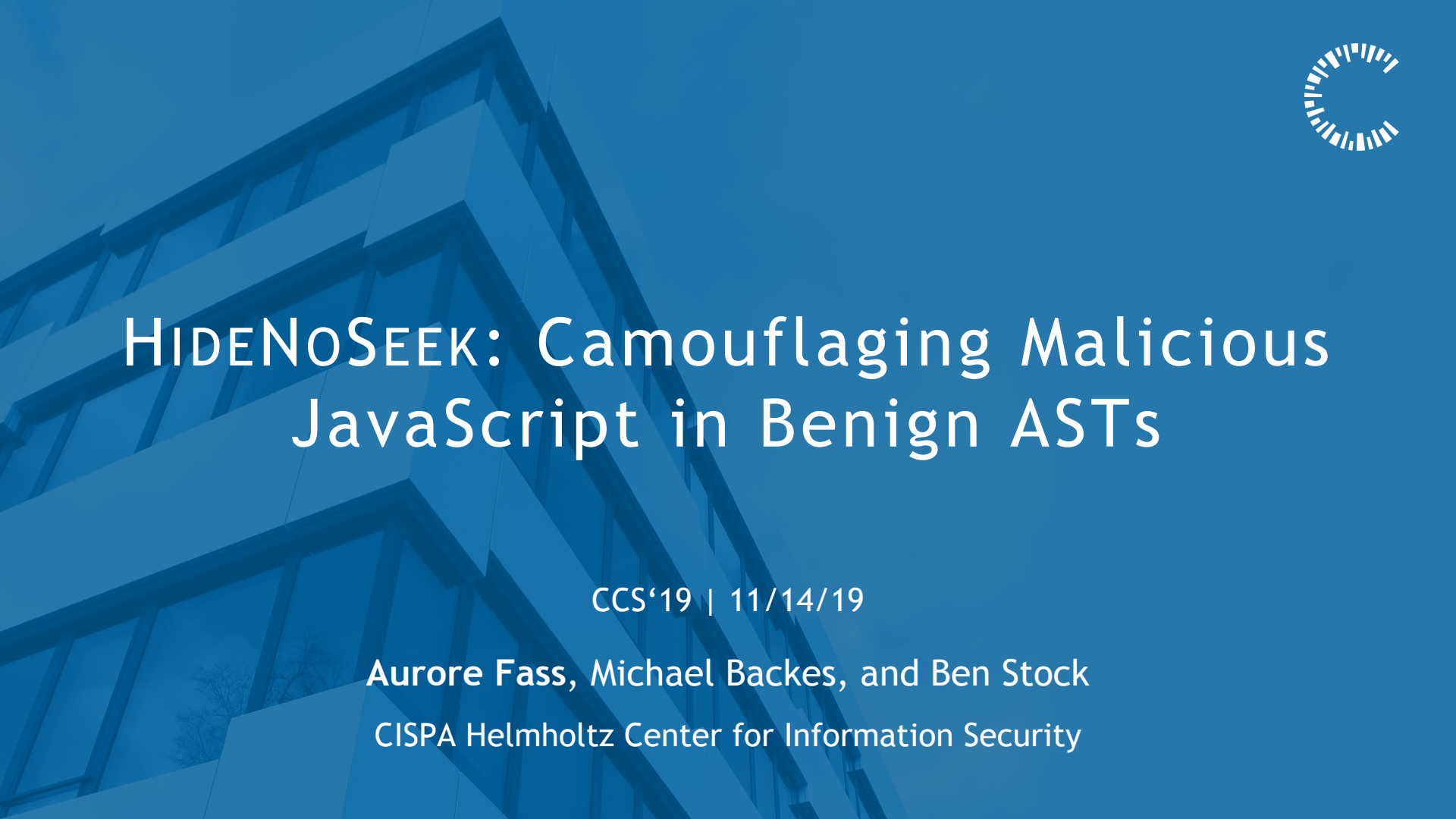


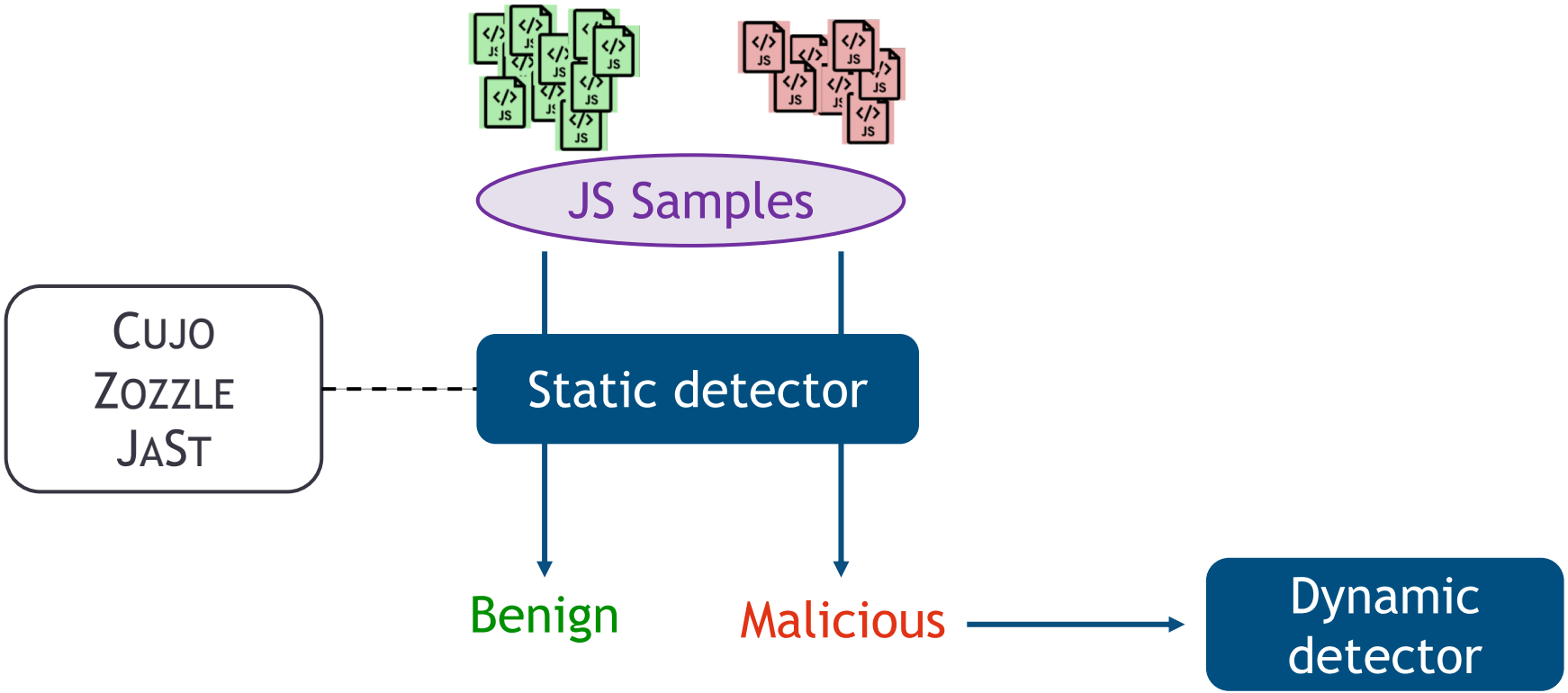
HideNoSeek: Camouflaging Malicious JavaScript in Benign ASTs

