Taint Mechanisms

Advanced topics in Computer Security

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December 7, 2016

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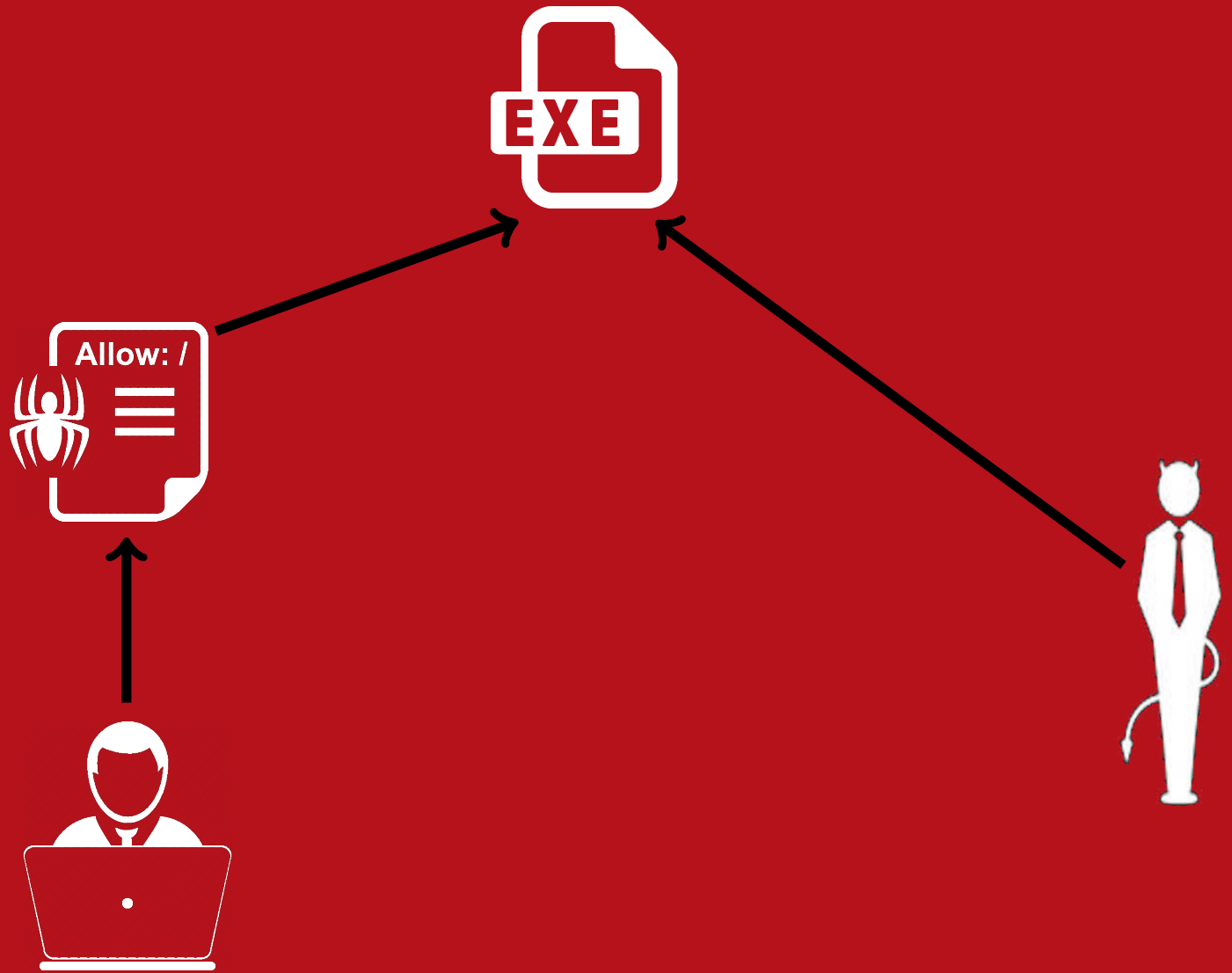
Outline

Of who or what do we trust?



