Taint Mechanisms

Advanced topics in Computer Security

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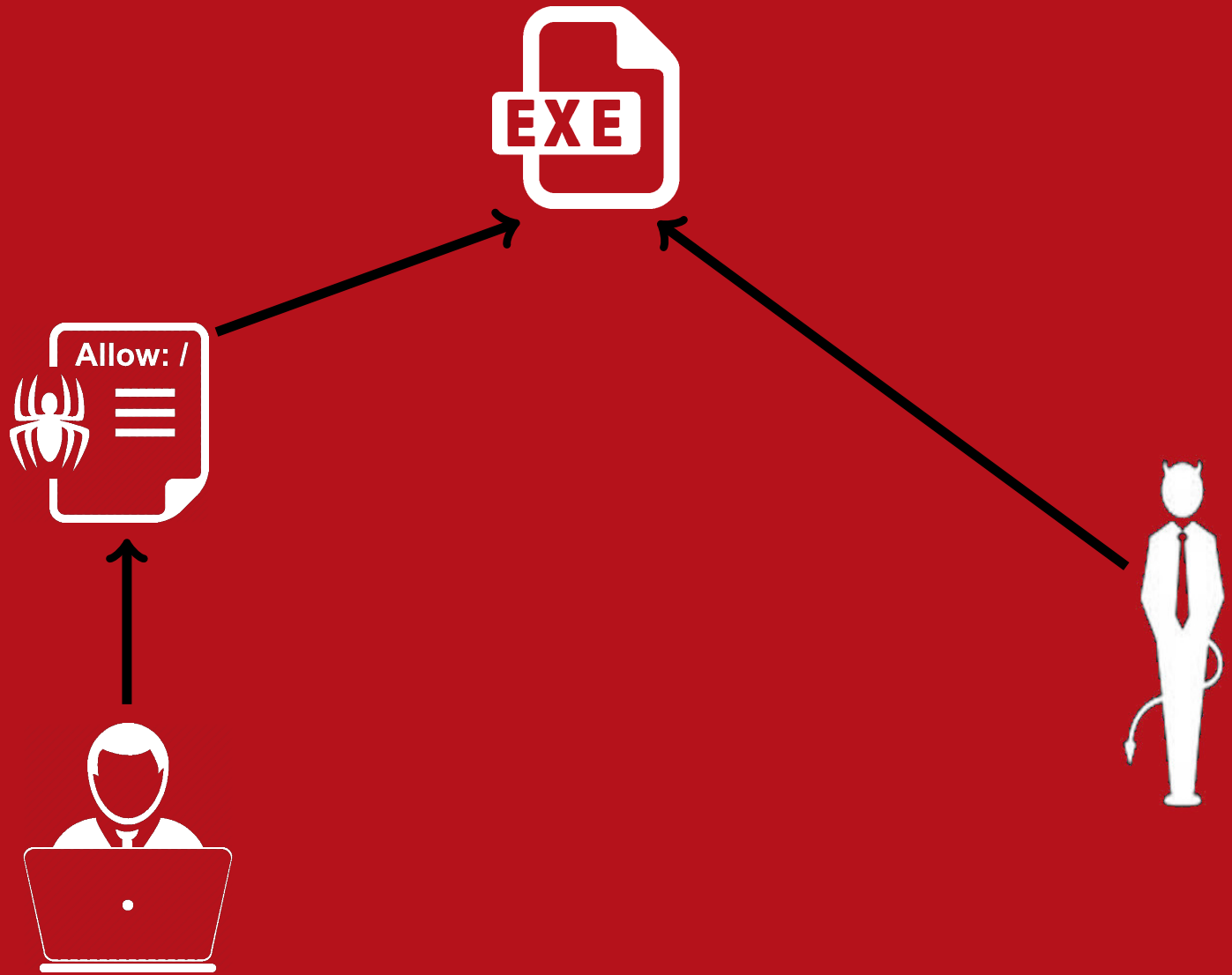
Outline

