Membrane: A Posteriori Detection of Malicious Code Loading by Memory Paging Analysis

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Malicious code loading

It’s still a threat

↓

A ***wide range of techniques***

Existing detection approaches

Focus on the code loading technique

Evasion is easy, ***attacks persist*** for a massive period of time

The idea is en route

Code loading from the OS's perspective

Idea: focus to the anomaly

After loading a code the OS needs to
behave differently

On-demand paging in Windows

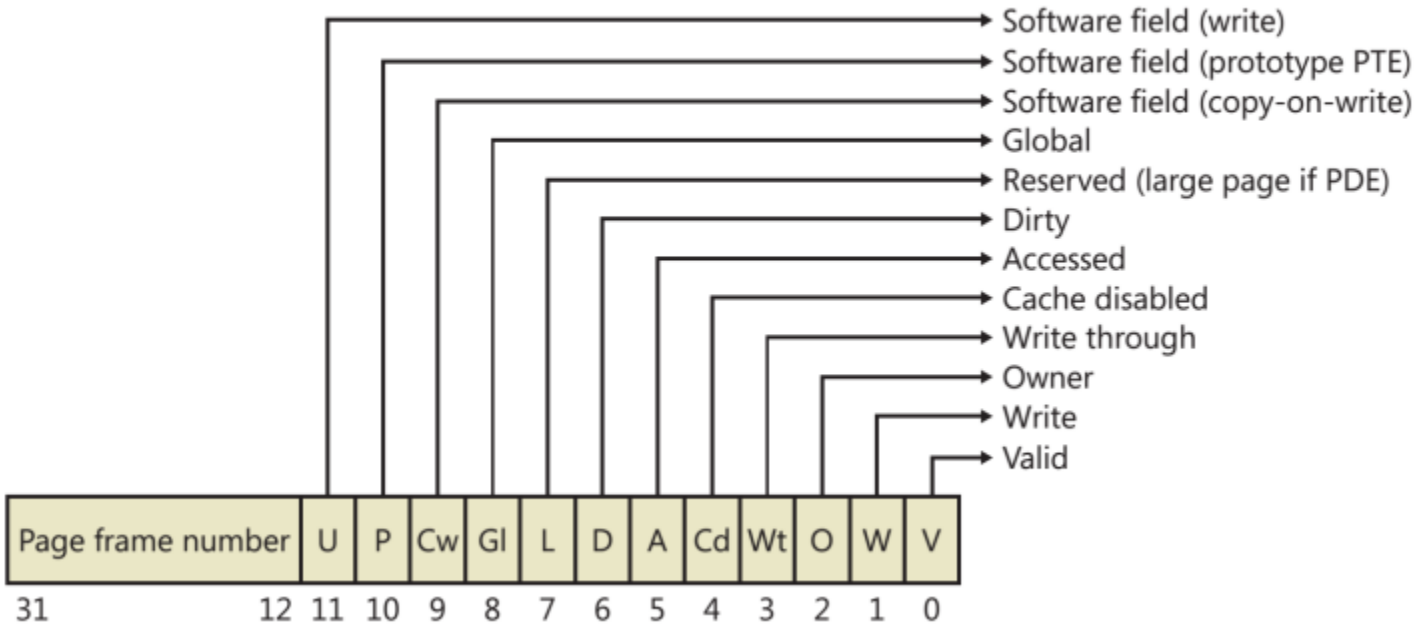
Lazy memory managment

Hardware page tables are built ***on-demand***

(stateful operation)

