JavaScript Template Attacks

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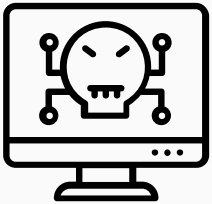
IAIK – Graz University of Technology

Motivation



- Many (undocumented) properties in JavaScript sandboxes

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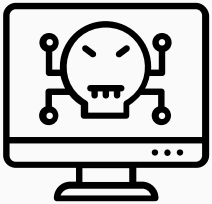

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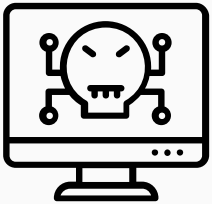

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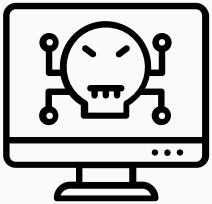

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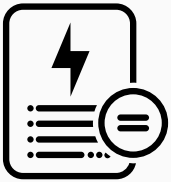
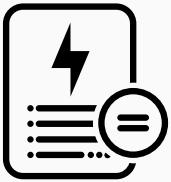
- Properties should not leak environment info
- Information useful for exploits and side-channel attacks
- Also usable for fingerprinting



- Theory: JavaScript sandbox is environment agnostic

Identifying Properties



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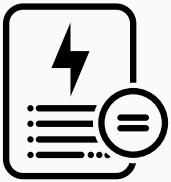

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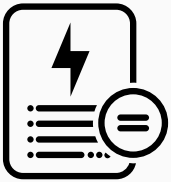

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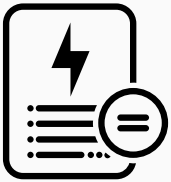

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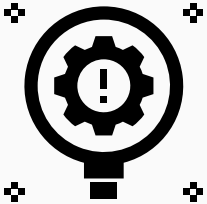
- Some defined exceptions, e.g., user agent
- Tor browser → identifying properties anonymized

Information Leakage



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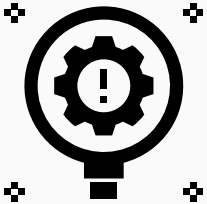
Information Leakage



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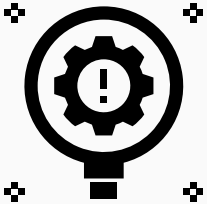

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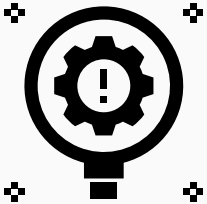

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  - ...can be used to track users ($\rightarrow$ fingerprinting)
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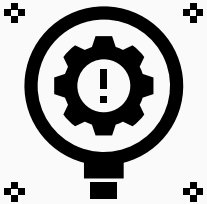
  - ...allow selecting fitting exploits



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  - ...allow selecting fitting exploits
  - ...provide necessary information for side-channel attacks

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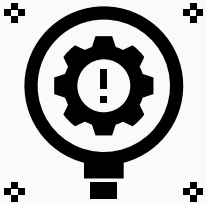
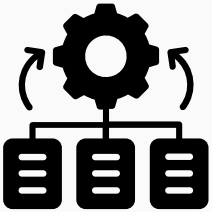


- Properties leaking info about hardware or software...
  - ...can be used to track users ($\rightarrow$ fingerprinting)
  - ...make phishing more plausible
  - ...allow selecting fitting exploits
  - ...provide necessary information for side-channel attacks
- $\rightarrow$ indirect security risk

Automated Leakage Identification



- Manually finding leakage → time consuming

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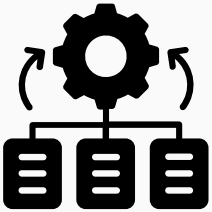

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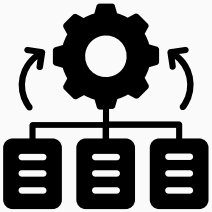
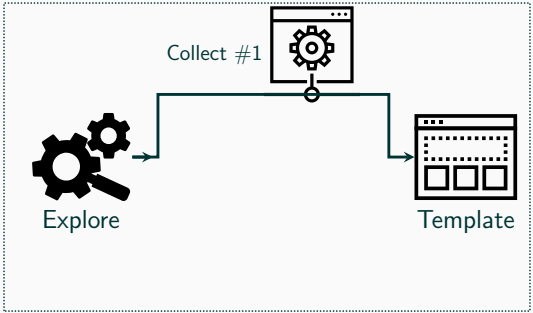