CCS'19 | 11/14/19

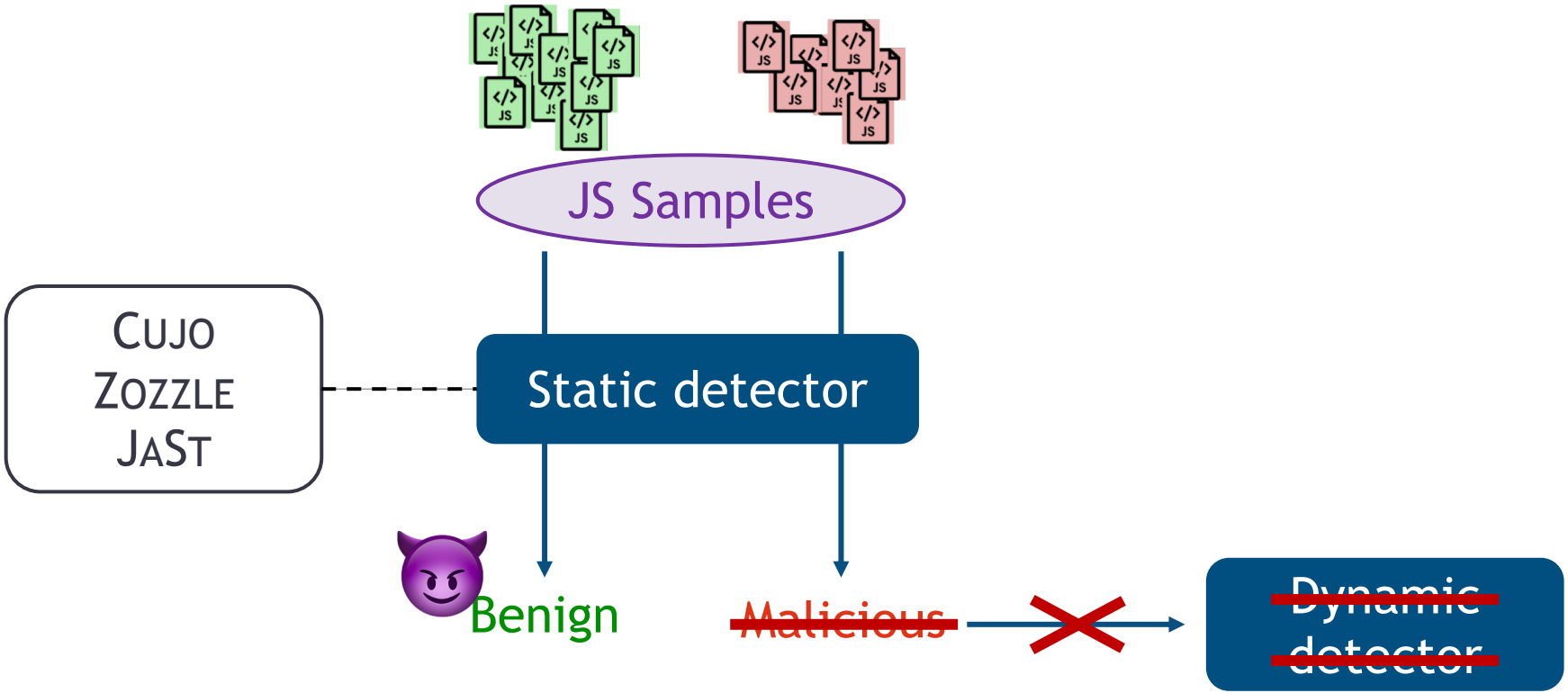
Aurore Fass, Michael Backes, and Ben Stock

CISPA Helmholtz Center for Information Security

Motivation


JS Samples
CUJO
ZOZZLE
JAST
Static detector
Benign
Malicious
Dynamic detector

Motivation


JS Samples
CUJO
ZOZZLE
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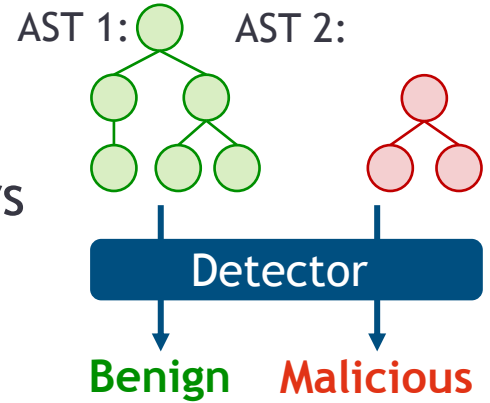
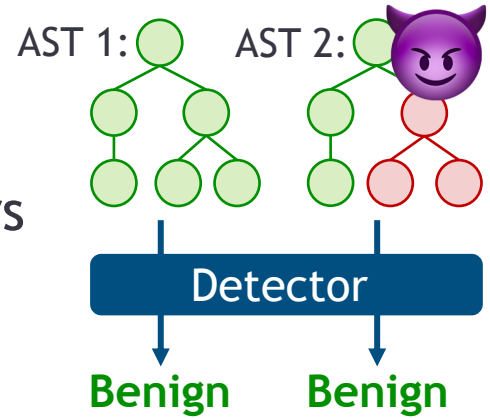
Static detector
Benign
Malicious
Dynamic detector

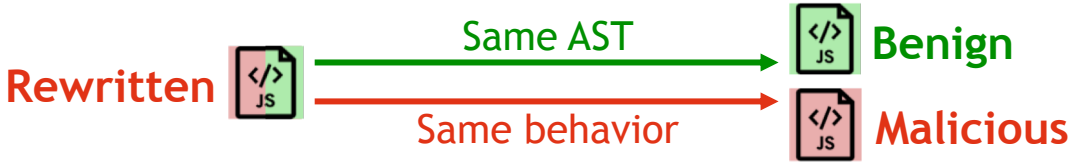
- Generic camouflage attack
  - ➢ Effective against static JavaScript detectors