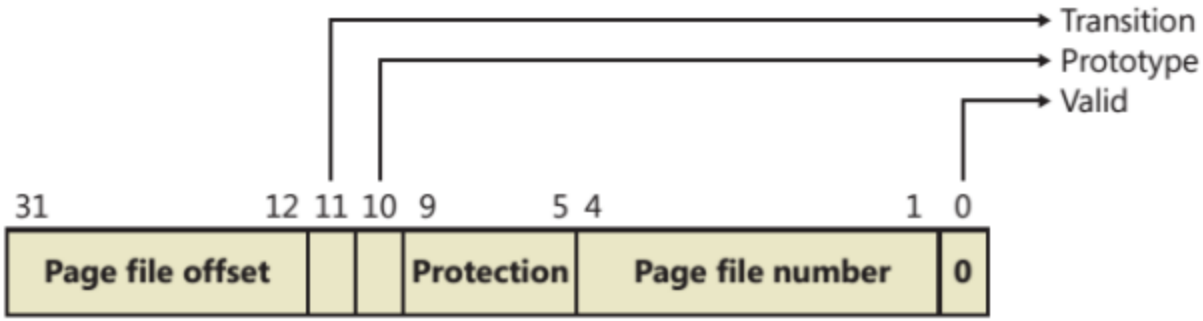
Hardware vs. Software MMU

Valid x86 hardware PTE



Mark E. Russinovich, David A. Solomon, Alex Ionescu: Windows Internals

x86 software PTE pointing to a page in a pagefile



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Example for a paging state

Demand Zero (Dz)

The MMU needs to provide a

zeroed out page.

Yes…!!! Another idea is coming

Calculate per process ***paging state cardinalities***

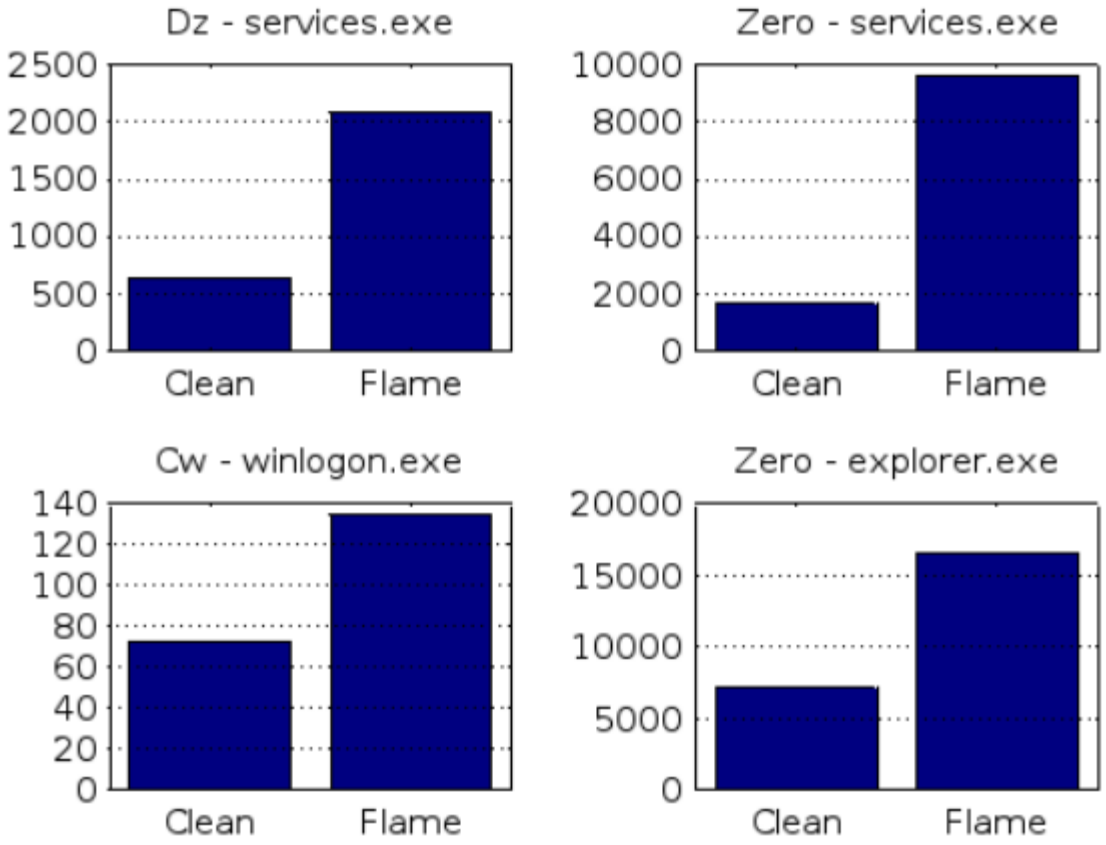
from

memory snapshots!

