Taint Mechanisms

Advanced topics in Computer Security

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Outline

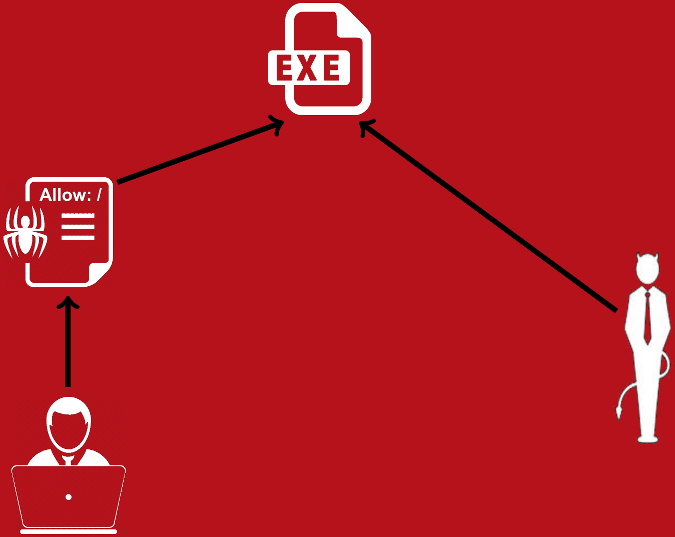
Introduction

Dynamic Taint Analysis

Forward Symbolic Execution

Conclusions

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

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

Dynamic Taint Analysis

Tainted

```
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```

x is derived from a tainted source

Dynamic Taint Analysis

```
x = get_input(😈)
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```

Untainted

z is a ”static” constant

Dynamic Taint Analysis

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x = get_input(😈)
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Is y taited?

Dynamic Taint Analysis

```
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```

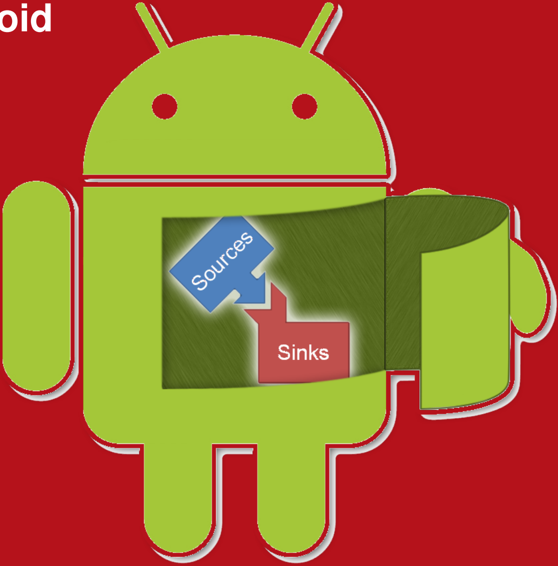
Is y taited?

It depends on the selected policy

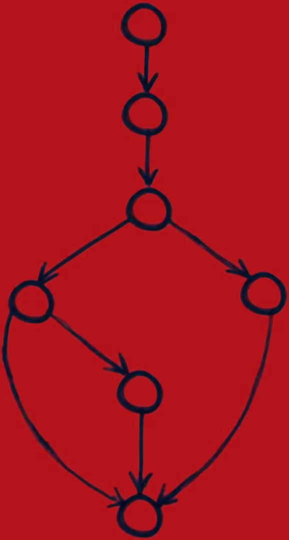
What’s a policy?

- 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

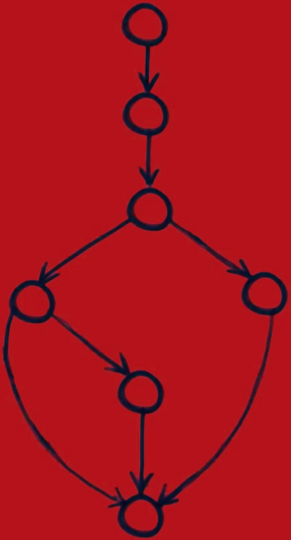


Limitations



- **Sanitization problem**

Limitations



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$$b := a \oplus a$$

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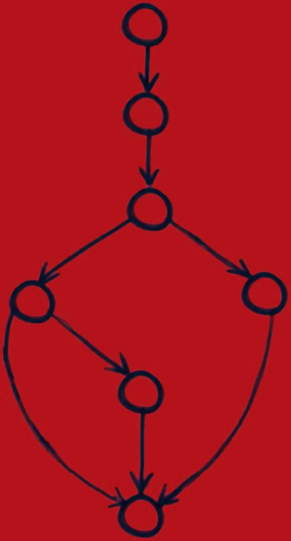


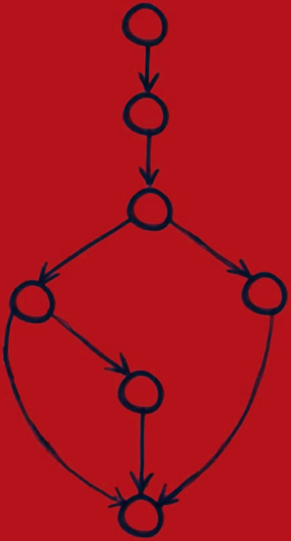
- **Sanitization problem**

$$b := a \oplus a$$

- Pure dynamic taint analysis considers **data flows**...
  ...but it ignores **control-flows**