- Manually finding leakage → time consuming
- Automate the task
- Idea of template attacks: change a factor, compare results


JS
Template Attacks

Explore

Profiling Phase



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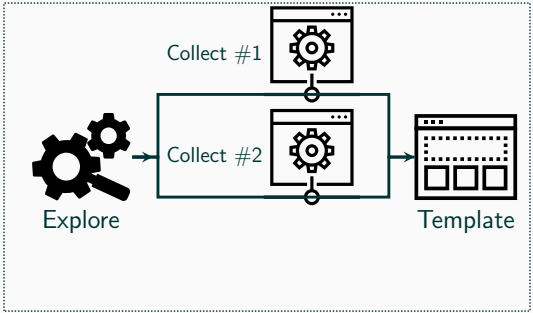

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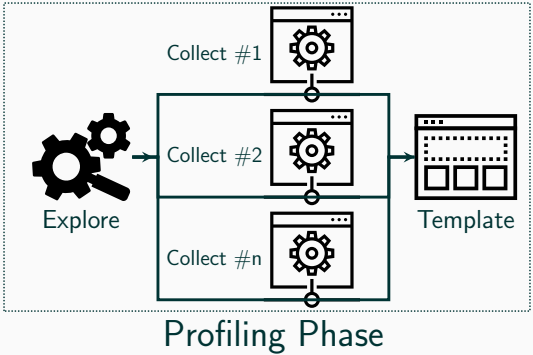
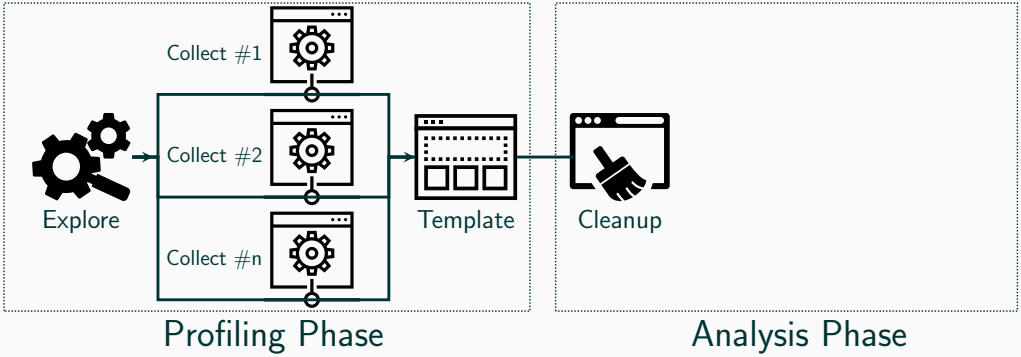

Collect #1
Collect #2
Collect #n
Explore
Template
Profiling Phase

JavaScript Template Attacks - Overview



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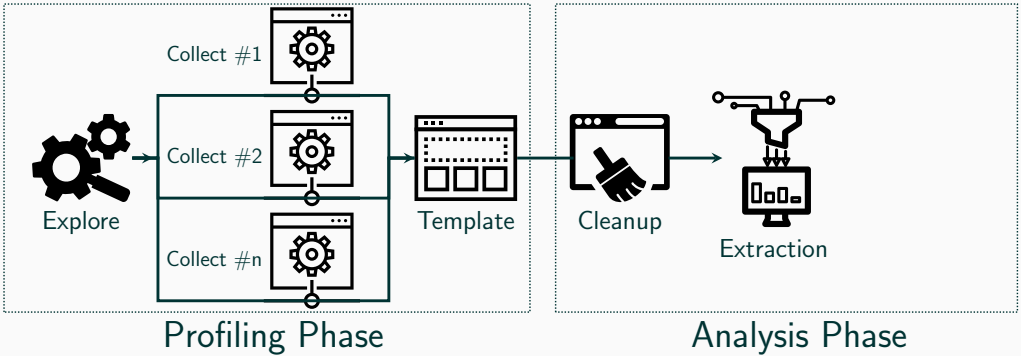