But how?

Let’s extend Volatility!

Cardinality of different paging states after Flame



Okay, but why?

No matter what technique is used

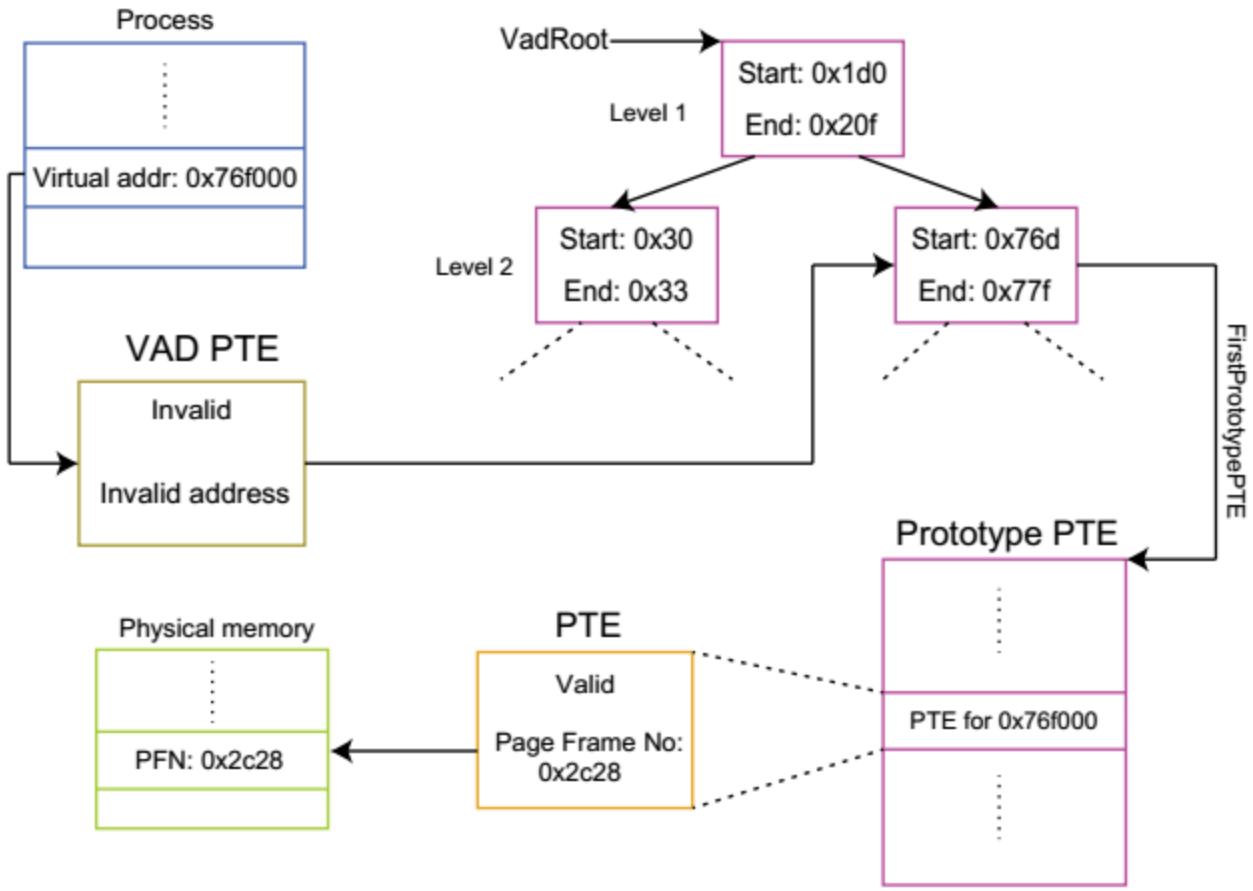
The loaded functionality ***distorts the paging state cardinalities*** of the original process

Collect paging states

We defined ***28 paging states***

(by exploring the realm of Windows)