- Generic camouflage attack
  - ➢ Effective against static JavaScript detectors



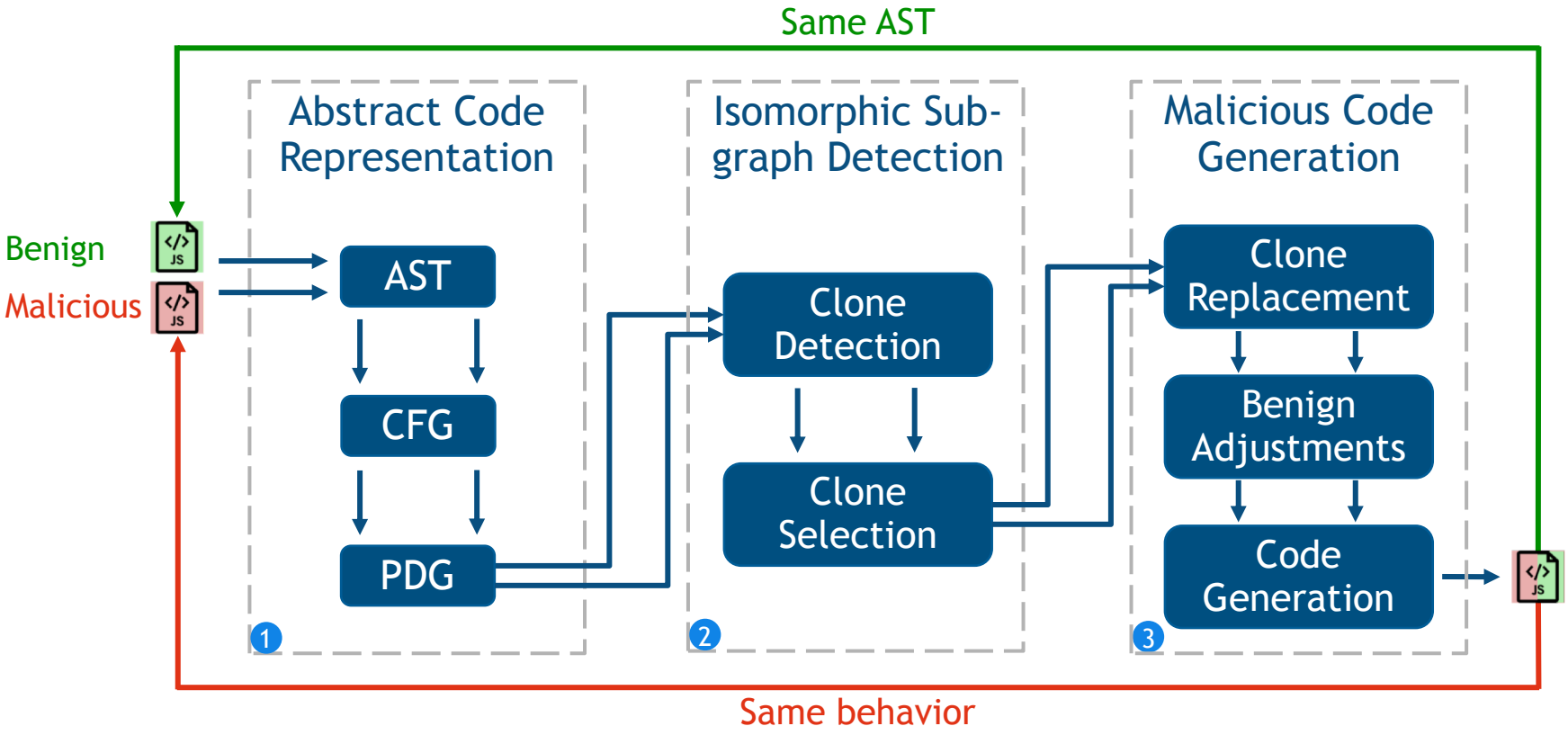
- Rewrites malicious JavaScript files



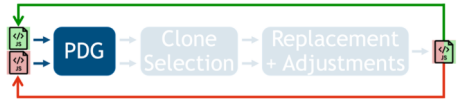
Contributions

- Perfect mapping onto a benign AST → very effective attack
- Generic attack, can be applied to several static detectors
- Independent of any machine learning systems
- Does not need any internal knowledge (e.g., model, dataset)

Methodology



Abstract Code Representation: PDG



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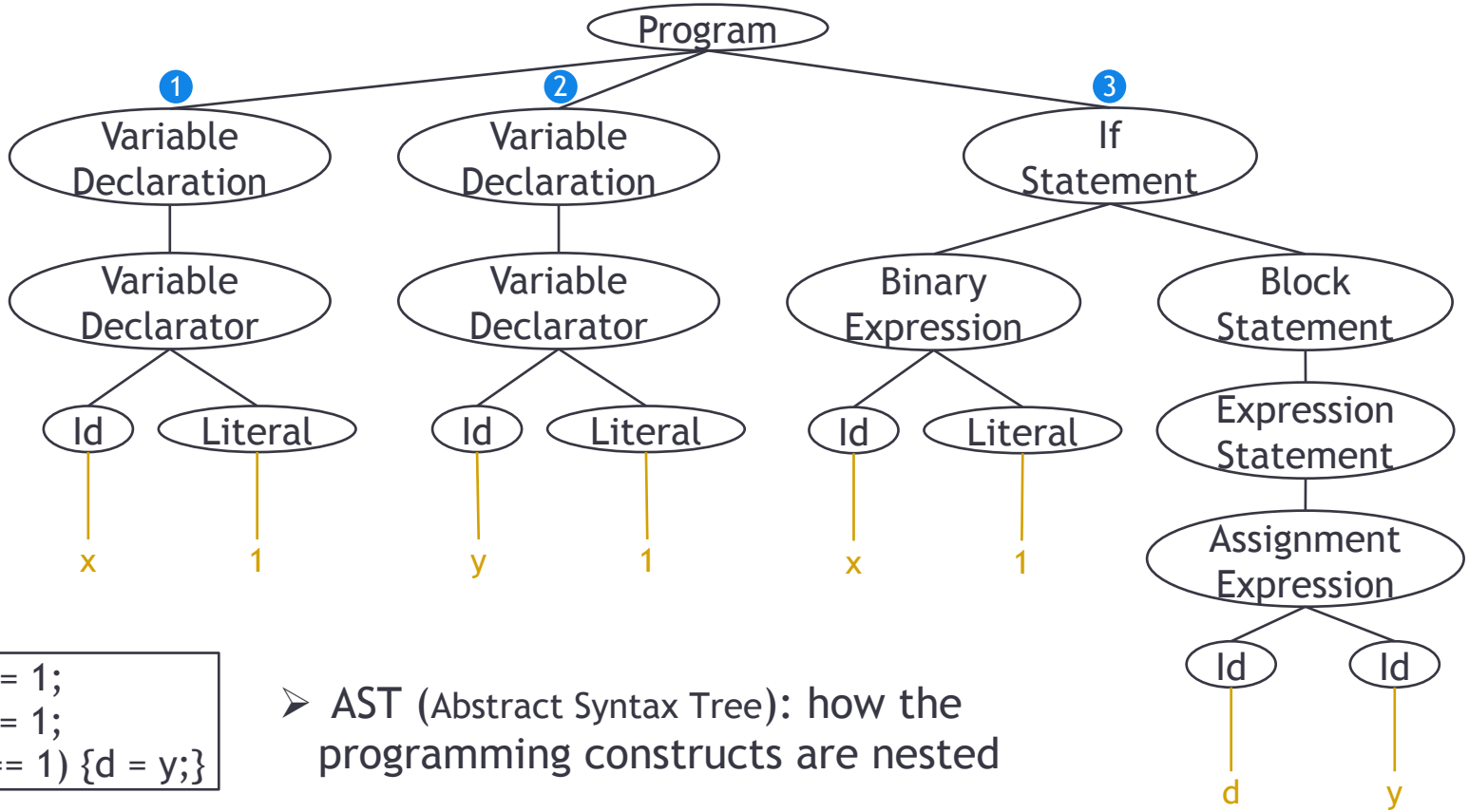
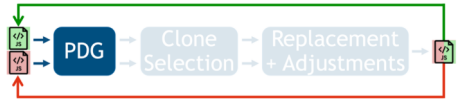


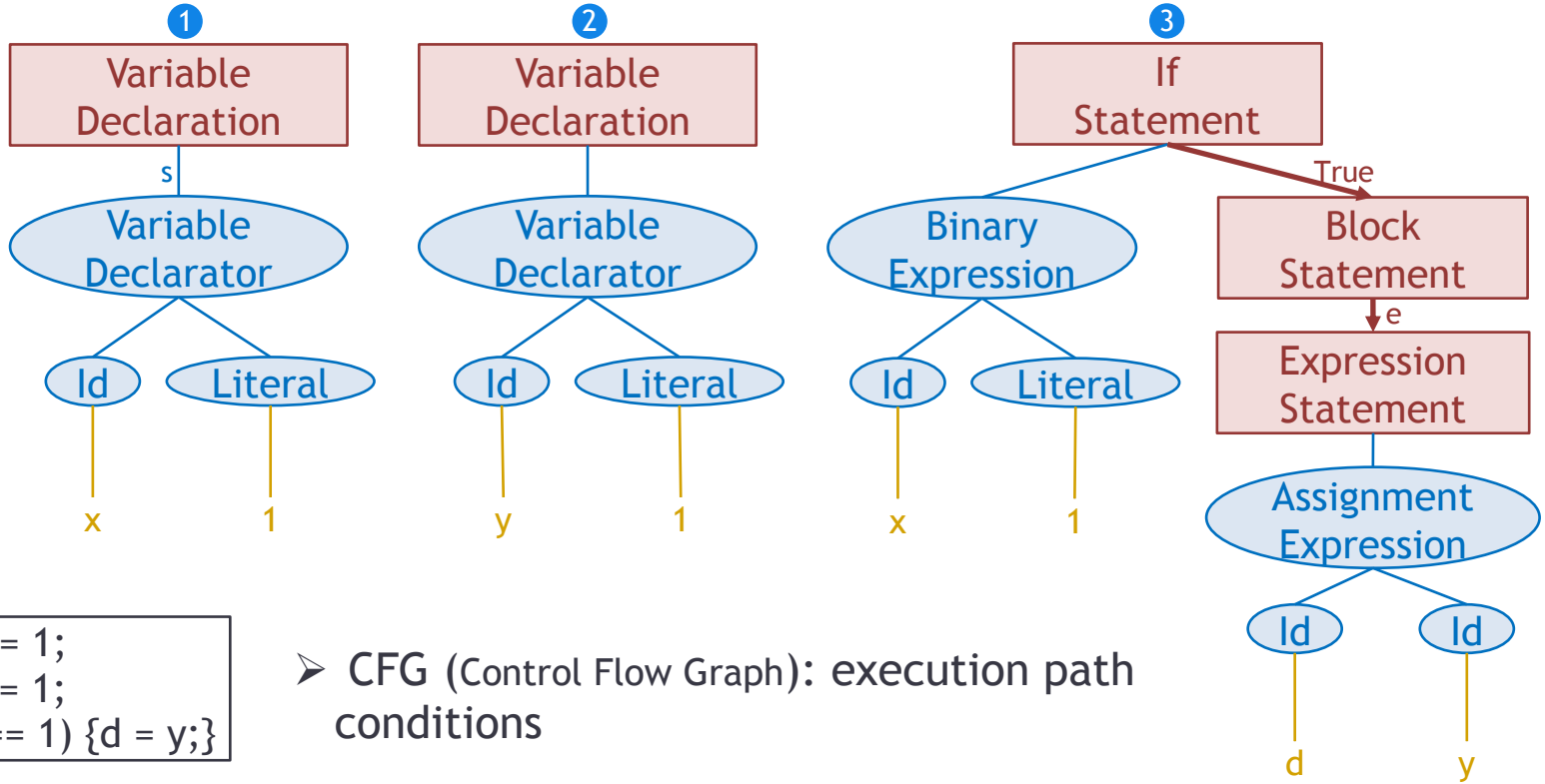

```
1 var x = 1;
2 var y = 1;
3 if (x == 1) {d = y;}
```