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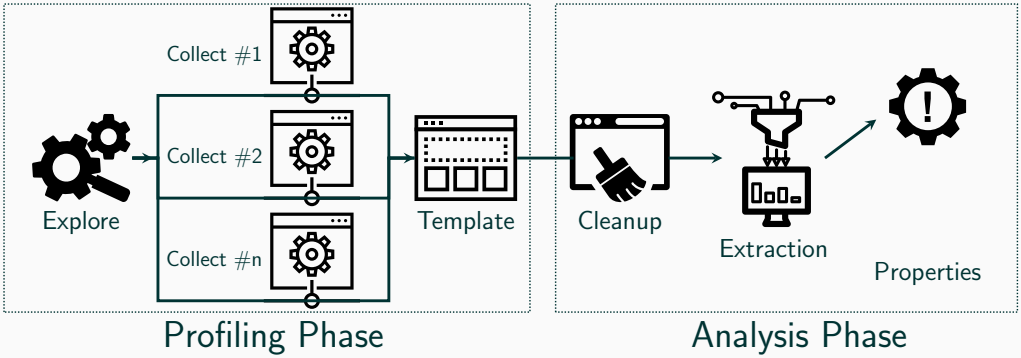

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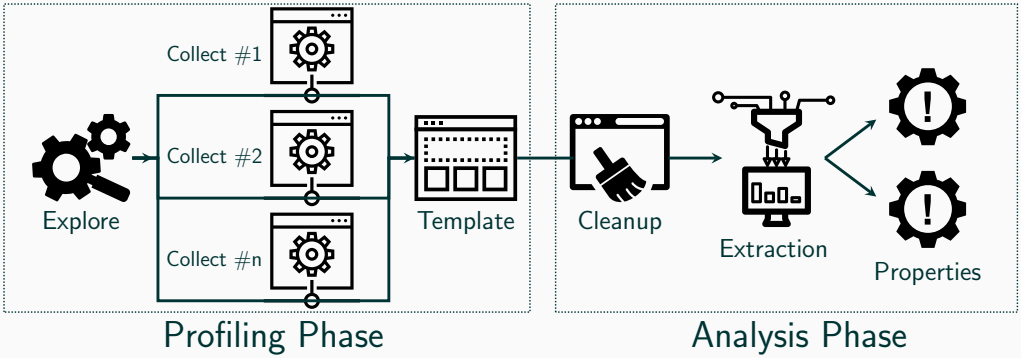

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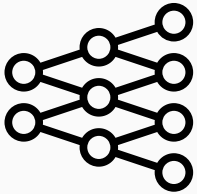

- Exploration of properties

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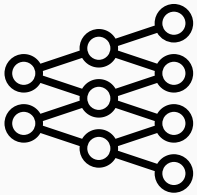

- Exploration of properties
  - Reflections to iterate over all objects

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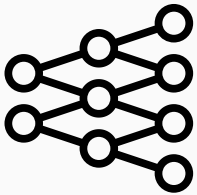

- Exploration of properties
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  - Recursively, until all objects are discovered

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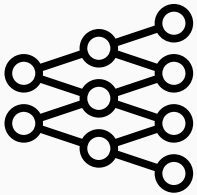

- Exploration of properties
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- Collection of property values

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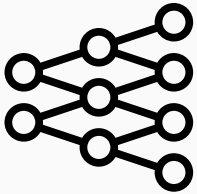

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- Collection of property values
  - For every discovered property, acquire value

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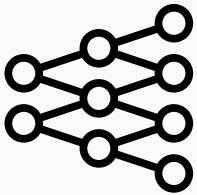

- Exploration of properties
  - Reflections to iterate over all objects
  - Recursively, until all objects are discovered
- Collection of property values
  - For every discovered property, acquire value
  - Repeat with changing environments

Template

- Template is a table, rows are properties, columns are environments

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Property
window.Array.name
window.window.Array.name
navigator.platform
performance.timeOrigin
window.SharedWorker
...

- Template is a table, rows are properties, columns are environments

Property	Environment 1
window.Array.name	Array
window.window.Array.name	Array
navigator.platform	Linux x86_64
performance.timeOrigin	1551003902225
window.SharedWorker	function SharedWorker()
...	...

- Template is a table, rows are properties, columns are environments

Property	Environment 1	Environment 2
window.Array.name	Array	Array
window.window.Array.name	Array	Array
navigator.platform	Linux x86_64	Linux armv7l
performance.timeOrigin	1551003902225	1551003815955
window.SharedWorker	function SharedWorker()	null
...	...	...