Membrane as a Volatility extension

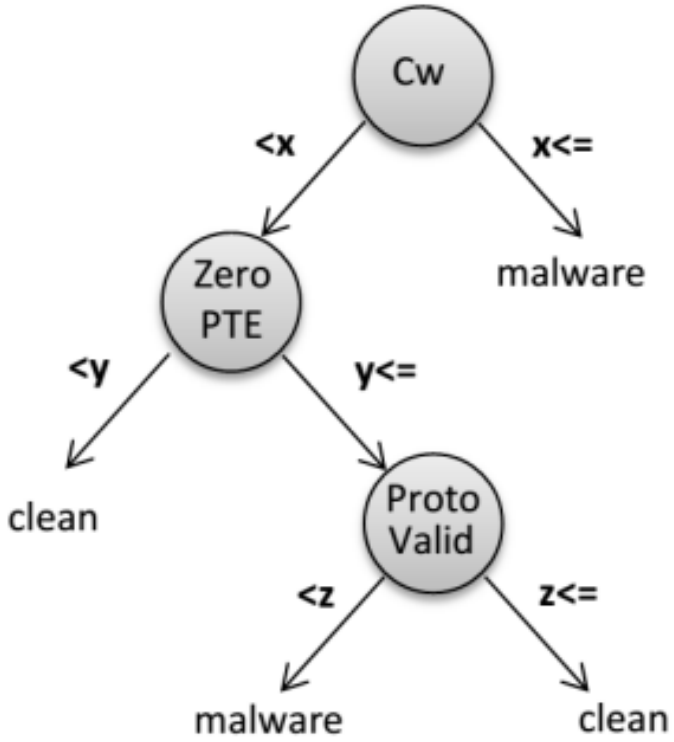


What if…machine learning is a fit now?