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**!
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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()
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y = x + z
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```
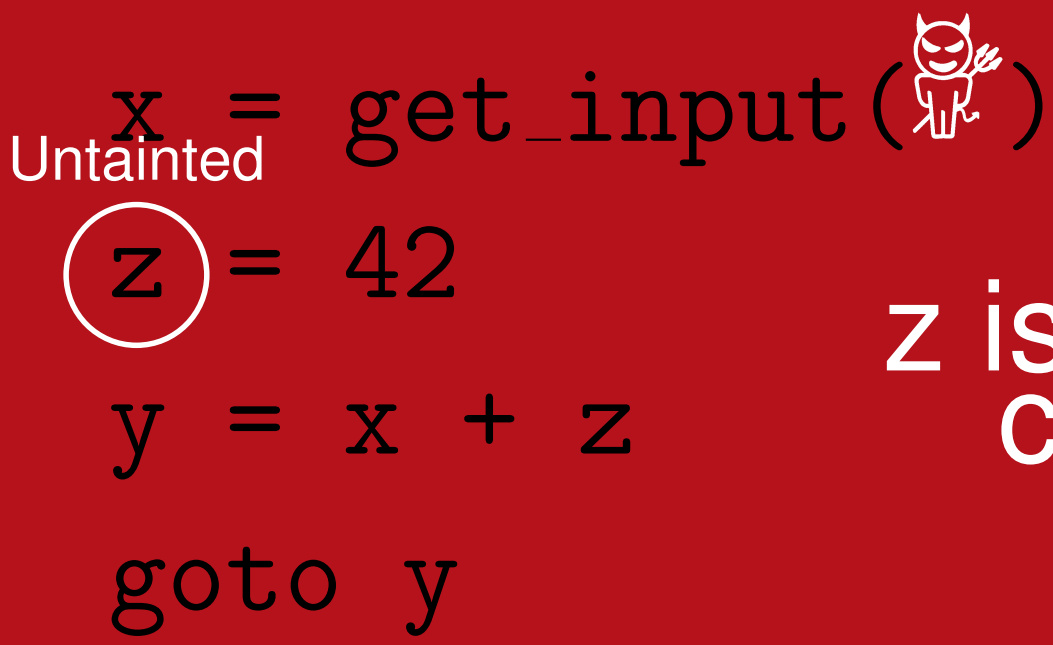
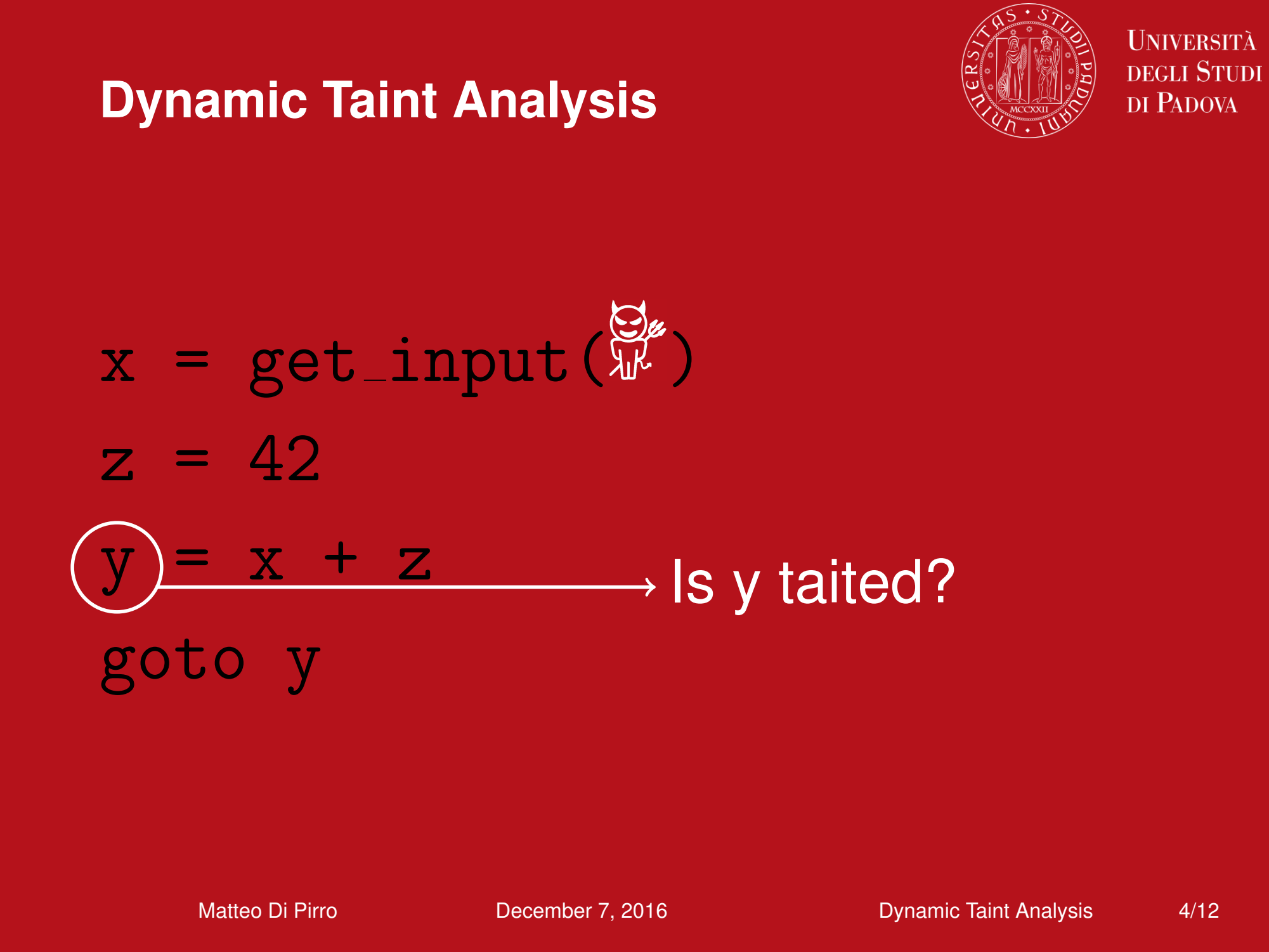

