NAUTILUS

Fishing for Deep Bugs with Grammars

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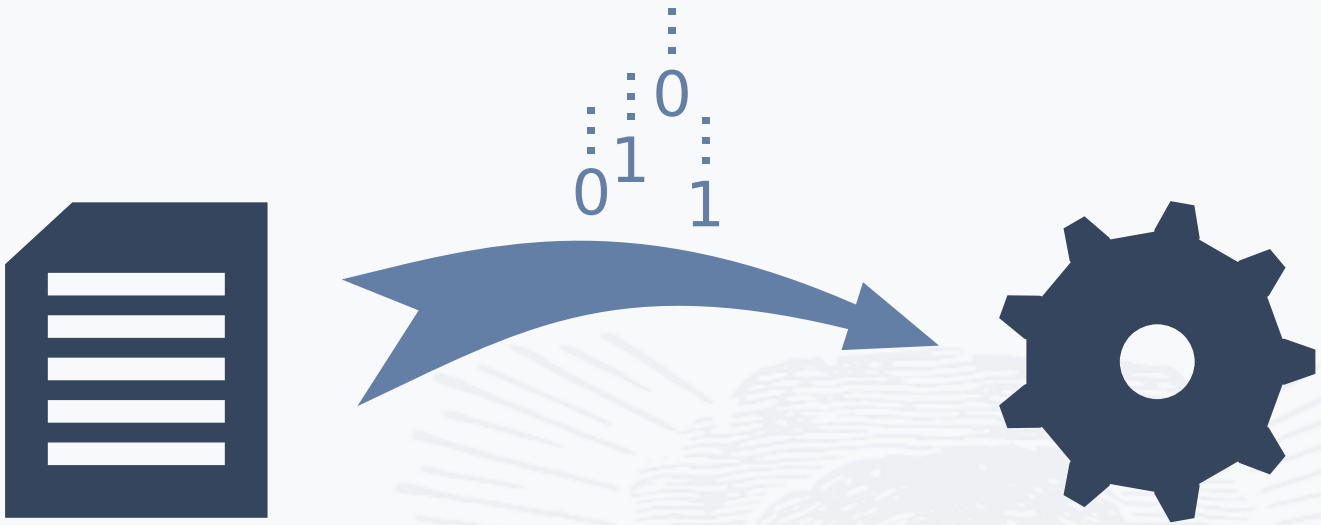
Patrick Jauernig, Ahmad-Reza Sadeghi and Daniel Teuchert
Ruhr-Universität Bochum & Technische Universität Darmstadt

Fuzzing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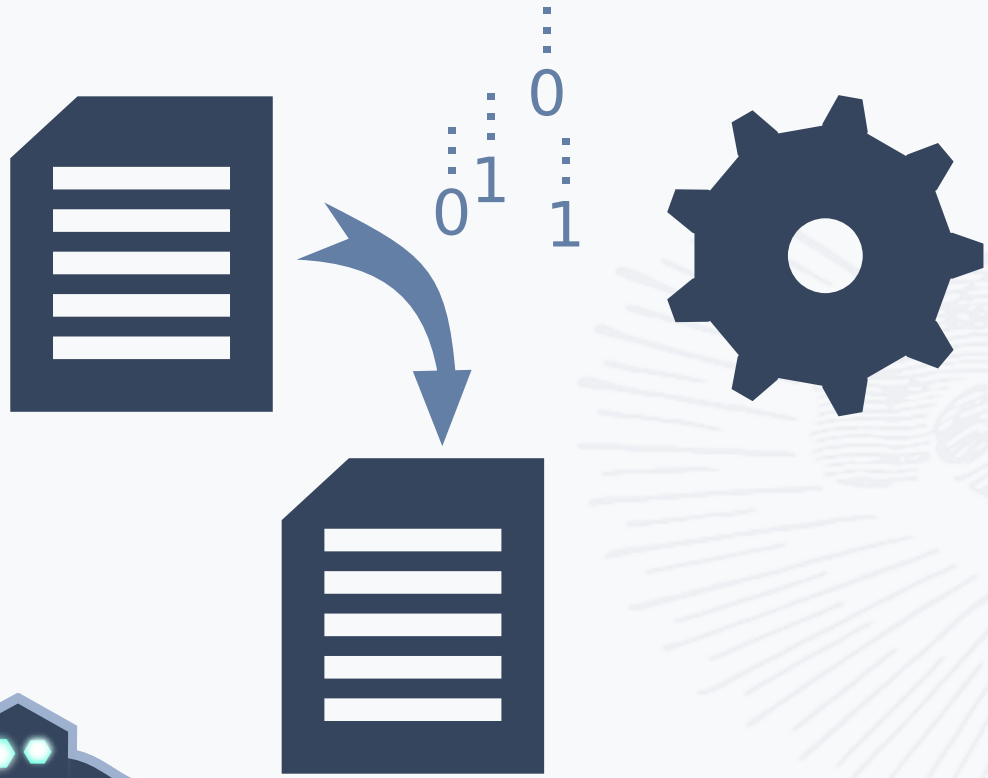
AFL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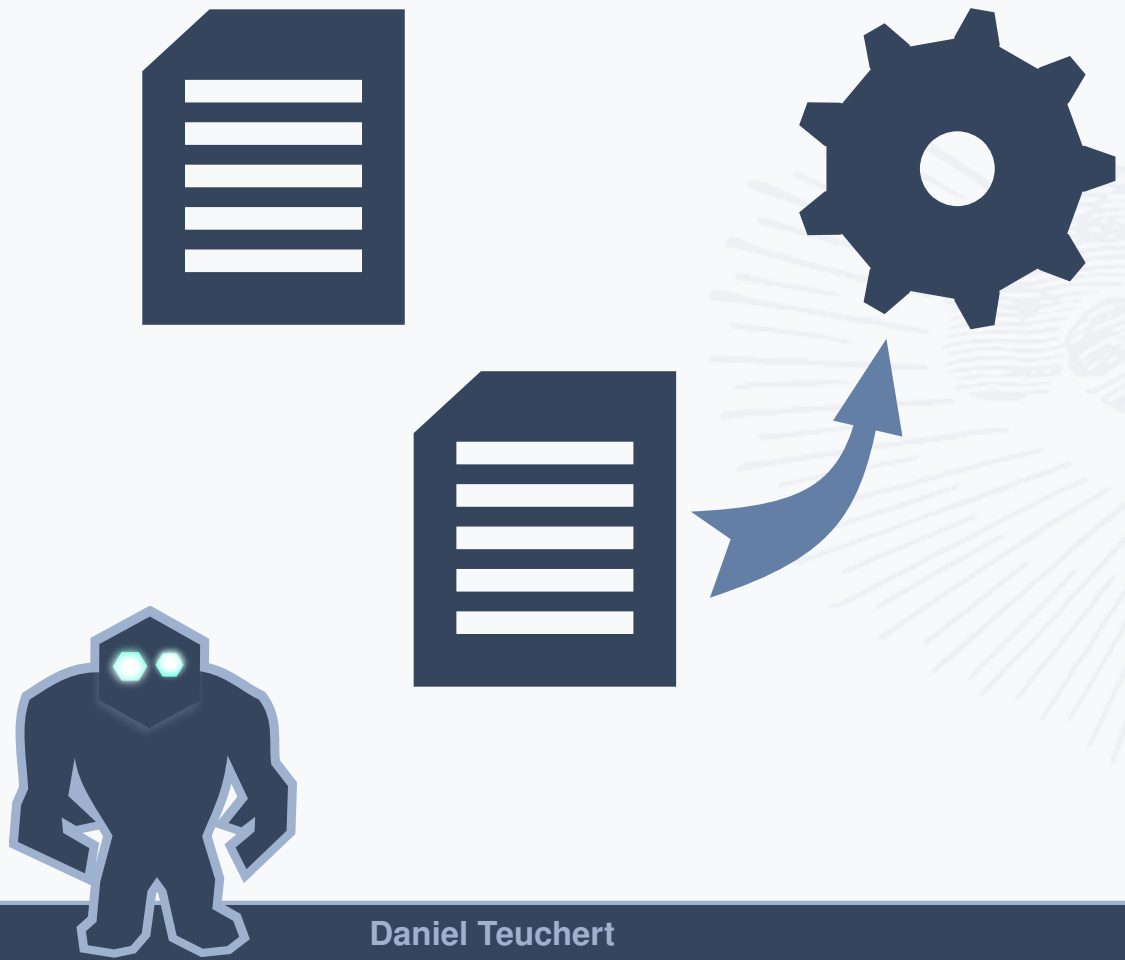

