RUHR UNIVERSITÄT BOCHUM RUB

Nautilus

Fishing for Deep Bugs with Grammars

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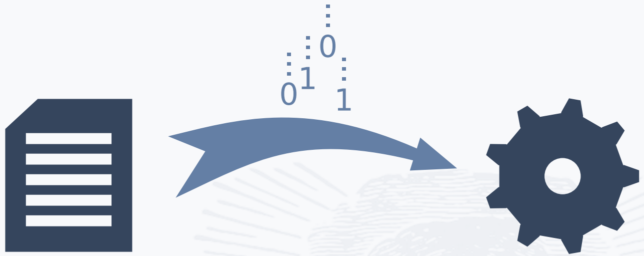
Patrick Jauernig, Ahmad-Reza Sadeghi and Daniel Teuchert
Ruhr-Universität Bochum & Technische Universität Darmstadt

Fuzzing

Daniel Teuchert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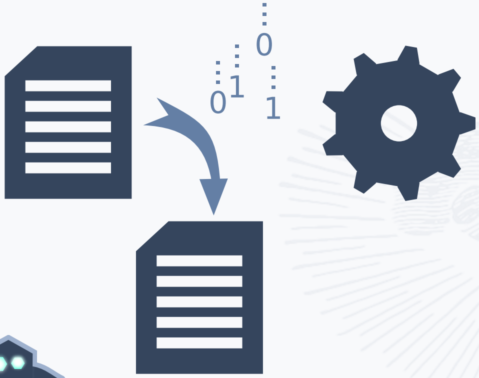
AFL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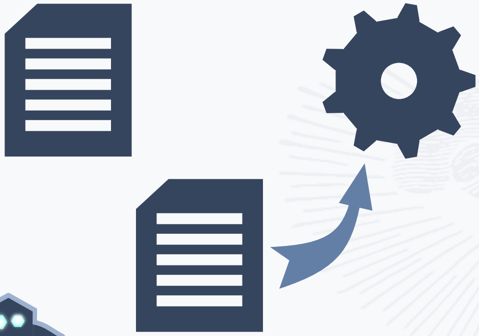