- Template is a table, rows are properties, columns are environments

Property	Environment 1	Environment 2	Environment 3
window.Array.name	Array	Array	Array
window.window.Array.name	Array	Array	Array
navigator.platform	Linux x86_64	Linux armv7l	Win32
performance.timeOrigin	1551003902225	1551003815955	1551003721632
window.SharedWorker	function SharedWorker()	null	function SharedWorker()
...	...	...	...

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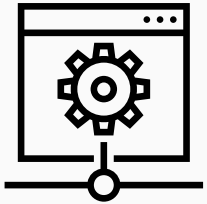
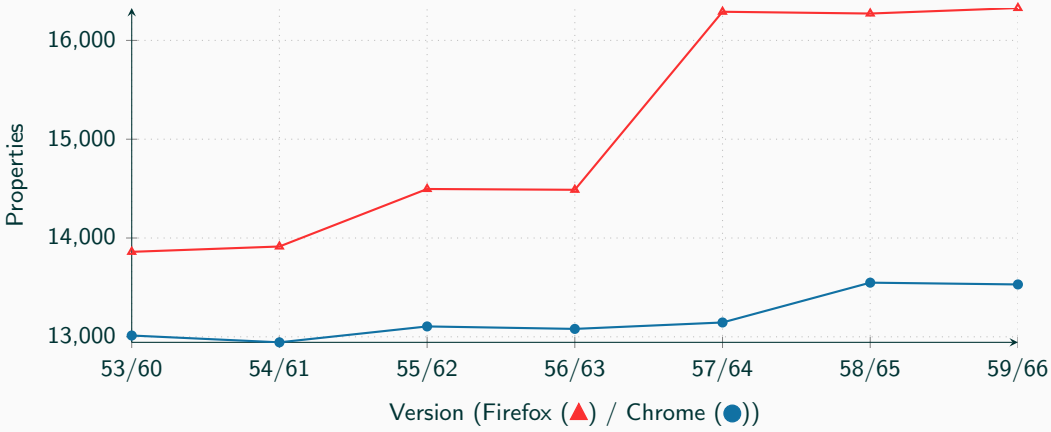


Browser	MDN	JavaScript Template
Firefox	2247	15 709
Chrome	2698	13 570
Edge	1806	9666
Firefox Android	2104	15 612
Chrome Android	2676	13 119
Tor browser	2247†	15 639

Properties - Trend



Analysis Phase

- Analyse template (remove values which are the same for all environments)

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window.SharedWorker	function SharedWorker()	null	function SharedWorker()
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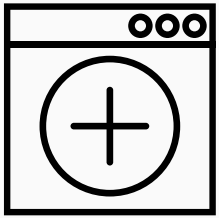
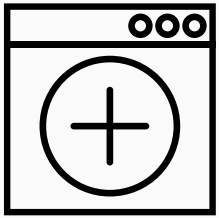


- JavaScript allows defining properties at runtime

Artifical Properties



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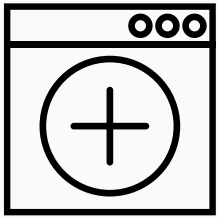

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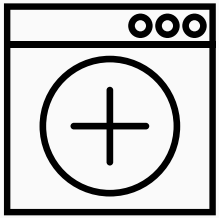
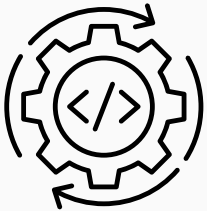


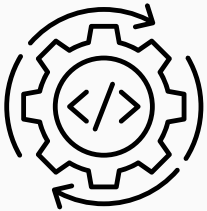
- JavaScript allows defining properties at runtime
- Add “artifical” properties before the profiling phase
- Artificial properties are properties containing results of functions
- → Gather even more information about the environment

JIT Artificial Properties



- We show 2 new side channels against the JIT compiler

JIT Artificial Properties



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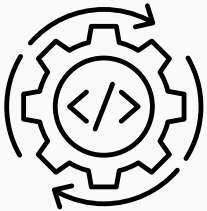

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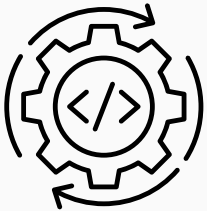

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- Distinguish 32 bit from 64 bit systems