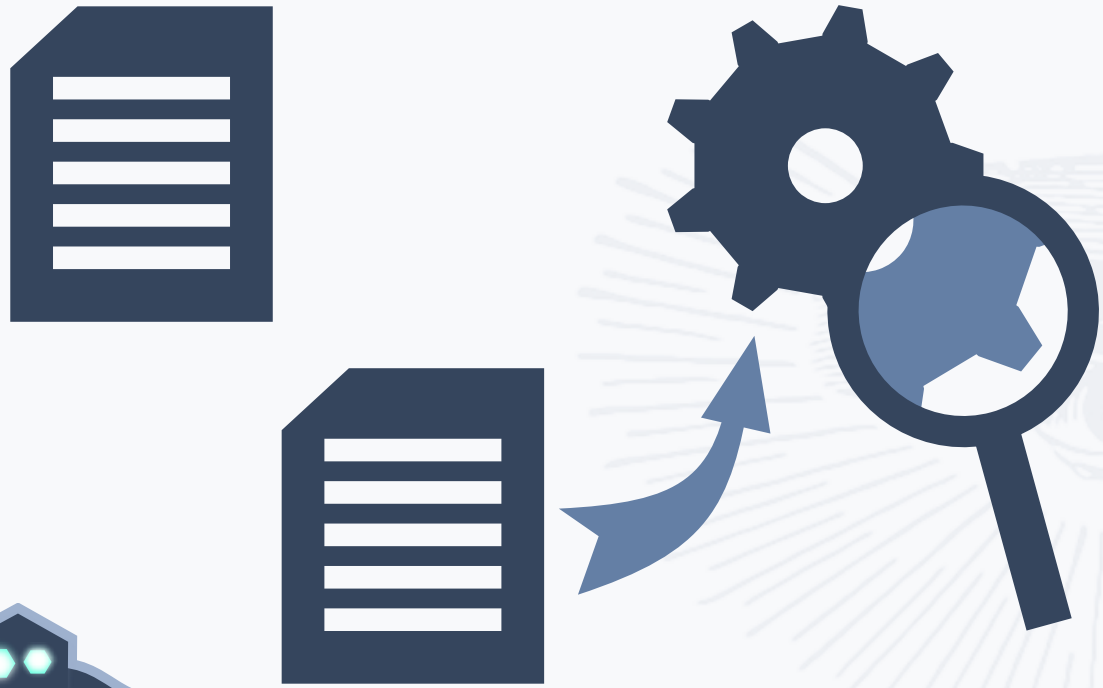

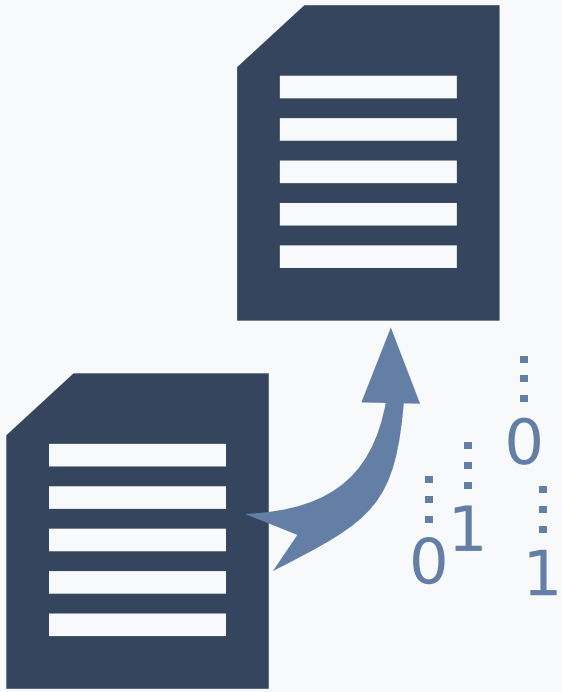
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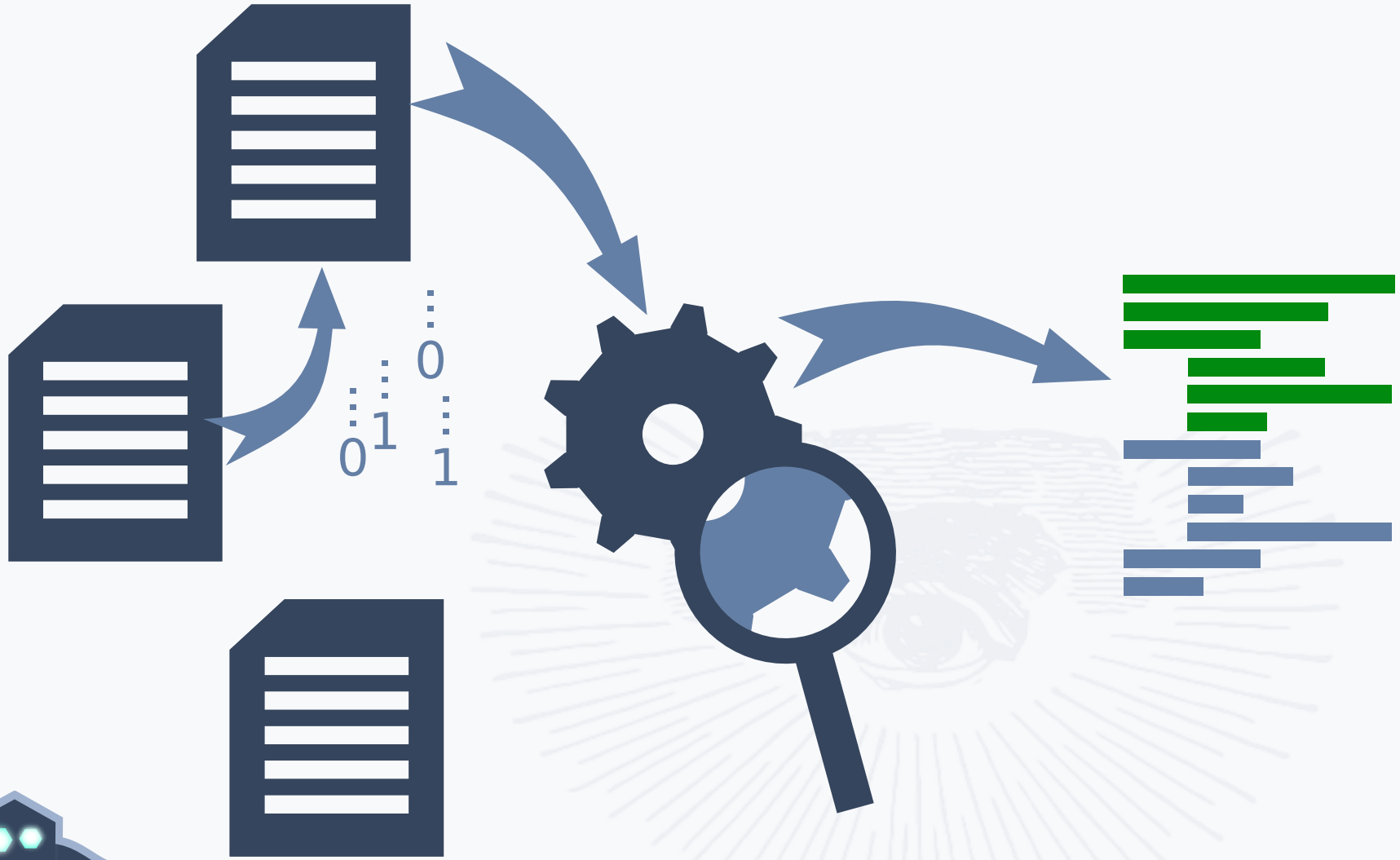
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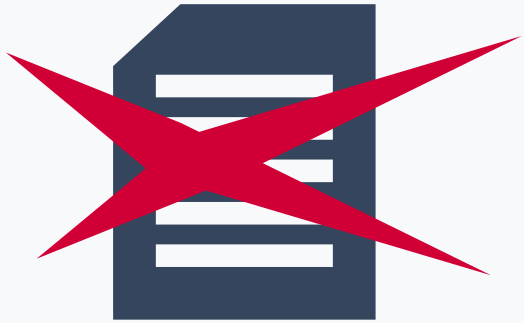