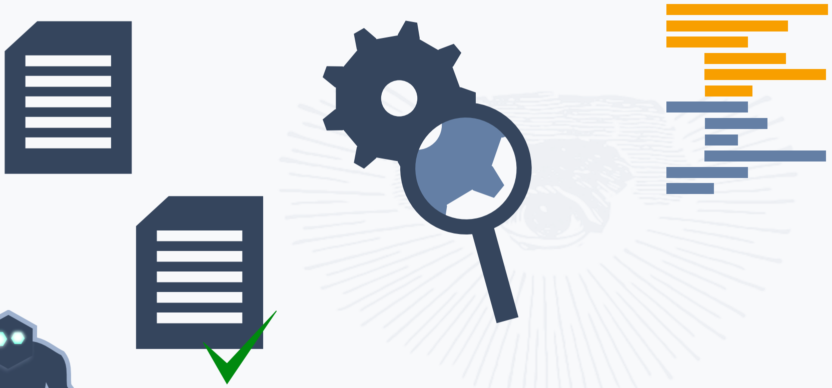

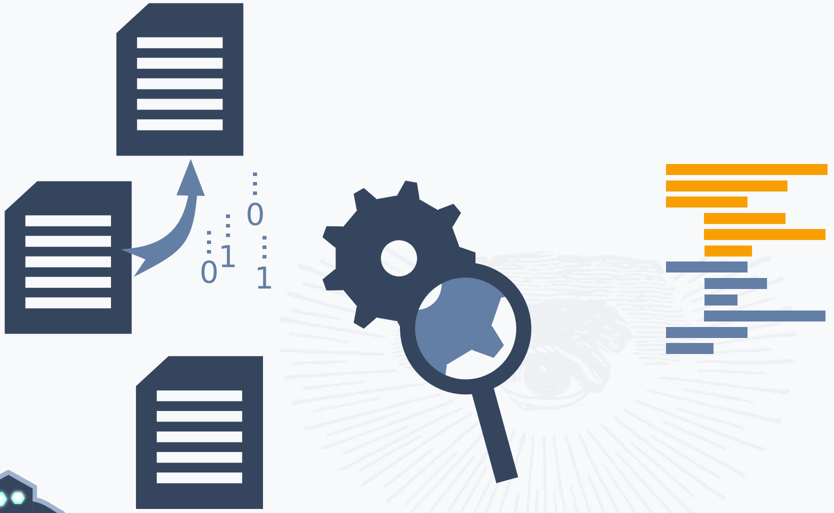
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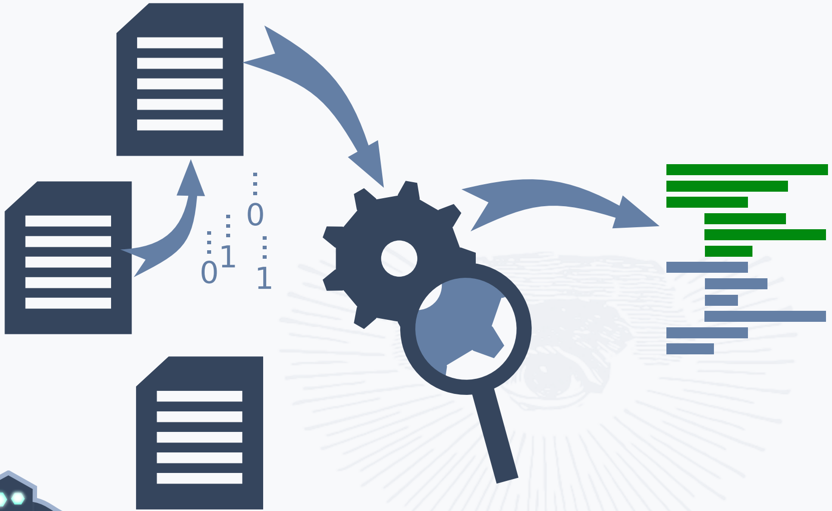
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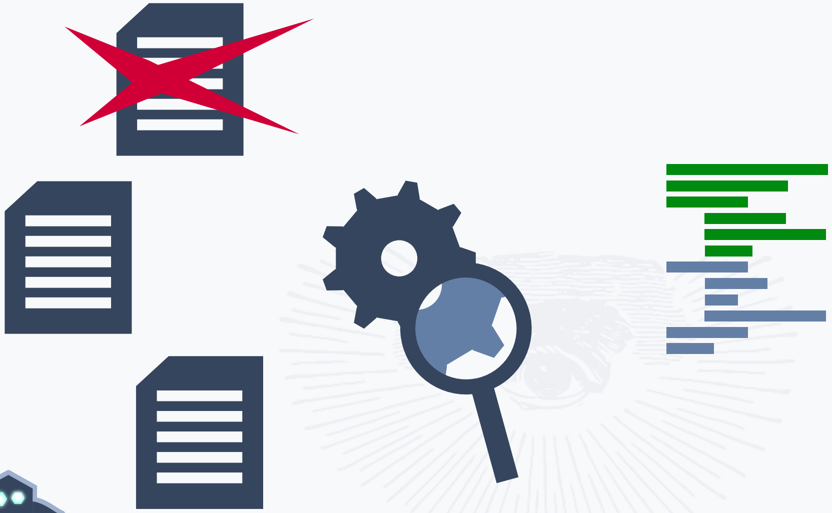

