Towards a unifying framework for tuning analysis precision by program transformation

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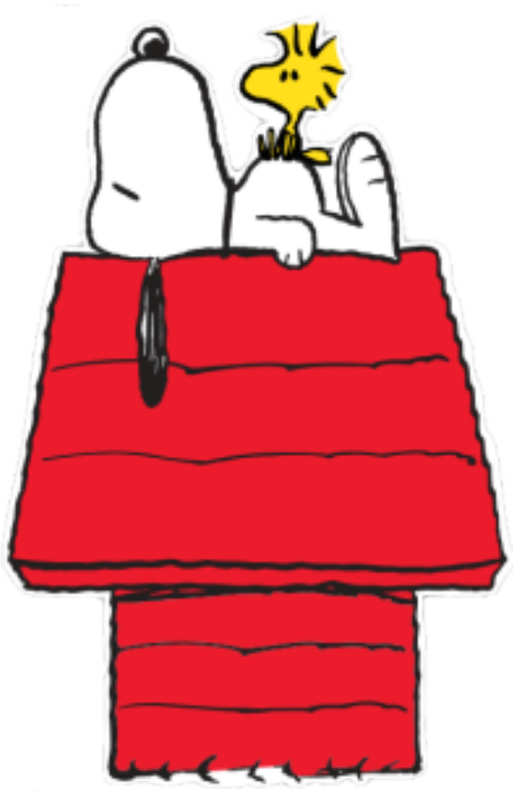
Program Analysis