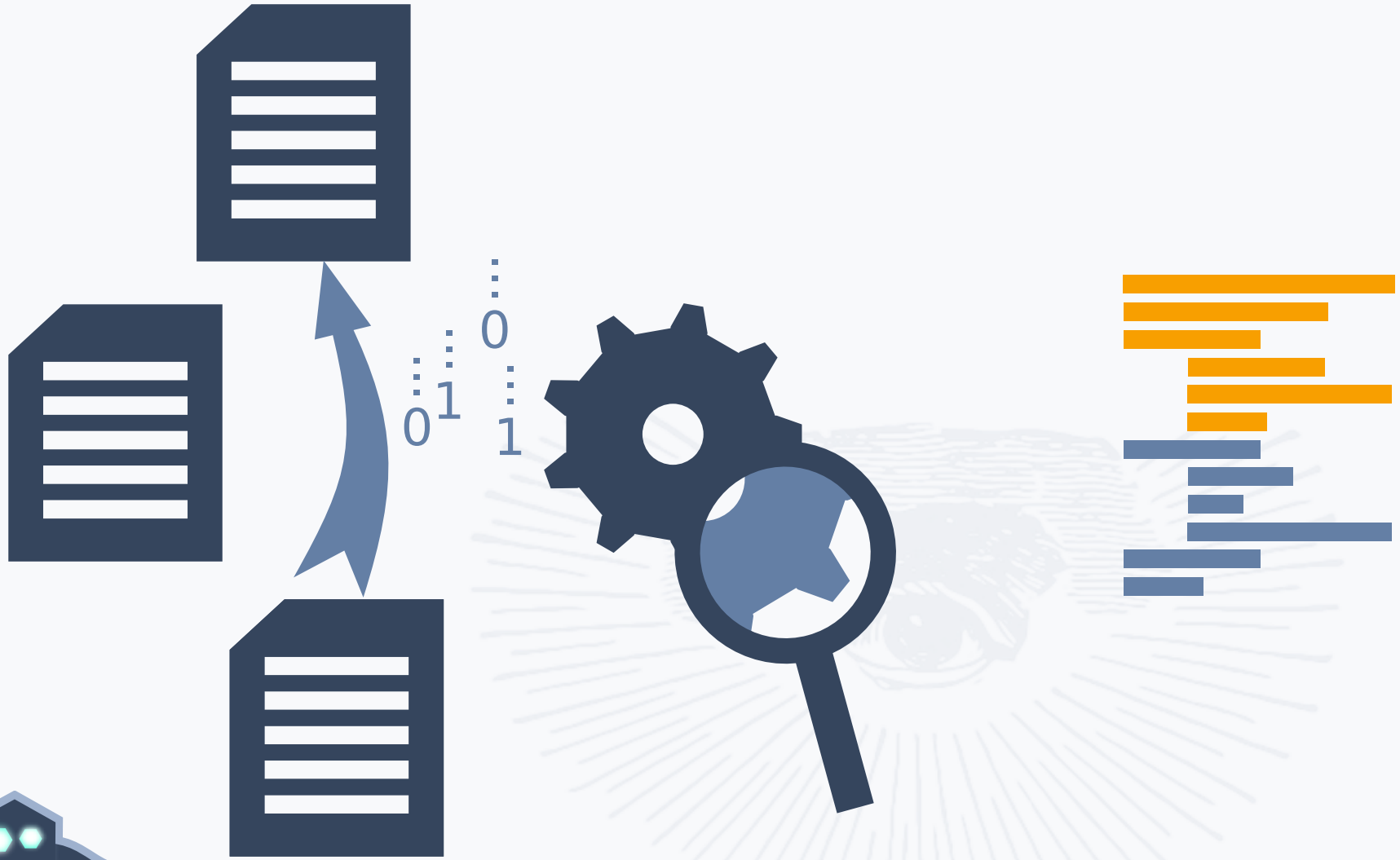
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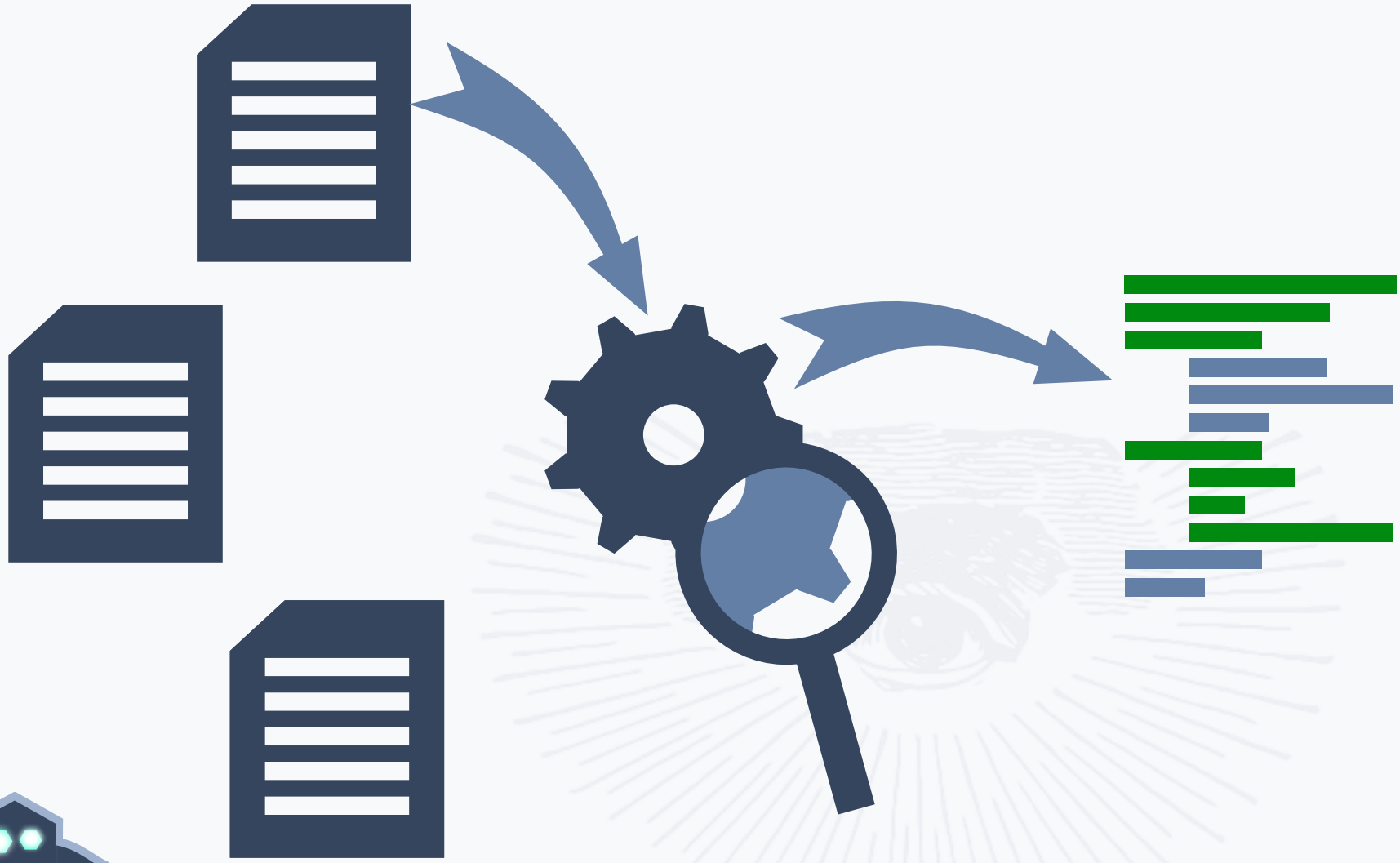