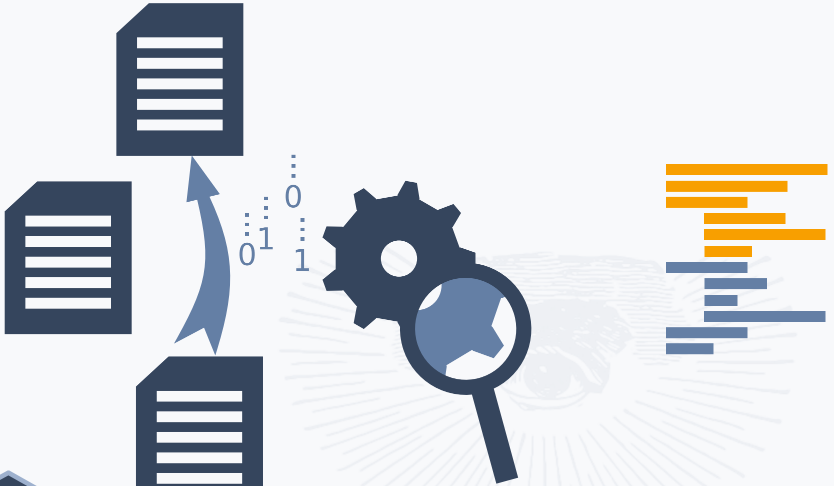
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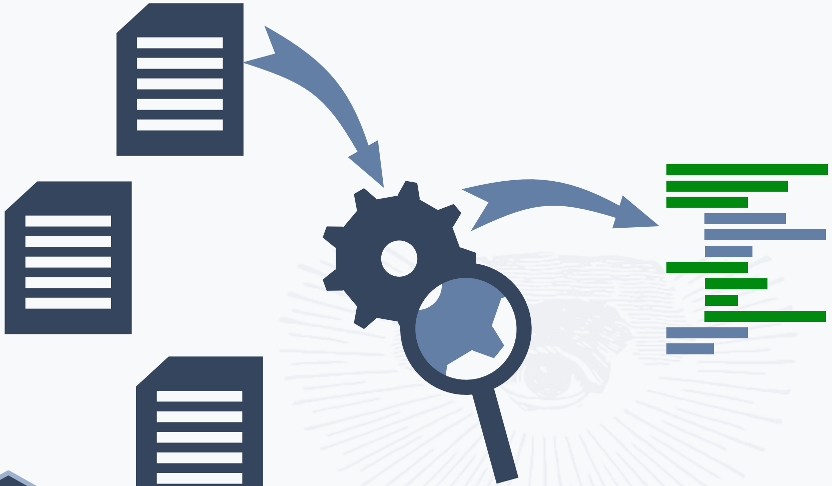

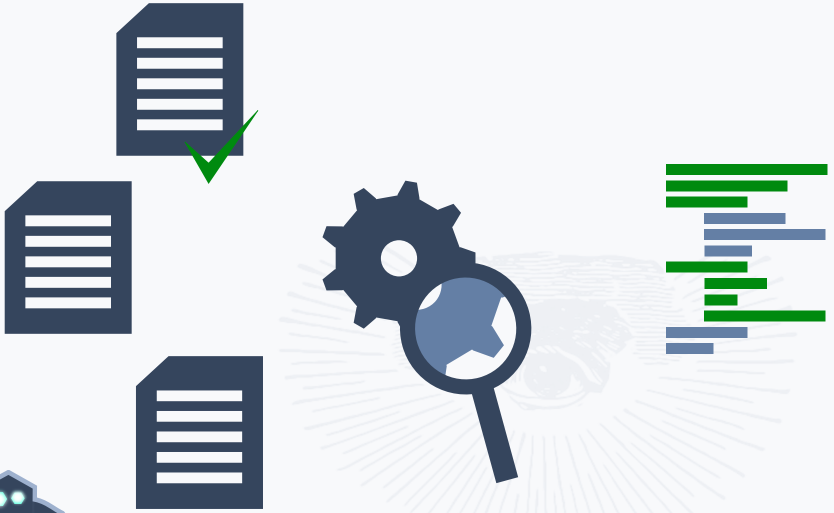

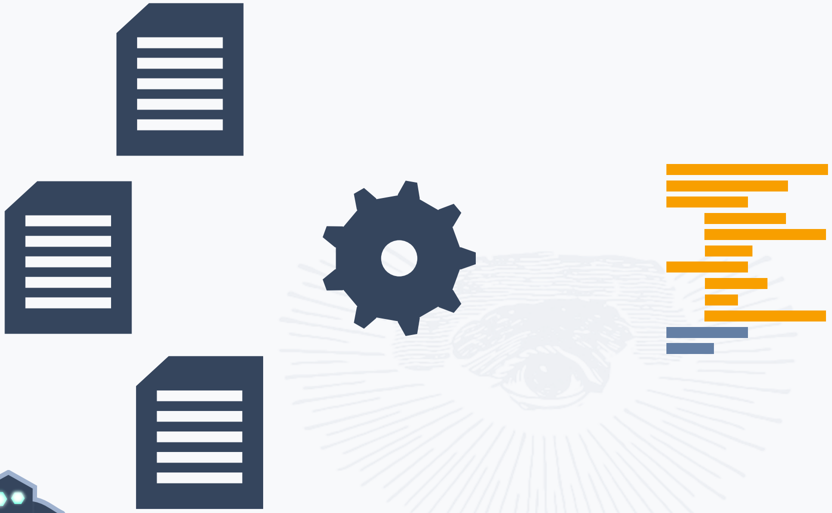

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if !input.parse() {
    exit()
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```