Input Analysis

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1. **Is the final value affected by user input?**
   - **Dynamic Taint Analysis**!
   - Tracks information flow between sources and sinks

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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

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

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```
x := get_input( )
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```

Untainted

z is a ”static” constant

Dynamic Taint Analysis


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Is y taited?

Dynamic Taint Analysis


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```

Is y taited?

It depends on the selected policy

What's a policy?

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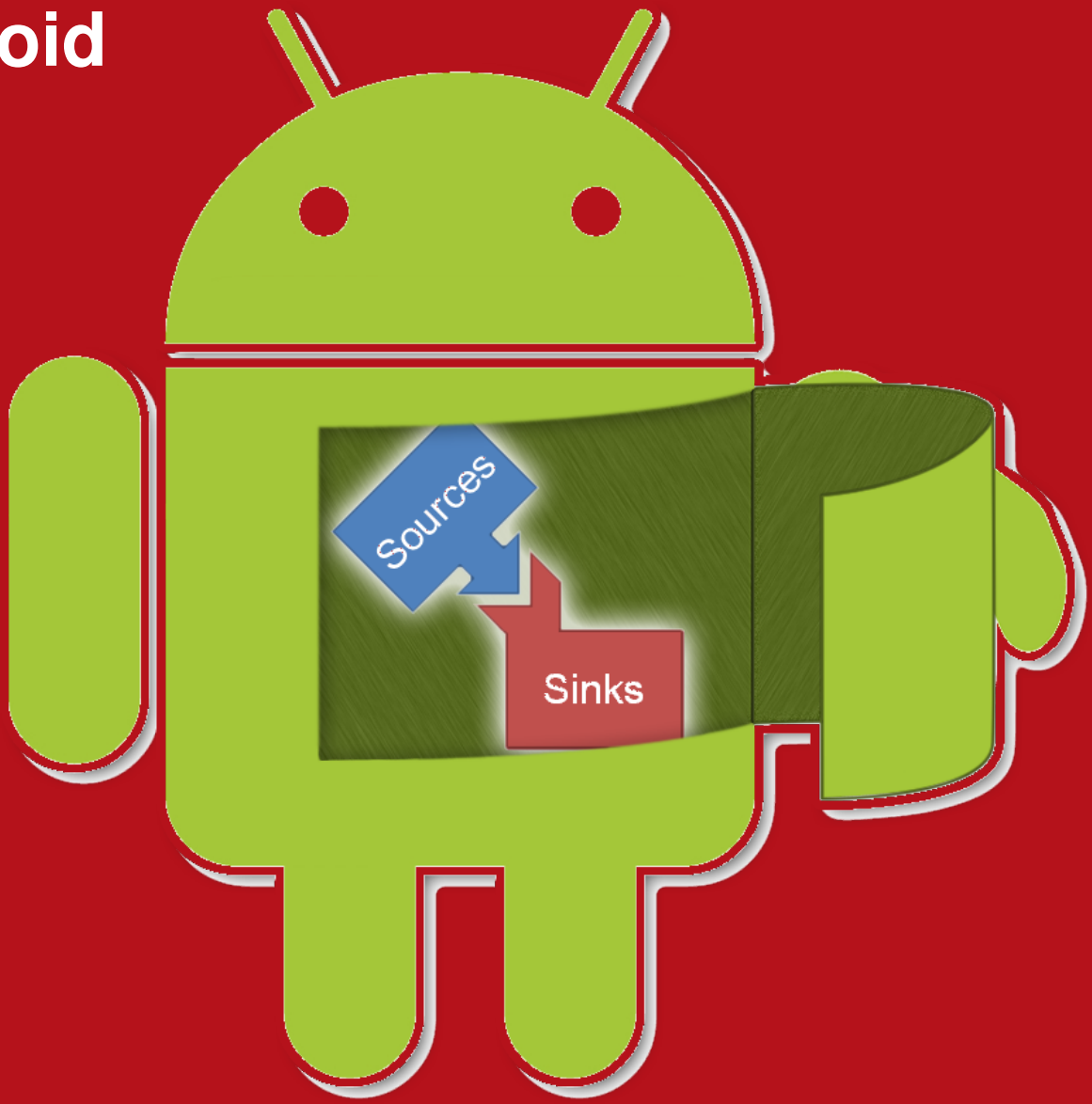
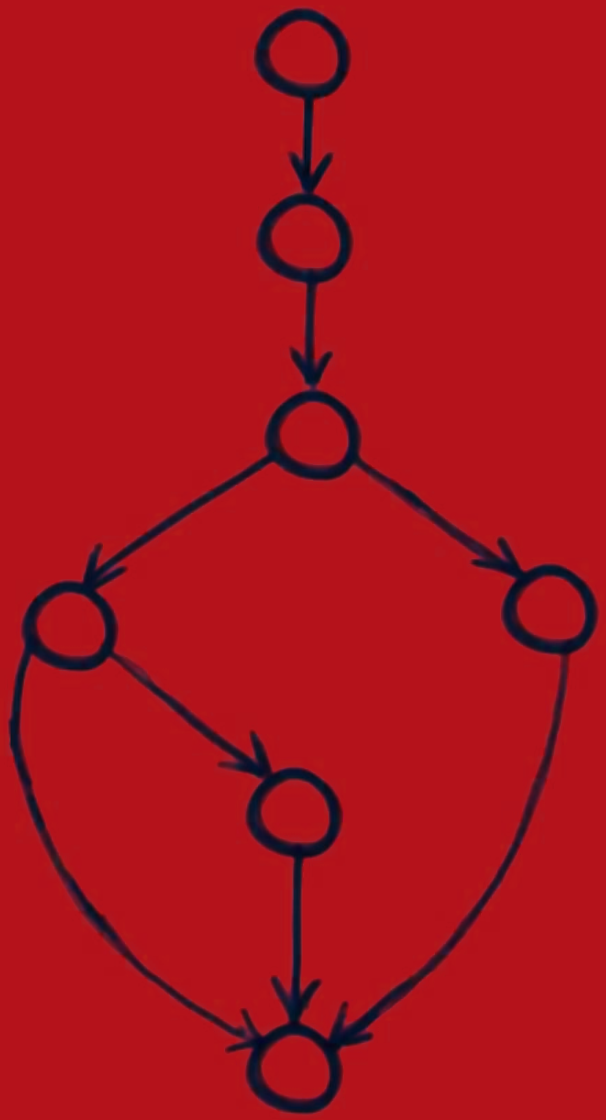
- A taint policy specifies three properties:
  - **Taint Introduction**
    - How is taint introduced into a system?
  - **Taint Propagation**
    - How does taint propagate into a system?
  - **Taint Checking**
    - Is the current operation secure?
- **Undertainting** vs **Overtainting**

