Frankenstein

Stitching Malware from Benign Binaries

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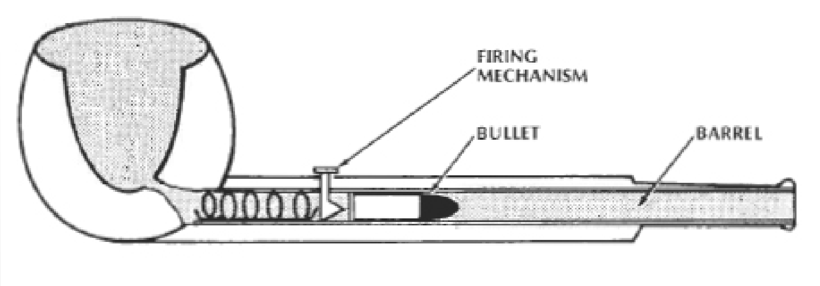
Agenda

- (Drawbacks in) current approaches to obfuscation
- Our approach
- Implementation
- Results

The motivation

- Extend the malware obfuscation arsenal



The motivation

- The current state of detection -
  - Largely static and feature-based
  - Complex analysis only for suspicious files

- The current state of obfuscation -
  - Encryption

  - Virtualization

  - Metamorphism

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  - Virtualization, or "I'm going to carry a virtual machine around"

  - Metamorphism, or "I'm going to change my code each time (but only in simple, detectable ways)"

The motivation

- Gadgets are very interesting
  - Turing-complete functionality
  - Found everywhere
  - Classifiably benign!
- So why not use gadgets to compose your malware

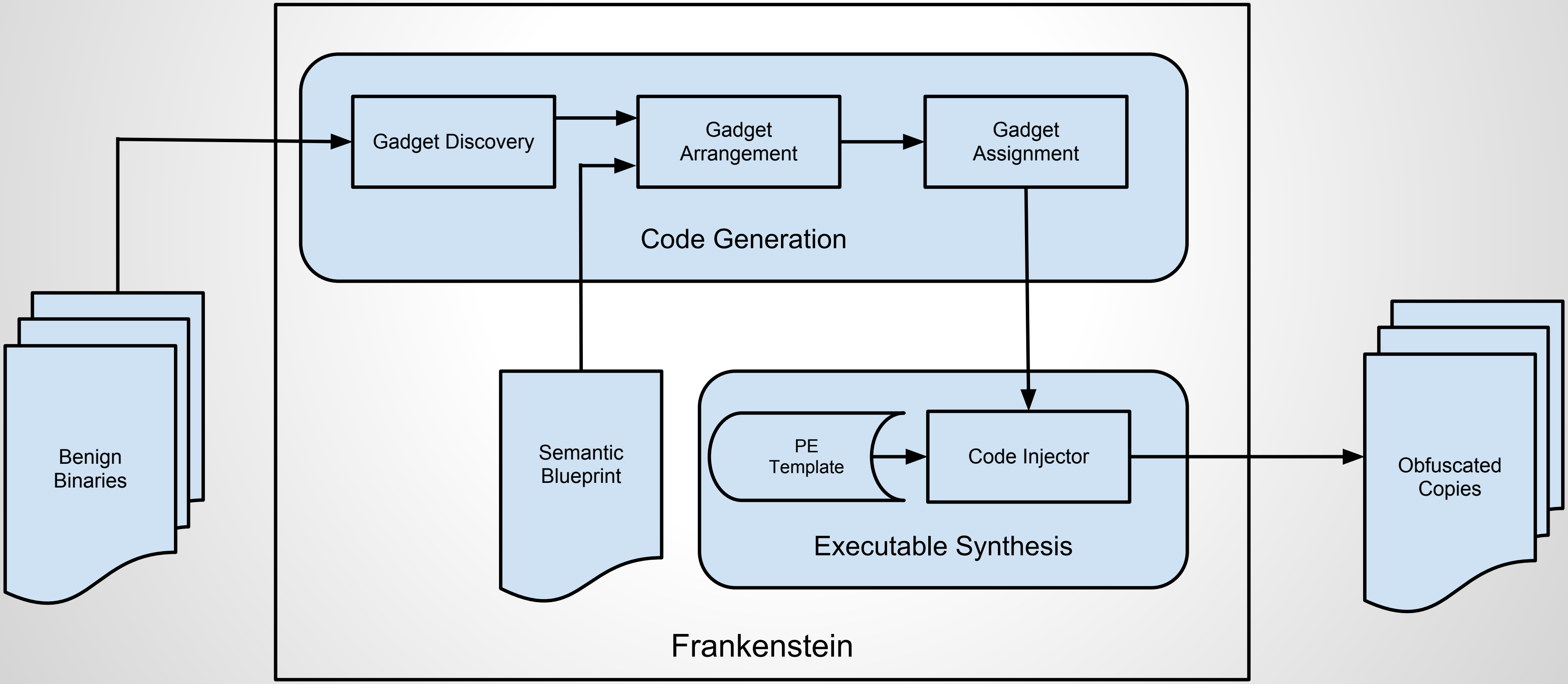
Gadget:
A sequence of bytes representing a valid instruction sequence, and ending in return, that can be used to perform a semantically specific task.

