Code-Analyse und Grammar-based Fuzzing

An Unholy Alliance

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FFG Forschung wirkt.

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Bundesministerium Verkehr, Innovation und Technologie

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Warum eigentlich Fuzzing?

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Bye-bye bugs

Over 16,000 bugs later, Google's fuzz tester is now open source

February 11, 2019 Sarah Schlothauer

Twitter Facebook Google+

Billions and Billions
Whitebox Fuzz Testi

Ella Bounimova
Microsoft Research, USA

Patrice Go
Microsoft Res

Abstract—We report experiences with constraint-based white-box fuzz testing in production across hundreds of large Windows applications and over 500 machine years of computation from 2007 to 2013. Whitebox fuzzing leverages symbol
on binary traces and constraint solvi
to a program. These i
solved with a *constrai*
to new i

acmqueue

SAGE: Whitebox Fuzzing for Security Testing

SAGE has had a remarkable impact at Microsoft.

Godefroid, Michael Y. Levin, David Molnar, Microsoft

m verification research" as mostly theoretical with
lines on a PC running some

ZDNet

Researchers find 36 new security flaws in LTE protocol

South Korean researchers apply fuzzing techniques to LTE protocol and find 51 vulnerabilities, of which 36 were new.

By Catalin Cimpanu for Zero Day | March 23, 2019 -- 08:00 GMT (08:00 GMT) | Topic: Security

MIDDLE EAST SCANDINAVIA AFRICA UK ITALY SPAIN MORE NEWSLETTERS ALL W

Security

Hot fuzz: Bug detectives whip up smarter version of classic AFL fuzzer to hunt code vulnerabilities

Flaw-spotting toolkit already has 42 zero-days to its name

By Shaun Nichols in San Francisco 28 Nov 2018 at 08:03 3 SHARE ▼

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Fuzzing Success Stories

AFL	compile-time instrumentation, genetic algorithms	Vulnerabilities in Firefox, IE, Safari, Adobe Flash, sqlite, OpenSSL, LibreOffice, OpenSSH, PuTTY, tcpdump, JavaScript, Wireshark, Android, iOS, LLVM, Perl, VLC, Adobe Reader, Tor, MySQL, Linux Kernel, ... [1]
ClusterFuzz	Highly scalable (~25000 cores), Support for AFL and libFuzzer	~16,000 Bugs in Chrome, ~11,000 Bugs in Open Source Projects [2]
libFuzzer	coverage guided mutation	Vulnerabilities in SQLite, Python, OpenSLL, Linux Kernel, LLVM, Tensorflow, Wireshark, and more ... [3]
langfuzz	grammar-based code generation & code mutation	~4000 Bugs in JavaScript interpreter, 105 Vulnerabilities in Firefox [4]

[1] http://lcamtuf.coredump.cx/afl/
[2] https://google.github.io/clusterfuzz/
[3] http://llvm.org/docs/LibFuzzer.html
[4] https://issta2016.cispa.saarland/interview-with-christian-holler/

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Was passiert eigentlich beim Fuzzing?