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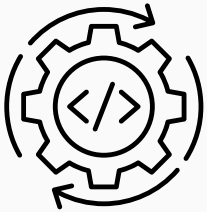

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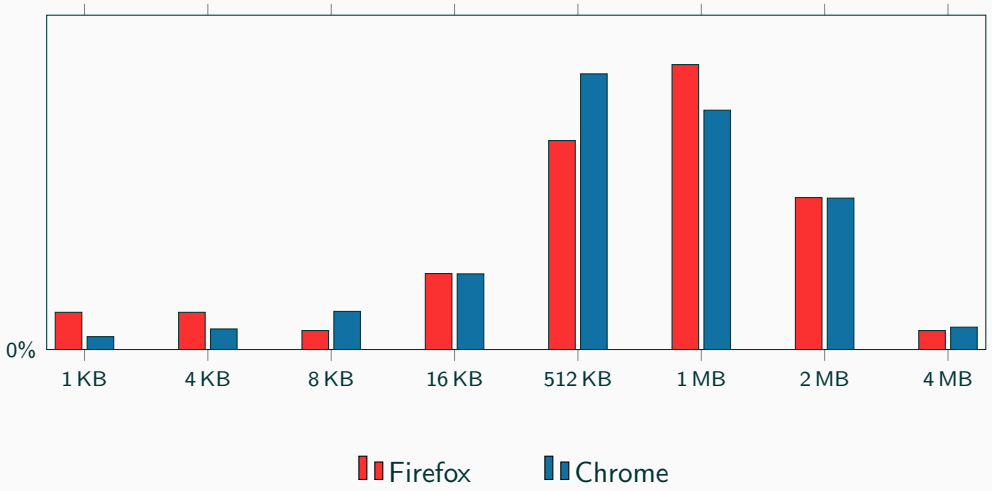
→ Timing differences when re-allocating memory

- Distinguish 32 bit from 64 bit systems

→ JIT can use more registers on 64-bit systems

Memory Allocator Side Channel



```
var a = 0.9, b = c = d = e = f = g
    = 0;
for(var i = 0; i < 10000000; i++)
    {
  b = 1.0 / a;
  c = 2.2 / b;
  d = 3.4 / c;
  e = 4.1 / d;
  f = 5.8 / e;
  g = 6.6 / f;
  // no operation
  a = a + b + c + d + e + f + g +
    g;
}
```

```
var a = 0.9, b = c = d = e = f = g
    = h = 0;
for(var i = 0; i < 10000000; i++)
    {
  b = 1.0 / a;
  c = 2.2 / b;
  d = 3.4 / c;
  e = 4.1 / d;
  f = 5.8 / e;
  g = 6.6 / f;
  h = 7.1 / g;
  a = a + b + c + d + e + f + g +
    h;
}
```

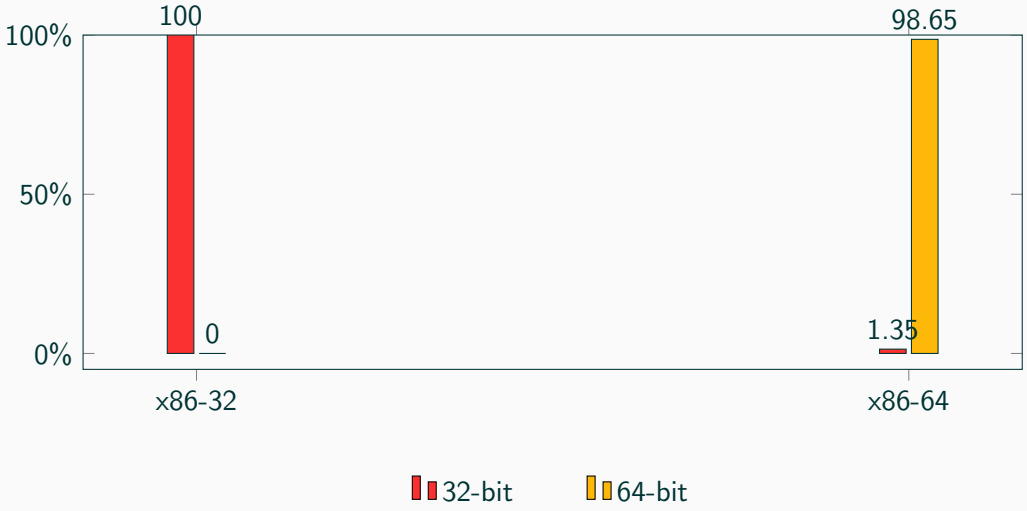
```
vaddss %xmm0,%xmm1,%xmm1
vdivsd %xmm7,%xmm6,%xmm6
vmovsd %xmm7,0x8(%esp)
vxorpd %xmm2,%xmm2,%xmm2
vxorpd %xmm7,%xmm7,%xmm7
```