Eg:
  mov eax, ebx
  ret
is a gadget that moves a value from one register (*ebx*) to another (*eax*)

The idea - Or Mary Shelley's recipe

- Consult a high-level blueprint of the ~~human body~~ malware
- Harvest ~~organs~~ gadgets from ~~cadavers~~ benign programs
- Stitch them together to (re)create ~~Frankenstein~~ the malware

Overview


Gadget Discovery
Gadget Arrangement
Gadget Assignment
Code Generation
Benign Binaries
Semantic Blueprint
PE Template
Code Injector
Executable Synthesis
Obfuscated Copies
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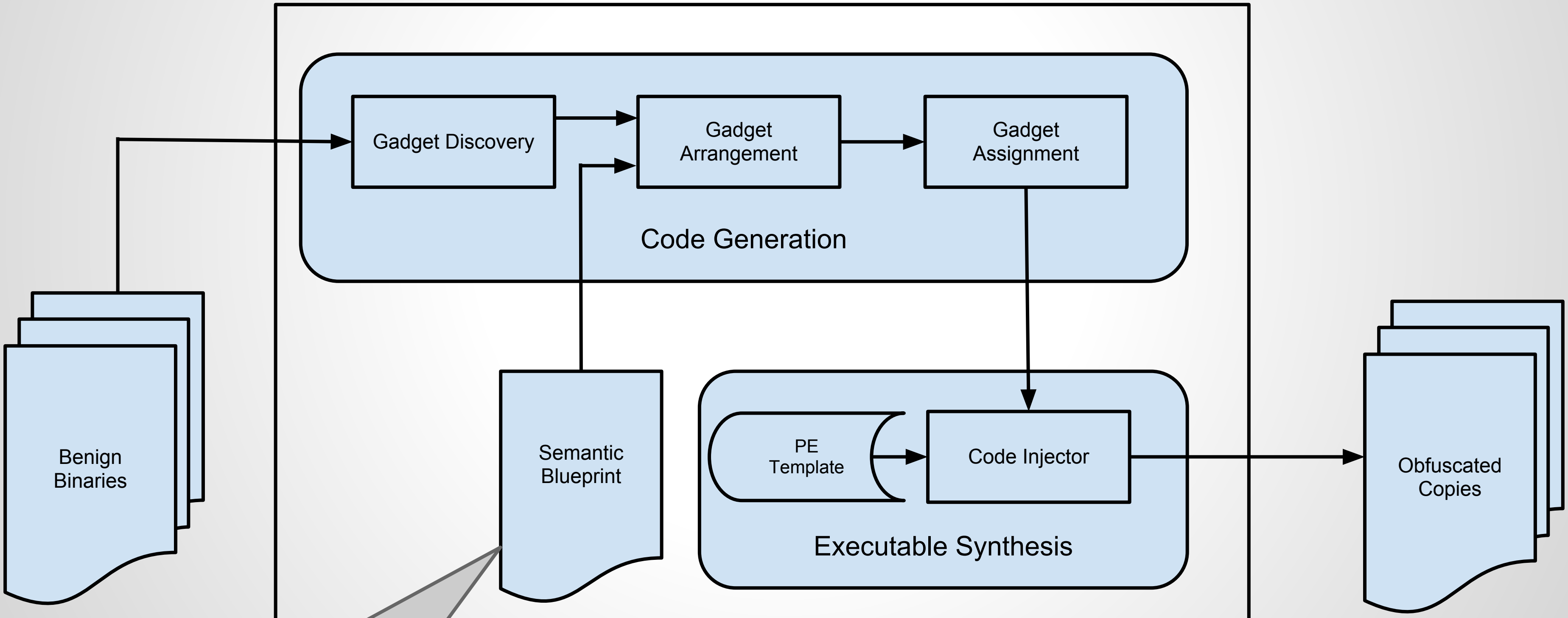


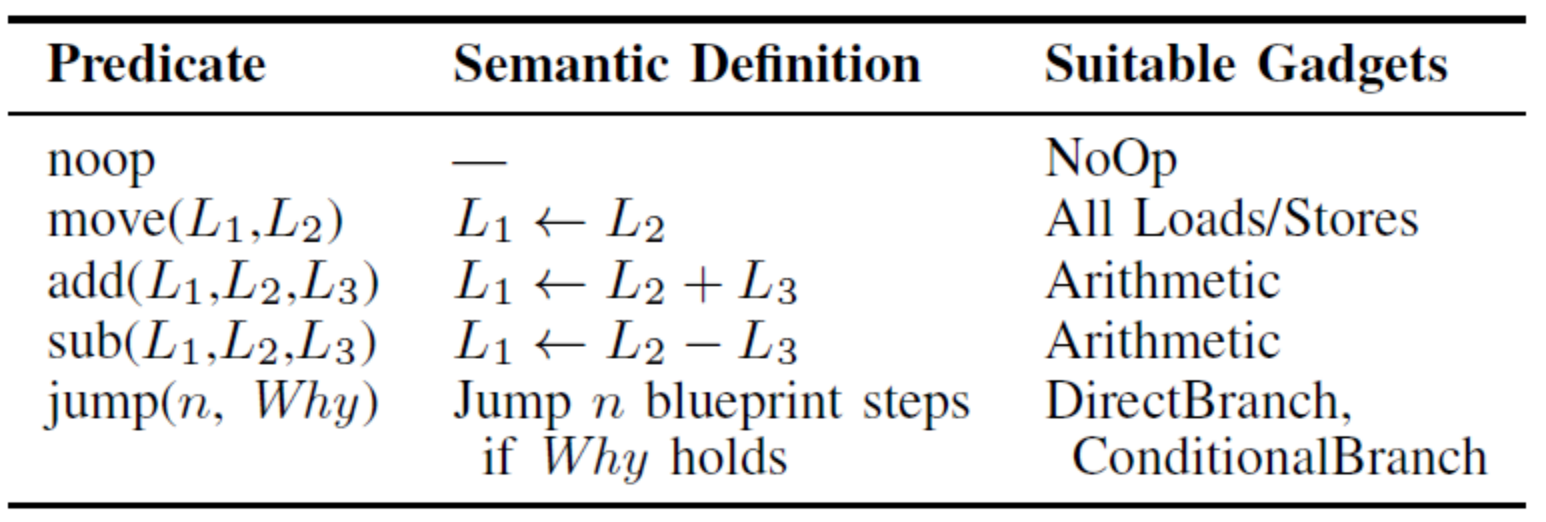
Malware functionality expressed as a set of logical predicates.