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Beispiel: Expression Parser

Parser für einfache mathematische Ausdrücke

```
> expr 3
1
> expr 3 + 2
3
> expr (3 + 2) * 5
7
> expr (3 + 2) * 5 - 2)
-1
...
```

```java
public class ExprParser {

    public static int parse(char[] in) {

        int pos = expr(0, in);
        if (pos < in.length) {
            syntaxError("End of input", pos);
            pos = -1;
        }
        return pos;
    }

    public static int expr(int pos, char[] in) {
        pos = term(pos, in);
        if (pos == -1)
            return pos;
        if (pos == in.length)
            return pos;

        if (in[pos] == '+') {
            pos++;
            pos = term(pos, in);
        } else if (in[pos] == '-') {
            pos++;
            pos = term(pos, in);
        }

        return pos;
    }

    public static int term(int pos, char[] in) {
        pos = factor(pos, in);
        if (pos == -1)
            return pos;
        if (pos == in.length)
            return pos;

        if (in[pos] == '*') {
            pos++;
            pos = factor(pos, in);
        } else if (in[pos] == '/') {
            pos++;
            pos = factor(pos, in);
        }

        return pos;
    }
```

```java
    public static int factor(int pos, char[] in) {
        if (pos == in.length)
            return -1;

        if (in[pos] == '1')
            return pos + 1;
        if (in[pos] == '2')
            return pos + 1;
        if (in[pos] == '3')
            return pos + 1;
        if (in[pos] == '(') {
            pos++;
            pos = expr(pos, in);
            if (pos == -1)
                return pos;
            if (pos == in.length)
                return -1;
            if (in[pos] == ')') {
                pos++;
                return pos;
            } else {
                syntaxError("invalid factor ", pos);
            }
        }
        return -1;
    }

    public static void syntaxError(String msg, int pos) {
        final boolean log = false;
        if (log) {
            System.out.print("Syntax error ");
            System.out.print(msg);
            System.out.print(" col: ");
            System.out.println(pos);
        }
    }
}
```

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Beispiel: Expression Parser

Random Fuzzing

Input	k3iou5j
Code Coverage	37,8%

```
5  public class ExprParser {
6
7      public static int parse(char[] in) {
8
9          int pos = expr(0, in);
10         if (pos < in.length) {
11             syntaxError("End of input", pos);
12             pos = -1;
13         }
14         return pos;
15     }
16
17     public static int expr(int pos, char[] in) {
18         pos = term(pos, in);
19         if (pos == -1)
20             return pos;
21         if (pos == in.length)
22             return pos;
23
24         if (in[pos] == '+') {
25             pos++;
26             pos = term(pos, in);
27         } else if (in[pos] == '-') {
28             pos++;
29             pos = term(pos, in);
30         }
31
32         return pos;
33     }
34
35     public static int term(int pos, char[] in) {
36         pos = factor(pos, in);
37         if (pos == -1)
38             return pos;
39         if (pos == in.length)
40             return pos;
41
42         if (in[pos] == '*') {
43             pos++;
44             pos = factor(pos, in);
45         } else if (in[pos] == '/') {
46             pos++;
47             pos = factor(pos, in);
48         }
49
50         return pos;
51     }
```

```
53     public static int factor(int pos, char[] in) {
54         if (pos == in.length)
55             return -1;
56
57         if (in[pos] == '1')
58             return pos + 1;
59         if (in[pos] == '2')
60             return pos + 1;
61         if (in[pos] == '3')
62             return pos + 1;
63         if (in[pos] == '(') {
64             pos++;
65             pos = expr(pos, in);
66             if (pos == -1)
67                 return pos;
68             if (pos == in.length)
69                 return -1;
70             if (in[pos] == ')') {
71                 pos++;
72                 return pos;
73             } else {
74                 syntaxError("invalid factor ", pos);
75             }
76         }
77         return -1;
78     }
79
80     public static void syntaxError(String msg, int pos) {
81         final boolean log = false;
82         if (log) {
83             System.out.print("Syntax error ");
84             System.out.print(msg);
85             System.out.print(" col: ");
86             System.out.println(pos);
87         }
88     }
89 }
```

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Beispiel: Expression Parser

Random Fuzzing

Input	k3iou5j
Code Coverage	37,8%

Grammar-based Fuzzing

S	=	**Expr**
Expr	=	**Term** [("+" | "-") **Term**]
Term	=	**Factor** [("*" | "/") **Factor**]
Factor	=	"*1*" | "*2*" | "*3*" | "*(*" **Expr** "*)*"