- AST (Abstract Syntax Tree): how the programming constructs are nested

Abstract Code Representation: PDG



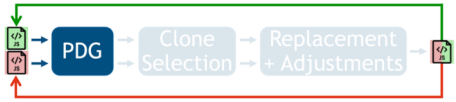
CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY



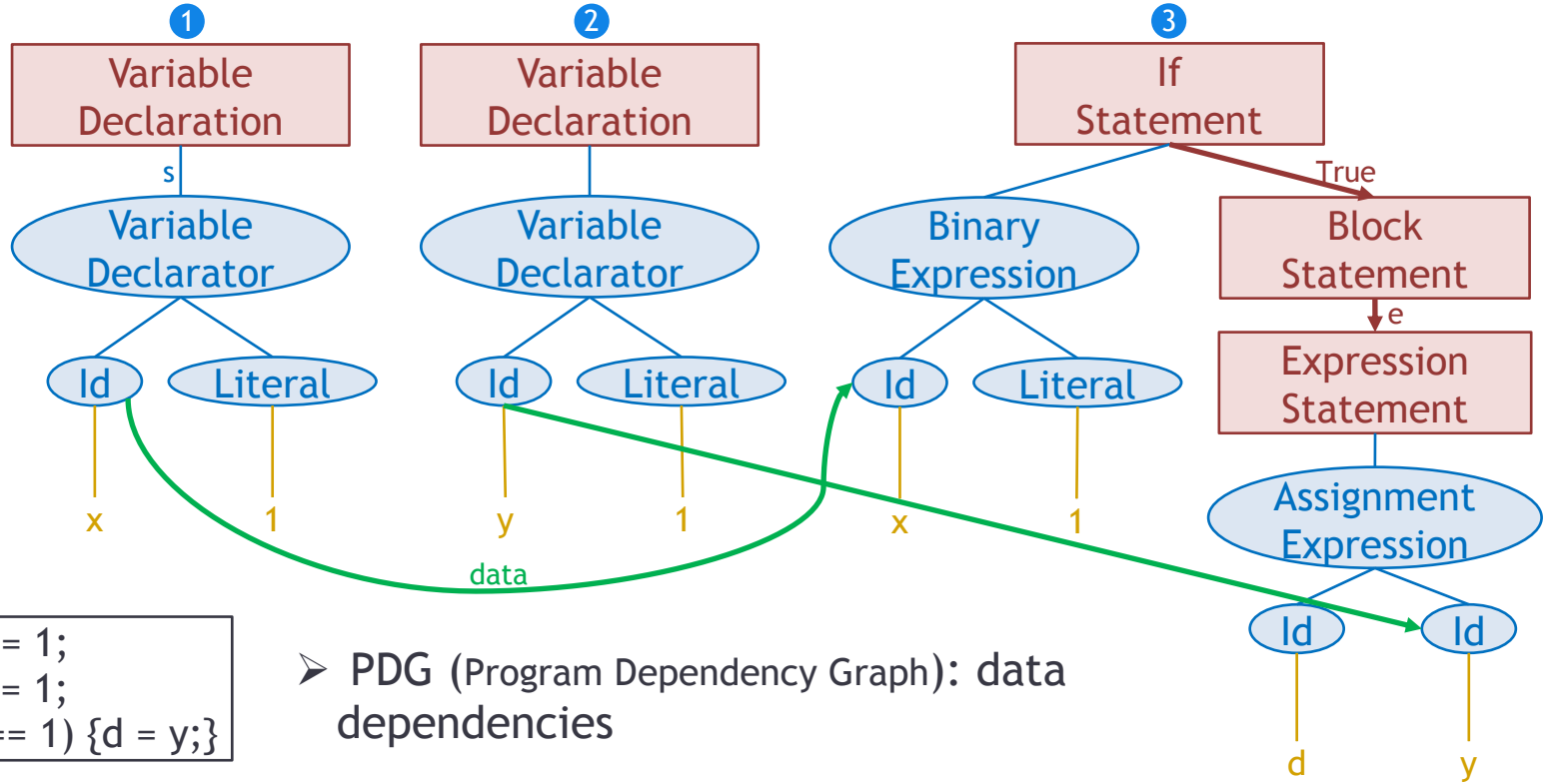
1. `var x = 1;`
2. `var y = 1;`
3. `if (x == 1) {d = y;}`

- CFG (Control Flow Graph): execution path conditions

Abstract Code Representation: PDG



CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY




```
1 var x = 1;
2 var y = 1;
3 if (x == 1) {d = y;}
```

- PDG (Program Dependency Graph): data dependencies

Clone Detection – Code Level

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Benign input

```
1 obj = document.createElement("object");
2 obj.setAttribute("id", this.internal.flash.id);
3 obj.setAttribute("type", "application/x-shockwave-flash");
4 createParam(obj, "bgcolor", this.options.backgroundColor);
5 createParam(obj, "wmode", this.options.wmode);
```

Malicious seed

```
A wscript = WScript.CreateObject('WScript.Shell');
B wscript.run("cmd.exe /c \"<malicious powershell command>;\"", "0");
```

Clone:

```
Identifier = Identifier . Identifier ( Literal )

Identifier . Identifier ( Literal , Literal )
```

Clone Detection – PDG Level

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

Benign input

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Malicious seed

```
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B wscript.run("cmd.exe /c \"<malicious powershell command>;\"", "0");
```

Benign PDG

```
1 Identifier = Identifier . Identifier ( Literal )
2 Identifier . Identifier ( Literal , ThisExpression )
3 Identifier . Identifier ( Literal , Literal )
4 Identifier ( Identifier , Literal , ThisExpression )
5 Identifier ( Identifier , Literal , ThisExpression )
```

Malicious PDG

```
A Identifier = Identifier . Identifier ( Literal )
B Identifier . Identifier ( Literal , Literal )
```

Clone Detection – PDG Level

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

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```

Malicious PDG

```
A Identifier = Identifier . Identifier ( Literal )
B Identifier . Identifier ( Literal , Literal )
```

=

	Benign	Malicious
Clone 1	1	A

Clone Detection – PDG Level

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

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Malicious seed

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Benign PDG

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5 Identifier ( Identifier , Literal , ThisExpression )
```

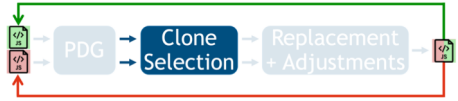
Malicious PDG