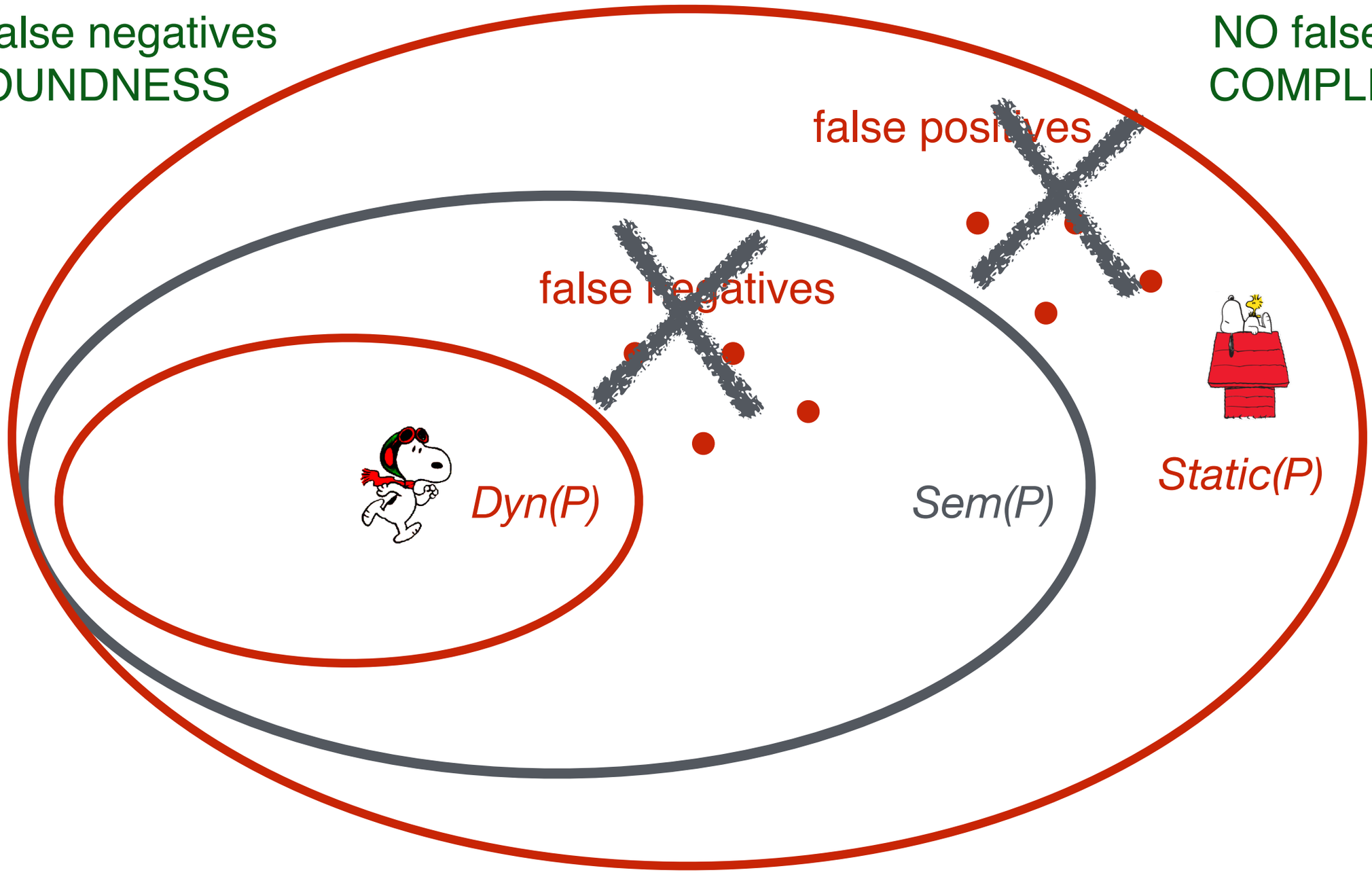
Static program analysis

Dynamic program analysis

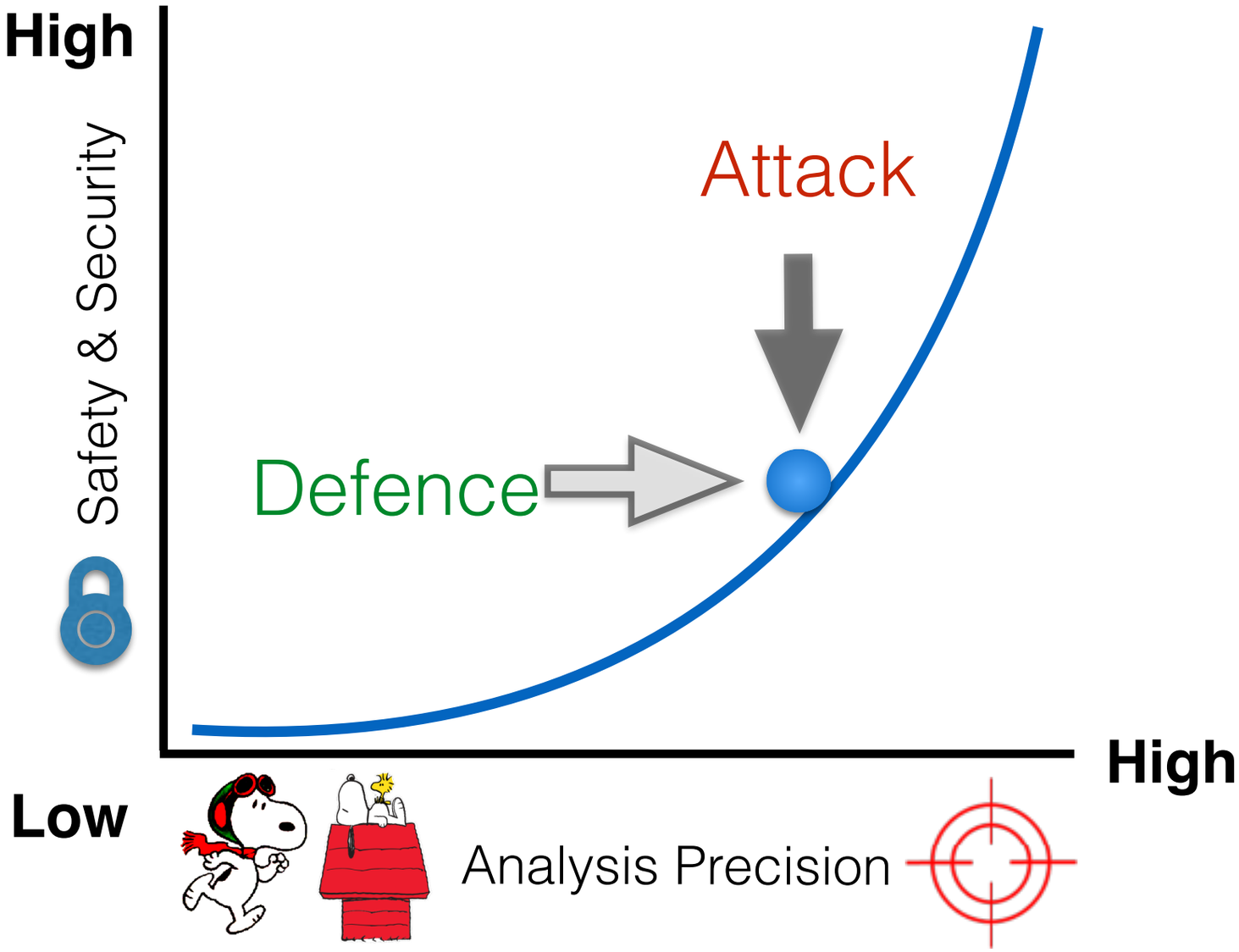
Program Analysis

NO false negatives
SOUNDNESS

NO false positives
COMPLETENESS

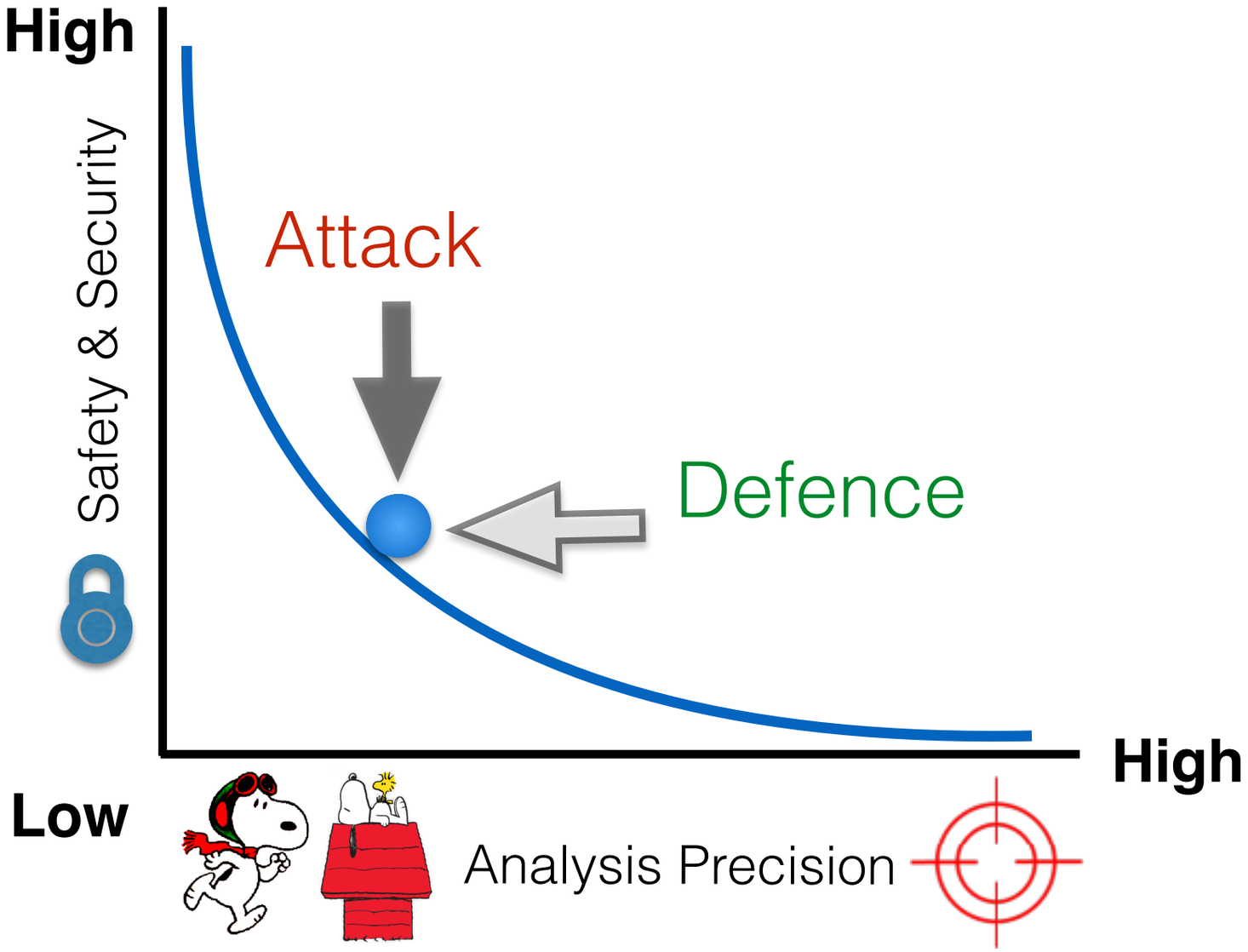


Code Debugging/Verification



The attacker exploits bugs

Software Protection



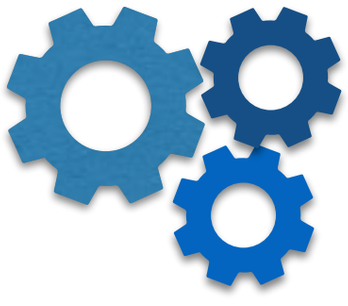
The attacker reverse engineer code

Code Obfuscation

[Collberg et al. POPL 1998]
A program transformation O: Programs ⟶ Programs is a code obfuscation if:

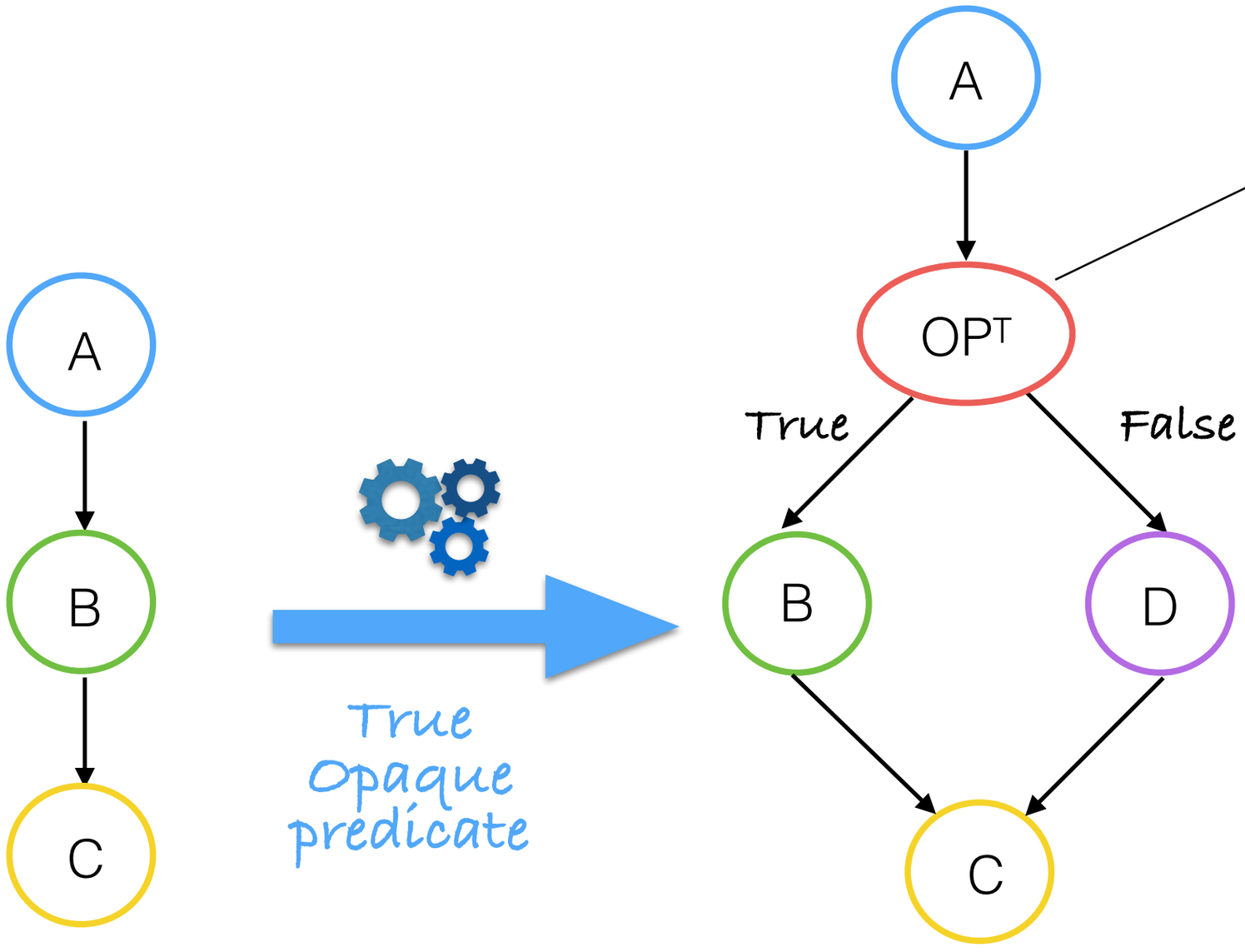
- O **preserves the observational behavior** of programs
- O(P) is **more difficult to analyse**

```
class A { public int Count() { return 1; } }

class Program
{
    static void Main(string[] args)
    {
        var seq = "Roslyn";
        var a = new A();

        if (seq.Count() > 0 && seq.Count() < 10) Console.WriteLine();
        if (0 < seq.Count()) Console.WriteLine();

        if ("Roslyn".Count() >= 1) {
            Console.WriteLine();
        }

        if (1 <= "Roslyn".Count()) {
            Console.WriteLine();
        }

        // these should not trigger our code issue
        if (a.Count() > 0) Console.WriteLine();
        if (0 < a.Count()) Console.WriteLine();

        if (1 < seq.Count()) {
            Console.WriteLine();
        }

        if (0 < seq.Count()) {
            Console.WriteLine();
        }

        if (seq.Count() > 1) Console.WriteLine();
        if (1 < seq.Count()) Console.WriteLine();
```