Semantic Blueprint

- Eg: semantic blueprint to find the slope of a line given two points (x1,y1) and (x2,y2)

```
evil_slope :=
  sub(L1, y1, y2), // L1 = y1 - y2
  sub(L2, x1, x2), // L2 = x1 - x2
  div(L3, L1, L2).  // L3 = (y1-y2) / (x1-x2)
```

Semantic Blueprint



Predicate	**Semantic Definition**	**Suitable Gadgets**
noop	—	NoOp
move(L_1,L_2)	$L_1 \leftarrow L_2$	All Loads/Stores
add(L_1,L_2,L_3)	$L_1 \leftarrow L_2 + L_3$	Arithmetic
sub(L_1,L_2,L_3)	$L_1 \leftarrow L_2 - L_3$	Arithmetic
jump(n, Why)	Jump n blueprint steps if Why holds	DirectBranch, ConditionalBranch

- Logical predicates represent actions
  - Predicates can be layered for abstraction
  - Lowest layer predicates match multiple gadgets
  - The goal is to encode *what* rather than *how*

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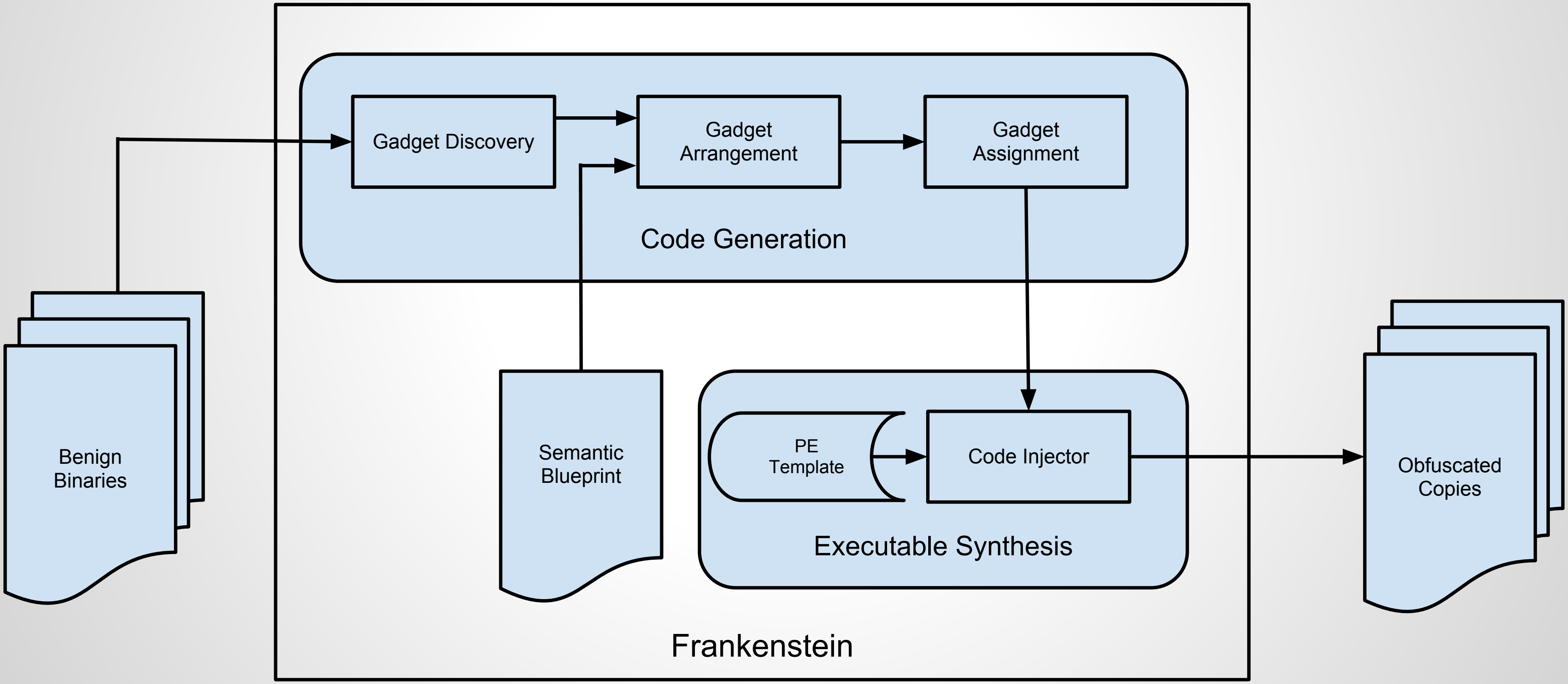
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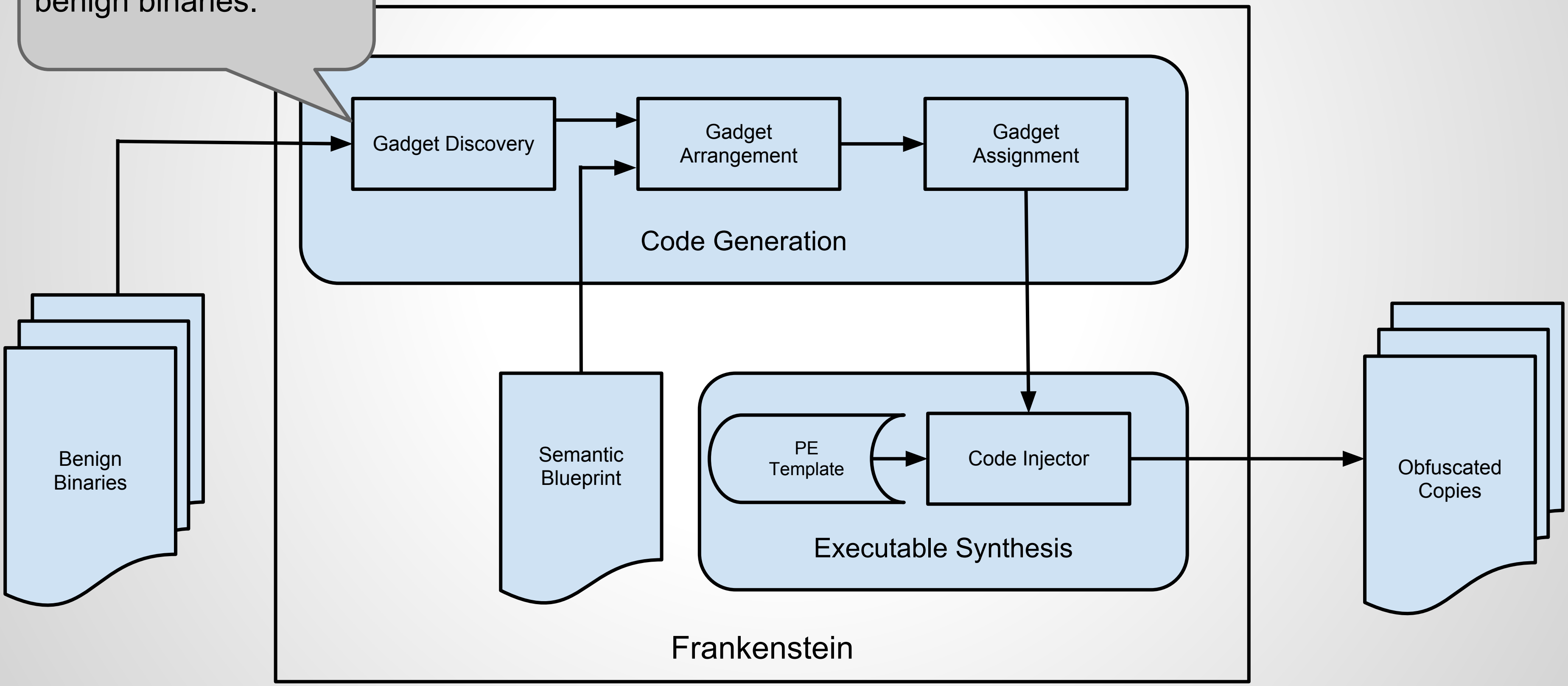
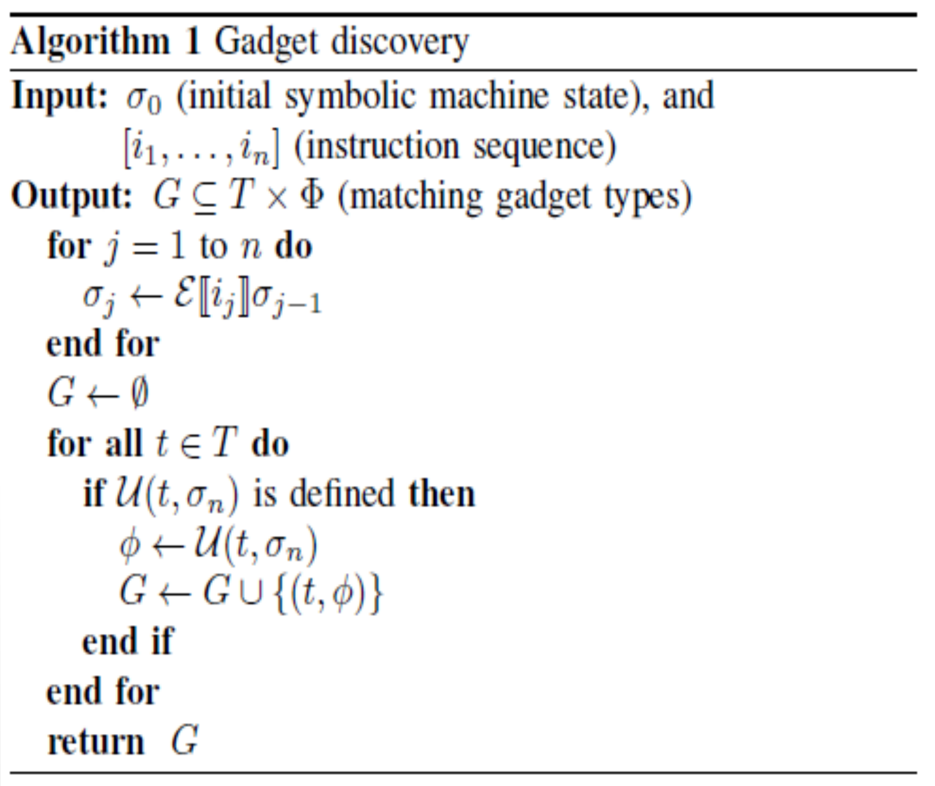
Builds a database of gadgets from the benign binaries.