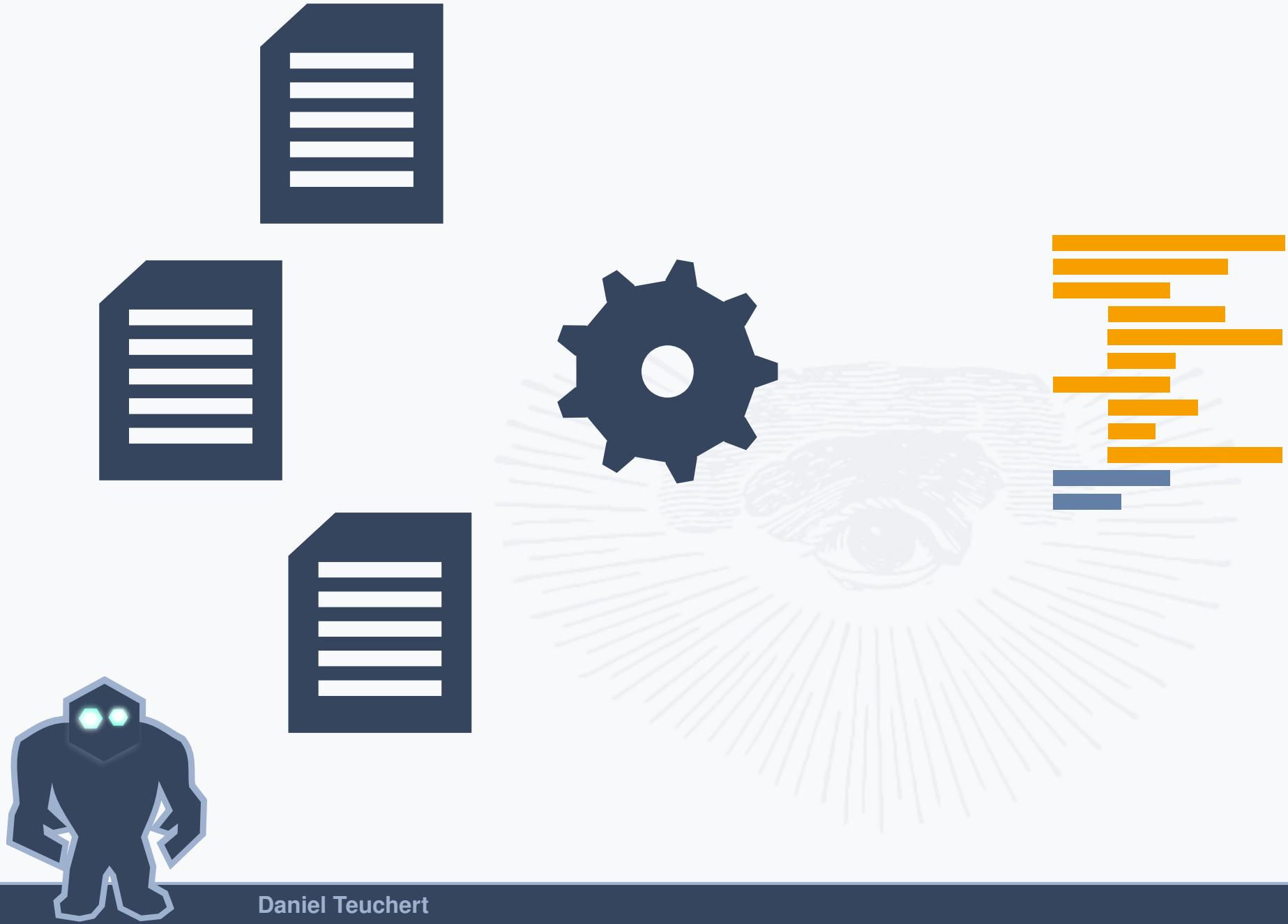

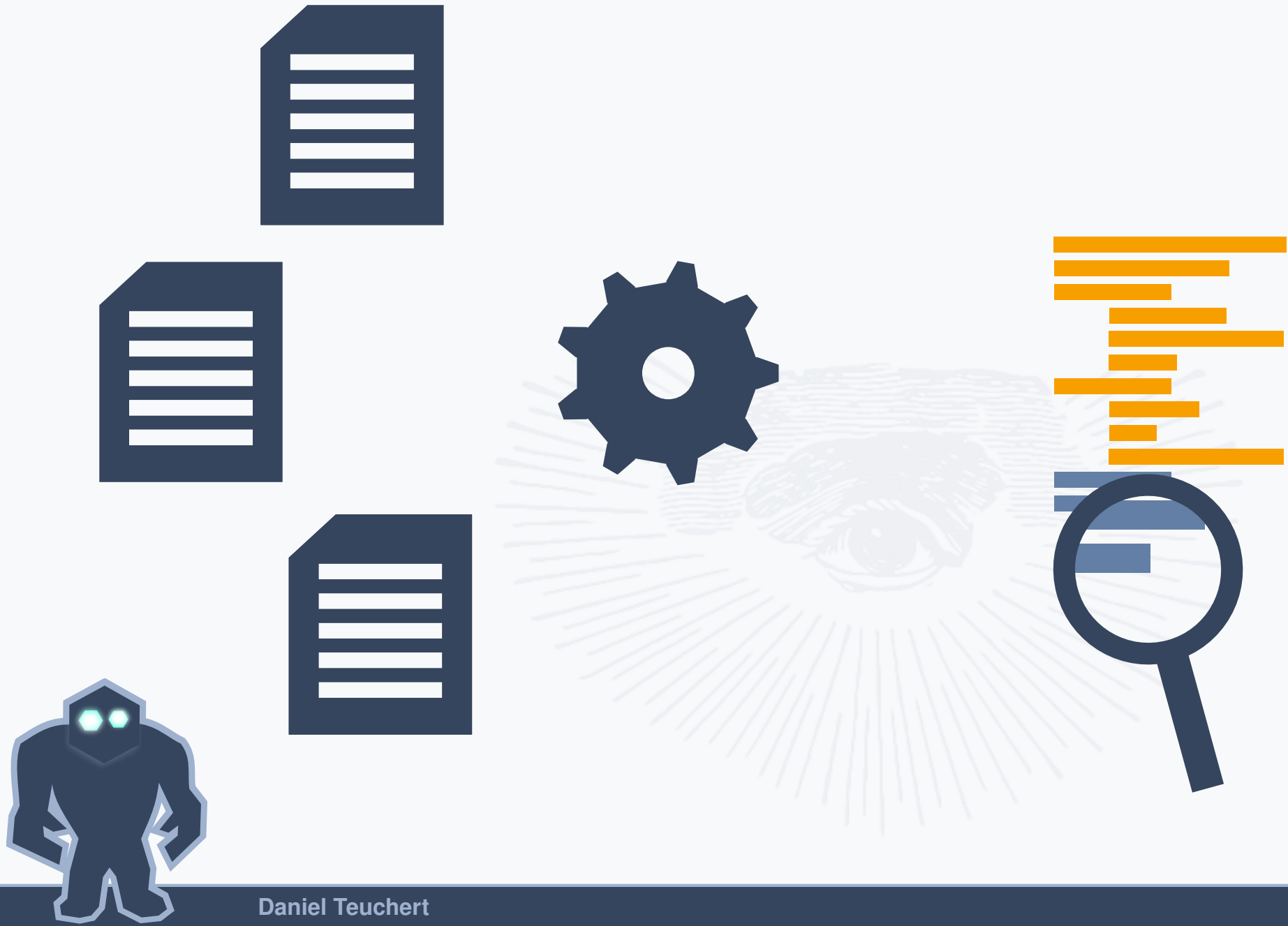

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if !input.parse() {
      exit()
}
```

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if !input.check() {
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do_stuff()
```

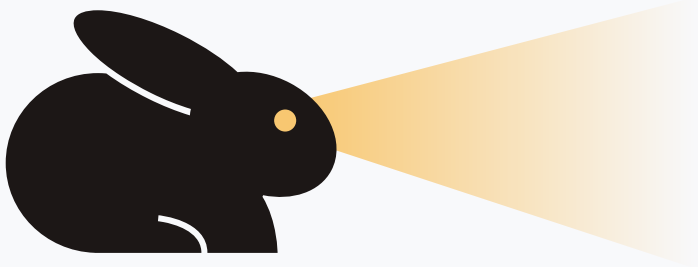

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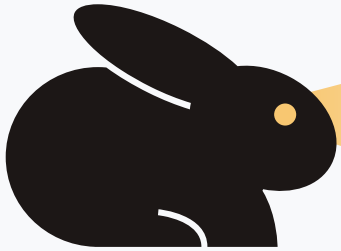

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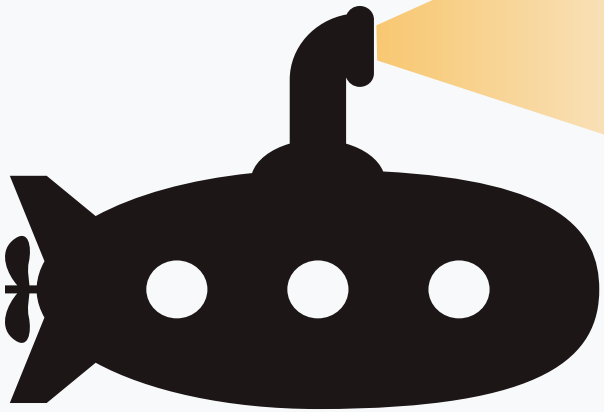

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Grammars
+
Feedback

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

Context-Free Grammars

PROG	→	STMT
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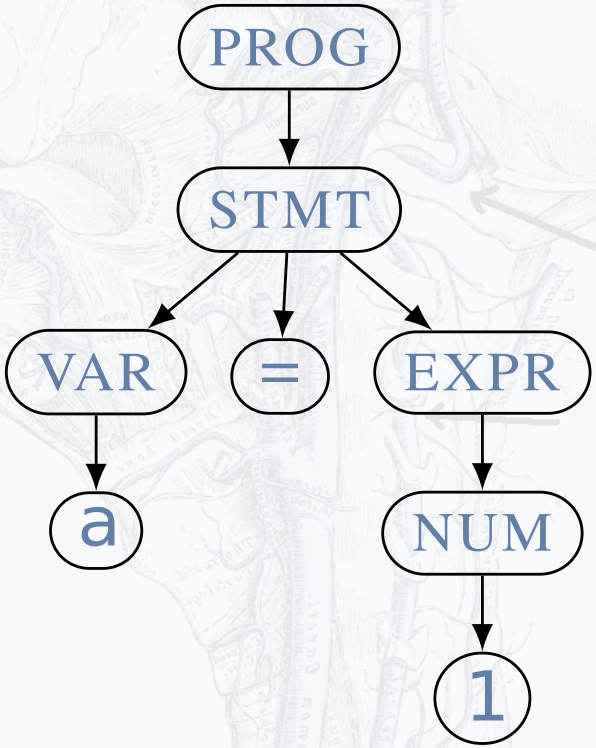