Code obfuscation

Code Obfuscation & Static Analysis

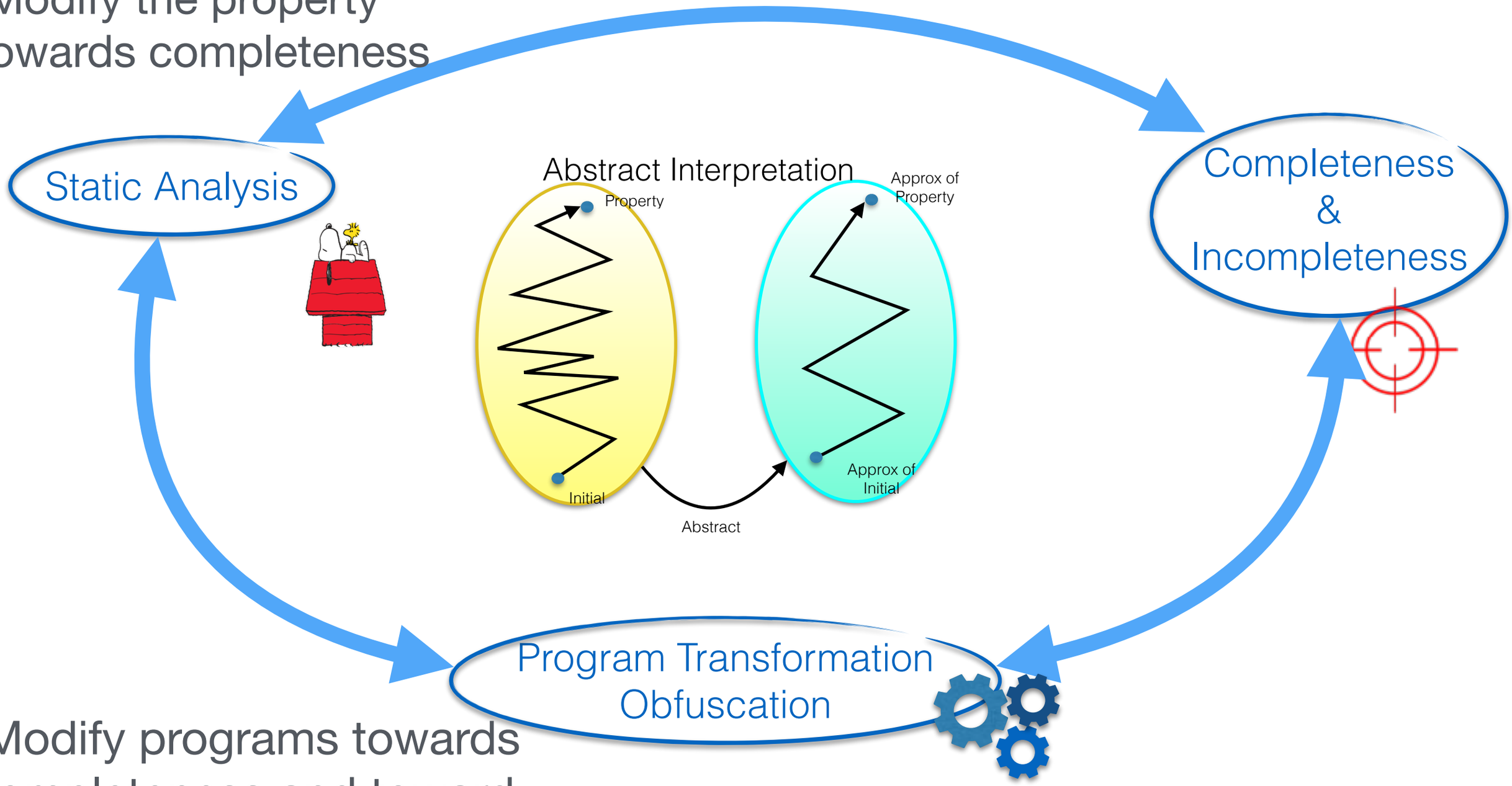


Add *false positive* for the control flow analysis

Incompleteness

Code Transformations & Static Analysis

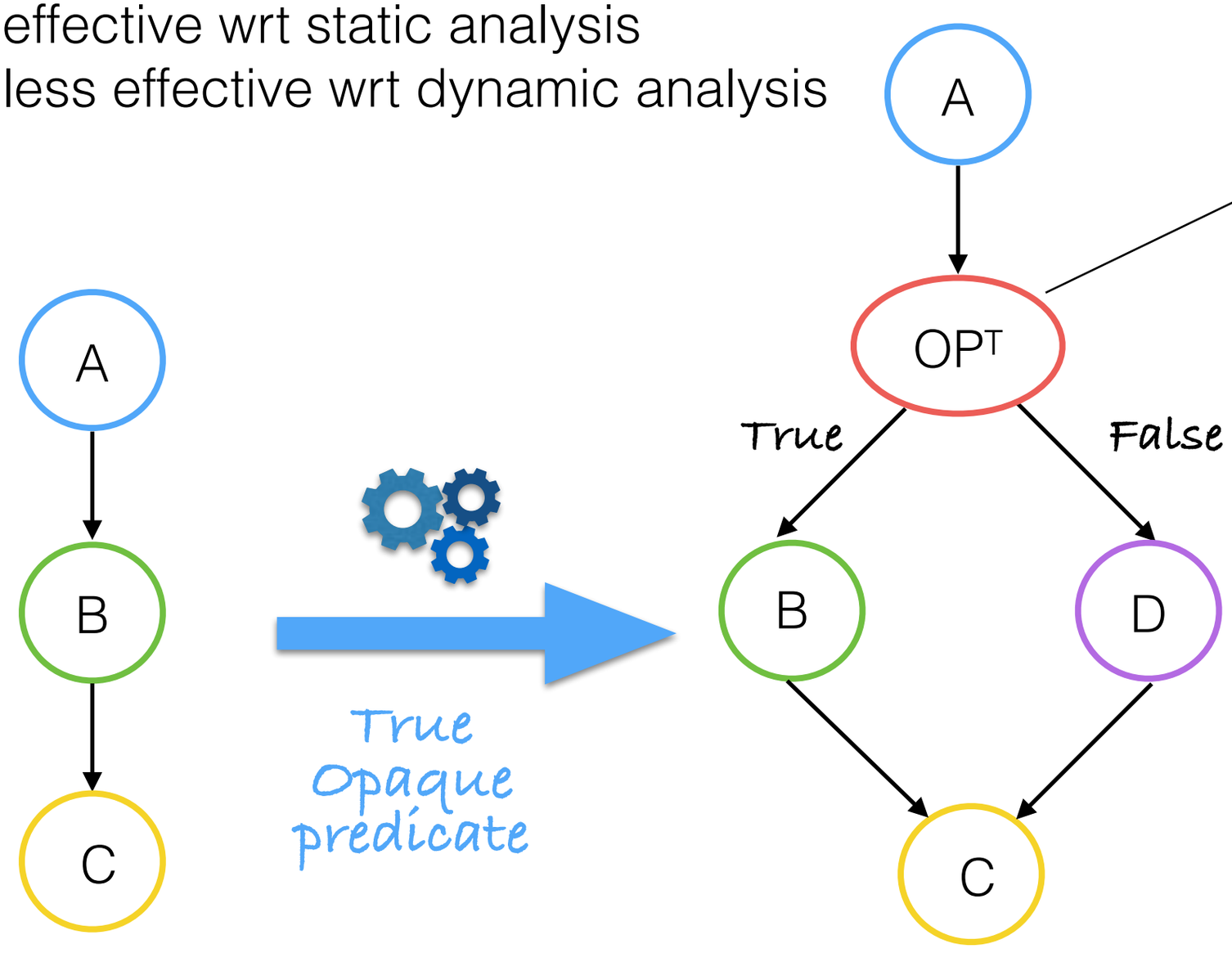
➡Modify the property towards completeness



➡Modify programs towards completeness and toward incompleteness

Code Obfuscation & Static Analysis

➡ effective wrt static analysis
➡ less effective wrt dynamic analysis



Add *false positive* for the control flow analysis

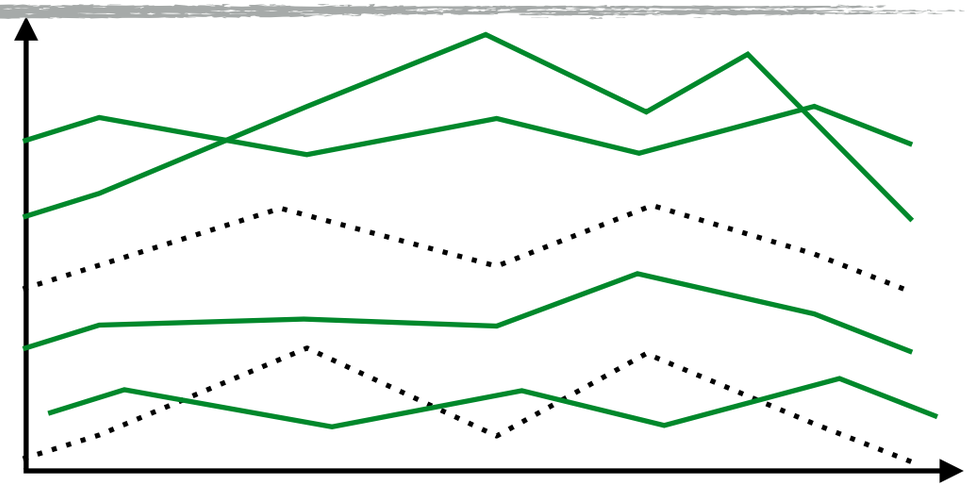
Incompleteness

Code Obfuscation & Dynamic Analysis

What does it mean to complicate/confuse dynamic analysis?