Abstract Evaluator

- Input: Instruction sequence, abstract state
- Output: All gadget types that it can match
- Algorithm:



Algorithm 1 Gadget discovery

```
Input: $\sigma_0$ (initial symbolic machine state), and
       $[i_1, \ldots, i_n]$ (instruction sequence)
Output: $G \subseteq T \times \Phi$ (matching gadget types)
  for $j = 1$ to $n$ do
    $\sigma_j \leftarrow \mathcal{E}[\![i_j]\!]\sigma_{j-1}$
  end for
  $G \leftarrow \emptyset$
  for all $t \in T$ do
    if $\mathcal{U}(t, \sigma_n)$ is defined then
      $\phi \leftarrow \mathcal{U}(t, \sigma_n)$
      $G \leftarrow G \cup \{(t, \phi)\}$
    end if
  end for
  return $G$
```

Abstract Evaluator

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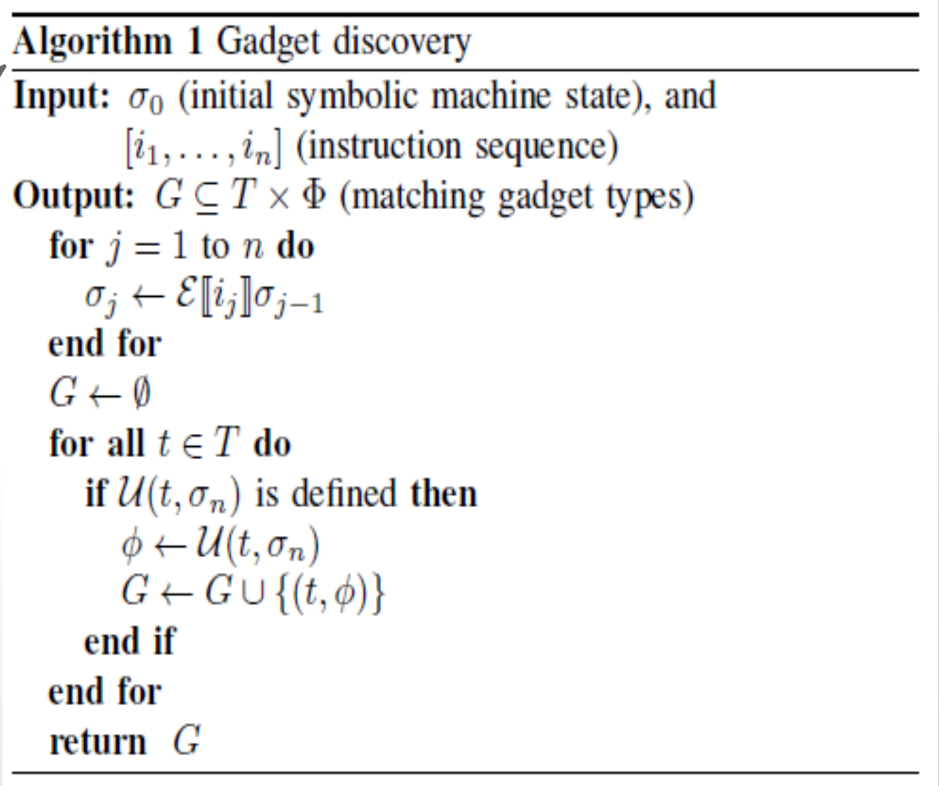
- Algorithm:

A (contrived) example:
Input:
add eax, ebx
mov ecx, edx

Matched gadget types:
1) Arithmetic(eax **<--** eax + ebx)
clobbers[ecx]

2) LoadReg(ecx **<--** edx)
clobbers[eax]

3) Nop
clobbers[eax, ecx]