Input	(1+3)/2
Code Coverage	78,7%

```
5  public class ExprParser {
6
7      public static int parse(char[] in) {
8
9          int pos = expr(0, in);
10         if (pos < in.length) {
11             syntaxError("End of input", pos);
12             pos = -1;
13         }
14         return pos;
15     }
16
17     public static int expr(int pos, char[] in) {
18         pos = term(pos, in);
19         if (pos == -1)
20             return pos;
21         if (pos == in.length)
22             return pos;
23
24         if (in[pos] == '+') {
25             pos++;
26             pos = term(pos, in);
27         } else if (in[pos] == '-') {
28             pos++;
29             pos = term(pos, in);
30         }
31
32         return pos;
33     }
34
35     public static int term(int pos, char[] in) {
36         pos = factor(pos, in);
37         if (pos == -1)
38             return pos;
39         if (pos == in.length)
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42         if (in[pos] == '*') {
43             pos++;
44             pos = factor(pos, in);
45         } else if (in[pos] == '/') {
46             pos++;
47             pos = factor(pos, in);
48         }
49
50         return pos;
51     }
```

```
53     public static int factor(int pos, char[] in) {
54         if (pos == in.length)
55             return -1;
56
57         if (in[pos] == '1')
58             return pos + 1;
59         if (in[pos] == '2')
60             return pos + 1;
61         if (in[pos] == '3')
62             return pos + 1;
63         if (in[pos] == '(') {
64             pos++;
65             pos = expr(pos, in);
66             if (pos == -1)
67                 return pos;
68             if (pos == in.length)
69                 return -1;
70             if (in[pos] == ')') {
71                 pos++;
72                 return pos;
73             } else {
74                 syntaxError("invalid factor ", pos);
75             }
76         }
77         return -1;
78     }
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80     public static void syntaxError(String msg, int pos) {
81         final boolean log = false;
82         if (log) {
83             System.out.print("Syntax error ");
84             System.out.print(msg);
85             System.out.print(" col: ");
86             System.out.println(pos);
87         }
88     }
89 }
```

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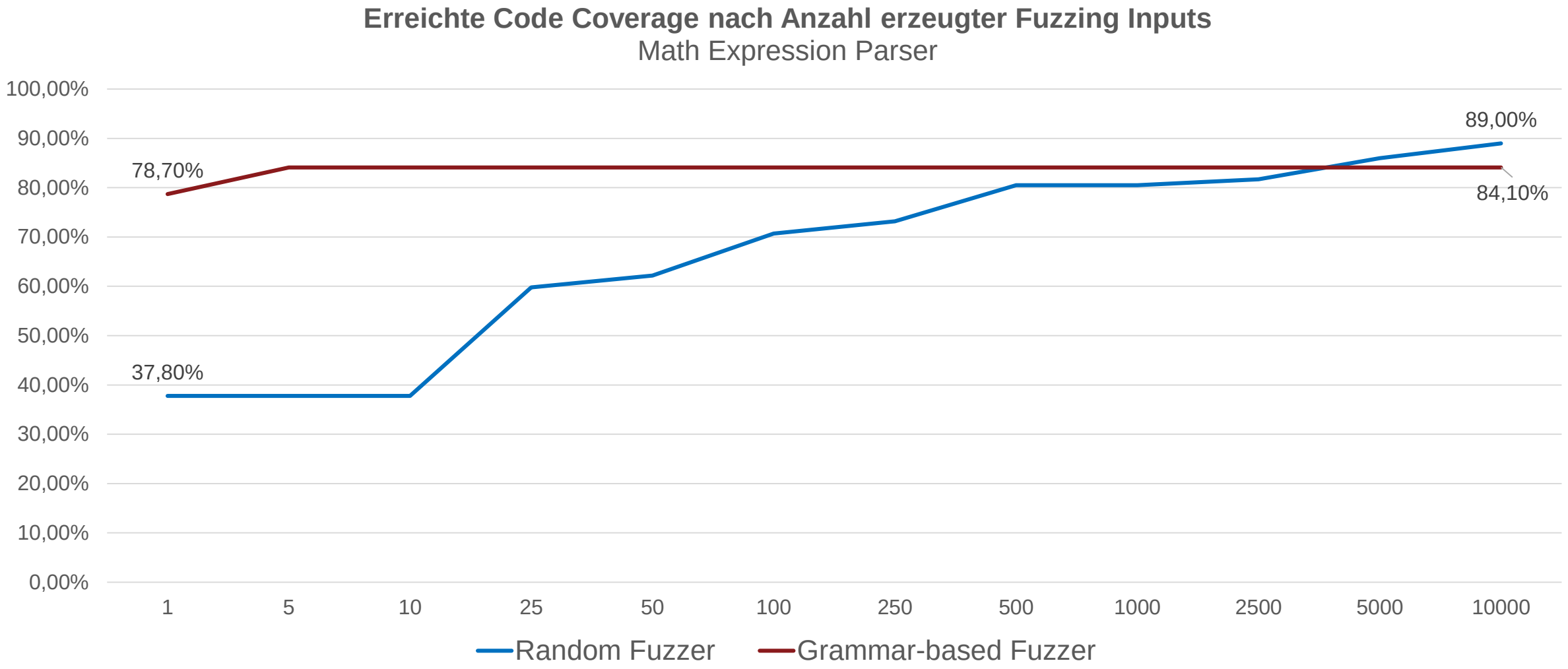
Random Fuzzing VS Grammar-based Fuzzing