Dynamic Analysis

Analyze a finte subset of finte program traces to infer informations of the whole program, like in program testing and fuzzing

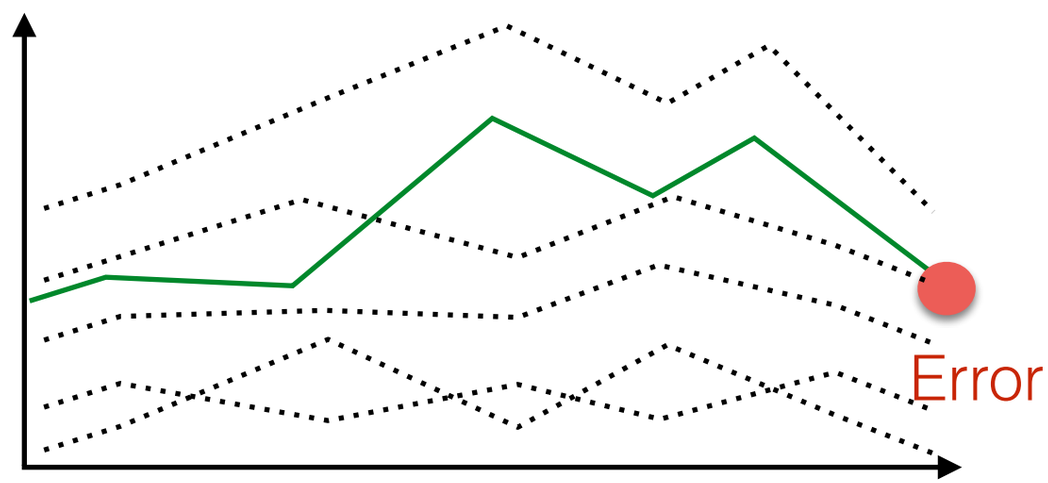


➡ Increase false negatives?

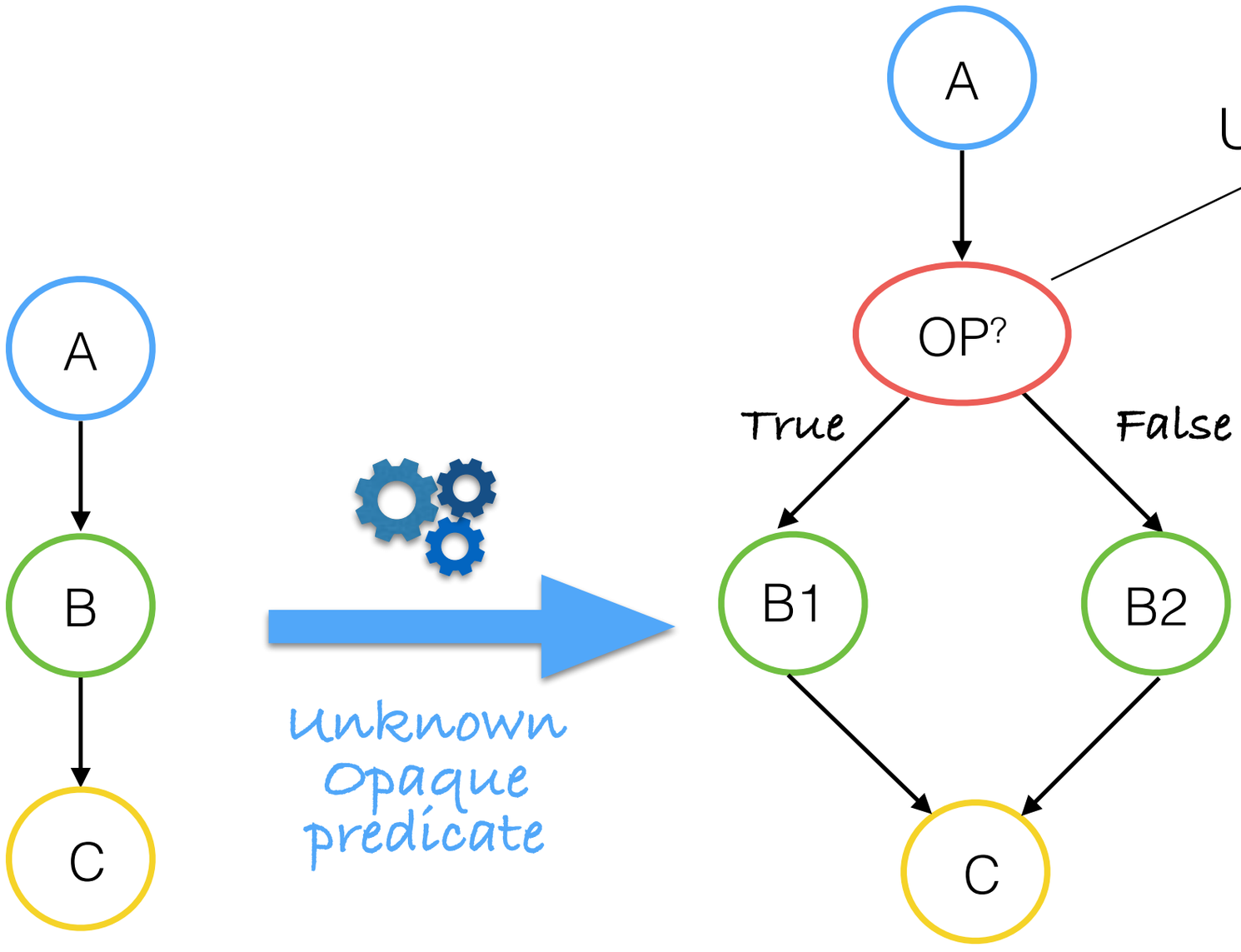
➡ Soundness can be forced or harmed by transforming the analysis or the program?

Analyze a single trace to better understand what went wrong or for runtime monitoring/verification

➡ Insert useless computations



Code Obfuscation & Dynamic Analysis



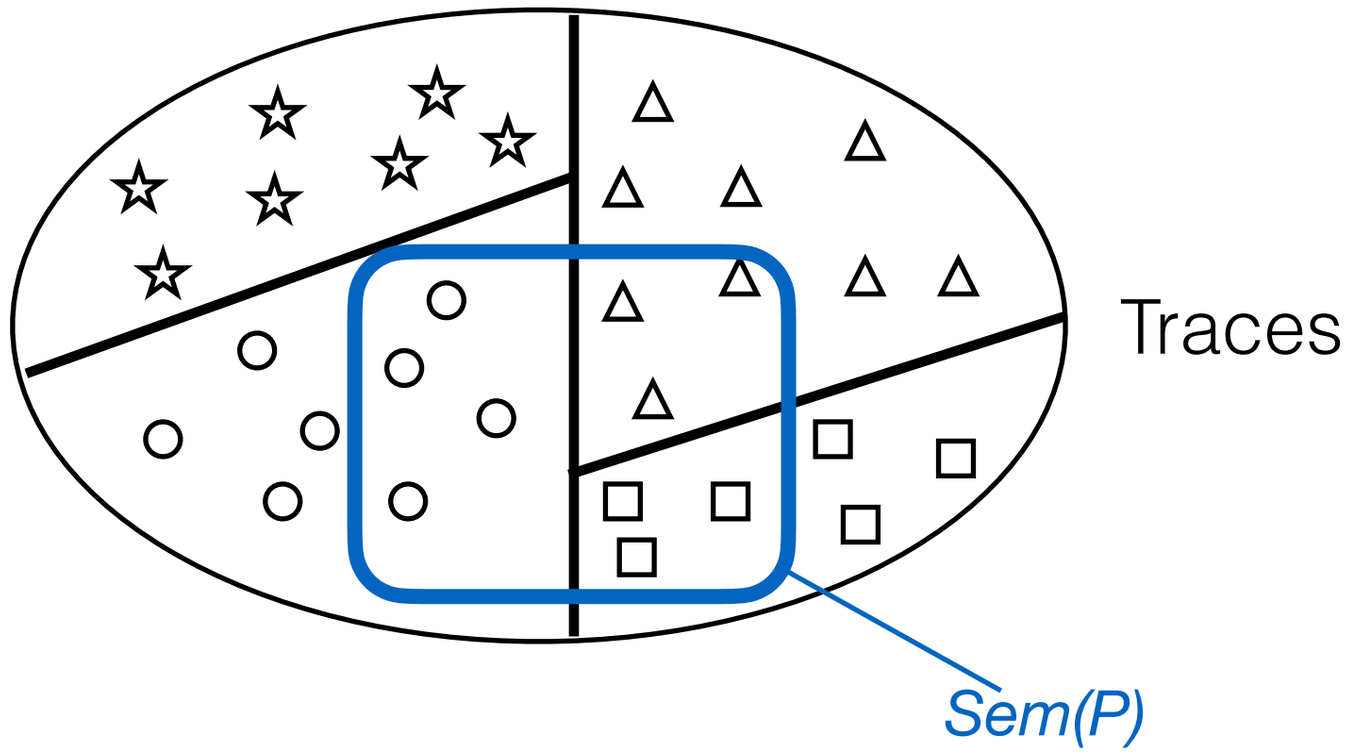
Add *diversification* for the control flow analysis