Accumulate ***per process paging state cardinalities*** into a ***feature set***

Use ***machine learning*** to select prominent features

Decision tree used by the random forest classifier

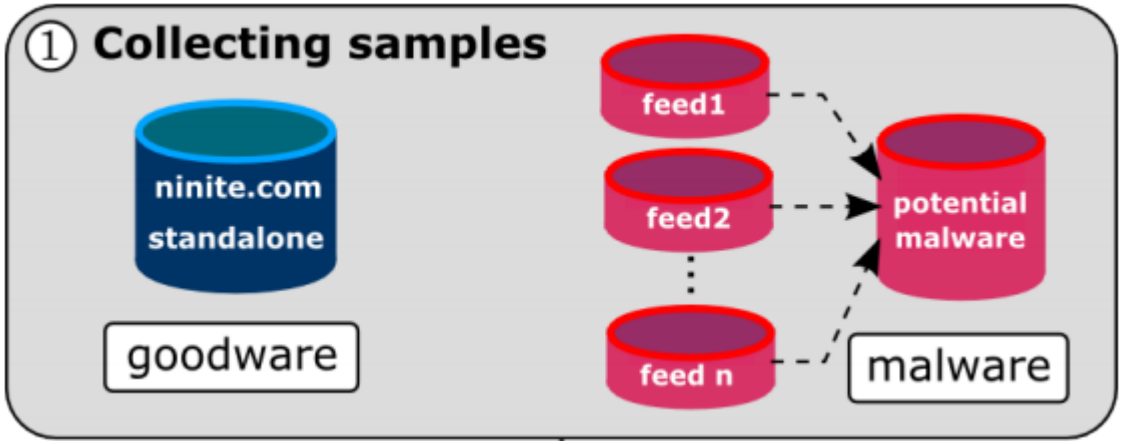


The idea seems to be complete…

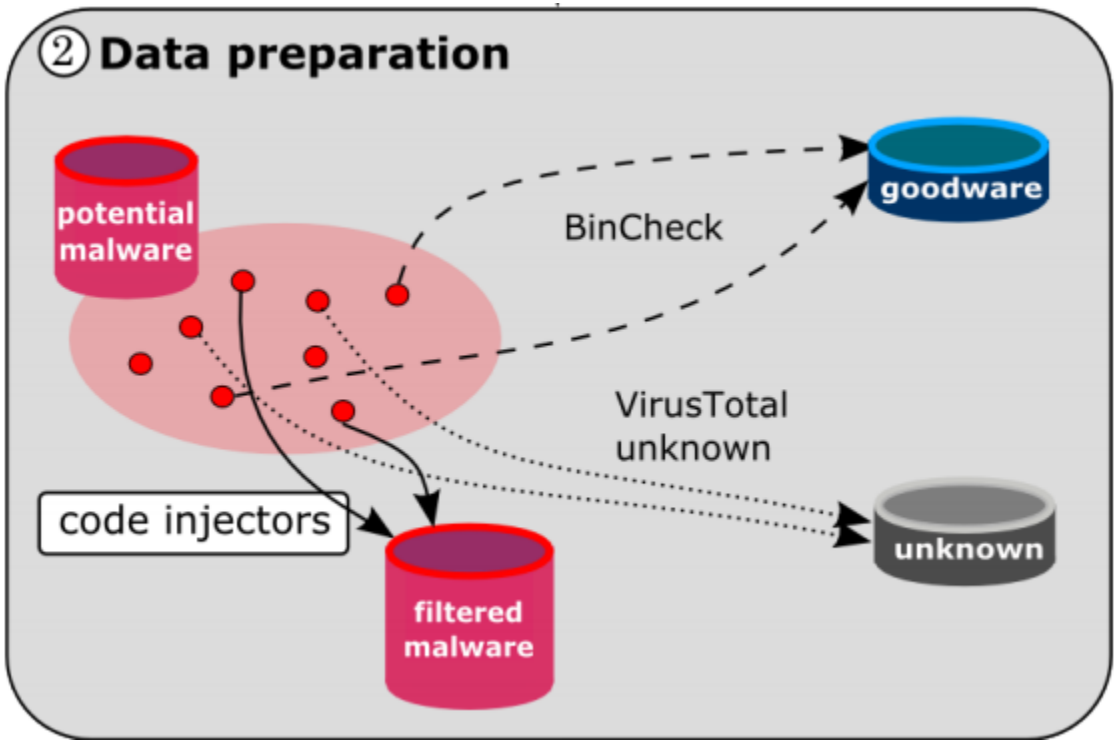
Oh my…

but we need a good corpus to do that

Methodology – #1 Collecting samples



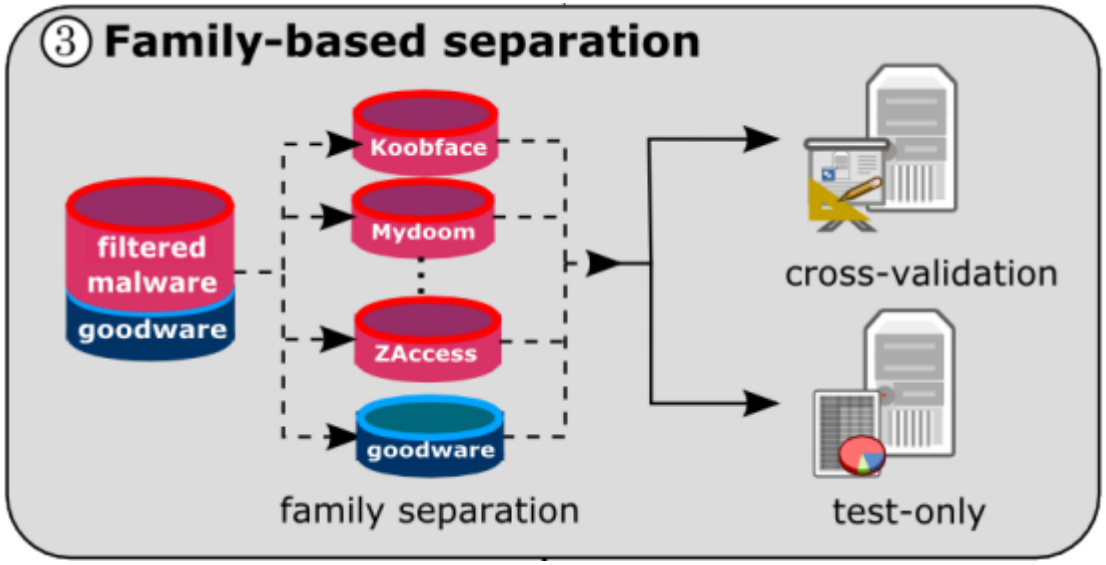