```
A Identifier = Identifier . Identifier ( Literal )
B Identifier . Identifier ( Literal , Literal )
```

≠

	Benign	Malicious
Clone 1	1	A

Clone Detection – PDG Level



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```

Malicious PDG

```
A Identifier = Identifier . Identifier ( Literal )
B Identifier . Identifier ( Literal , Literal )
```

≠

	Benign	Malicious
Clone 1	1	A

Clone Detection – PDG Level

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Malicious PDG

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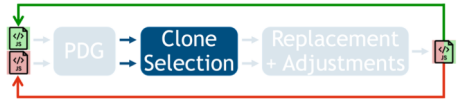
≠

	Benign	Malicious
Clone 1	1	A

Clone Detection – PDG Level



CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

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Benign PDG

1. Identifier = Identifier . Identifier (Literal)
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4. Identifier (Identifier , Literal , ThisExpression)
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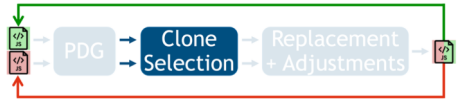
≠

Malicious PDG

A. Identifier = Identifier . Identifier (Literal)
B. Identifier . Identifier (Literal , Literal)

	Benign	Malicious
Clone 1	1	A

Clone Detection – PDG Level



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5 Identifier ( Identifier , Literal , ThisExpression )
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Malicious PDG

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≠

	Benign	Malicious
Clone 1	1	A

Clone Detection – PDG Level

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Malicious PDG

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≠

	Benign	Malicious
Clone 1	1	A

Clone Detection – PDG Level

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

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Malicious PDG

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```
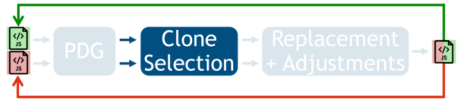

=

	Benign	Malicious
Clone 1	1	A
Clone 2	3	B

Clone Detection – PDG Level



CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

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Benign PDG

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Malicious PDG

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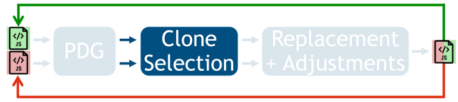
```

≠

	Benign	Malicious
Clone 1	1	A
Clone 2	3	B

Clone Detection – PDG Level



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Malicious seed

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Benign PDG

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Malicious PDG

```
A Identifier = Identifier . Identifier ( Literal )
B Identifier . Identifier ( Literal , Literal )
```

=

	Benign	Malicious
Clone 1	1	A
Clone 2	3 1	B A

Clone Detection – PDG Level

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

Benign input

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```

Malicious seed

```
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```

Benign PDG

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5 Identifier ( Identifier , Literal , ThisExpression )
```

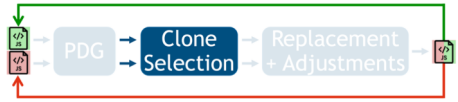
Malicious PDG

```
A Identifier = Identifier . Identifier ( Literal )
B Identifier . Identifier ( Literal , Literal )
```

≠

	Benign	Malicious
Clone 1	1	A
Clone 2	3 1	B A

Clone Detection – PDG Level



CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

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Malicious seed

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Benign PDG

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```

Malicious PDG

```
A Identifier = Identifier . Identifier ( Literal )
B Identifier . Identifier ( Literal , Literal )
```

≠

	Benign	Malicious
Clone 1	1	A
Clone 2	3 1	B A

Clone Selection

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

Benign input

```
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```

Malicious seed

```
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```

Clone:

```
Identifier = Identifier . Identifier ( Literal )
Identifier . Identifier ( Literal , Literal )
```

	Benign	Malicious
~~Clone 1~~	~~1~~	~~A~~
Clone 2	3 1	B A

Clone Replacement

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Benign input

```
1 obj = document.createElement("object");
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```

Malicious seed

```
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```

Crafted sample

```
1 obj = document.createElement("object");
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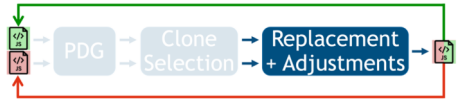
Clone Replacement



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Benign:

```
obj = document.createElement("object");
```

Malicious:

```
wscript = WScript.CreateObject('WScript.Shell');
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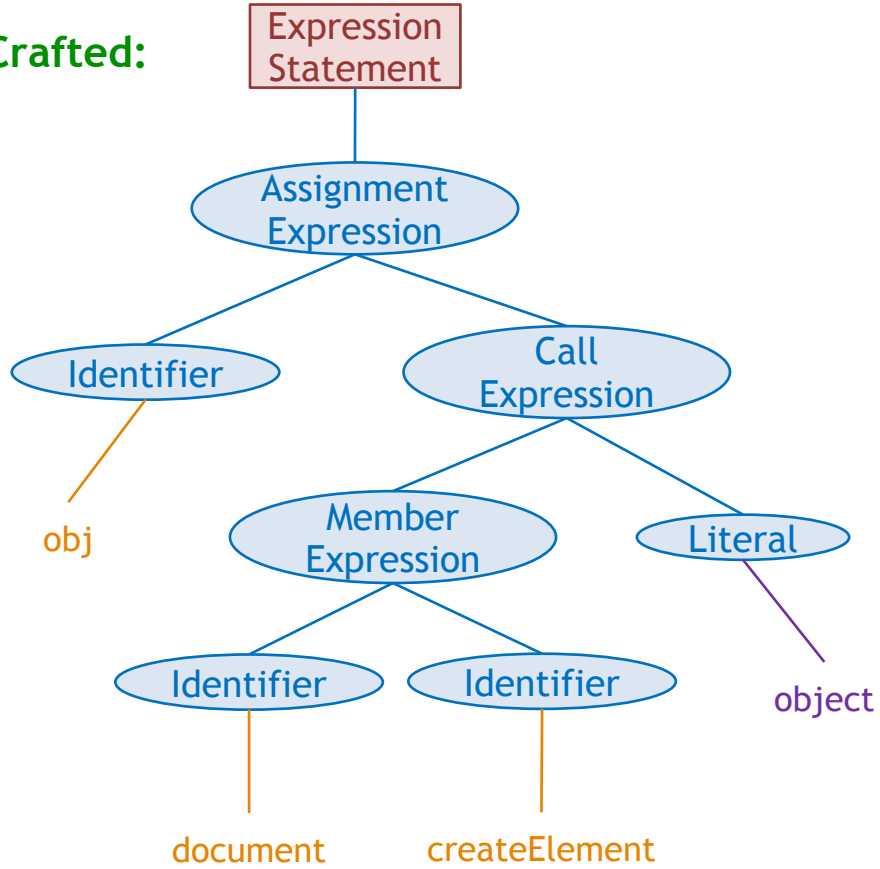
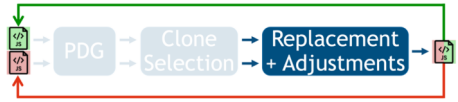
Crafted:



Clone Replacement



CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

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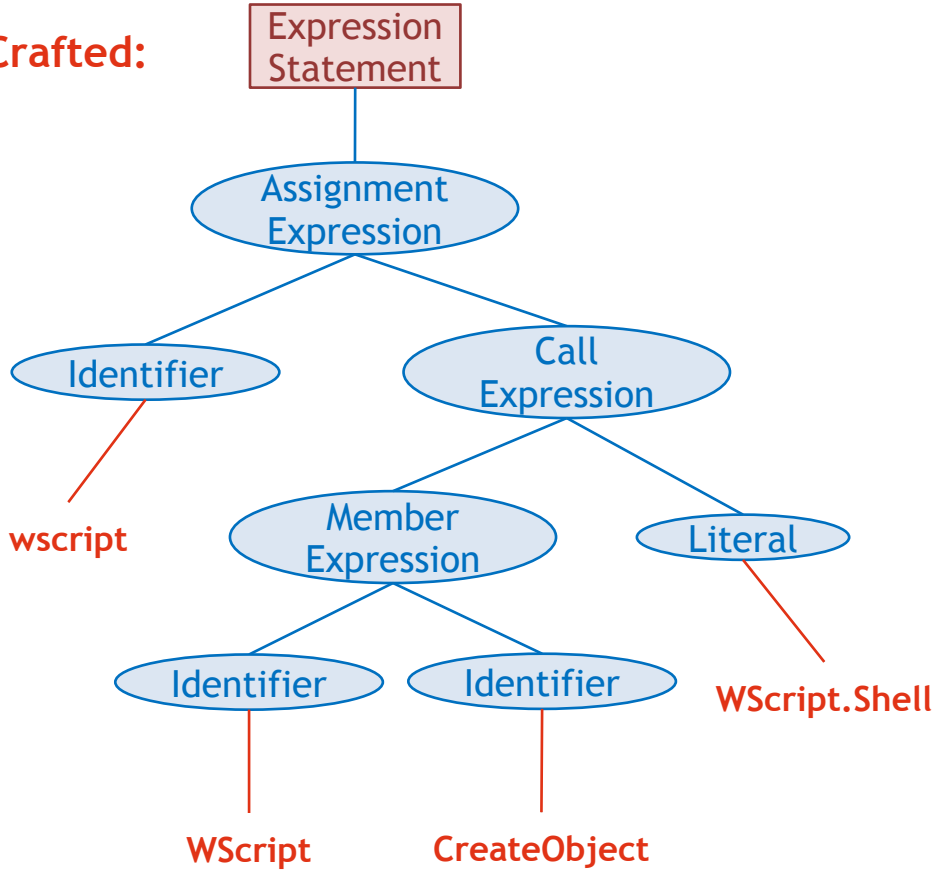

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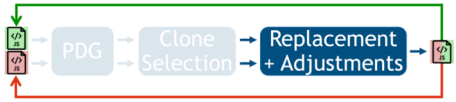

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Malicious seed

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B wscript.run("cmd.exe /c \"<malicious powershell command>;\"", "0");
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Crafted sample

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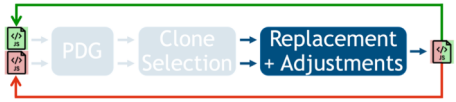

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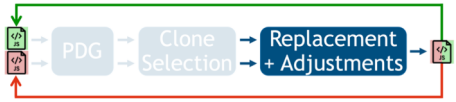

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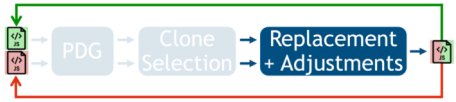

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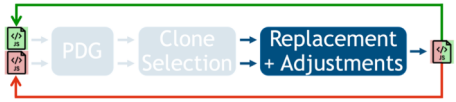

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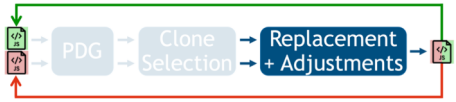

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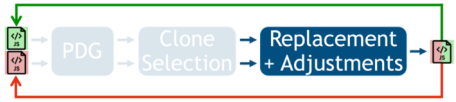

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4 decodeURI(wscript, "bgcolor", this.options.backgroundColor);
5 parseFloat(wscript, "wmode", this.options.wmode);
```

Code Generation With Escodegen

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Malicious seed

```
A wscript = WScript.CreateObject('WScript.Shell');
B wscript.run("cmd.exe /c \"<malicious powershell command>;\"", "0");
```

Same behavior

Crafted sample

Same AST

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wscript.toString("id", this.internal.flash.id);
wscript.run("cmd.exe /c \"<malicious powershell command>;\"", "0");
decodeURI(wscript, "bgcolor", this.options.backgroundColor);
parseFloat(wscript, "wmode", this.options.wmode);
```
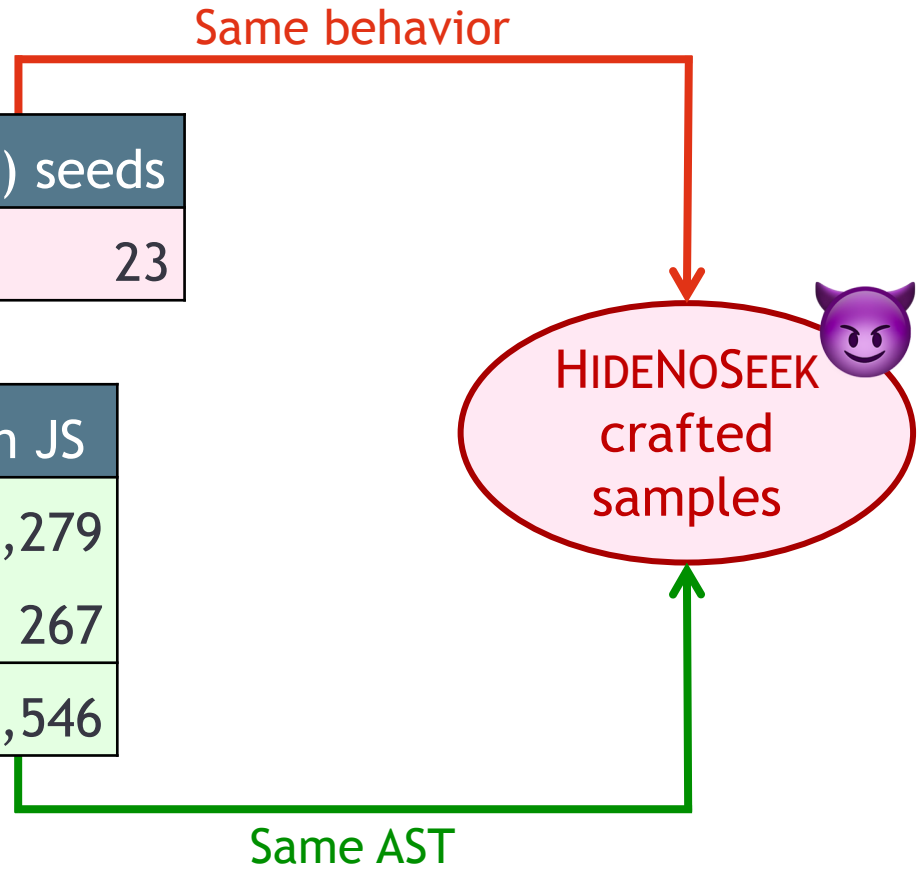

Experimental Setup

#Malicious JS	#Malicious (deobf) seeds
122,345	23

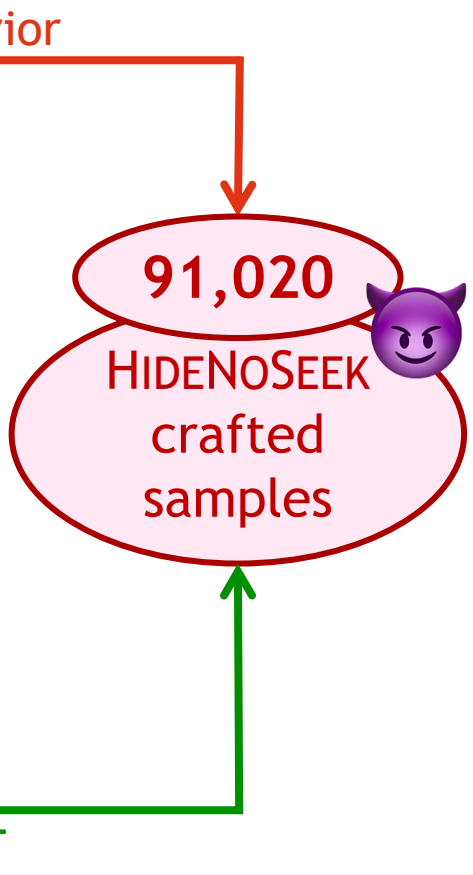
Benign JS - Source	#Benign JS
Alexa Top 10k	8,279
Libraries	267
Sum	8,546