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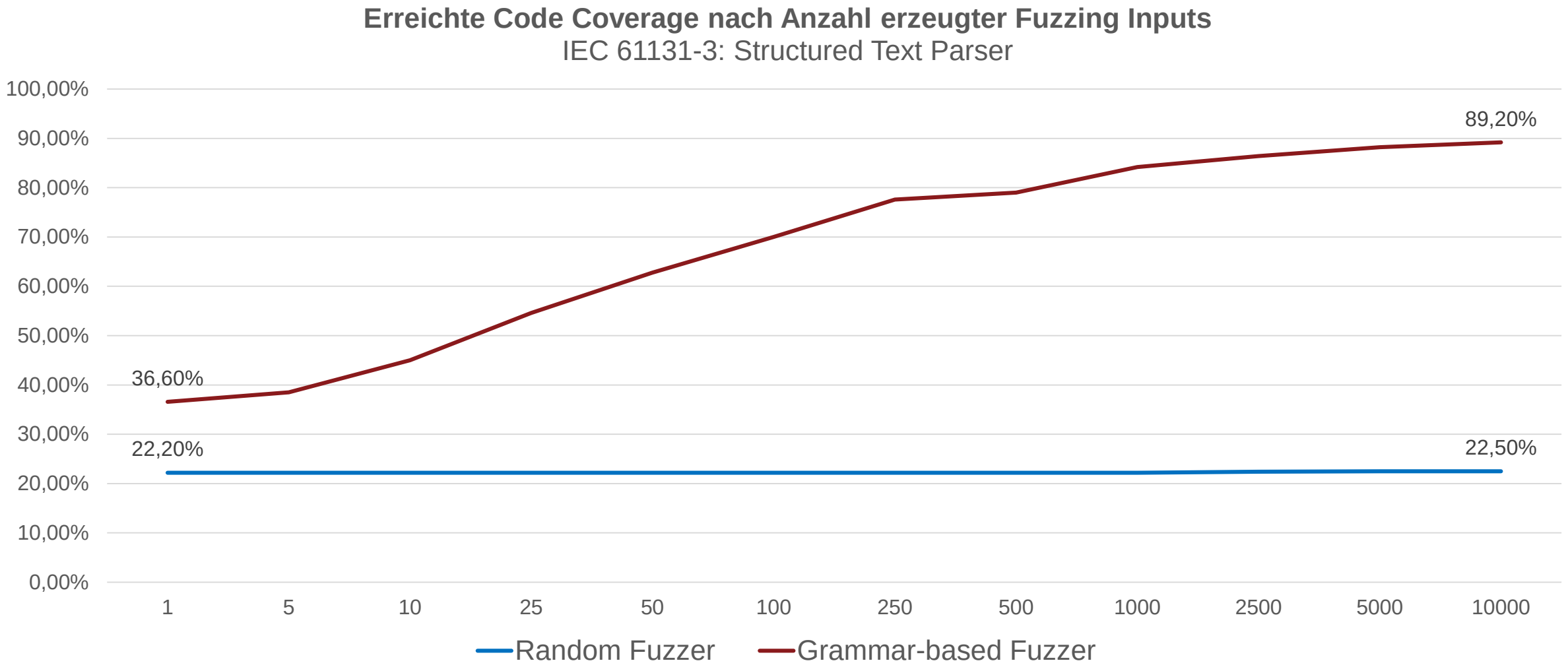
Random Fuzzing VS Grammar-based Fuzzing



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Alles schön und gut, aber woher kommt die Grammatik?