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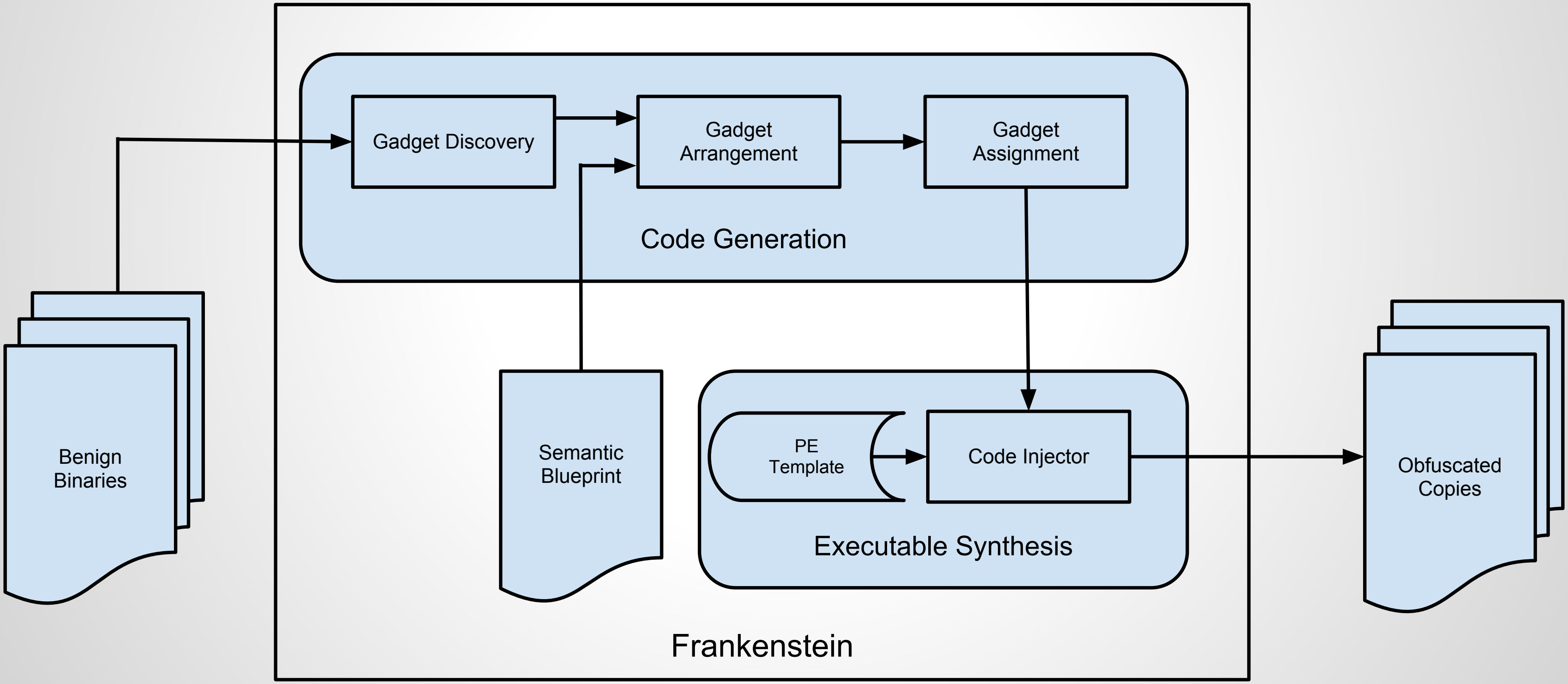

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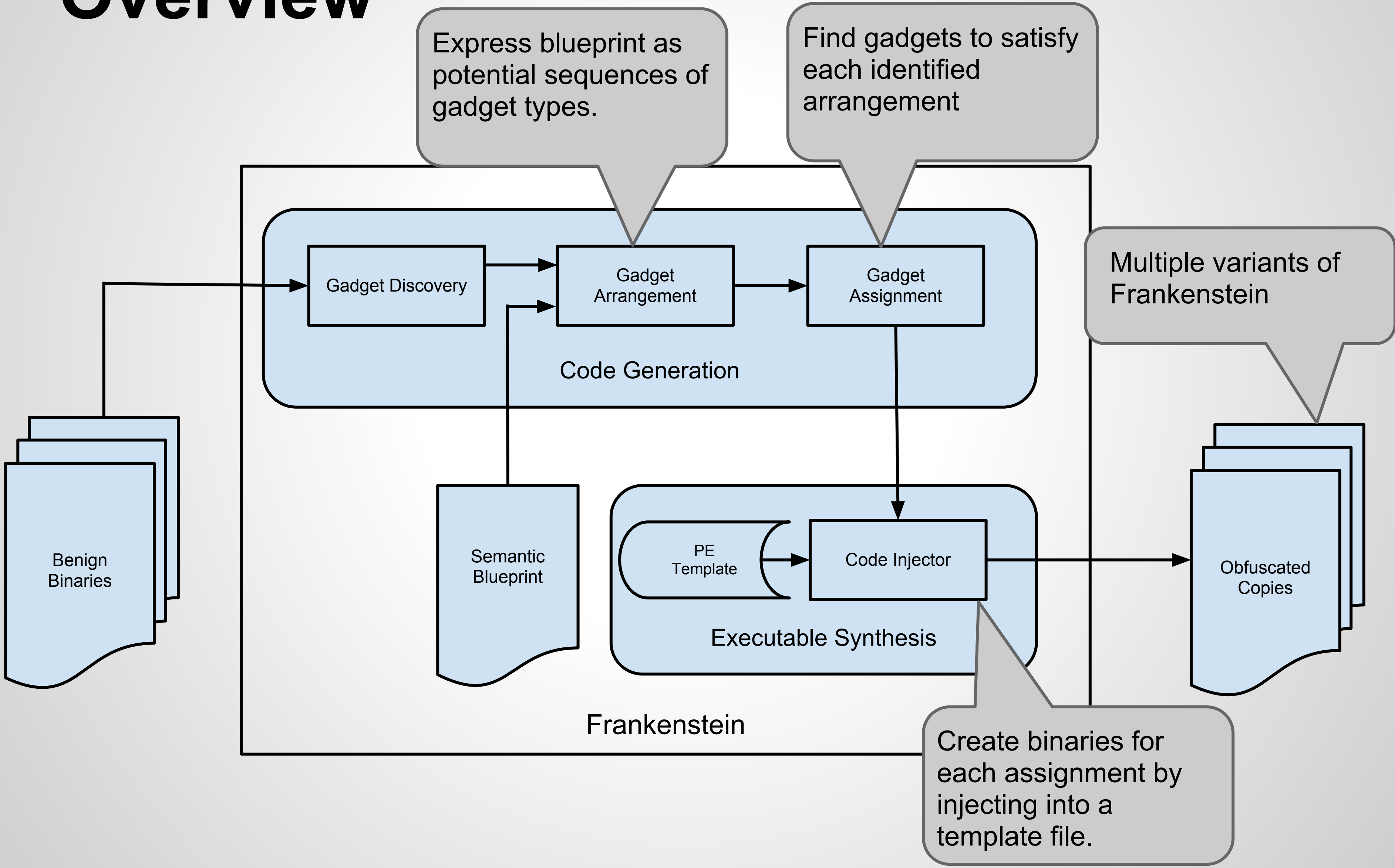


Express blueprint as potential sequences of gadget types.