Evasive Samples Generation

#Malicious JS	#Malicious (deobf) seeds
122,345	22 / 23

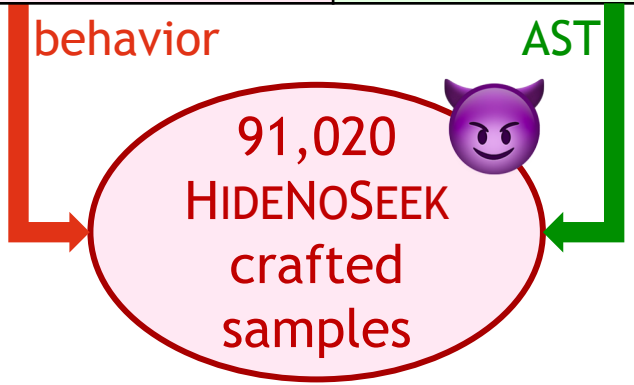
Benign JS - Source	#Benign JS
Alexa Top 10k	8,279
Libraries	267
Sum	8,546



Evasive Samples Generation – per Seed

Malicious seeds	#Crafted samples
Misc	6,487
EK	6,487
Injected1	6,447
…	…
RIG1	244
Dropper	10
RIG2	0
Sum	91,020

#Malicious seeds	#Alexa Top 10k
22 / 23	8,279



- Success: depends on common syntactic structures between seeds and benign scripts

Impact of our Attack

Alexa Top 10	#Seeds hidden (/23)
1 google.com	18
2 youtube.com	18
3 facebook.com	13
4 baidu.com	8
5 wikipedia.org	0
6 qq.com	14
7 yahoo.com	14
8 taobao.com	19
9 tmall.com	17
10 amazon.com	17

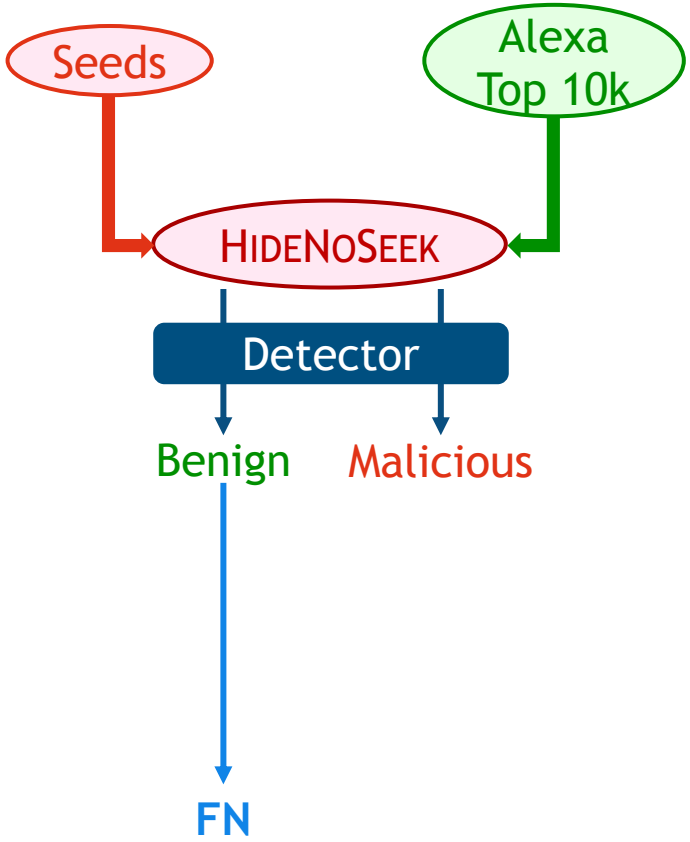
Libraries	#Seeds hidden (/23)
jQuery	17
Bootstrap	12
Modernizr	5
MooTools	15
Angular	17

- jQuery 1.12.4 → 30% websites
- HIDENOSEEK can craft on average:
  - 14 malware for each Alexa Top 10
  - 13 malware for each Top 5 library

Properties of the Crafted Samples

- Same AST for crafted and benign samples
- Most of the tokens: identical between crafted and benign samples
- 72% of the crafted samples are still running
- 67% of the running samples have a malicious behavior

Evaluation Against Real-World Classifiers



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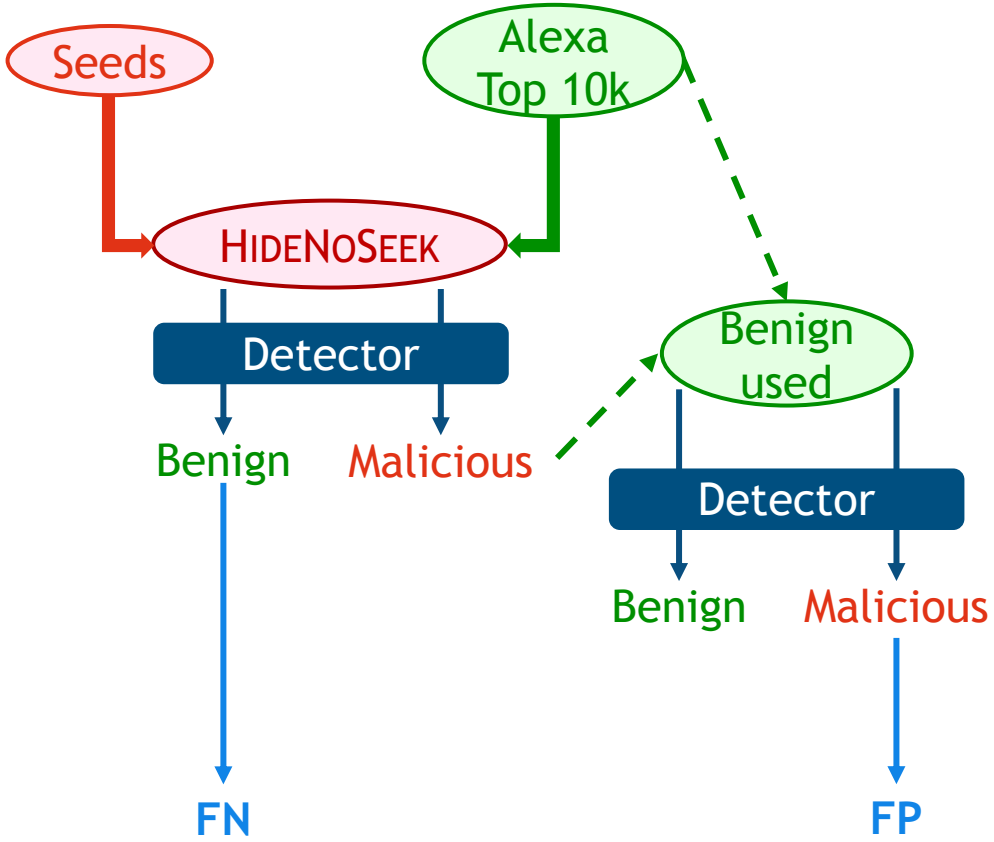