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Grammar Mining

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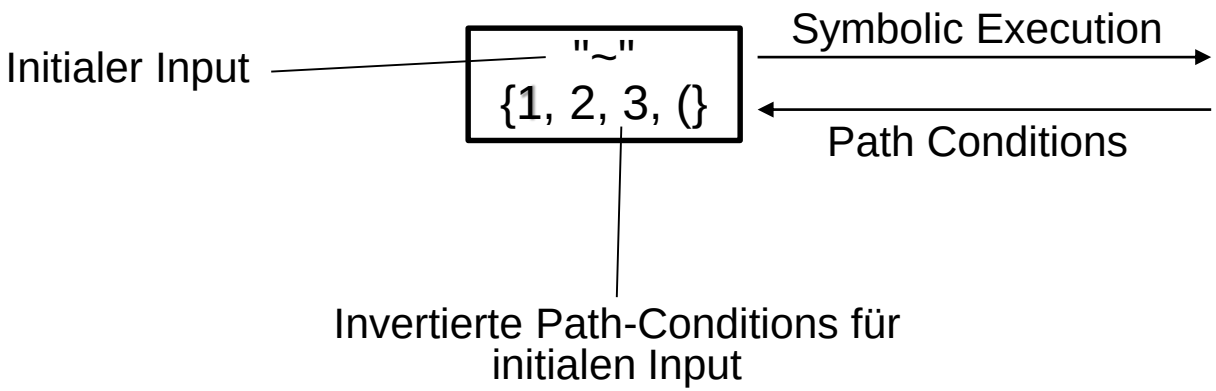
Grammar Mining – Schritt 1: Suche nach gültigen Inputs




```java
public class ExprParser {

    public static int parse(char[] in) {

        int pos = expr(0, in);
        if (pos < in.length) {
            syntaxError("End of input", pos);
            pos = -1;
        }
        return pos;
    }

    public static int expr(int pos, char[] in) {
        pos = term(pos, in);
        if (pos == -1)
            return pos;
        if (pos == in.length)
            return pos;

        if (in[pos] == '+') {
            pos++;
            pos = term(pos, in);
        } else if (in[pos] == '-') {
            pos++;
            pos = term(pos, in);
        }

        return pos;
    }

    public static int term(int pos, char[] in) {
        pos = factor(pos, in);
        if (pos == -1)
            return pos;
        if (pos == in.length)
            return pos;

        if (in[pos] == '*') {
            pos++;
            pos = factor(pos, in);
        } else if (in[pos] == '/') {
            pos++;
            pos = factor(pos, in);
        }

        return pos;
    }
```

```java
    public static int factor(int pos, char[] in) {
        if (pos == in.length)
            return -1;

        if (in[pos] == '1')
            return pos + 1;
        if (in[pos] == '2')
            return pos + 1;
        if (in[pos] == '3')
            return pos + 1;
        if (in[pos] == '(') {
            pos++;
            pos = expr(pos, in);
            if (pos == -1)
                return pos;
            if (pos == in.length)
                return -1;
            if (in[pos] == ')') {
                pos++;
                return pos;
            } else {
                syntaxError("invalid factor ", pos);
            }
        }
        return -1;
    }

    public static void syntaxError(String msg, int pos) {
        final boolean log = false;
        if (log) {
            System.out.print("Syntax error ");
            System.out.print(msg);
            System.out.print(" col: ");
            System.out.println(pos);
        }
    }
}
```