```
x = get_input(src)
if x == 1 then
    y = 1
z = 42
```

Limitations



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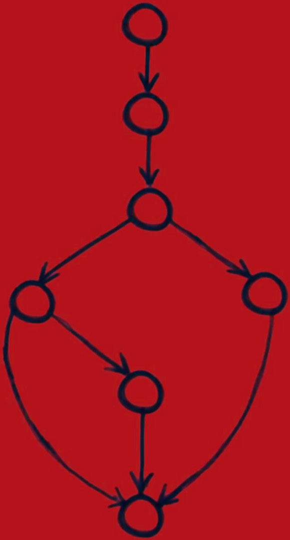
Limitations



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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
```

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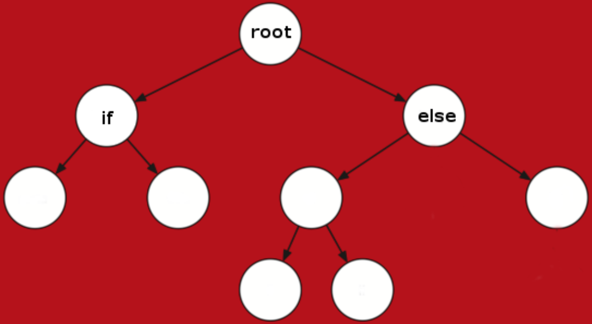
```

- `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



Solutions

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

Solutions

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- **Path Selection Heuristics**
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...but solving a logical formula is a $\mathcal{NP}$**-Complete** problem!

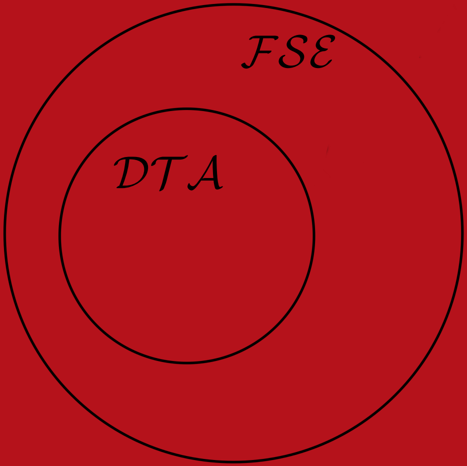
A small comparison

Dynamic
Taint
Analysis

$\overset{?}{\substack{\subset \\ = \\ \supset}}$

Forward
Symbolic
Execution

A small comparison



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

Conclusions

v Conceptually simple methods of analysis

v 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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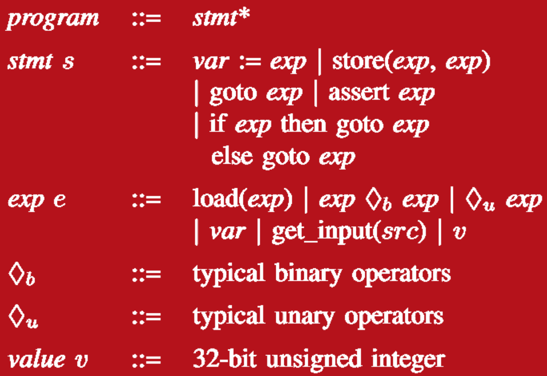
Thank you for allowing me to taint your time!

Questions?

DIPARTIMENTO
MATEMATICA

SimpIL Grammar



$$
\begin{array}{lcl}
\textit{program} & ::= & \textit{stmt}^* \\
\textit{stmt}\ s & ::= & \textit{var} := \textit{exp} \mid \text{store}(\textit{exp}, \textit{exp}) \\
 & & \mid \text{goto } \textit{exp} \mid \text{assert } \textit{exp} \\
 & & \mid \text{if } \textit{exp} \text{ then goto } \textit{exp} \\
 & & \quad \text{else goto } \textit{exp} \\
\textit{exp}\ e & ::= & \text{load}(\textit{exp}) \mid \textit{exp} \lozenge_b \textit{exp} \mid \lozenge_u \textit{exp} \\
 & & \mid \textit{var} \mid \text{get\_input}(\textit{src}) \mid v \\
\lozenge_b & ::= & \text{typical binary operators} \\
\lozenge_u & ::= & \text{typical unary operators} \\
\textit{value}\ v & ::= & \text{32-bit unsigned integer}
\end{array}
$$

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` → **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