Can we go further?
TaintDroid



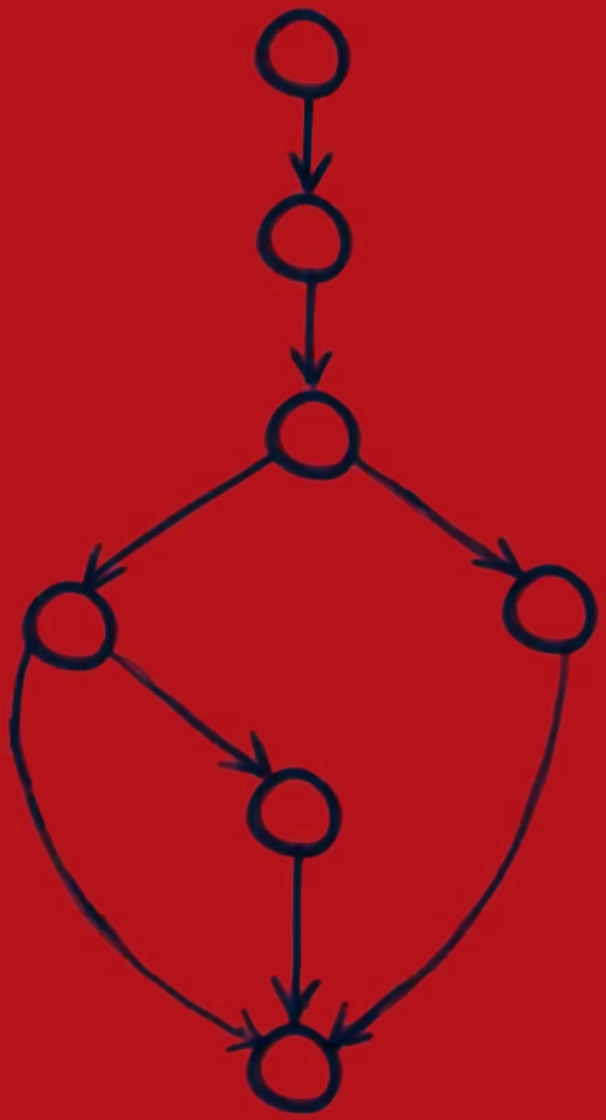
Malware detection and Pointer Tainting

Limitations



- **Sanitization problem**

Limitations



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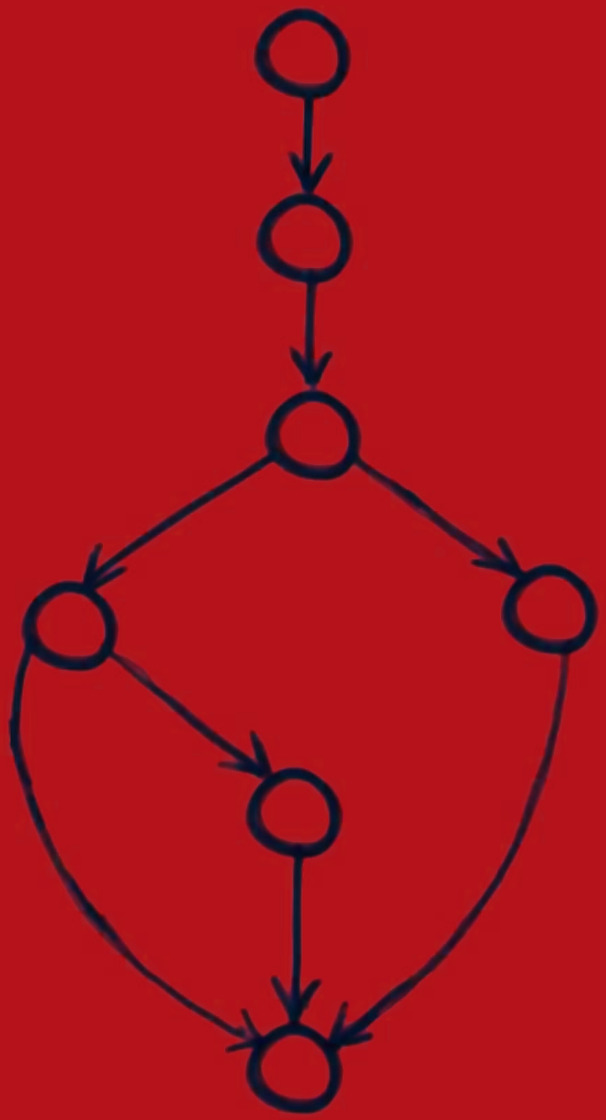
  `b := a` $\oplus$ `a`