Find gadgets to satisfy each identified arrangement

Multiple variants of Frankenstein

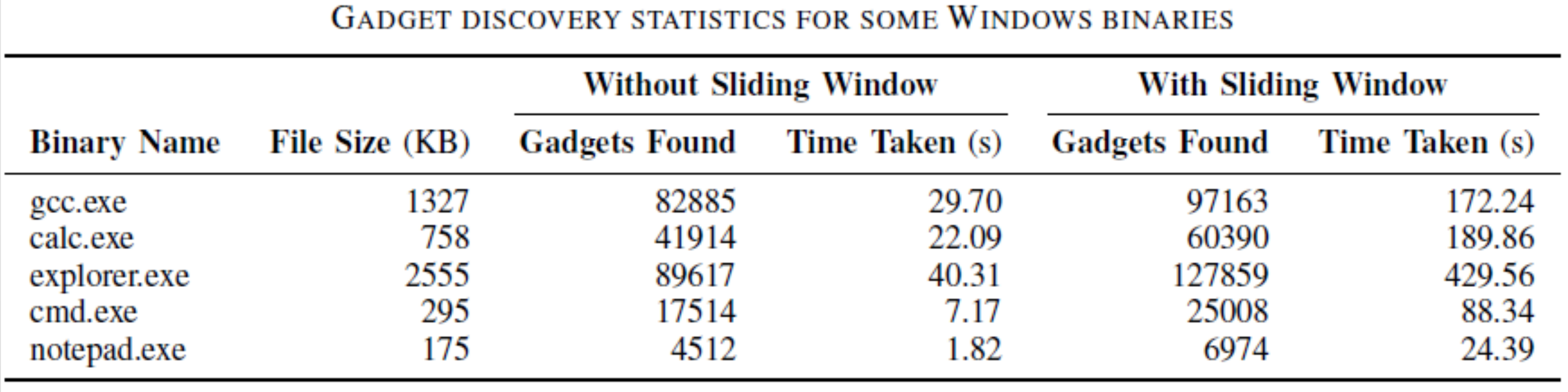
Create binaries for each assignment by injecting into a template file.

The implementation

- Combination of
  - Python - gadget discovery, executable synthesis
  - Prolog - gadget assignment
- Small abstract evaluator
  - Only identifies 8 non-branch instructions
  - Still more than sufficient for good results
- Not self-propagating (yet!)

The results

- Gadget discovery
  - Tested with files from *windows/system32*
  - Limited gadget size to 2-6 instructions



GADGET DISCOVERY STATISTICS FOR SOME WINDOWS BINARIES

		Without Sliding Window		With Sliding Window	
Binary Name	**File Size (KB)**	**Gadgets Found**	**Time Taken (s)**	**Gadgets Found**	**Time Taken (s)**
gcc.exe	1327	82885	29.70	97163	172.24
calc.exe	758	41914	22.09	60390	189.86
explorer.exe	2555	89617	40.31	127859	429.56
cmd.exe	295	17514	7.17	25008	88.34
notepad.exe	175	4512	1.82	6974	24.39

- Verdict:
  - 46 gadgets per KB of code
  - 2300 gadgets per second
  - Encouraging!

The results

- Generated working mutants
  - Gadgets only from explorer.exe
  - Insertion Sort
  - XOR-based olgimorphism
- Found over 10,000 viable gadget assignments each!
- Size increase a little less than double on average

The results

- Compositionally benign?
- Analyzed fresh n-grams across 20 mutants
  - 2% common across 3 or more
  - 0.3% common across 5 or more
  - 0% common across 7 or more
- i.e: No defining n-grams across 35% or more

Conclusion

- New way to obfuscate malware
- Principled approach to metamorphism
- Early results show high potential for non-distinguishability from benign programs
- Definitely worth developing further

Questions?

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Thank You

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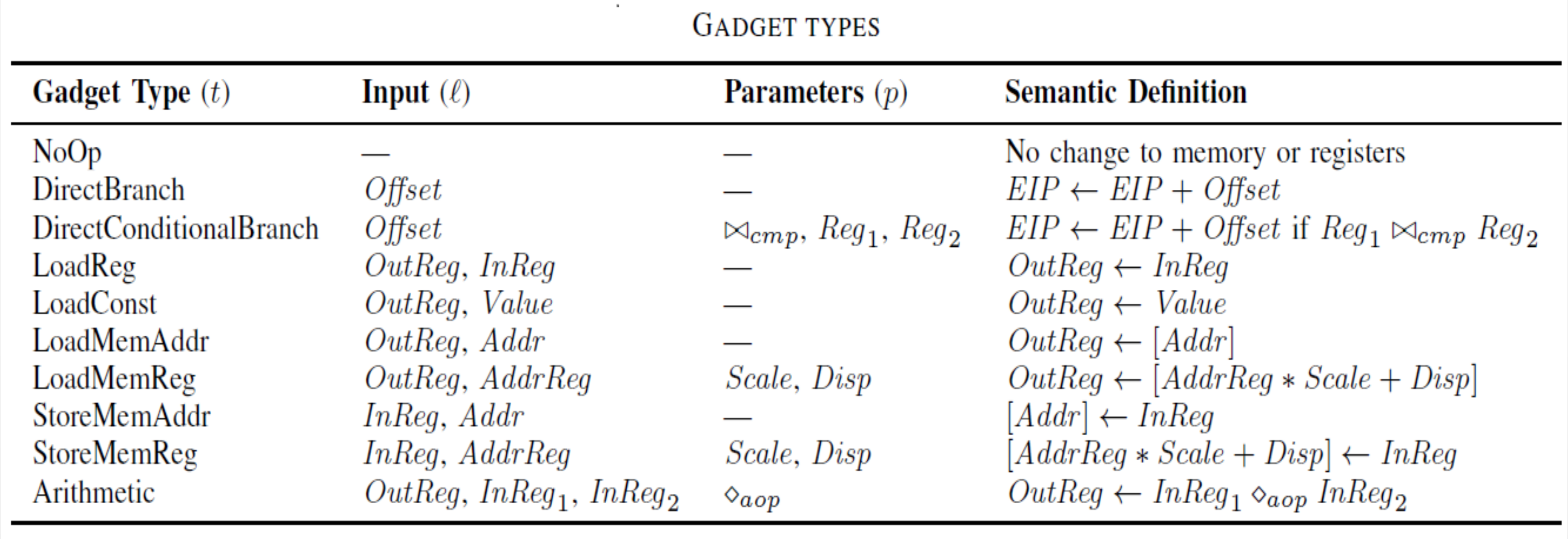
Gadgets