x86-32

```
vaddsd %xmm0,%xmm1,%xmm0
vdivsd %xmm2,%xmm11,%xmm3
vaddsd %xmm2,%xmm0,%xmm0
vdivsd %xmm3,%xmm10,%xmm4
```

x86-64

ISA Side Channel



Results

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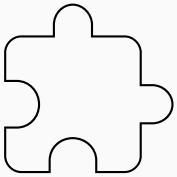

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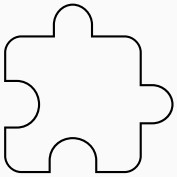

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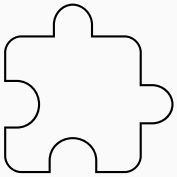

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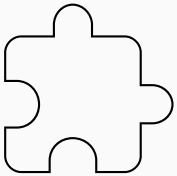

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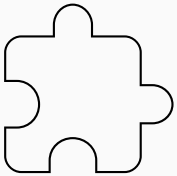

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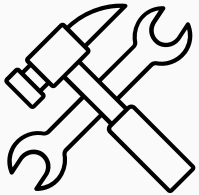
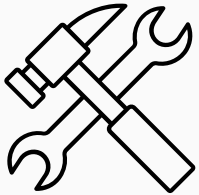
You can find our proof-of-concept implementation on:

- `https://github.com/IAIK/jstemplate`



- Properties returned by function calls



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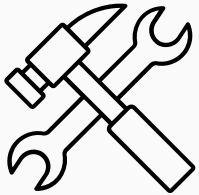

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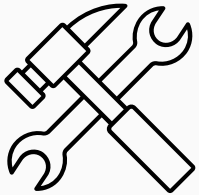
Future Work



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- New web standards (e.g., Web USB, Web NFC)

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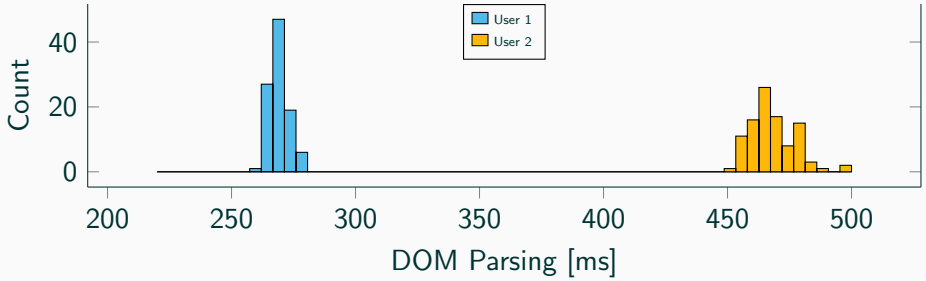

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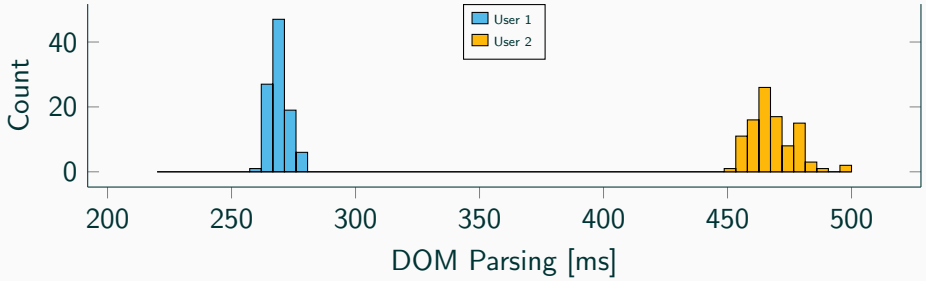

→ timings depends e.g., on CPU speed

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- Advances field of fingerprinting

JavaScript Template Attacks

Michael Schwarz (@misc0110), Florian Lackner, Daniel Gruss (@lavados)

Februrary 25, 2019

IAIK – Graz University of Technology