x is derived from a tainted source

Dynamic Taint Analysis



z is a ”static” constant

Dynamic Taint Analysis



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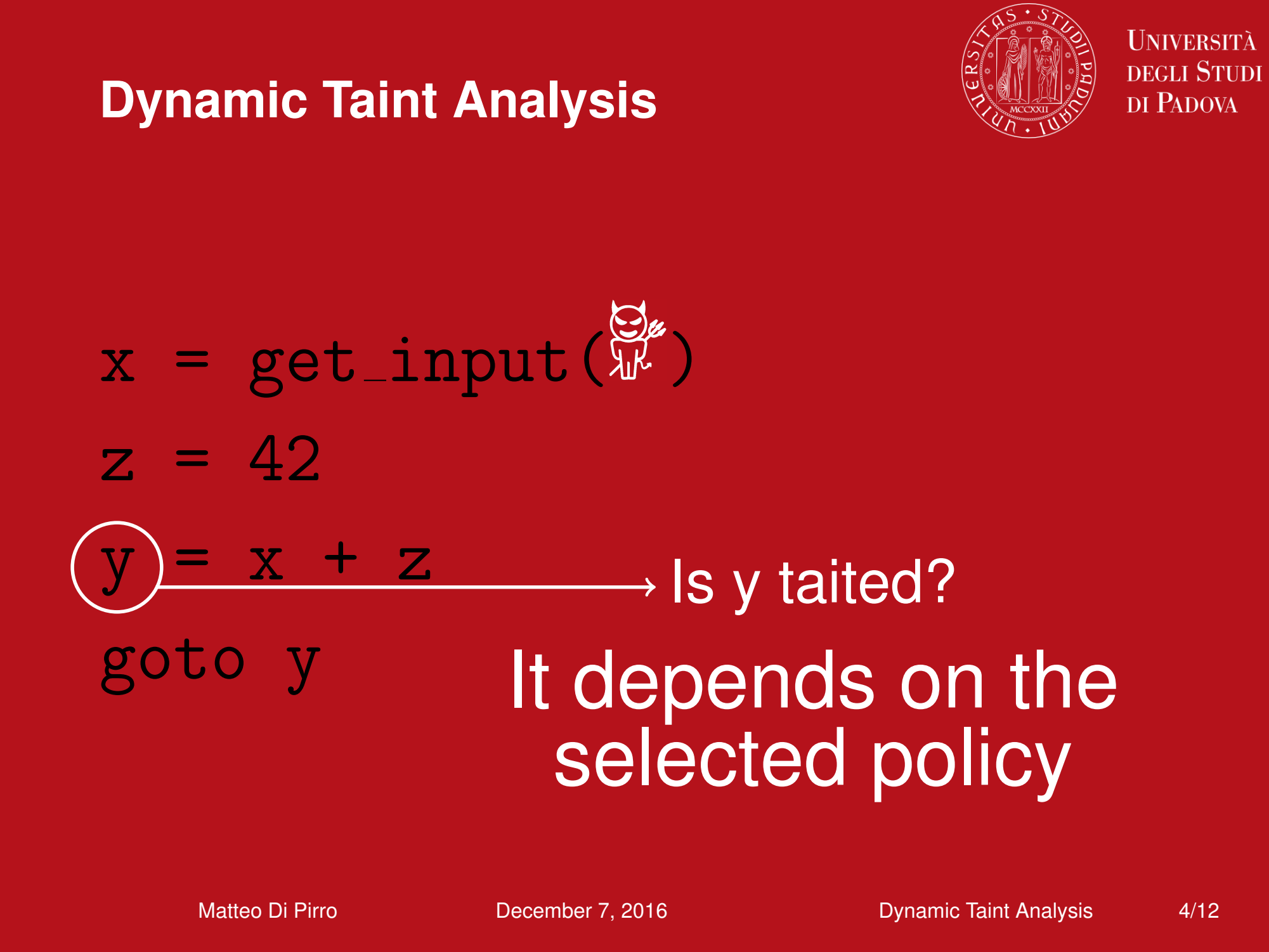