Methodology – #2 Data preparation



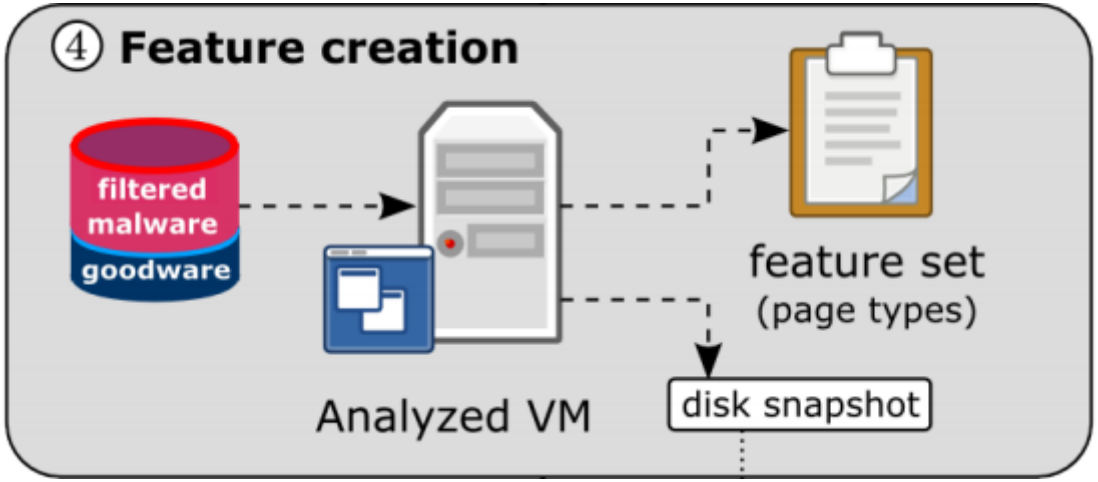
Preparing dataset

Stage	Count
Select malware samples	9,905
Remove goodware with BinCheck	9,903
Remove unknown with VirusTotal	9,121
Balance families	1,095
Select active + hide artifacts	658
Select code injecting malware	**194**

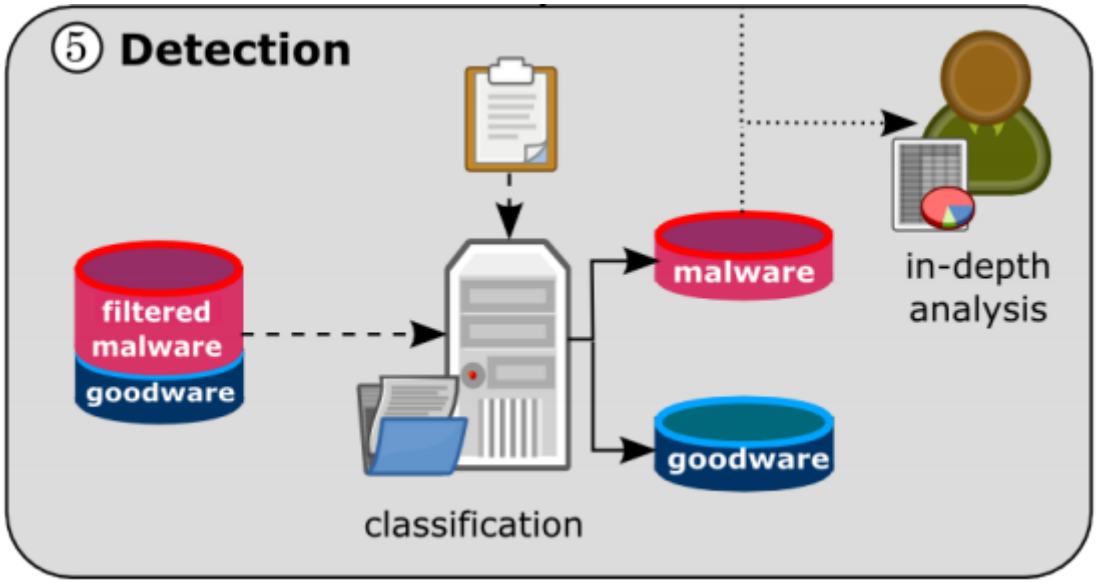
Methodology – #3 Family-based separation