Limitations



- **Sanitization problem**

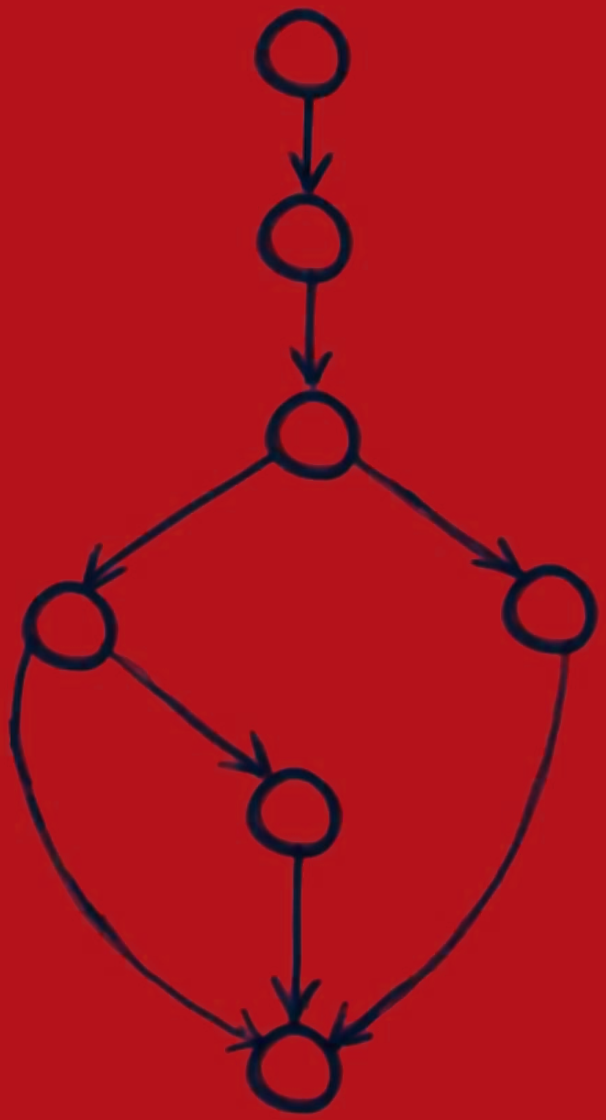
  $b := a \oplus a$

- Pure dynamic taint analysis considers **data flows**...

  ...but it ignores **control-flows**

```
x := get_input(src)
if x == 1 then goto 3 else goto 4
y := 1
z := 42
```

Limitations



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- What about different security policies for different I/O channels?

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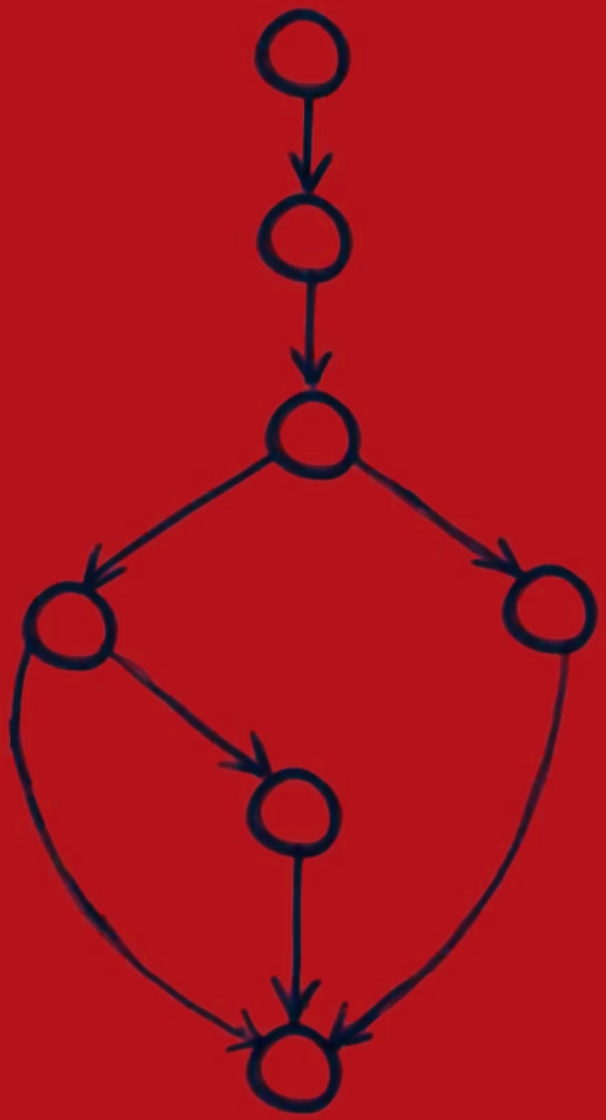