What's a policy?

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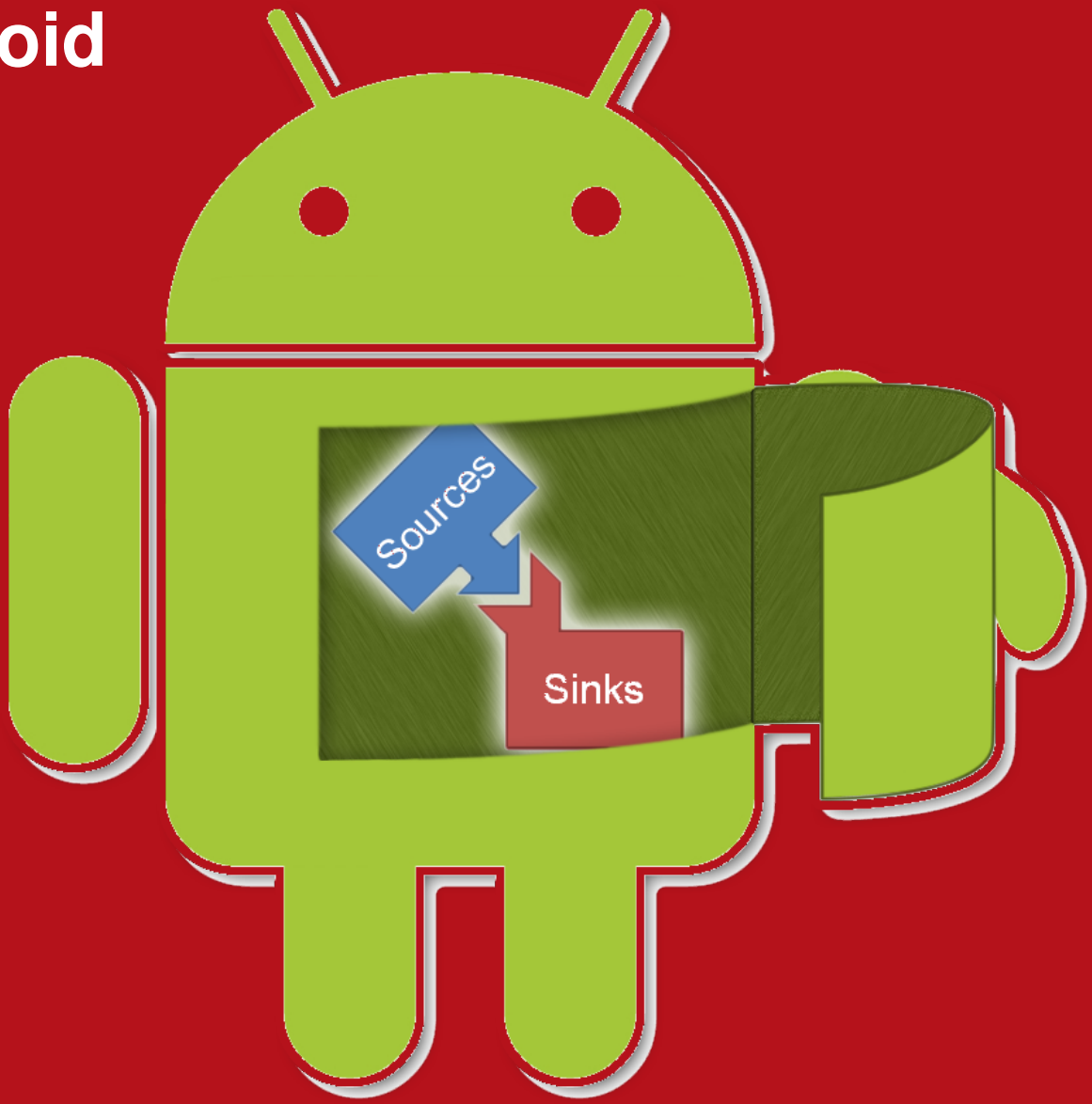
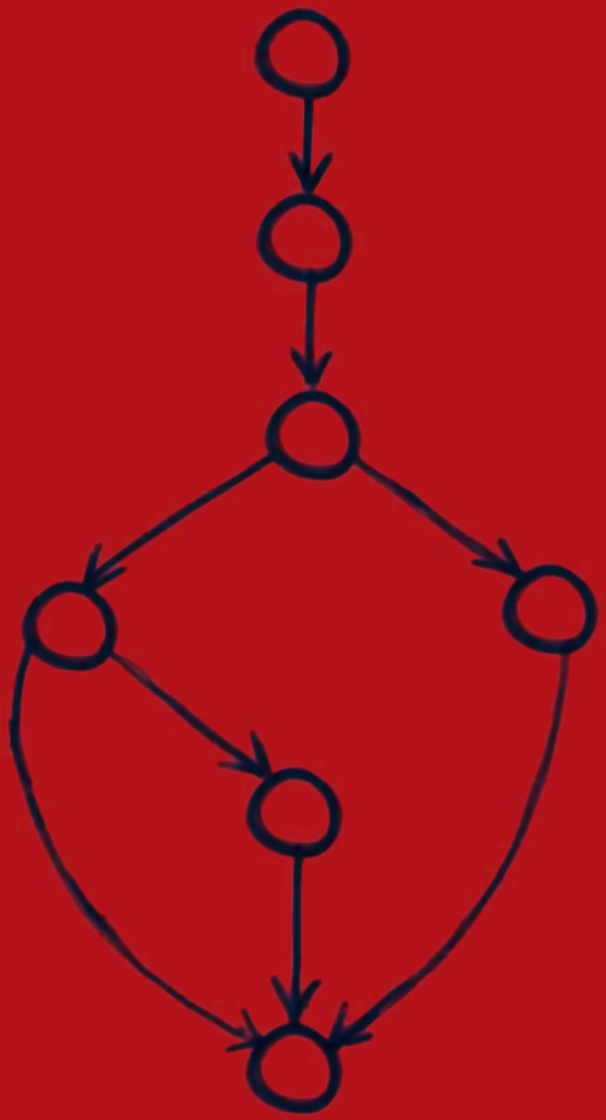
- A taint policy specifies three properties:
  - **Taint Introduction**
    - How is taint introduced into a system?
  - **Taint Propagation**
    - How does taint propagate into a system?
  - **Taint Checking**
    - Is the current operation secure?
- **Undertainting** vs **Overtainting**