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if !input.parse() {
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do_stuff()
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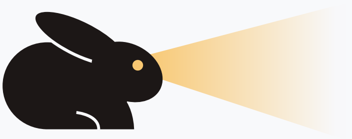

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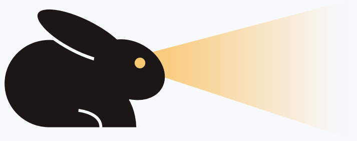

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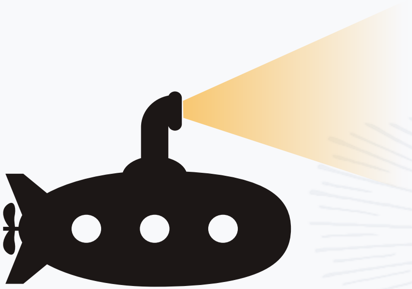

Grammars
+
Feedback

Context-Free Grammars

Context-Free Grammars

PROG	→	STMT
PROG	→	STMT ; PROG
STMT	→	return 1
STMT	→	VAR = EXPR
VAR	→	a
EXPR	→	NUM
EXPR	→	EXPR + EXPR
NUM	→	1 | 2

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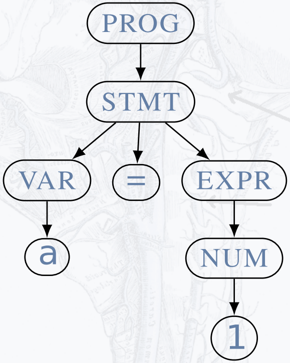

$$\begin{tikzcd}
 & \text{PROG} \arrow[d] & \\
 & \text{STMT} \arrow[dl] \arrow[d] \arrow[dr] & \\
\text{VAR} \arrow[d] & = & \text{EXPR} \arrow[d] \\
a & & \text{NUM} \arrow[d] \\
 & & 1
\end{tikzcd}$$

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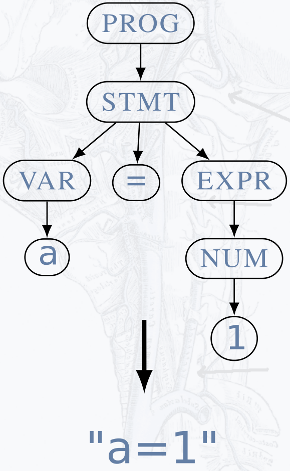

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 & \boxed{\text{PROG}} \arrow[d] & \\
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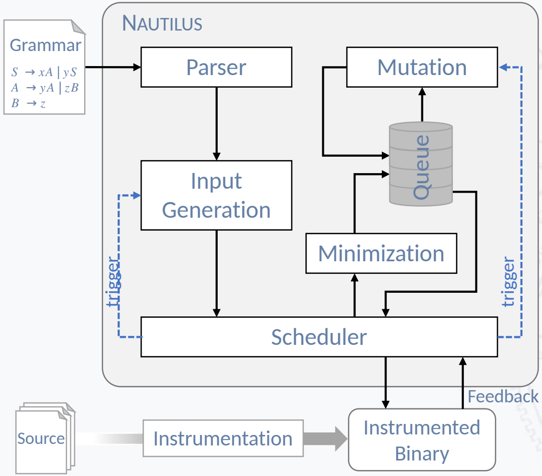
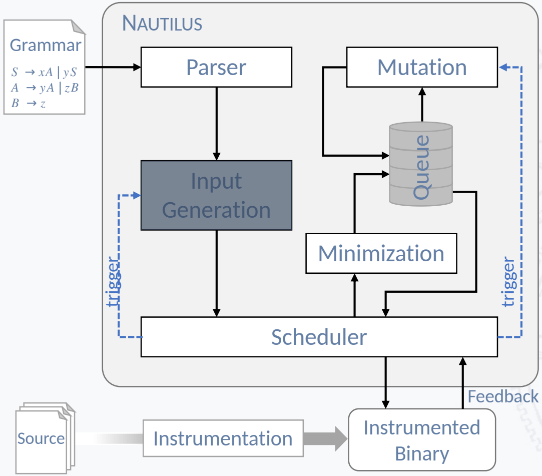
\boxed{\text{VAR}} \arrow[d] & \boxed{=} & \boxed{\text{EXPR}} \arrow[d] \\
\boxed{\text{a}} & & \boxed{\text{NUM}} \arrow[d] \\
 & \arrow[d] & \boxed{1} \\
 & \text{"a=1"} &
\end{tikzcd}$$