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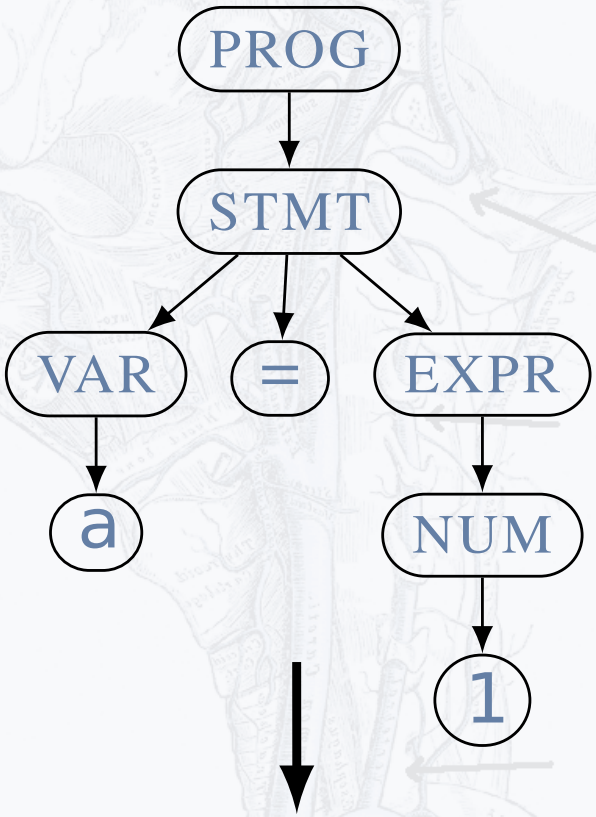
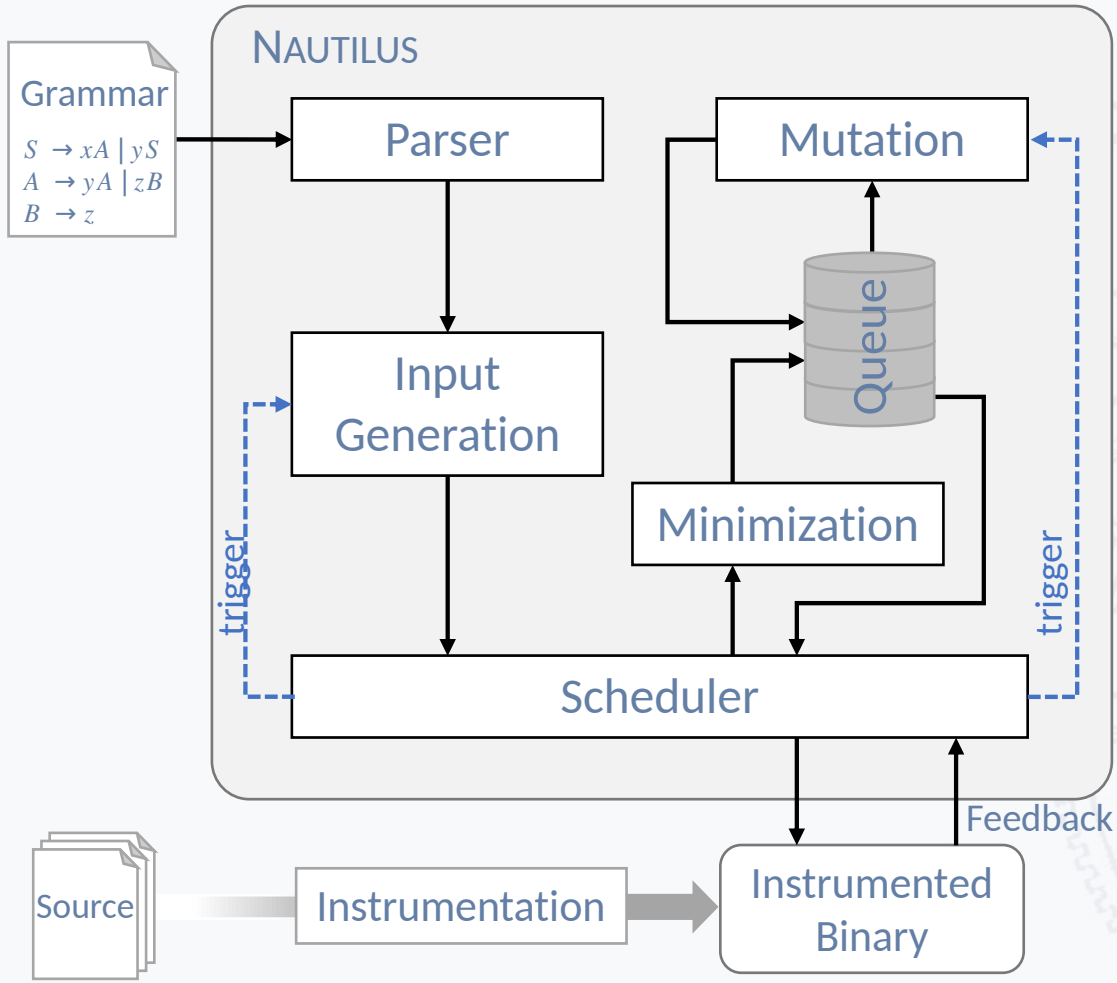
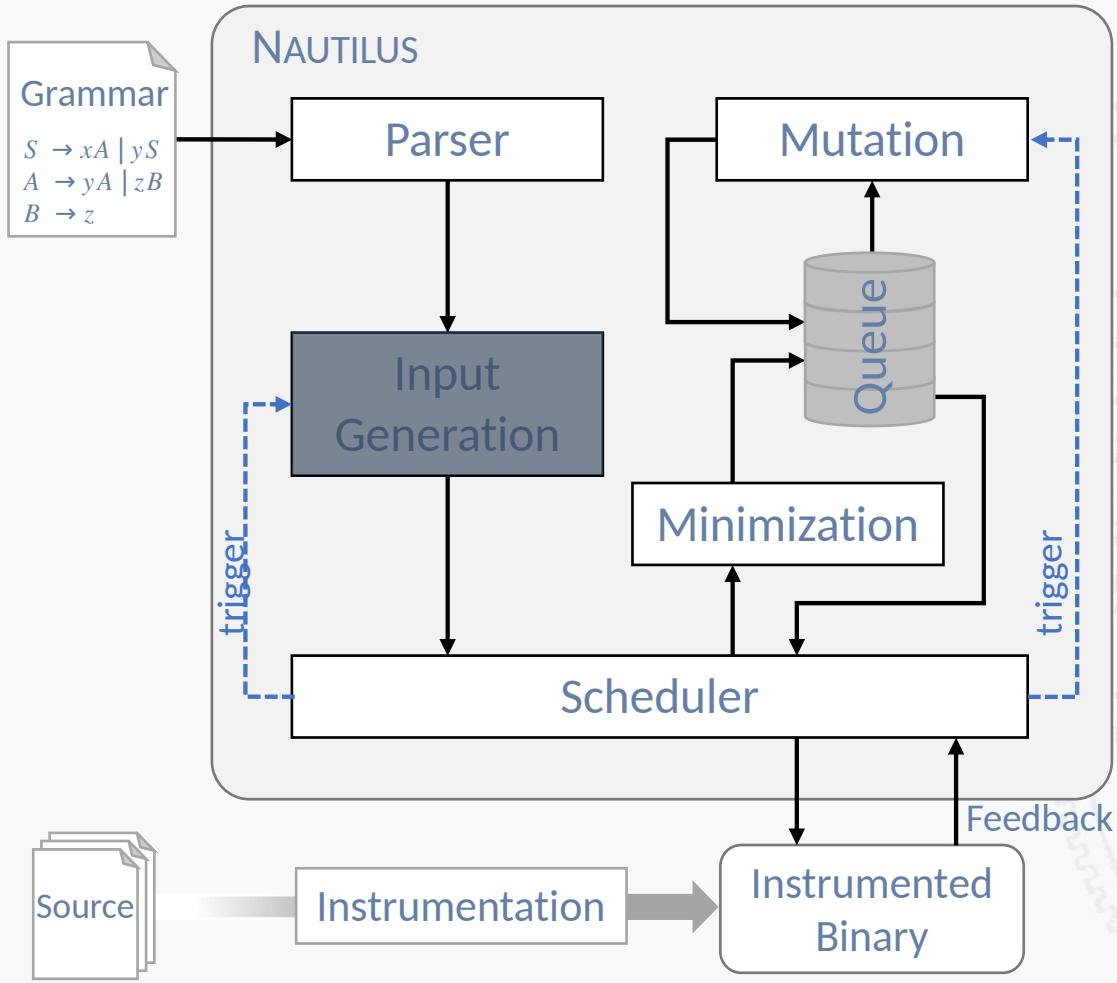


"a=1"

Design of Nautilus

Design of Nautilus




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

Generation:

Generation:

- Naive Generation

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-Naive Generation

PROG	→	STMT
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VAR	→	a
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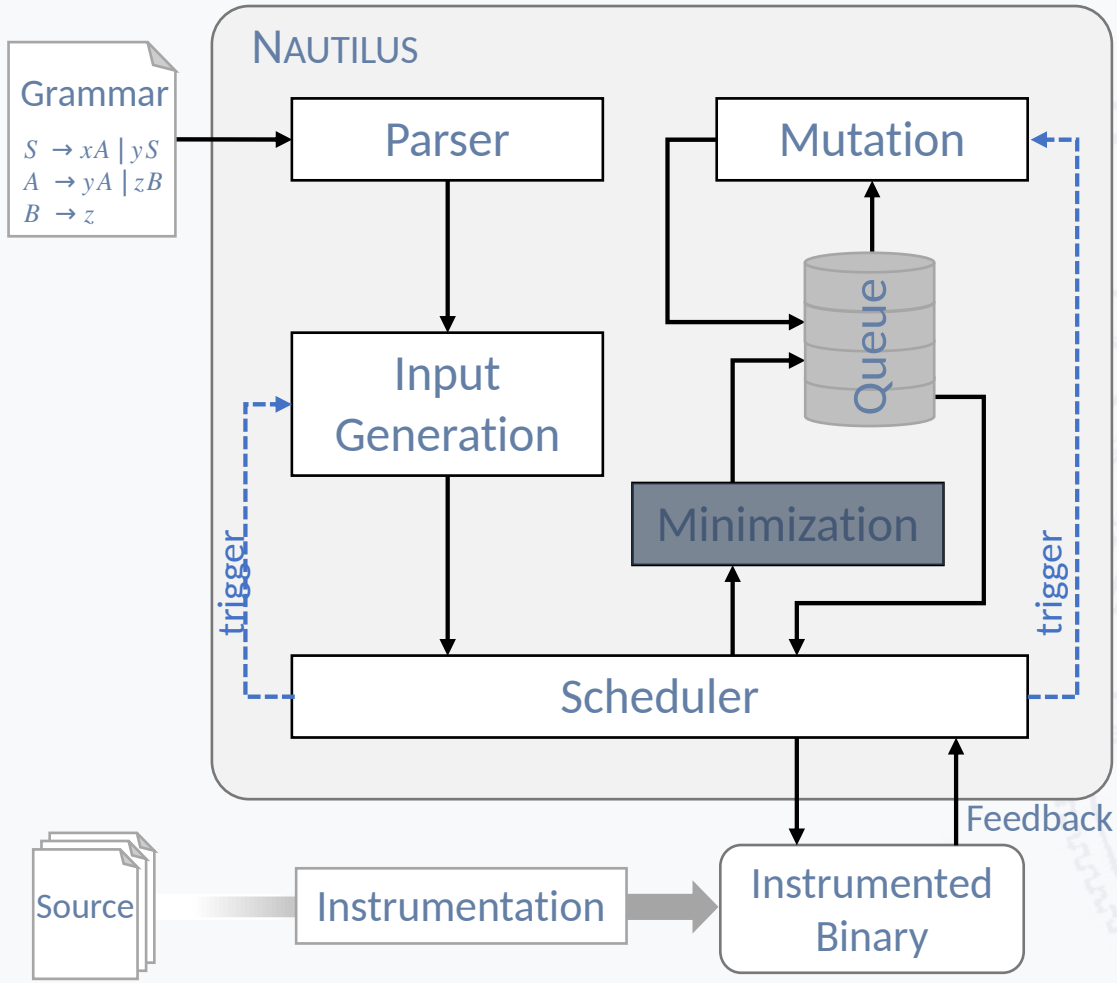
EXPR	→	EXPR + EXPR
NUM	→	1 | 2

Generation:

- -Naive Generation
- -Uniform Generation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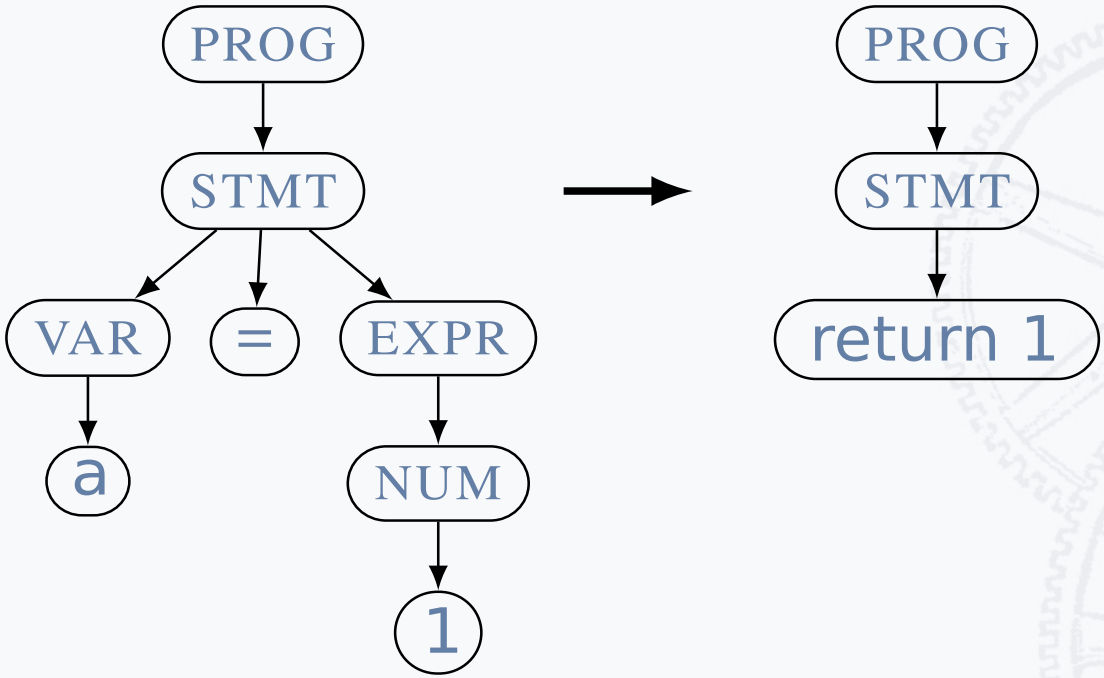
Minimization:

Minimization:

-Subtree Minimization

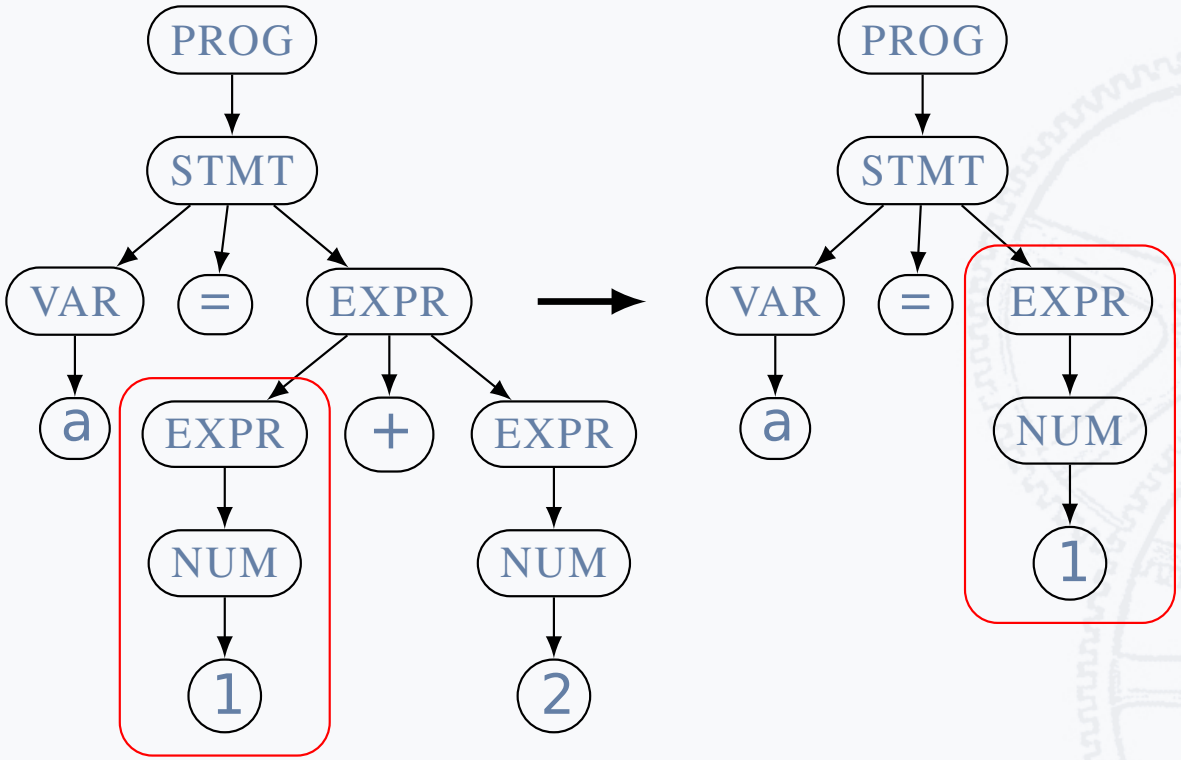


Subtree Minimization

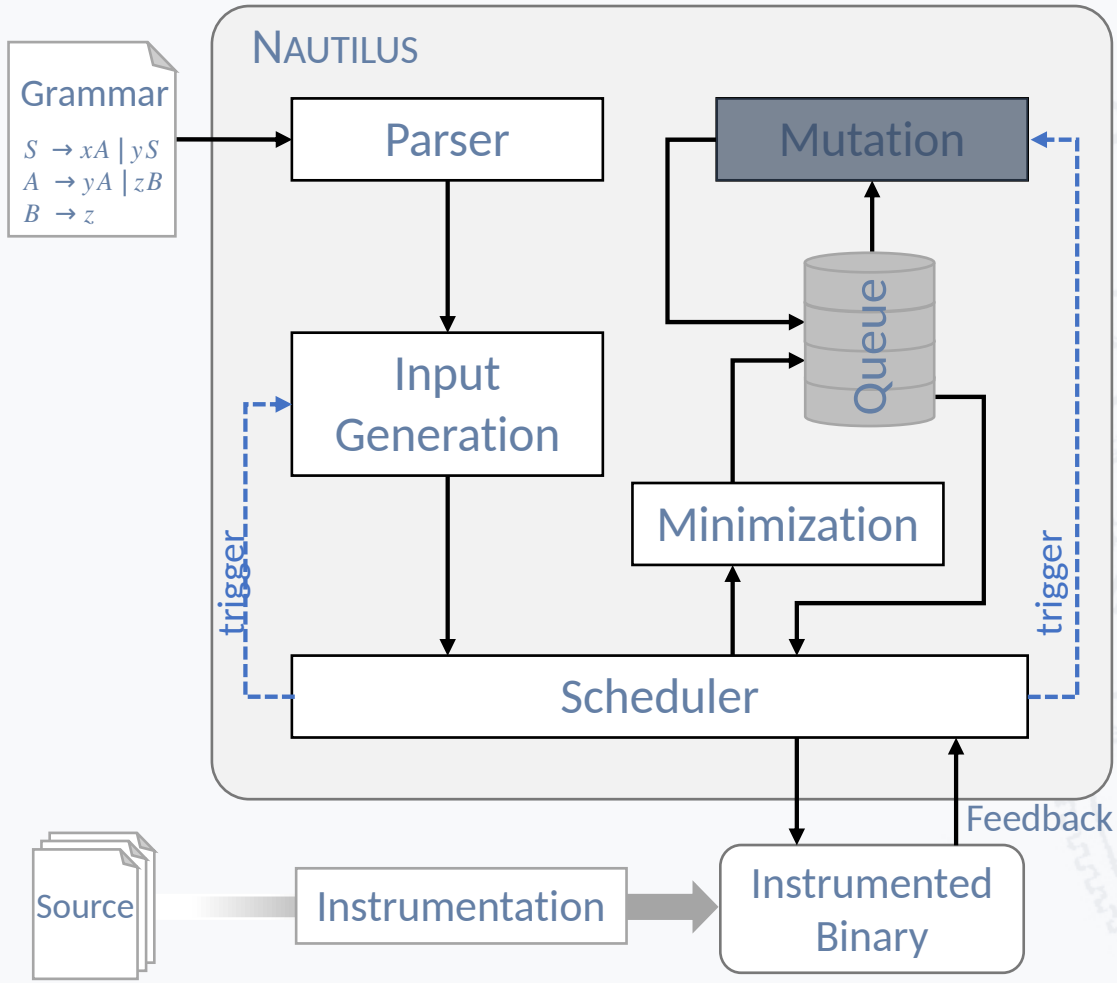
Minimization:

-Subtree Minimization

-Recursion Minimization



Recursive Minimization


NAUTILUS
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$S \rightarrow xA \mid yS$
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Mutation:

Mutation:

-Random

Mutation:

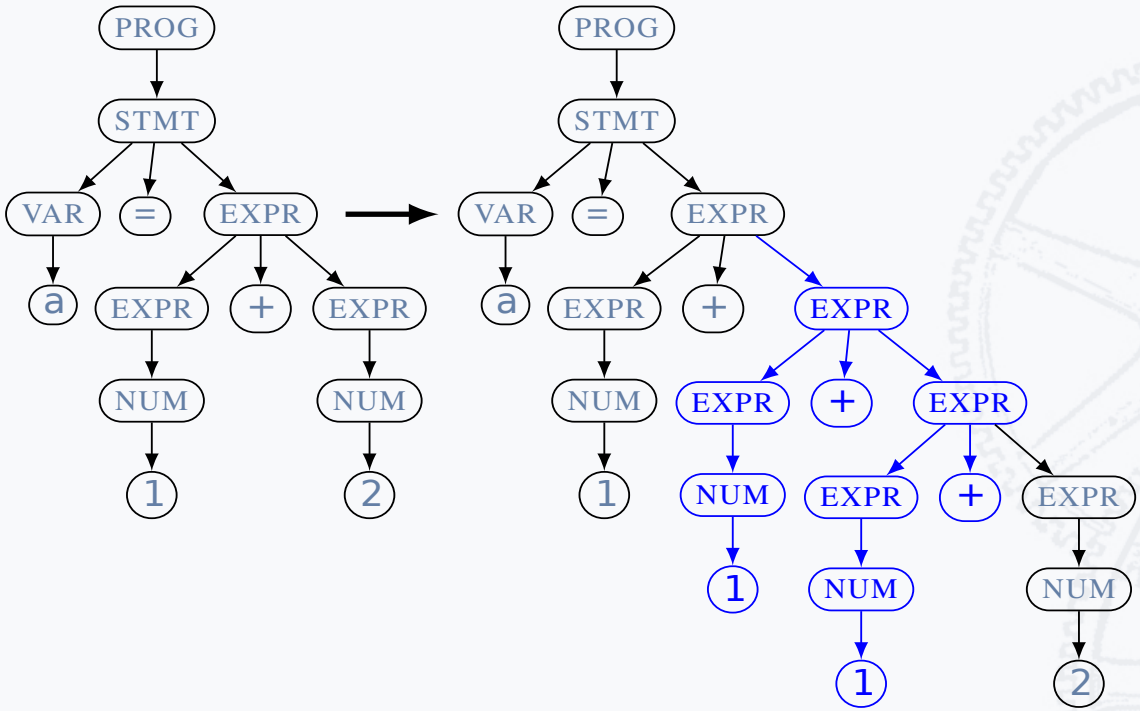
- -Random
- -Rules

Mutation:

-Random

-Rules

-Random Recursive



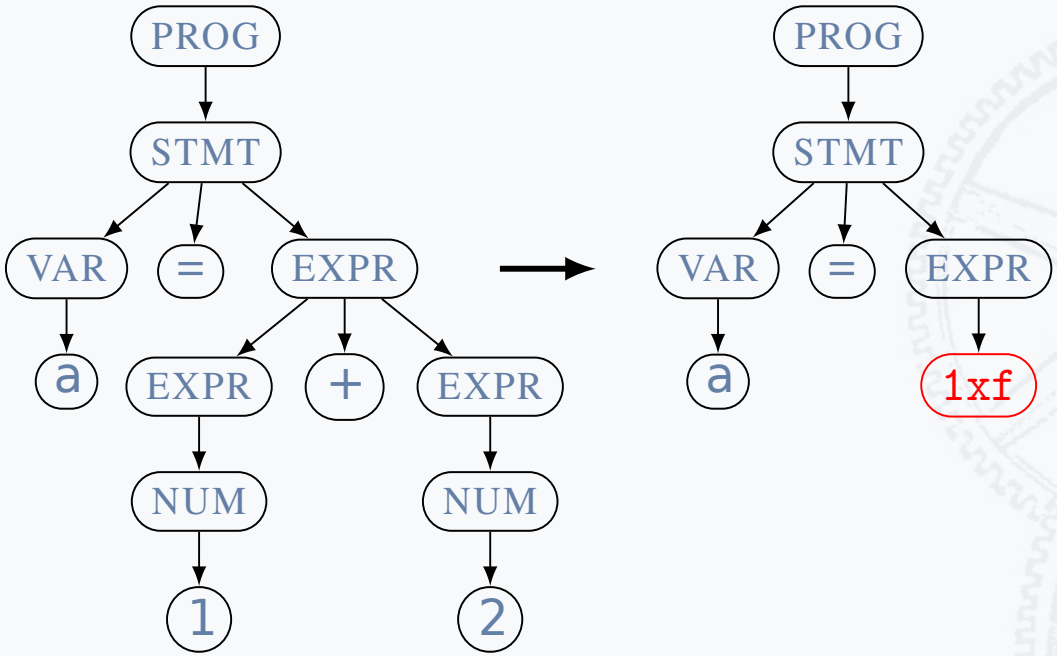
Random Recursive Mutation

Mutation:

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

Mutation:

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



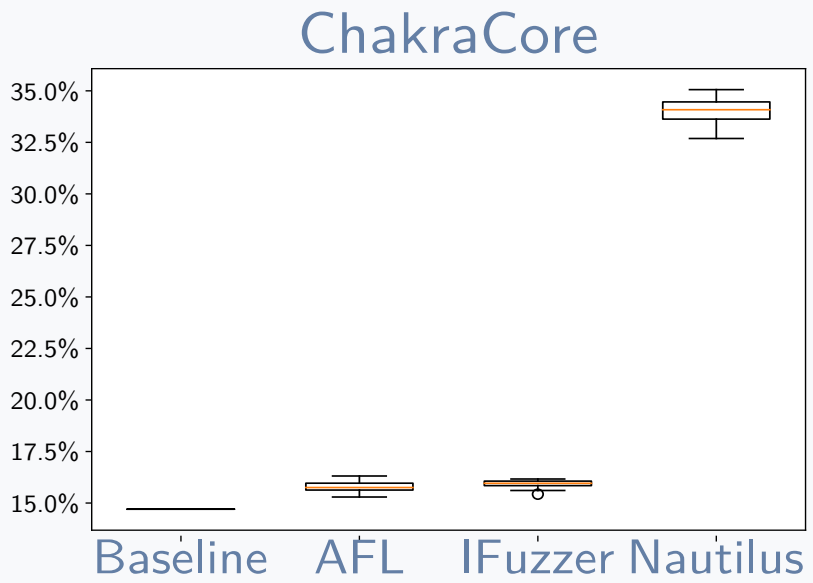
AFL Mutation

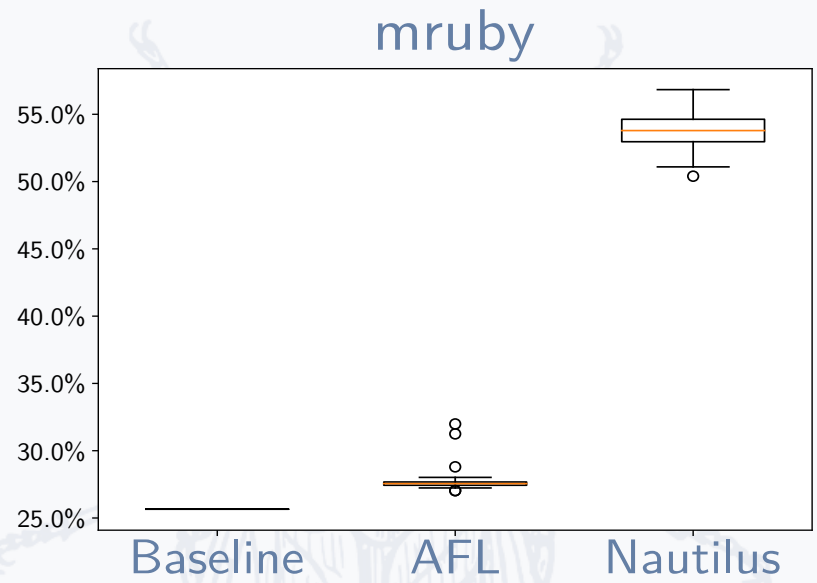
Evaluation

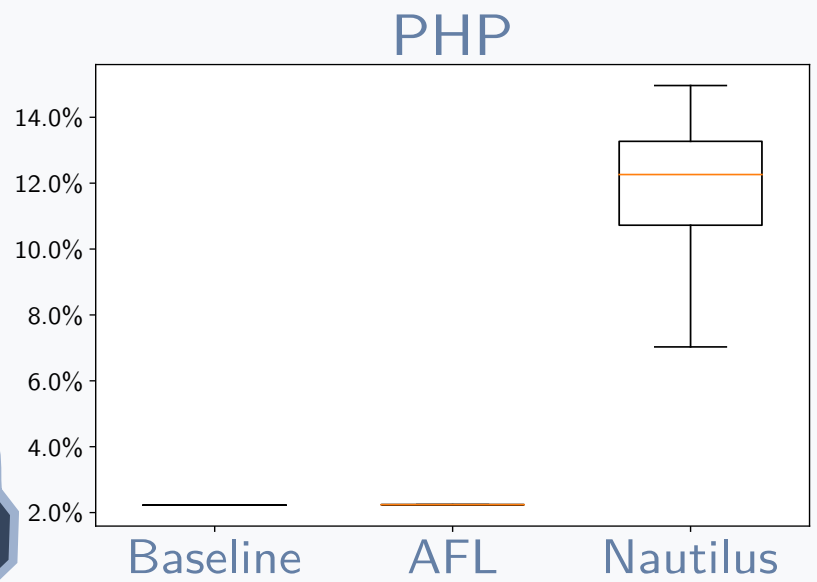
Targets:

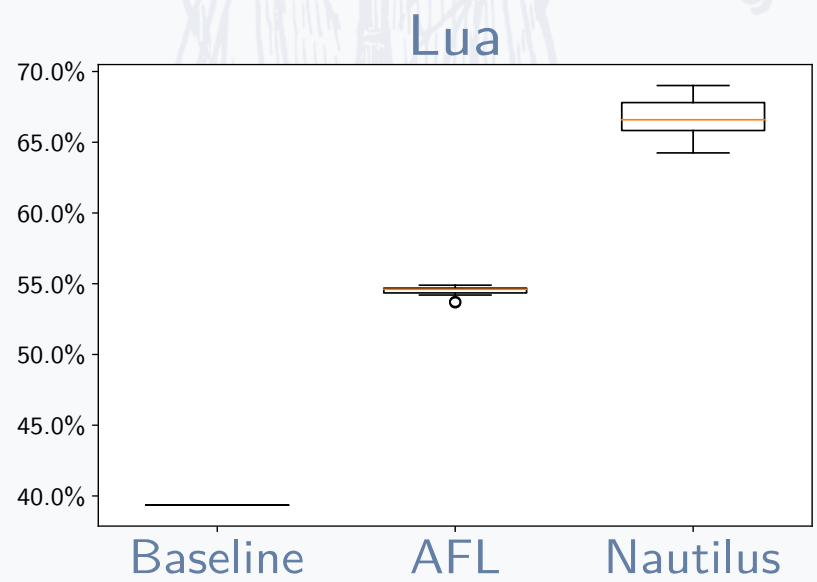
- -mruby
- -PHP
- -lua
- -ChackraCore

vs. AFL / IFuzzer

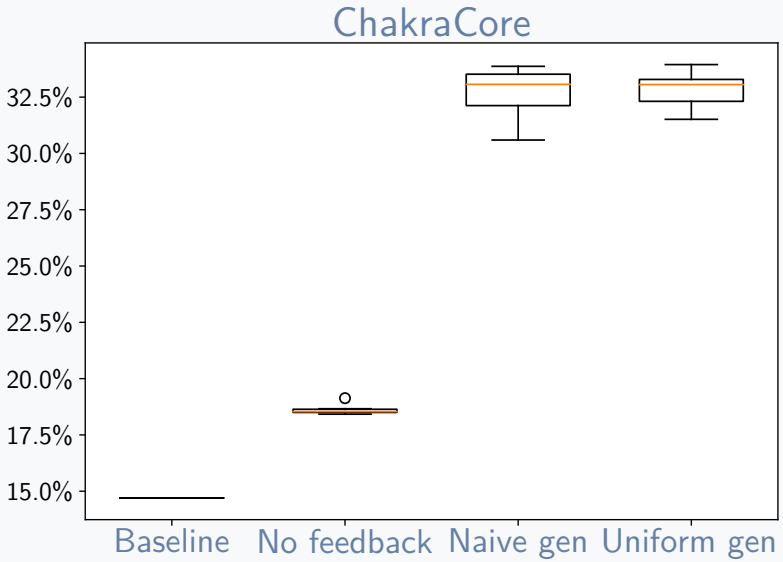


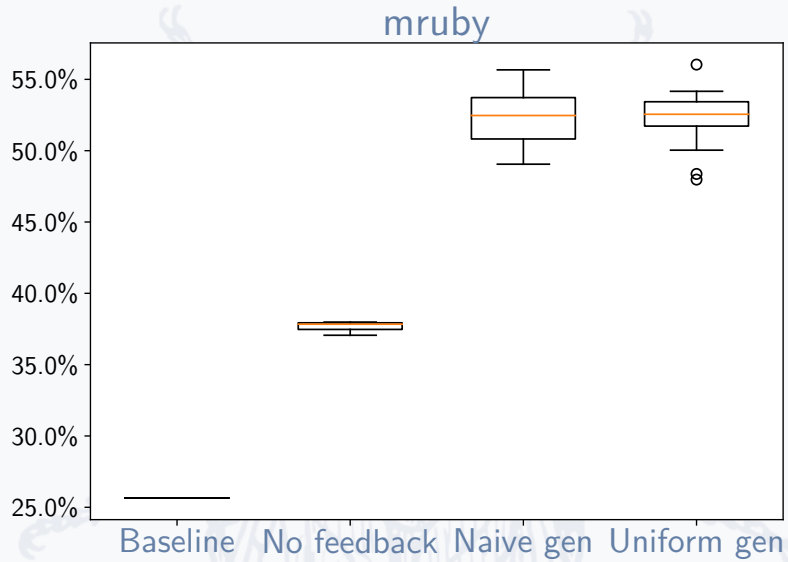


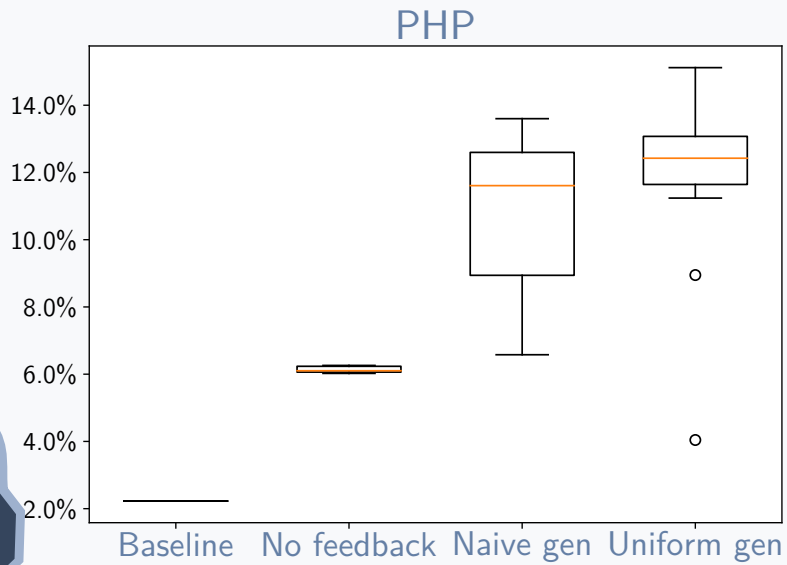


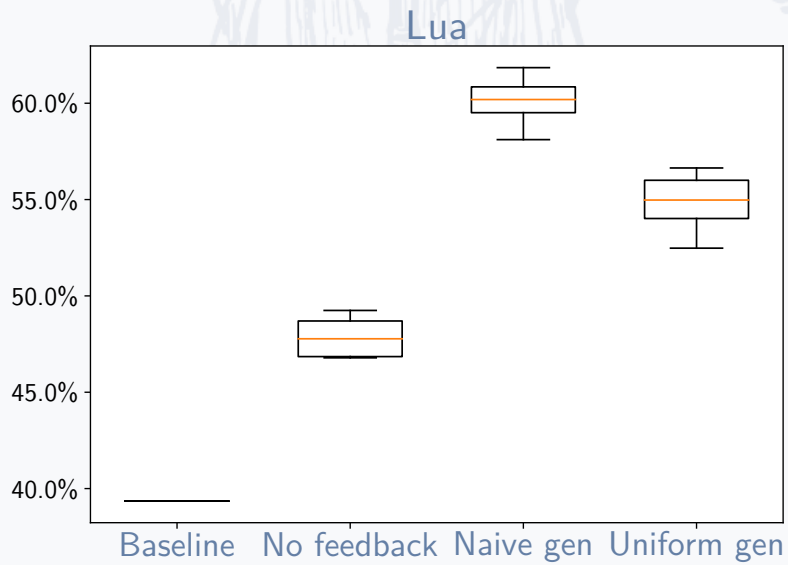


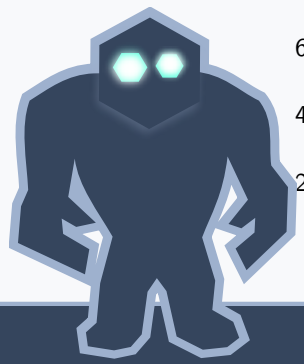
Configurations

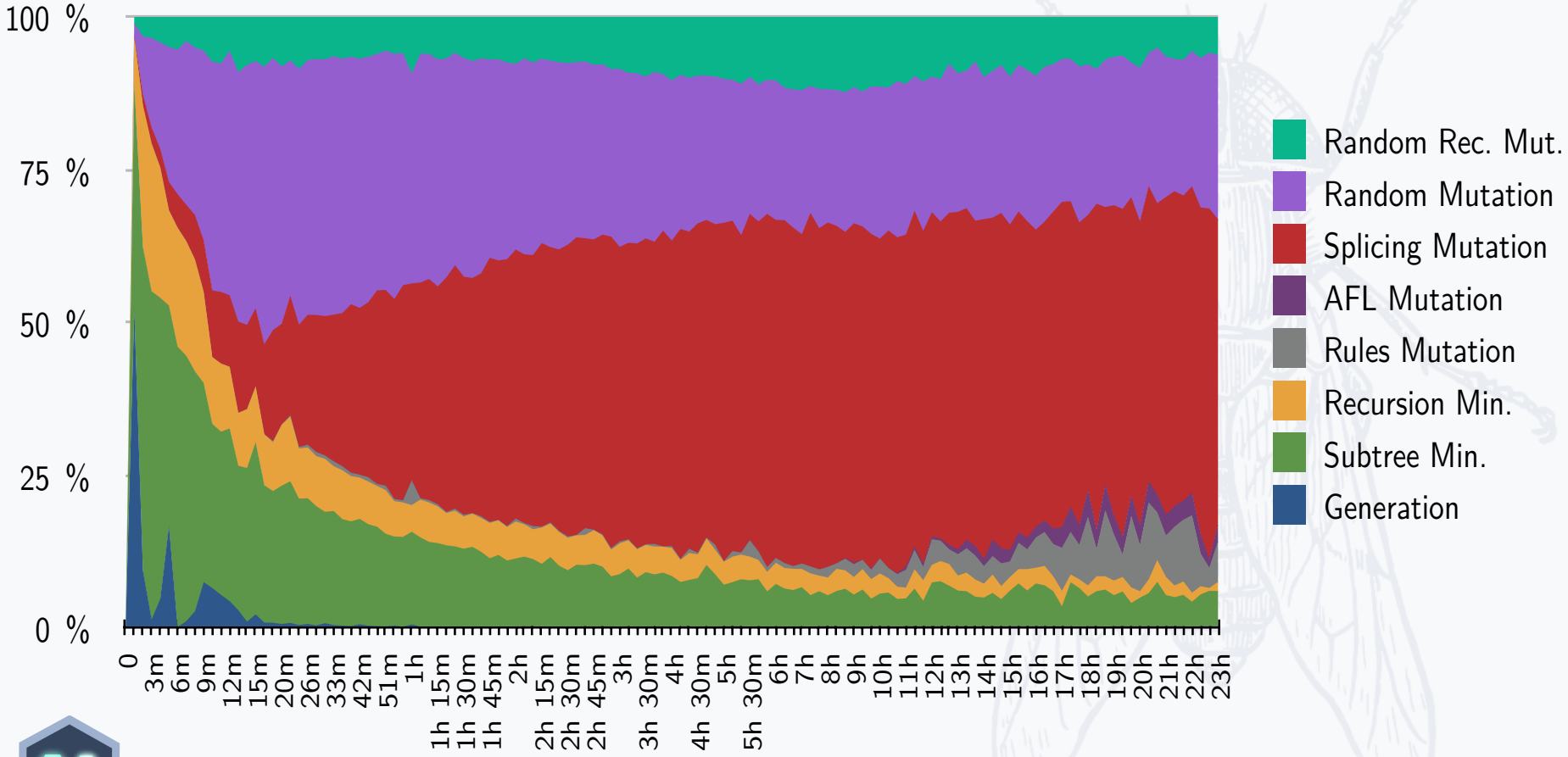








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50 %
25 %
0 %
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6m
9m
12m
15m
20m
26m
33m
42m
51m
1h
1h 15m
1h 30m
1h 45m
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17h
18h
19h
20h
21h
22h
23h
Random Rec. Mut.
Random Mutation
Splicing 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

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- Division by Zero
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lua:

- UAF

PHP:

- Division by Zero
- SEGV
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lua:

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ChakraCore:

- OOM Crash

Conclusion

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- Grammars & Feedback ++

Conclusion

- Grammars & Feedback ++
- Splicing is important!

Overview

Generation

Minimization

Mutations