Can we go further?
TaintDroid



Limitations



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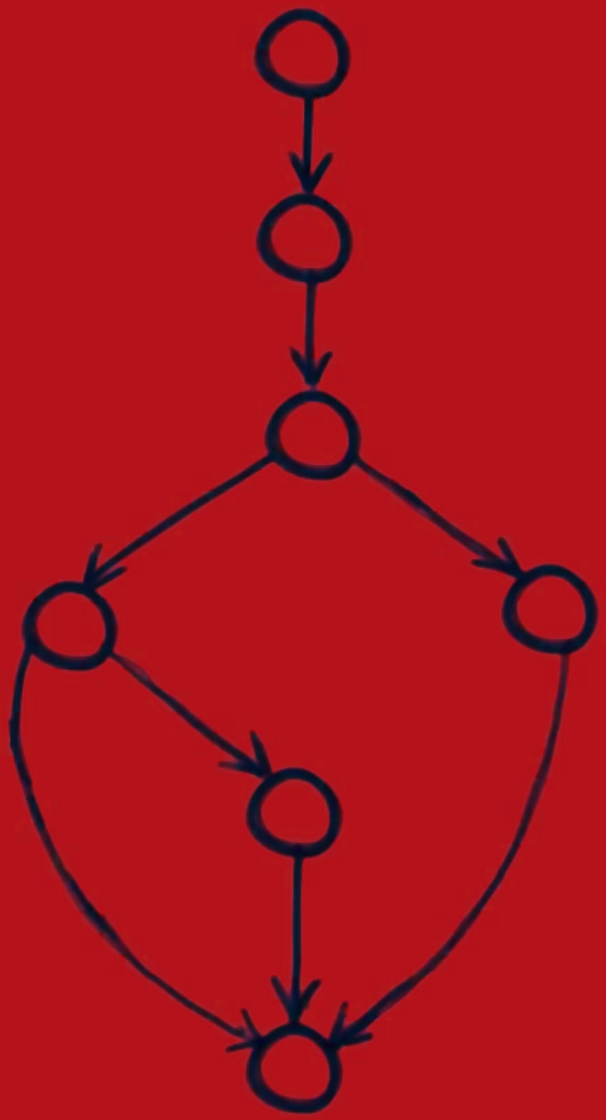
Limitations