- Less constrained notion of a gadget
- More varied (but less than micro-gadgets?)



GADGET TYPES

Gadget Type (t)	**Input** (ℓ)	**Parameters** (p)	**Semantic Definition**
NoOp	—	—	No change to memory or registers
DirectBranch	$Offset$	—	$EIP \leftarrow EIP + Offset$
DirectConditionalBranch	$Offset$	$\bowtie_{cmp}, Reg_1, Reg_2$	$EIP \leftarrow EIP + Offset$ if $Reg_1 \bowtie_{cmp} Reg_2$
LoadReg	$OutReg, InReg$	—	$OutReg \leftarrow InReg$
LoadConst	$OutReg, Value$	—	$OutReg \leftarrow Value$
LoadMemAddr	$OutReg, Addr$	—	$OutReg \leftarrow [Addr]$
LoadMemReg	$OutReg, AddrReg$	$Scale, Disp$	$OutReg \leftarrow [AddrReg * Scale + Disp]$
StoreMemAddr	$InReg, Addr$	—	$[Addr] \leftarrow InReg$
StoreMemReg	$InReg, AddrReg$	$Scale, Disp$	$[AddrReg * Scale + Disp] \leftarrow InReg$
Arithmetic	$OutReg, InReg_1, InReg_2$	$\diamond_{aop}$	$OutReg \leftarrow InReg_1 \diamond_{aop} InReg_2$

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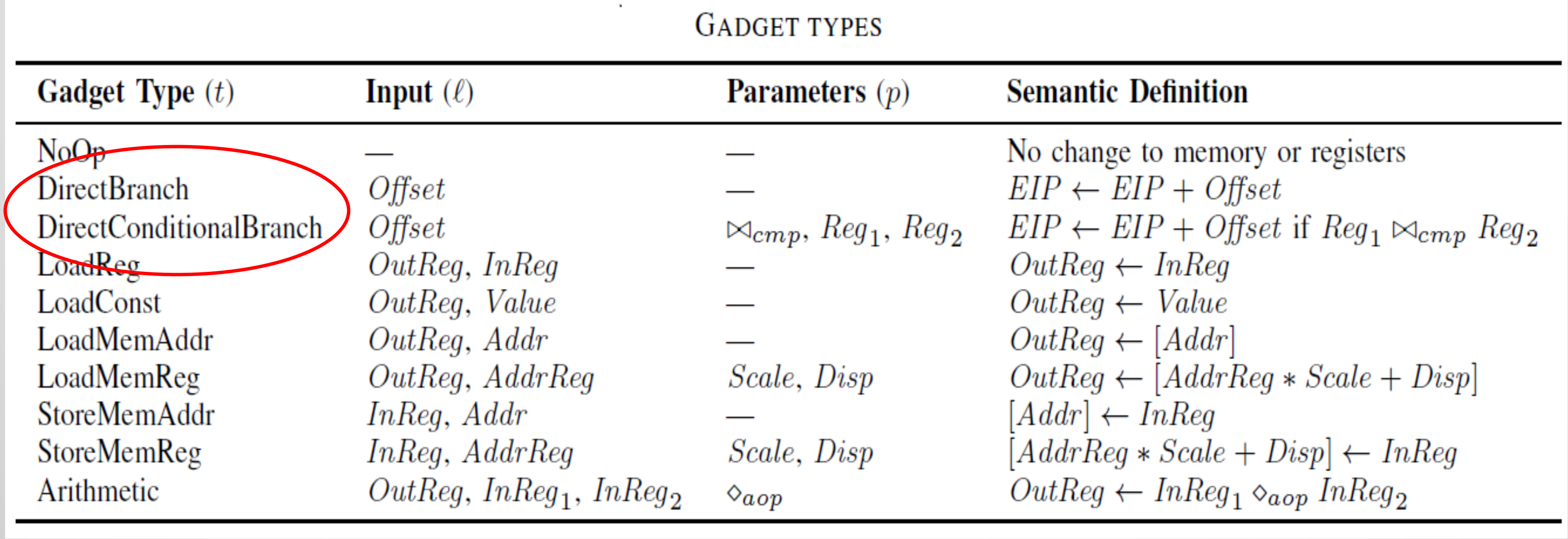

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