSc in Computer Science
Department of Mathematics

University of Padova

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Outline

Static and Dynamic Analysis

- **Static Analysis**
  - Examines a program's text to derive properties that hold for all executions
  - Program-centric analysis
- **Dynamic Analysis**
  - Examines the running program to derive properties hold for one or more executions
  - Detect violations of stated properties
  - Provide useful information about the behavior of the program
  - Input-centric analysis

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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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

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

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```
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

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```
x := get_input( )
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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

- 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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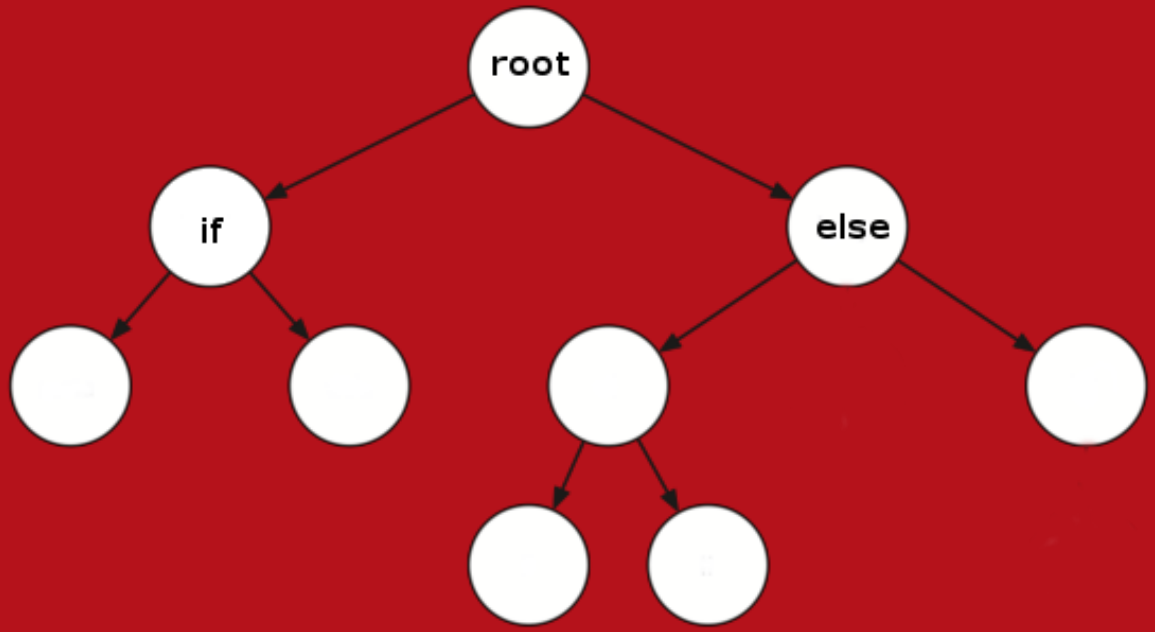
- `get_input(src)` now returns a **symbol** instead of a concrete value
- Expressions involving symbols **cannot** be fully evaluated to a concrete value

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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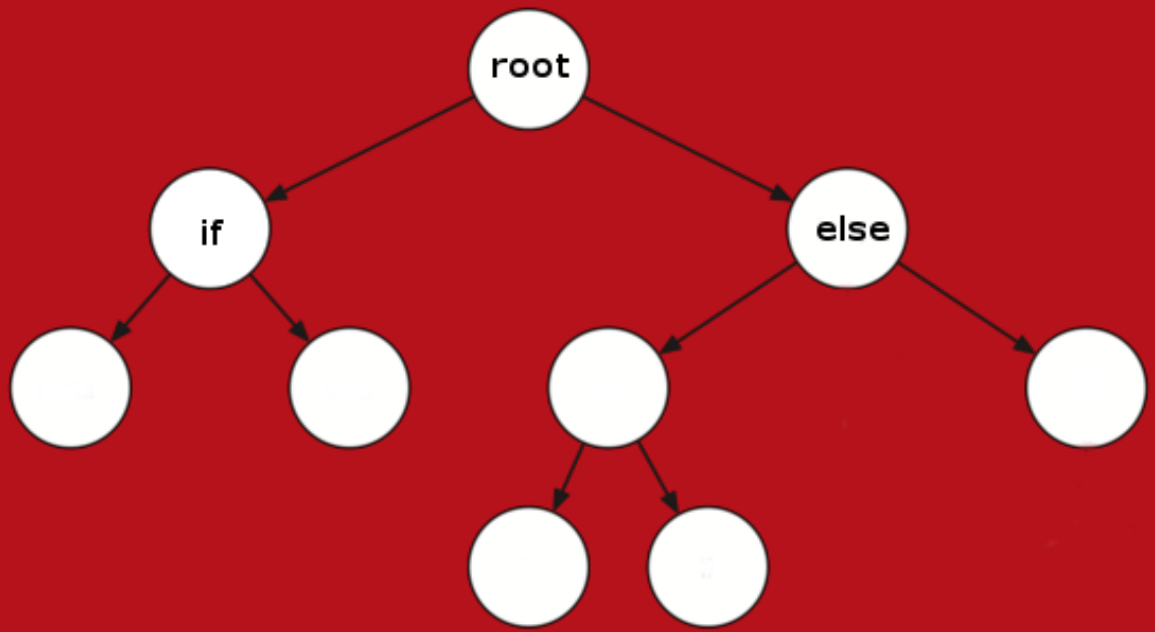

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- Solutions
  - **Path Selection Heuristic**
    - Concolic Testing
    - Depth-First or Random Search
  - More and faster **hardware**
  - Identify **redundancies** between formulas or **independent subformulas**

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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- **Symbolic Jumps**
  - The `GOTO` rule requires the address expression to evaluate to a concrete value
- 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