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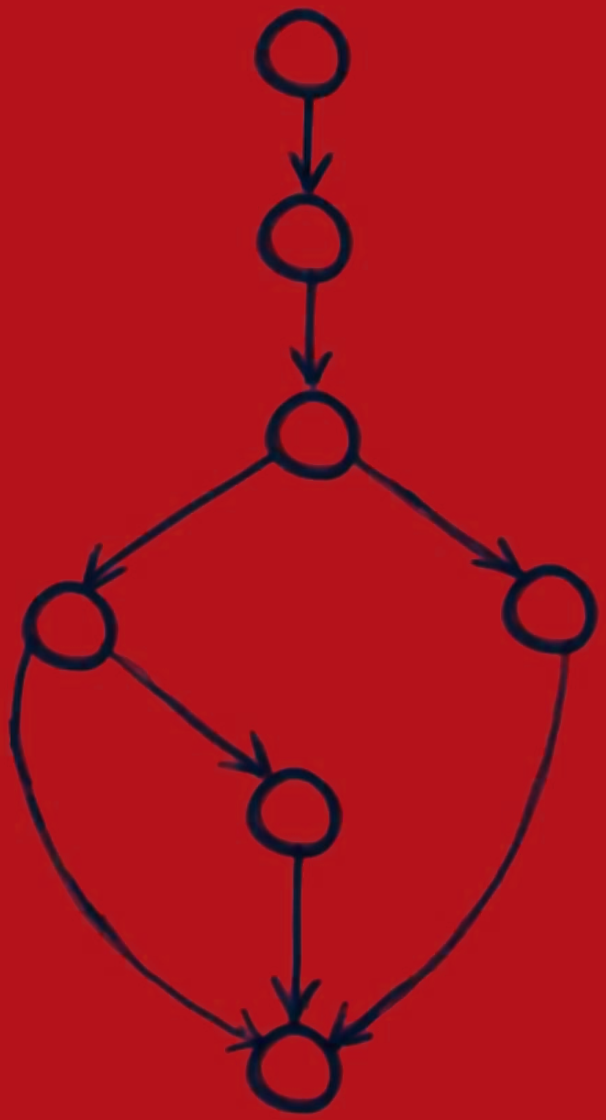

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- Pure dynamic taint analysis considers **data flows**...