Unsoundenss?

Formalizing Dynamic Analysis

Property of single trace (no properties of sets of traces)

Equivalence Relation $\mathcal{A}$



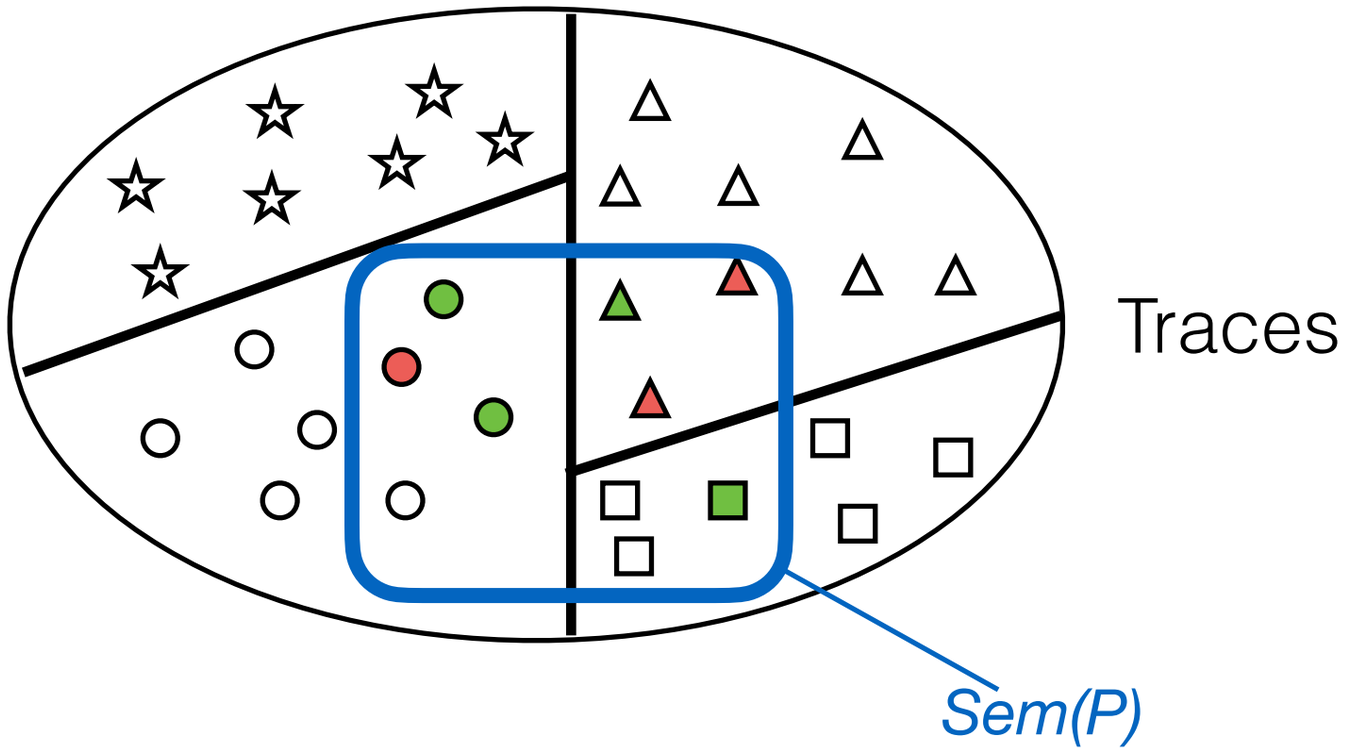
$$\mathcal{A}(Sem(P)) = \{[\sigma]_{\mathcal{A}} \mid \sigma \in Sem(P)\}$$

Formalizing Dynamic Analysis

Property of single trace (no properties of sets of traces)

