

Taint Mechanisms

Advanced topics in Computer Security

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December 7, 2016



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Outline

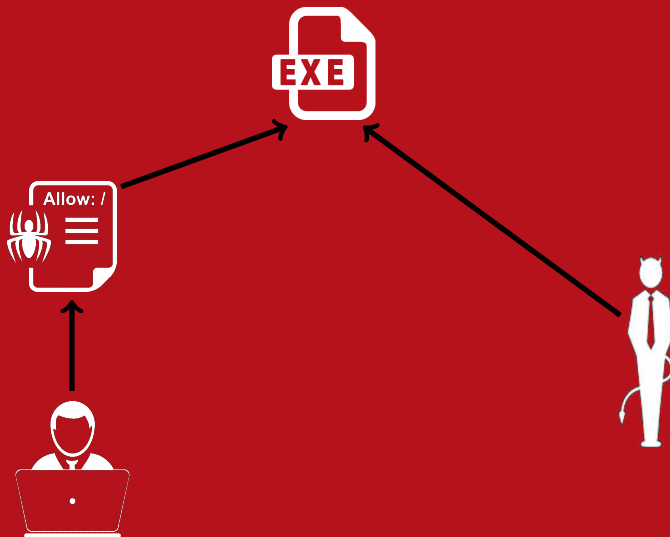
Introduction

Dynamic Taint Analysis

Forward Symbolic Execution

Conclusions

Of who or what do we trust?





Input Analysis

There are two essential questions about the input analysis:

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- **Dynamic Taint Analysis!**
- Tracks information flow between sources and sinks

Input Analysis

There are two essential questions about the input analysis:


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

```
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

Untainted `x := get_input()`

`z := 42`

`y := x + z`

`goto y`

`z` is a "static"
constant

Dynamic Taint Analysis

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

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z := 42
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```
 y := x + z → Is y tainted?
```

```
goto y
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Dynamic Taint Analysis

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goto y
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It depends on the
selected policy

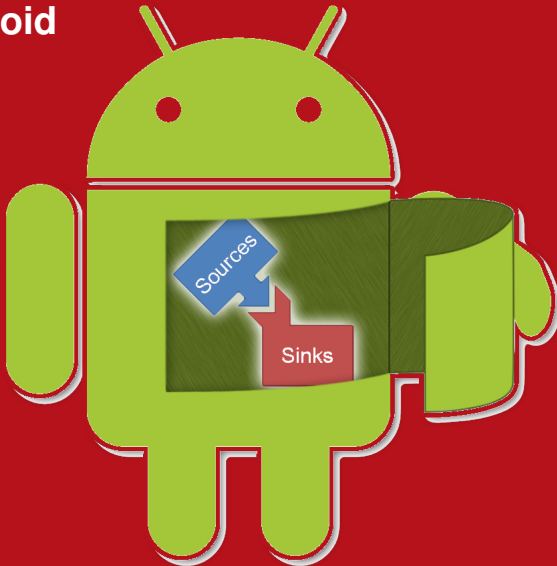
What's a policy?

- ▶ 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**

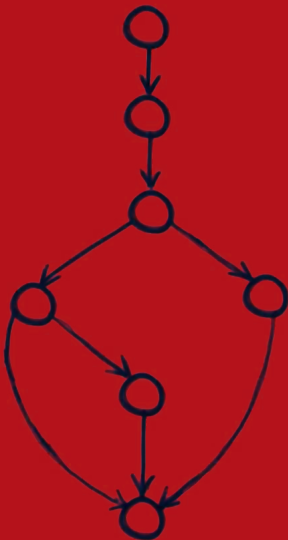
Can we go further?

TaintDroid



Limitations

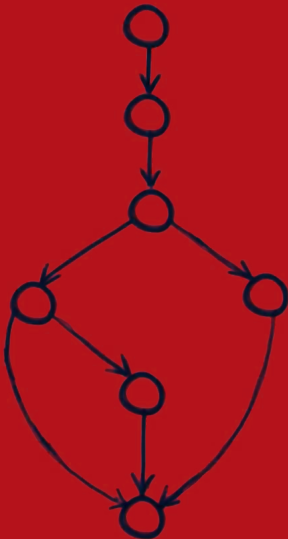
► Sanitization problem



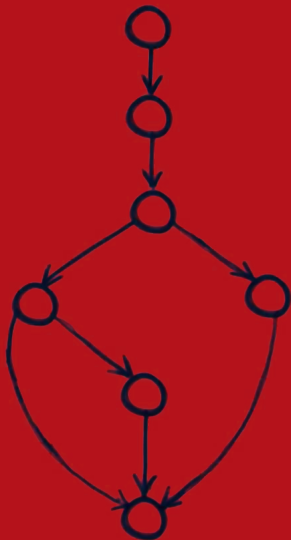
Limitations

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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**

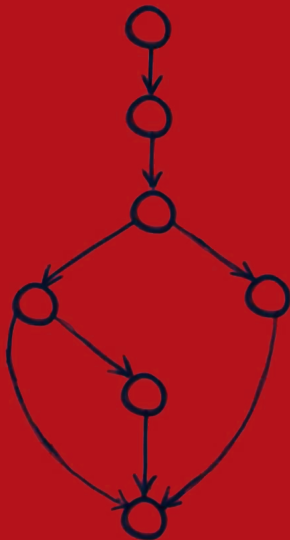
```
x := get_input(src)
```