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

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x = get_input(src)
if x == 1 then
    y = 1
...
goto y
```

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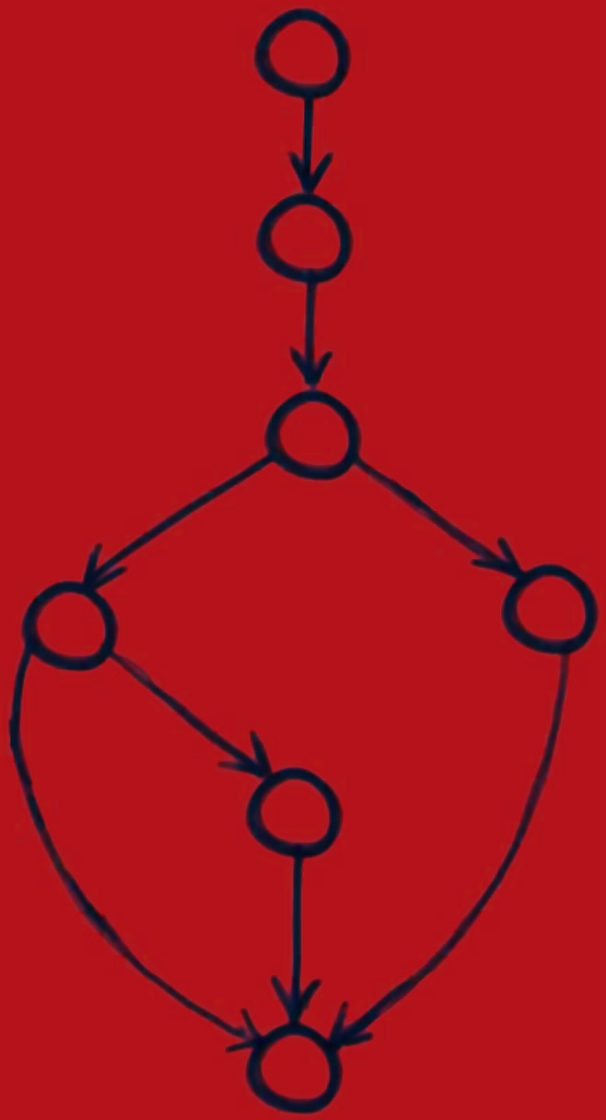

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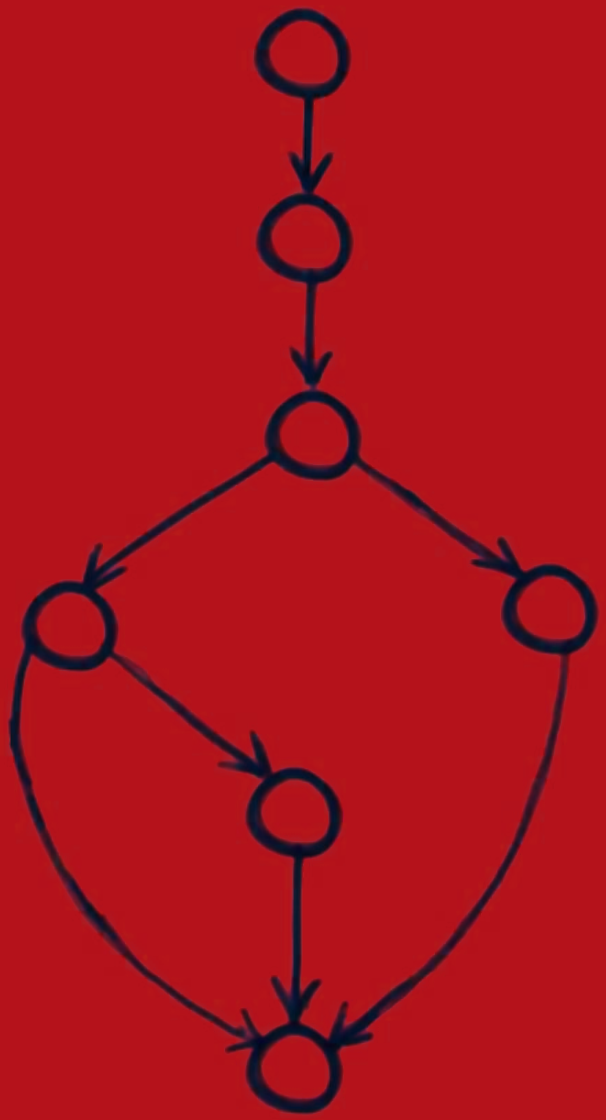

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- What about different security policies for different I/O channels?

  $\rightarrow$ **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
```