Design of Nautilus

Design of Nautilus




Grammar
$S \rightarrow xA \mid yS$
$A \rightarrow yA \mid zB$
$B \rightarrow z$
NAUTILUS
Parser
Mutation
Input Generation
Queue
Minimization
trigger
trigger
Scheduler
Feedback
Source
Instrumentation
Instrumented Binary

Generation:

Generation:

-Naive Generation

Generation:

-Naive Generation

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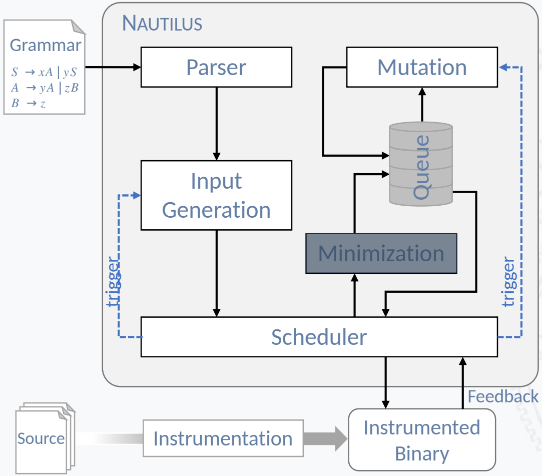
EXPR	→	EXPR + EXPR
NUM	→	1 | 2

Generation:

-Naive Generation

-Uniform Generation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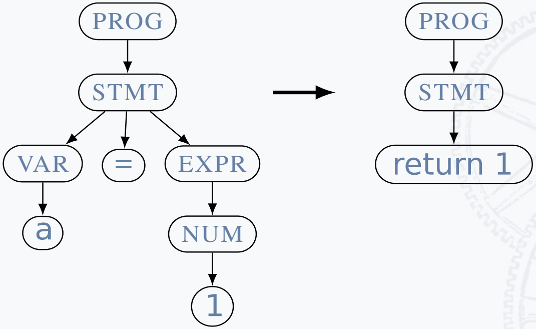
Minimization:

Minimization:

-Subtree Minimization

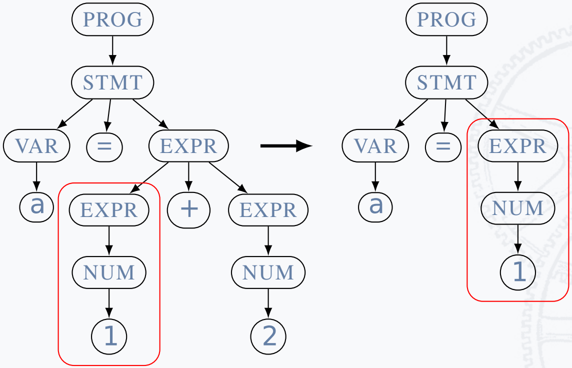


Subtree Minimization

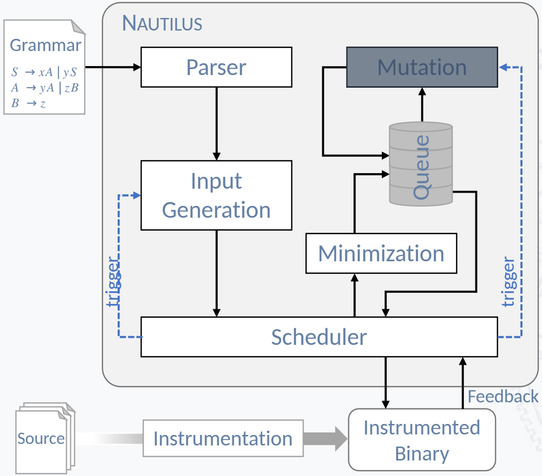
Minimization:

-Subtree Minimization

-Recursion Minimization



Recursive Minimization


NAUTILUS
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Mutation:

Mutation:

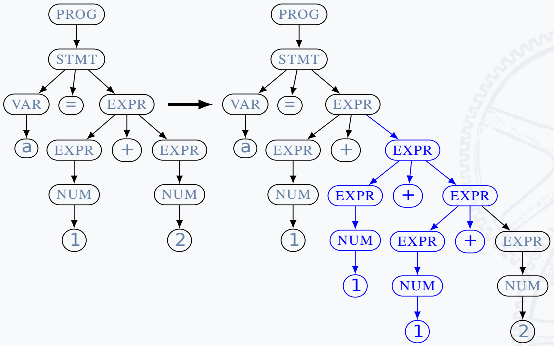
-Random

Mutation:

- -Random
- -Rules

Mutation:

- Random
- Rules
- Random Recursive



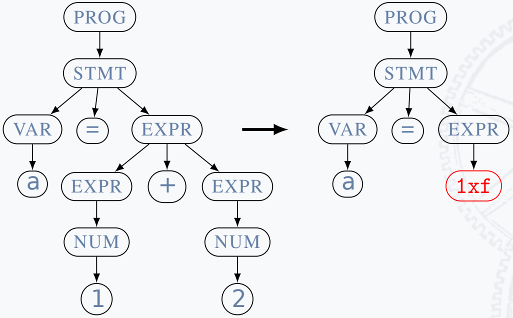
Random Recursive Mutation

Mutation:

- -Random
- -Rules
- -Random Recursive
- -Splicing

Mutation:

- -Random
- -Rules
- -Random Recursive
- -Splicing
- -AFL



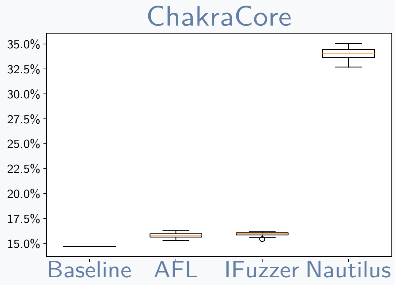
AFL Mutation

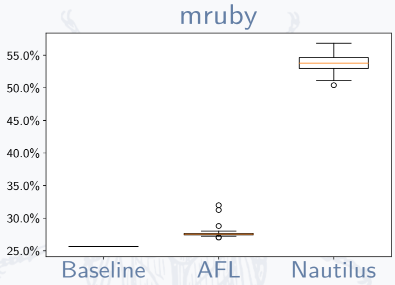
Evaluation

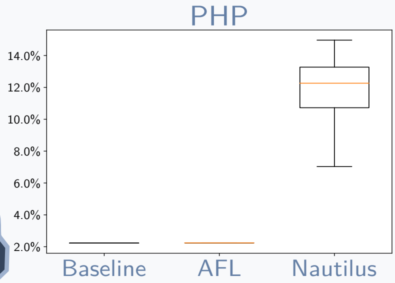
Targets:

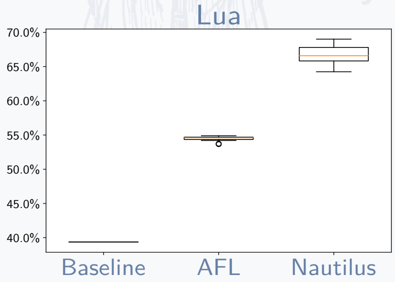
-mruby
-PHP
-lua
-ChackraCore

vs. AFL / IFuzzer

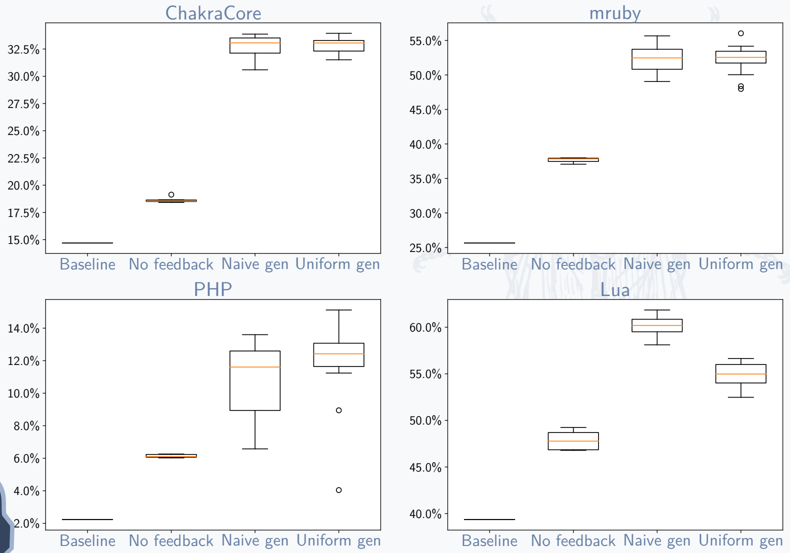


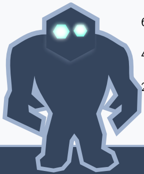


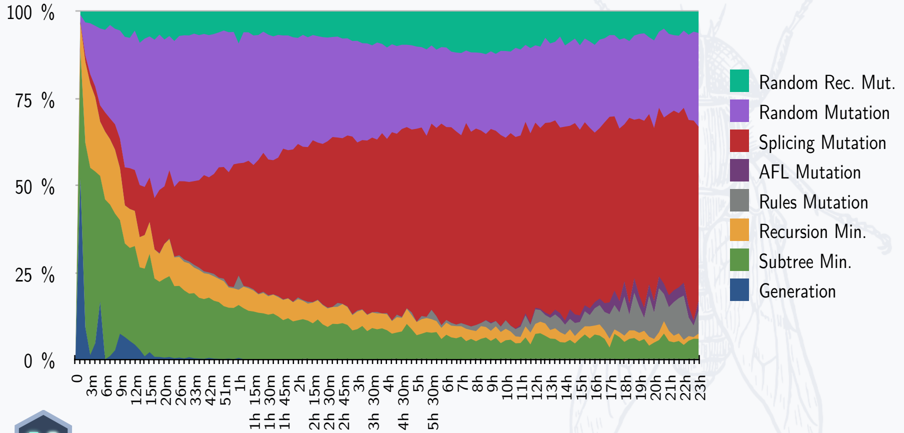




Configurations







100 %
75 %
50 %
25 %
0 %
0
3m
6m
9m
12m
15m
20m
26m
33m
42m
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1h
1h 15m
1h 30m
1h 45m
2h
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16h
17h
18h
19h
20h
21h
22h
23h
Random Rec. Mut.
Random Mutation
Splicing Mutation
AFL Mutation
Rules Mutation
Recursion Min.
Subtree Min.
Generation

```
ObjectSpace.each do |a|
    begin
        a.method(...)
    rescue
    end
end
```

Bugs?

mruby:

- CVE-2018-10191: UAF
- CVE-2018-10199: UAF
- CVE-2018-11743: Use of Uninitialized Pointer
- CVE-2018-12249: SEGV
- CVE-2018-12247: SEGV
- CVE-2018-12248: Heap Buffer Overflow
- Stack Overflow

PHP:

Division by Zero

SEGV

Stack Overflow

PHP:

- Division by Zero
- SEGV
- Stack Overflow

lua:

- UAF

PHP:

- Division by Zero
- SEGV
- Stack Overflow

lua:

- UAF

ChakraCore:

- OOM Crash

Conclusion

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- Grammars & Feedback ++

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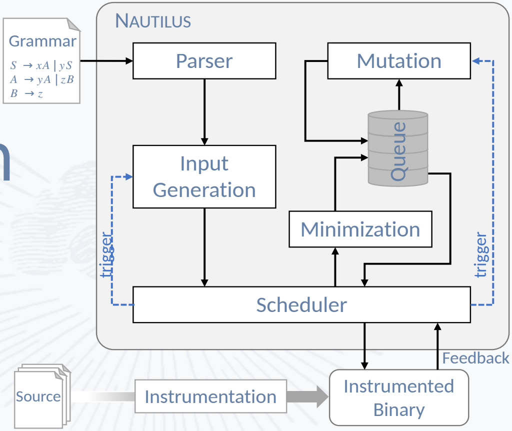
- Grammars & Feedback ++
- Splicing is important!

Overview

Generation

Minimization

Mutations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