- **Sanitization problem**

  $$\texttt{b := a} \oplus \texttt{a}$$

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y := 1
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```

- What about different security policies for different I/O channels?
  $\rightarrow$ **Static analysis**

Forward Symbolic Execution

- We can reason about the behavior of a program using the logic...
- ... and it 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 behavior
```

Forward Symbolic Execution

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```
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if x - 5 == 14 then goto 3 else goto 4
// line 3:  catastrophic failure
// line 4:  normal behavior
```
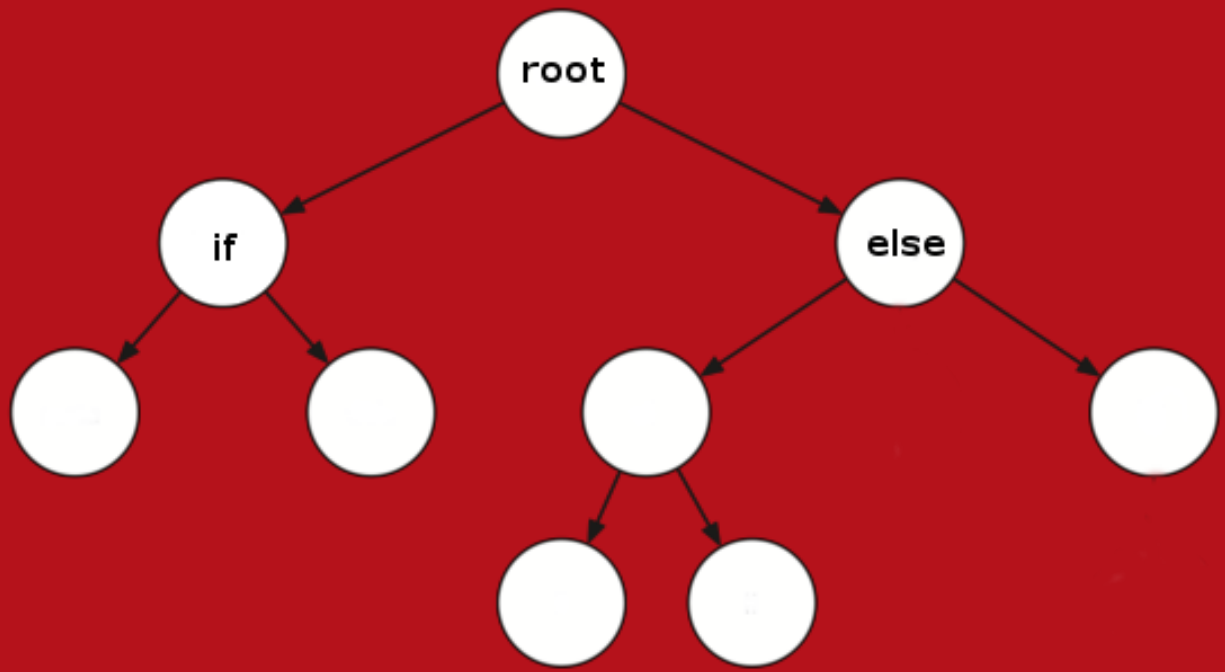

- `get_input(src)` now returns a **symbol** instead of a concrete value
- But now expressions **cannot** be fully evaluated to a concrete value

Path Selection and Performance

- For each conditional jump we must decide what path to follow first
  - But some path may never terminate
- Exponential blowup due to branches