Equivalence Relation $\mathcal{A}$

Dynamic Analysis
(Exe(P),$\mathcal{A}$)
sound
unsound



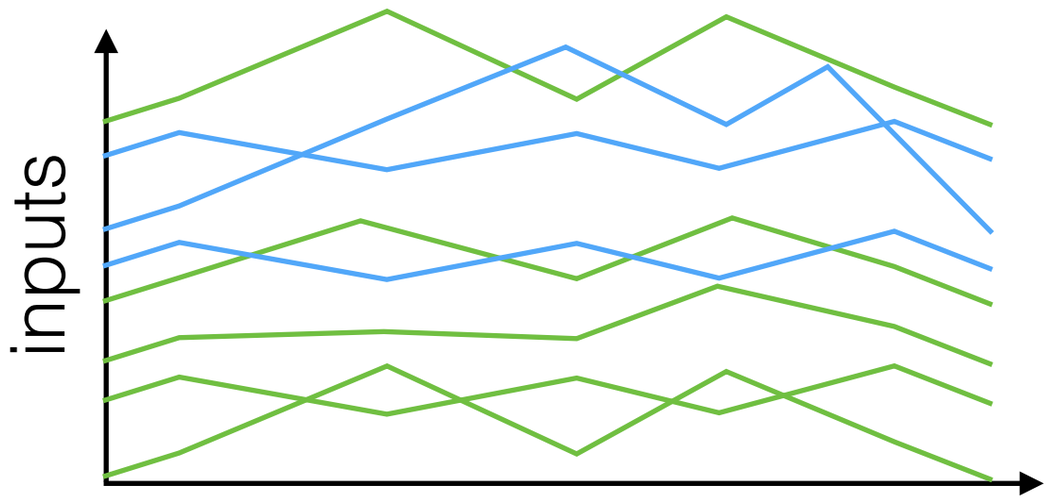
Soundness

$$\mathcal{A}(Sem(P)) = \mathcal{A}(Exe(P))$$

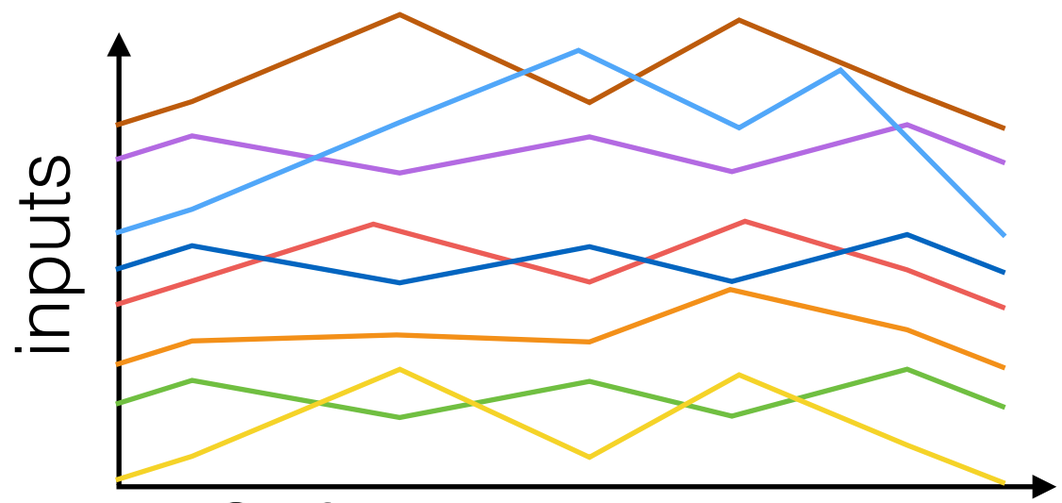
$$\mathcal{A}(Sem(P)) = \{[\sigma]_{\mathcal{A}} \mid \sigma \in Sem(P)\}$$

Obfuscating Dynamic Analysis

The key for harming dynamic analysis is **diversification wrt the property being analysed**



Original program



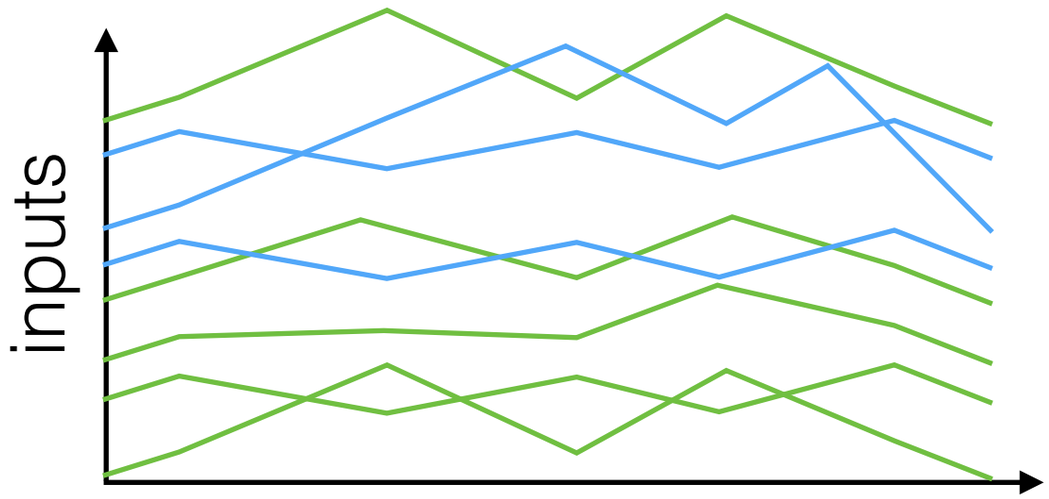
Obfuscated program

Colours represents the equivalence classes wrt $\mathcal{A}$

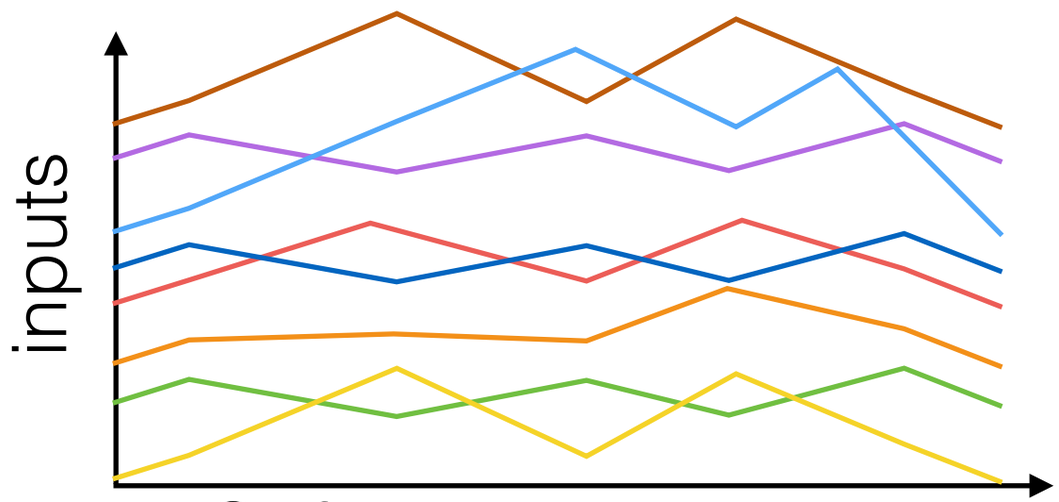
Ideally: specialise the program for every input wrt $\mathcal{A}$

Obfuscating Dynamic Analysis

The key for harming dynamic analysis is **diversification wrt the property being analysed**