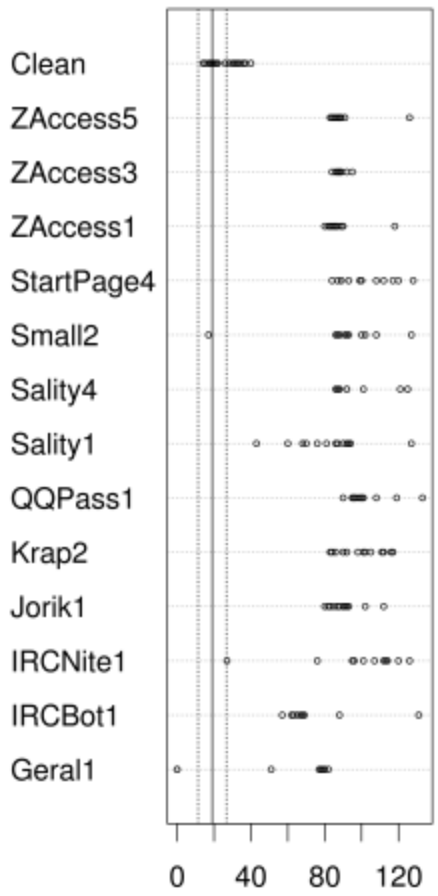
Methodology – #4 Feature creation



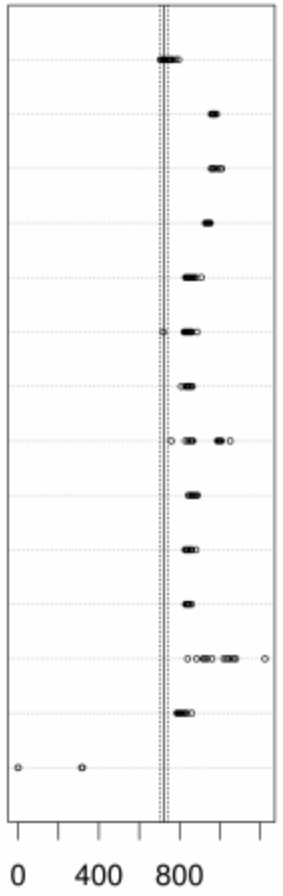
Methodology - Detection



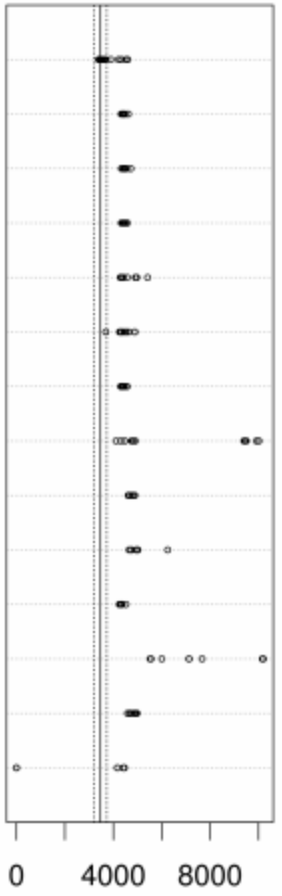
Birds-eye-view analysis of explorer.exe



(a) Copy-on-write



(b) DemandZero



(c) Zero PTE

Detecting generic and targeted malware in exp.exe

Internet	VM	ACC %	TPR %	FPR %
CROSS-VALIDATION DATASET				
no	WinXP	98.67	98.82	1.18
	Win7_1	73.59	75.92	28.46
yes	WinXP	92.81	90.88	5.45
	Win7_1	79.45	82.69	23.59
CROSS-VALIDATION DATASET WITH NO ADDITIONAL PROCESSES				
no	Win7_1	77.16	86.00	34.73
TEST-ONLY DATASET				
no	WinXP	100	100	-
	Win7_1	100	100	-

Membrane Live

Snapshot creation can be a ***heavy-duty operation***

We created a live monitoring version by extending a VMI framework

Questions?

```
git clone https://github.com/CrySyS/membrane.git
```