Path Selection and Performance

- For each conditional jump we must decide what path to follow first
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$$\texttt{while } (3^n + 4^n == 5^n) \texttt{ \{n++; ...\}}$$

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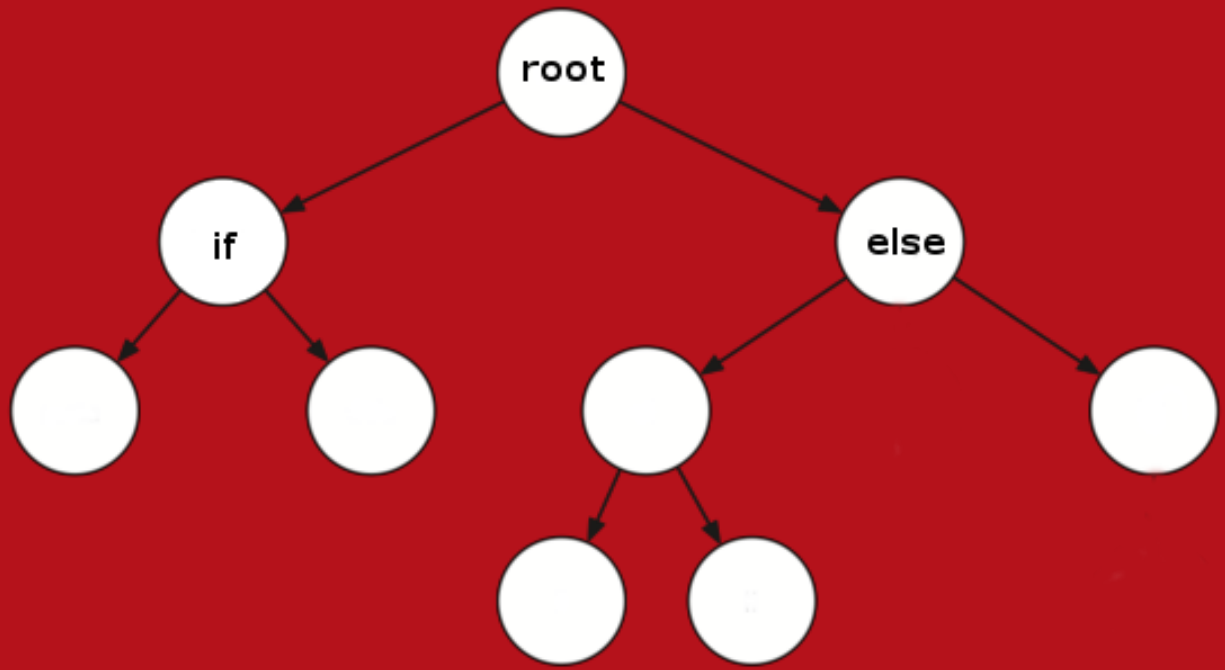

Path Selection and Performance

- For each conditional jump we must decide what path to follow first
  - But some path may never terminate

    `while (`$3^n + 4^n == 5^n$`) {n++; ...}`
- Exponential blowup due to branches
- Solutions
  - **Path Selection Heuristics**
    - Concolic Testing
    - Depth-First or Random Search
  - More and faster **hardware**
  - Identify **redundancies** between formulas
  - Identify **independent subformulas**