Original program

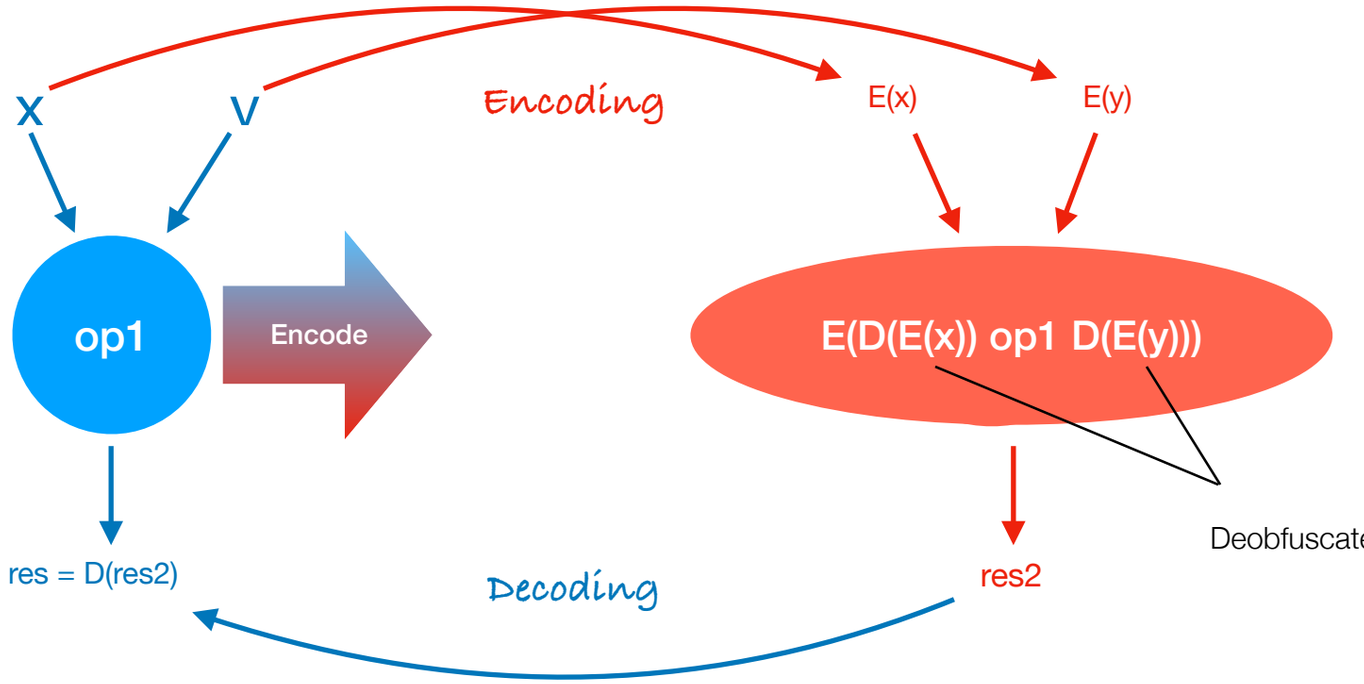


Obfuscated program

A program transformation O: Programs ⟶ Programs obfuscates property $\mathcal{A}$:

- O **preserves the observational behavior** of programs
- The property $\mathcal{A}$ of O(P) is **diversified** wrt P

Data Obfuscation



Data Obfuscation

P

```
input x;
sum := 0;
while x < 50
```

• $X = [x, 49]$

```
    sum := sum + x;
    x := x + 1;
```

$\mathcal{T}(P)$

```
input x;
x := 2*x;        (Encoding)
sum := 0;
while x < 2*50
```

• $X = [x, 2 * 50 - 1]$

```
    sum := sum + x/2;
    x := x + 2;
x:= x/2;         (Decoding)
```

No effects on dynamic analysis

Dynamic Data Obfuscation

P

```
input x;
sum := 0;
while x < 50
• X = [x, 49]
    sum := sum + x;
    x := x + 1;
```

Diversification
Parametric data encoding

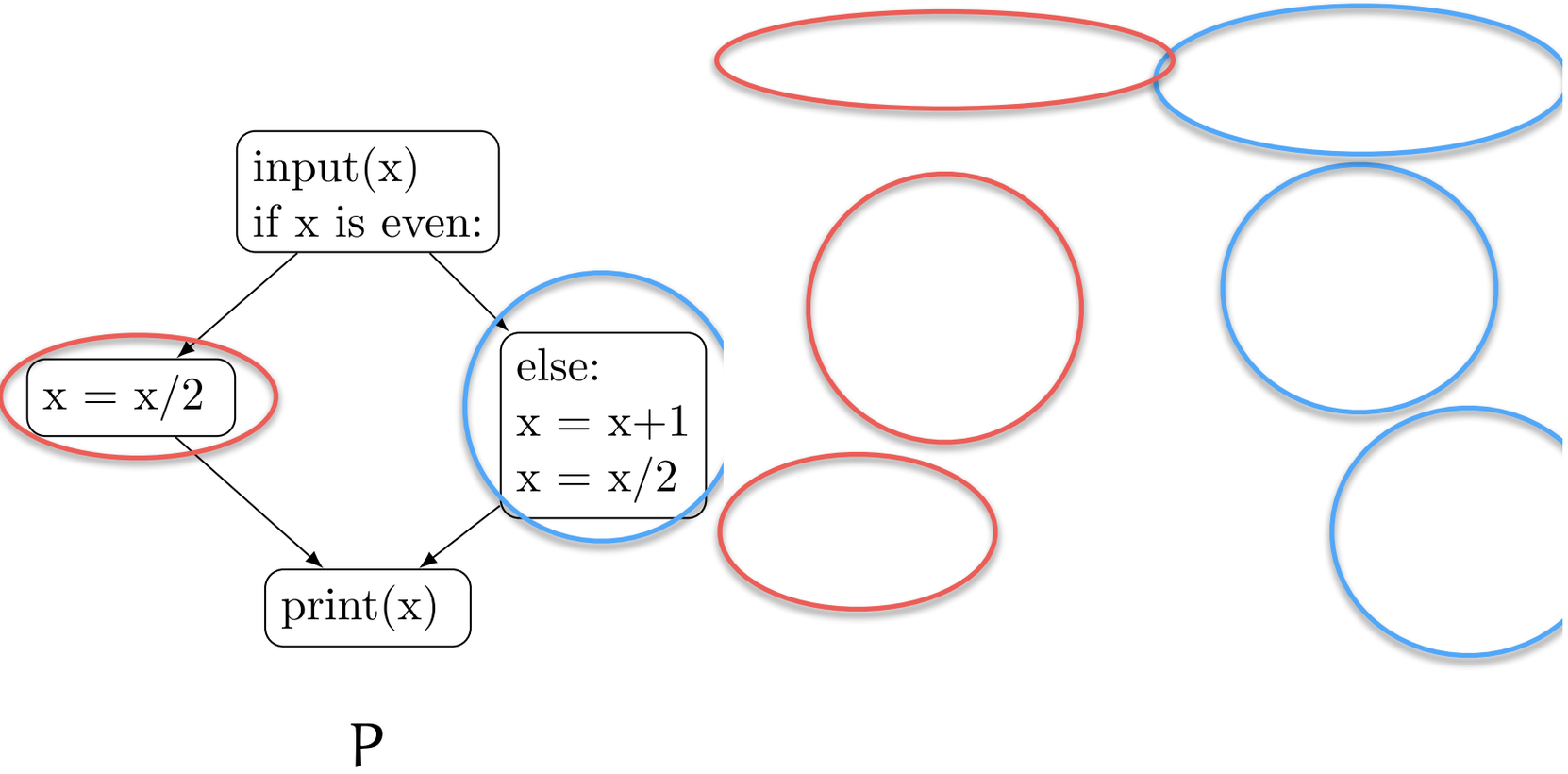
Dynamic analysis needs to observe at least n traces

$\mathcal{T}_n(P)$

```
input x;
n := select(N,x);
x := n*x;        Encoding
sum := 0;
while x < n*50
• X = [x, n * 50 − 1]
    sum := sum + x/n;
    x := x + n;
x:= x/n;         Decoding
```

Dynamic CFG Obfuscation

Diversification



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Open Issues

➡ Properties of set of traces, other properties? Topological characterisation wrt to the kind of property being analysed

➡Model validation (ORAM, fuzzers, input generator and recognisers,…)

➡Potentiality and limits of code obfuscation for dynamic analysis

➡ Extend the model with measure of likelihodd of the inputs (probability distribution over the input)

THANKS

I hope I haven't annoyed you too much !!!