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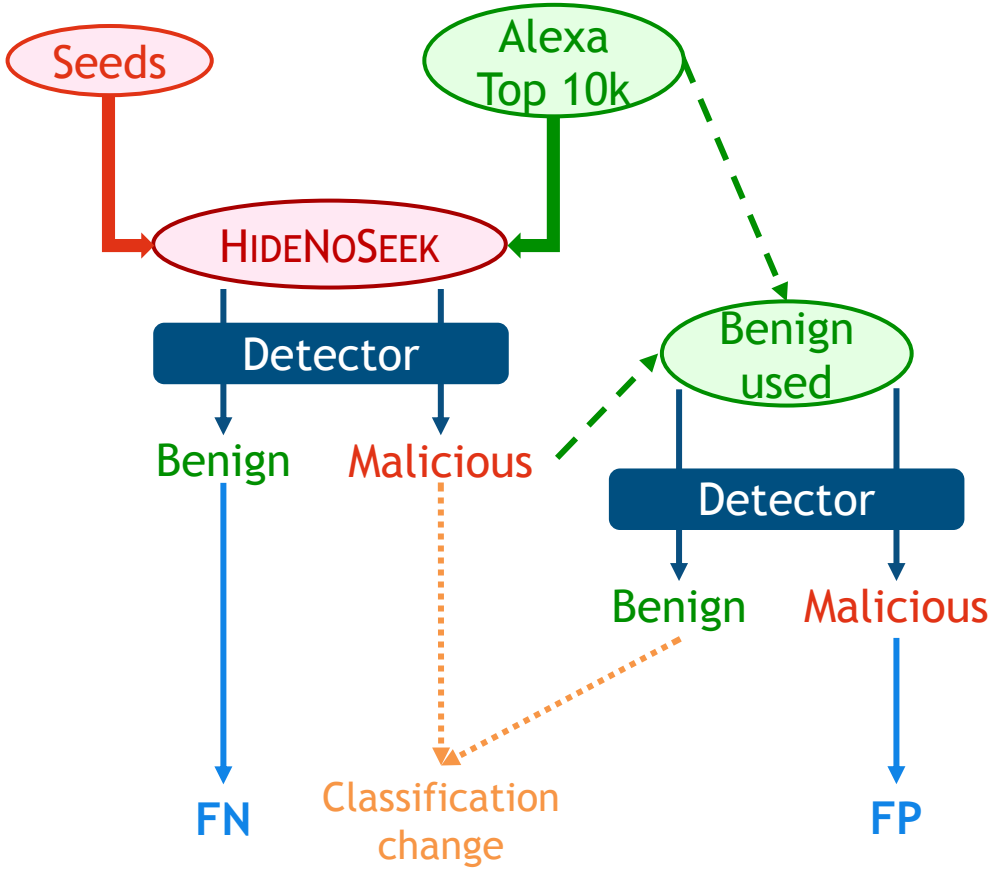

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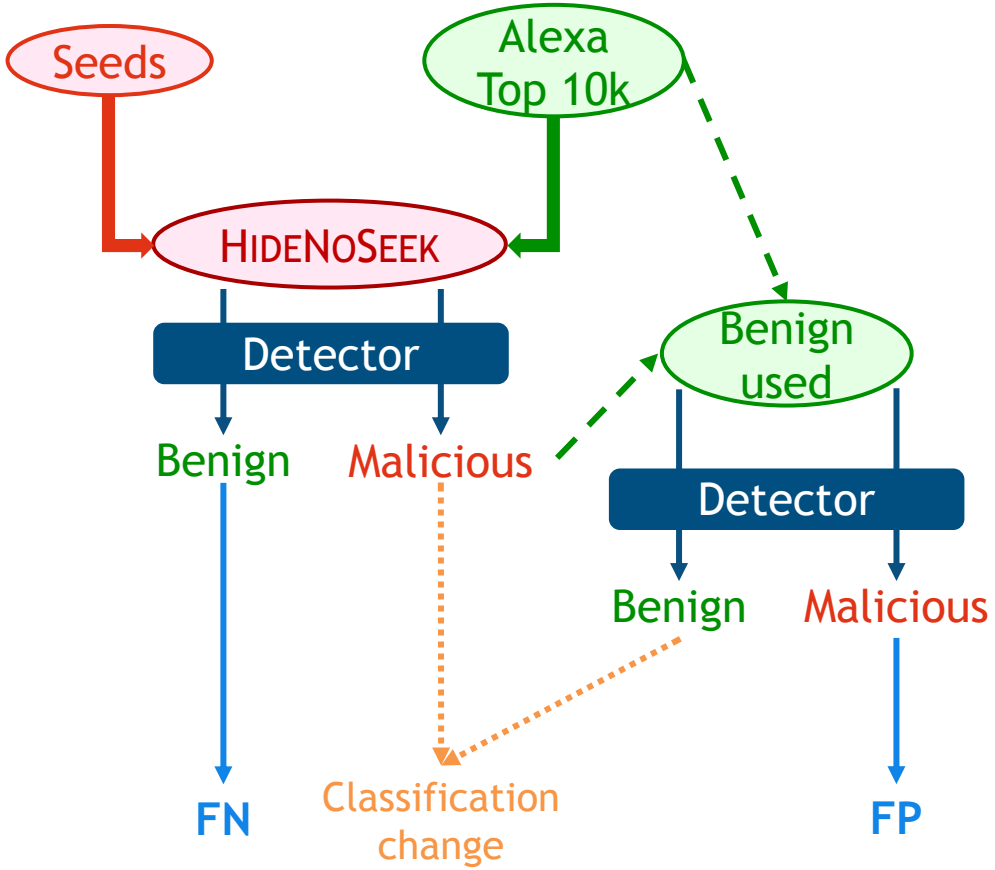


	Training set from the wild	Training set from the wild + HIDENOSEEK	
	FN	FN	FP
JAST (syntactic)	99.98%	4.32%	100.00%
ZOZZLE (syntactic)	~100.00%	8.44%	88.74%
CUJO (lexical)	99.99%	4.04%	95.96%

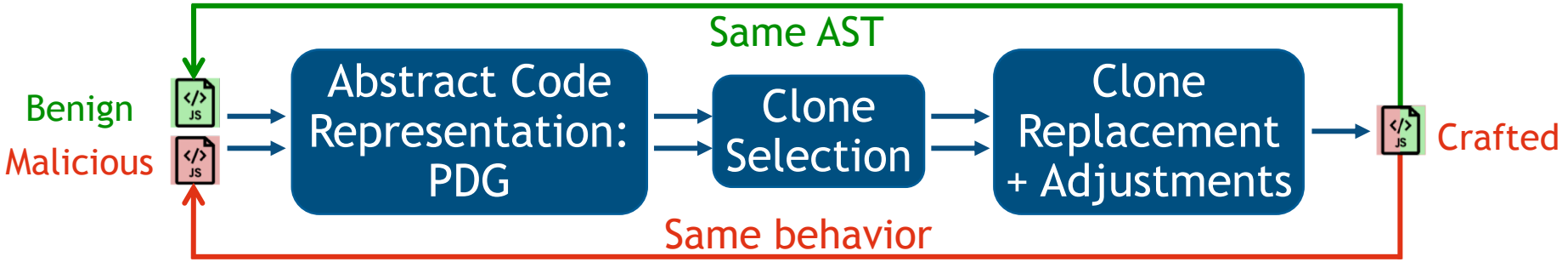
0.57%

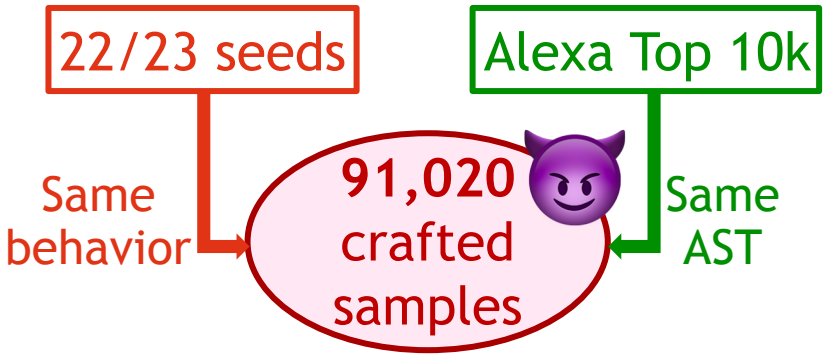
0.33%

≥ 99.98% FN

> 88.74% FP

Conclusion: HIDENOSEEK





- ✓Standard training set: ≥ **99.98% FN**
- ✓HIDENOSEEK in training set: > **88.74% FP**
- ➢Lexical/syntactic detectors: not reliable

Thank you

@AuroreFass @kcotsneb

Aurore54F/HideNoSeek