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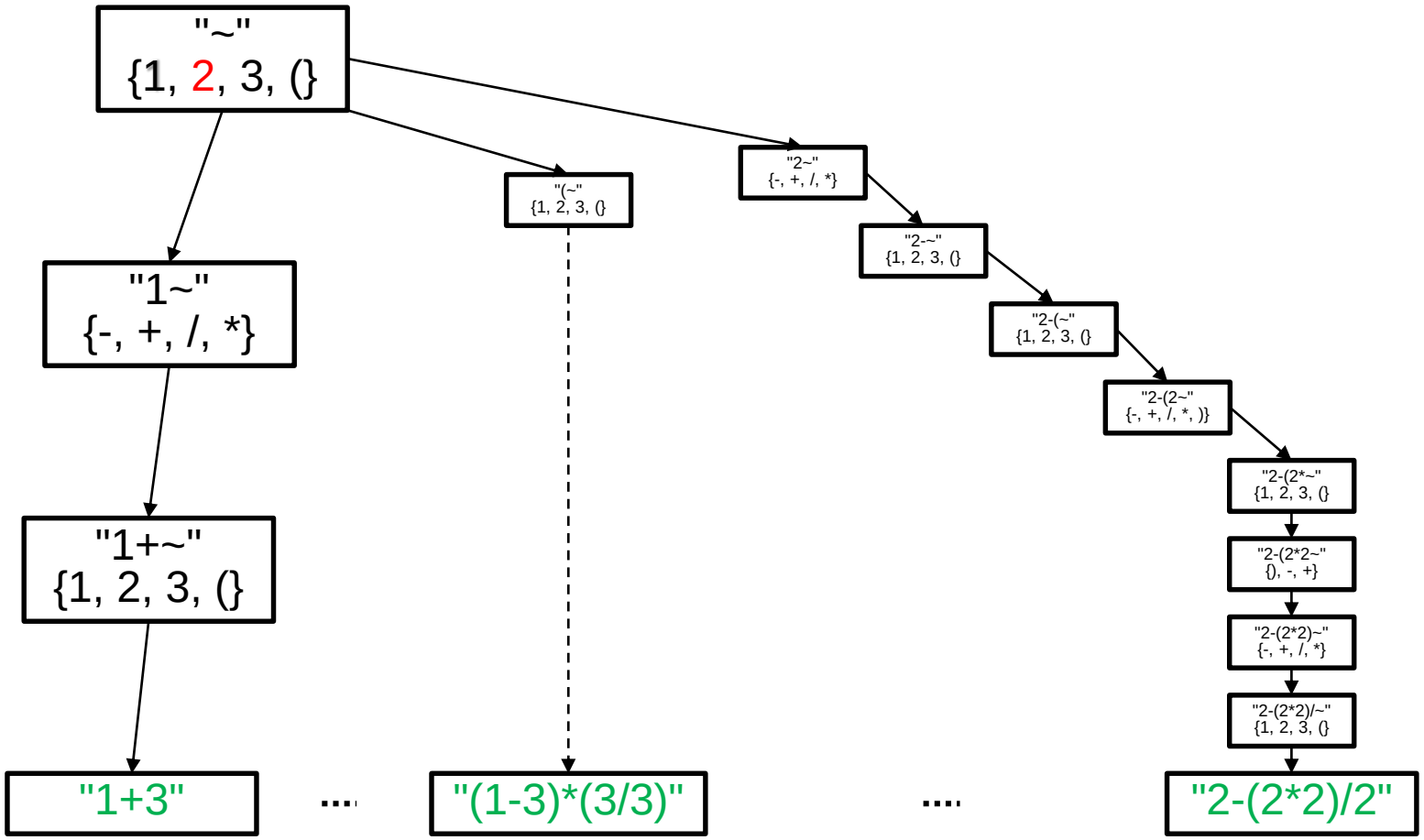
Grammar Mining – Schritt 1: Suche nach gültigen Inputs