```
if x == 1 then goto 3 else goto 4
```

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y := 1
```

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Limitations



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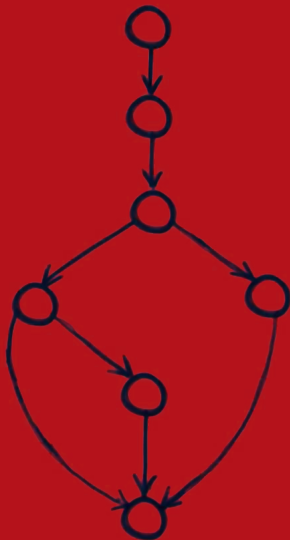
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- ▶ What about different security policies for different I/O channels?

Limitations



- ▶ **Sanitization problem**

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- ▶ What about different security policies for different I/O channels?
→ **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
```

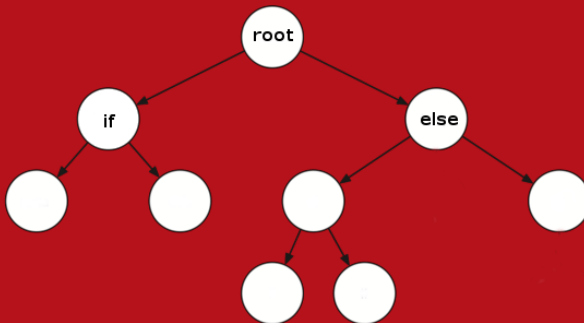
Forward Symbolic Execution

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x := 2 * get_input(src)
if x - 5 == 14 then goto 3 else goto 4
// line 3: catastrophic failure
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```
- ▶ `get_input(src)` now returns a **symbol** instead of a concrete value
- ▶ But now expressions **cannot** be fully evaluated to a concrete value

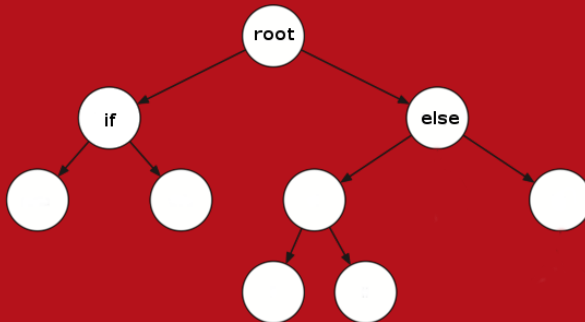
Path Selection and Performance

- ▶ 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

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 - $\text{while } (3^n + 4^n == 5^n) \{n++; \dots\}$
- ▶ Exponential blowup due to branches



Path Selection and Performance

- ▶ For each conditional jump we must decide what path to follow first
 - But some path may never terminate
$$\text{while } (3^n + 4^n == 5^n) \{n++; \dots\}$$
- ▶ 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**

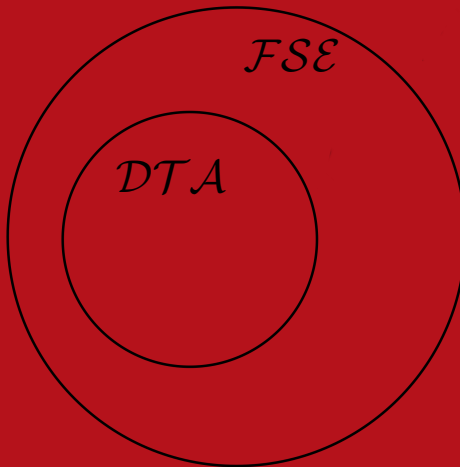
A small comparison

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



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Thank you for allowing me to
taint your time!

Questions?



DIPARTIMENTO
MATEMATICA



SimplL 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:

$$\frac{\text{computation}}{\langle \text{current state} \rangle, \text{stmt} \rightarrow \langle \text{end state} \rangle, \text{stmt}}$$

- The state is composed of:
 - Program statements (Σ)
 - 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 → **Symbolic Memory Address**
 - GOTO → **Symbolic Jumps**
- ▶ Solutions
 - Concolic testing
 - SMT (**S**atisfiability **M**odulo **T**heories) solvers
 - ▶ **\mathcal{NP} -Complete** problem!
 - Static and alias analysis