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// line 4:  normal behavior
```
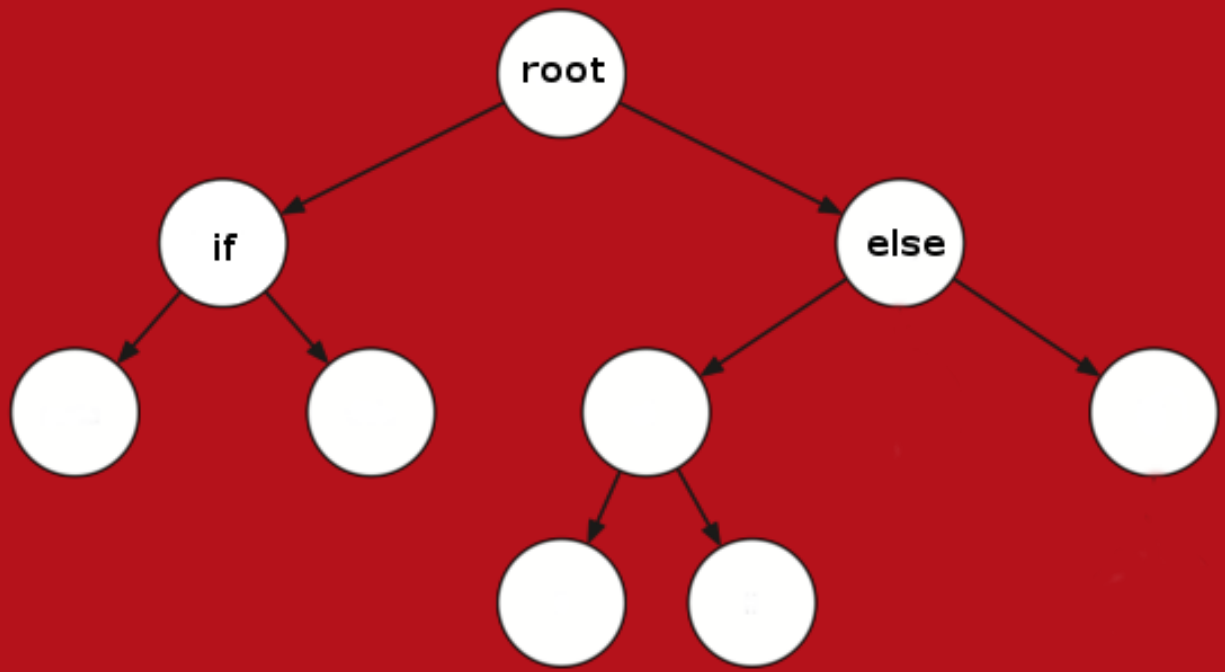

- `get_input(src)` now returns a **symbol** instead of a concrete value
- But now expressions **cannot** be fully evaluated to a concrete value

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



Solutions

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

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

A small comparison

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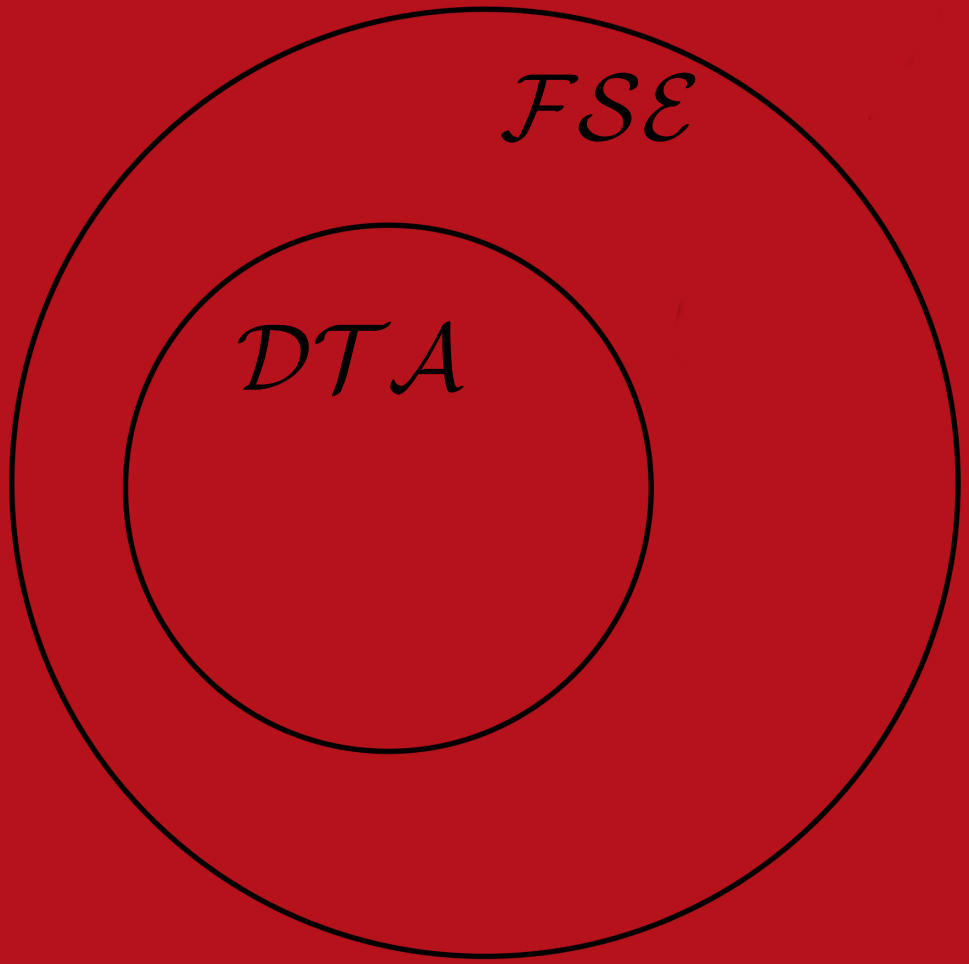
Dynamic
Taint
Analysis

Forward
Symbolic
Execution

A small comparison



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

Conclusions

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- ✓ 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