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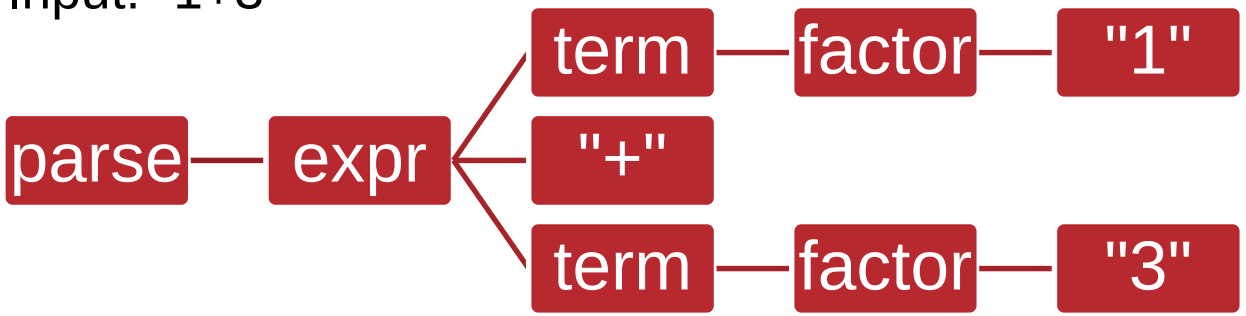
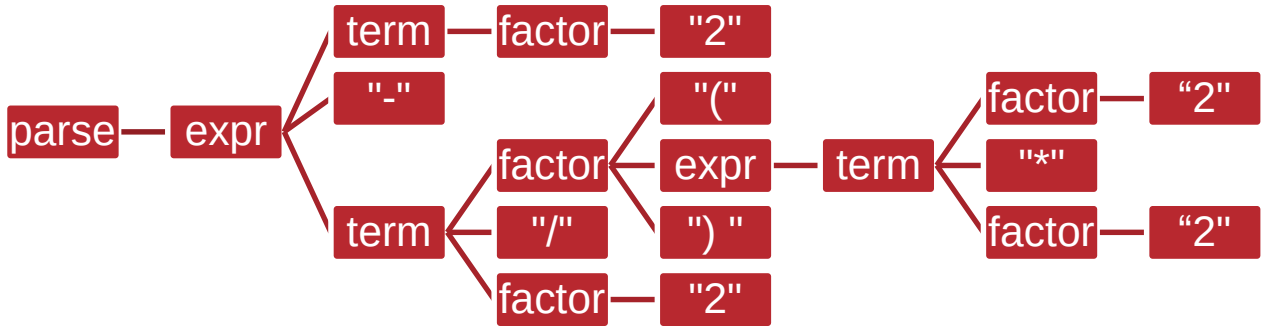
Grammar Mining – Schritt 2: Ableiten der Parse-Trees

Input: "1+3"



parse	=	**expr**
expr	=	**term** "+" **term**
term	=	**factor**
factor	=	"*1*" | "*3*"

Input: "2-(2*2)/2"



parse	=	**expr**
expr	=	**term** "-" **term** | **term**
term	=	**factor** | **factor** "*" **factor** | **factor** "/" **factor**
factor	=	"*2*" | "*(*" **expr** ")"

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Grammar Mining – Schritt 3: Zusammenfügen der Grammatik

```
parse   =  expr
expr    =  term "+" term
term    =  factor
factor  =  "1" | "3"
```



```
parse   =  expr
expr    =  term "-" term | term
term    =  factor | factor "*" factor | factor "/" factor
factor  =  "2" | "(" expr ")"
```

```
parse   =  expr
expr    =  term "+" term | term "-" term | term
term    =  factor | factor "*" factor | factor "/" factor
factor  =  "1" | "3" | "2" | "(" expr ")"
```

```
S       =  Expr
Expr    =  Term [ ( "+" | "-" ) Term ]
Term    =  Factor [ ( "*" | "/" ) Factor ]
Factor  =  "1" | "2" | "3" | "(" Expr ")"
```