A small comparison

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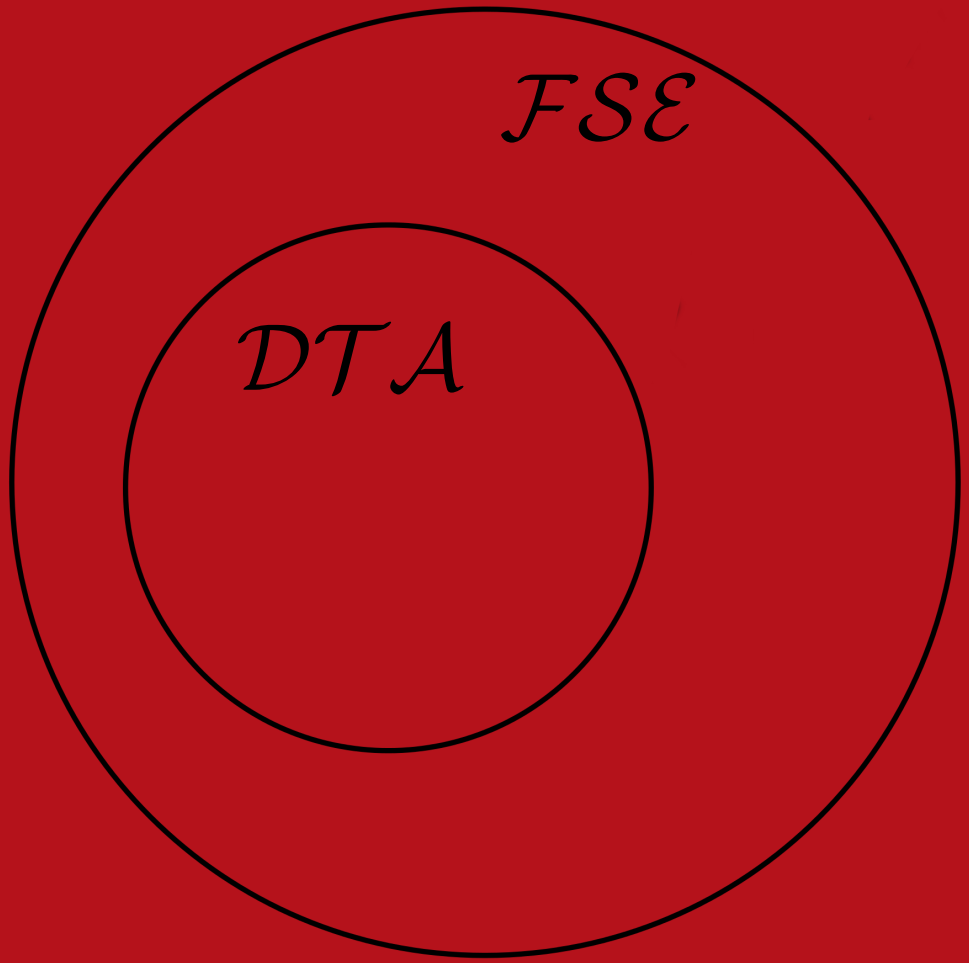
Dynamic Taint Analysis

Forward Symbolic Execution

A small comparison



Dynamic taint analysis analyzes only ***feasible*** paths

Conclusions

- ✓ Conceptually simple methods of analysis
- ✓ There are a lot of possible use cases
  - Malware detection and analysis
  - Automatic testing
  - Automatic programs understanding

- ✗ Usable with some care
- ✗ The effectiveness depends on the application

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Thank you for allowing me to taint your time!

Questions?

DIPARTIMENTO
MATEMATICA

SimpIL Grammar

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

SimplL Operational Semantic

- **Each** statement rule of the operational semantic is like:

$$\frac{\text{computation}}{<\text{current state}>, \text{stmt} \rightarrow <\text{end state}>, \text{stmt}}$$

- The `state` is composed of:
  - Program statements ($\sum$)
  - Current memory state (μ)
  - Current values for variables (Δ)
  - Program counter (***pc***)
  - Current statement (***i***)

Memory Address Problems
Forward Symbolic Execution

- What are we supposed to do if a referenced address is derived from user input?
  - `LOAD`, `STORE` $\rightarrow$ **Symbolic Memory Address**
  - `GOTO` $\rightarrow$ **Symbolic Jumps**
- Solutions
  - Concolic testing
  - SMT (**S**atisfiability **M**odulo **T**heories) solvers
    - $\mathcal{NP}$**-Complete** problem!
  - Static and alias analysis