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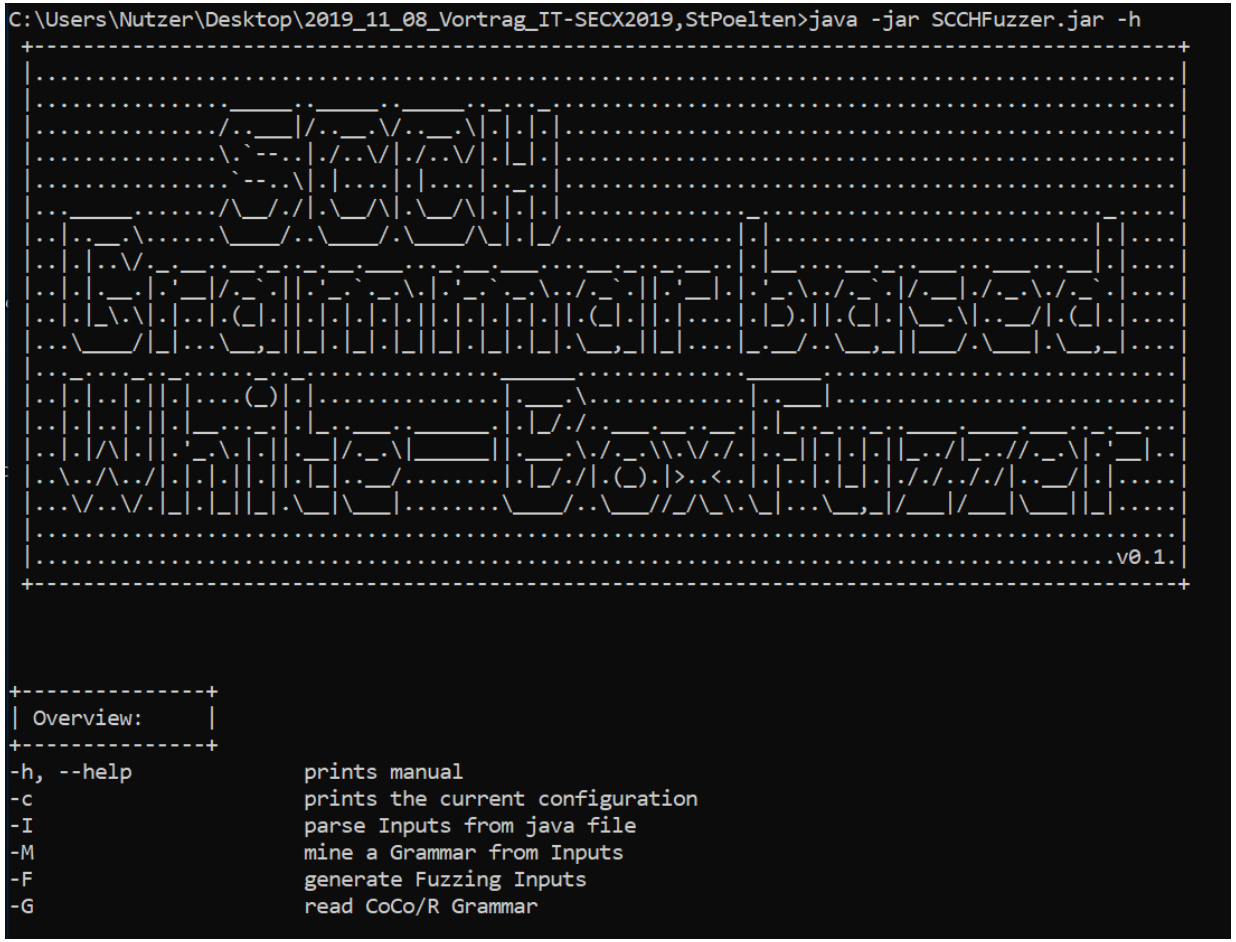
Und wie sieht das jetzt live aus?

Demo


C:\Users\Nutzer\Desktop\2019_11_08_Vortrag_IT-SECX2019,StPoelten>java -jar SCCHFuzzer.jar -h
v0.1.
+---------------+
| Overview: |
+---------------+
-h, --help prints manual
-c prints the current configuration
-I parse Inputs from java file
-M mine a Grammar from Inputs
-F generate Fuzzing Inputs
-G read CoCo/R Grammar

Vielen Dank!

Hannes Sochor MSc

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Secure Software Analytics

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