Ruleguard
vs
CodeQL
vs
Semgrep

Iskander (pronounced as “Alex”) @quasilyte

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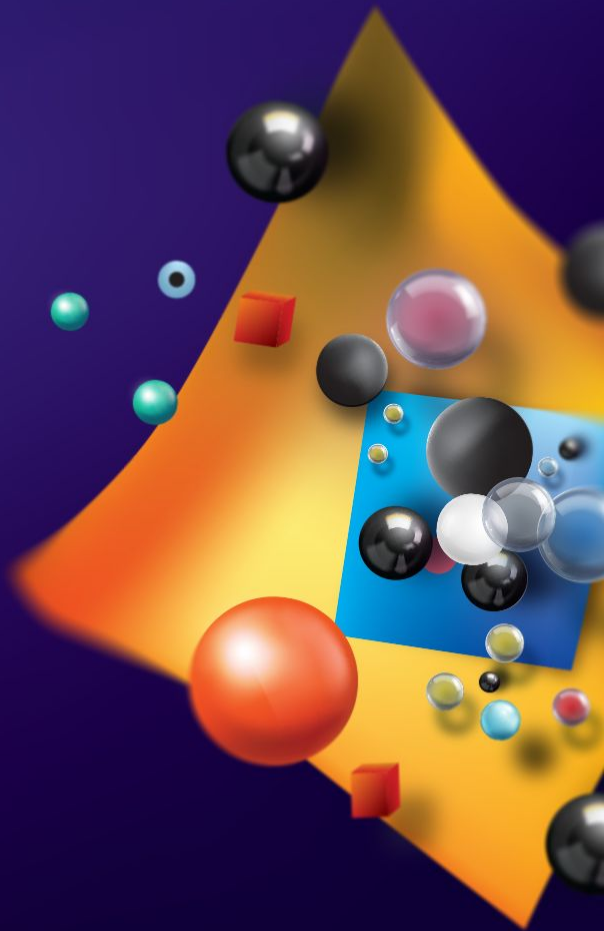
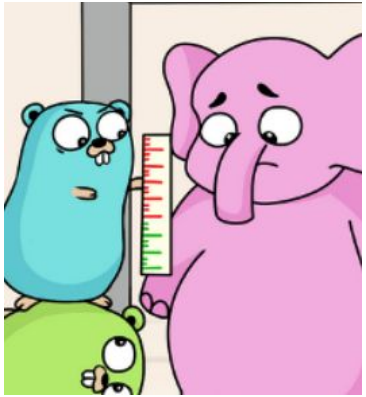


Me & static analysis

go-critic



NoVerify

Ruleguard

Our starting point

We assume that:

- You know that static analysis is cool

Our starting point

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- You know that static analysis is cool
- You're using *golangci-lint*

Our starting point

We assume that:

- You know that static analysis is cool
- You're using *golangci-lint*
- You want to create custom code checkers

Trying to come up with linting idea...

/browsing memes/

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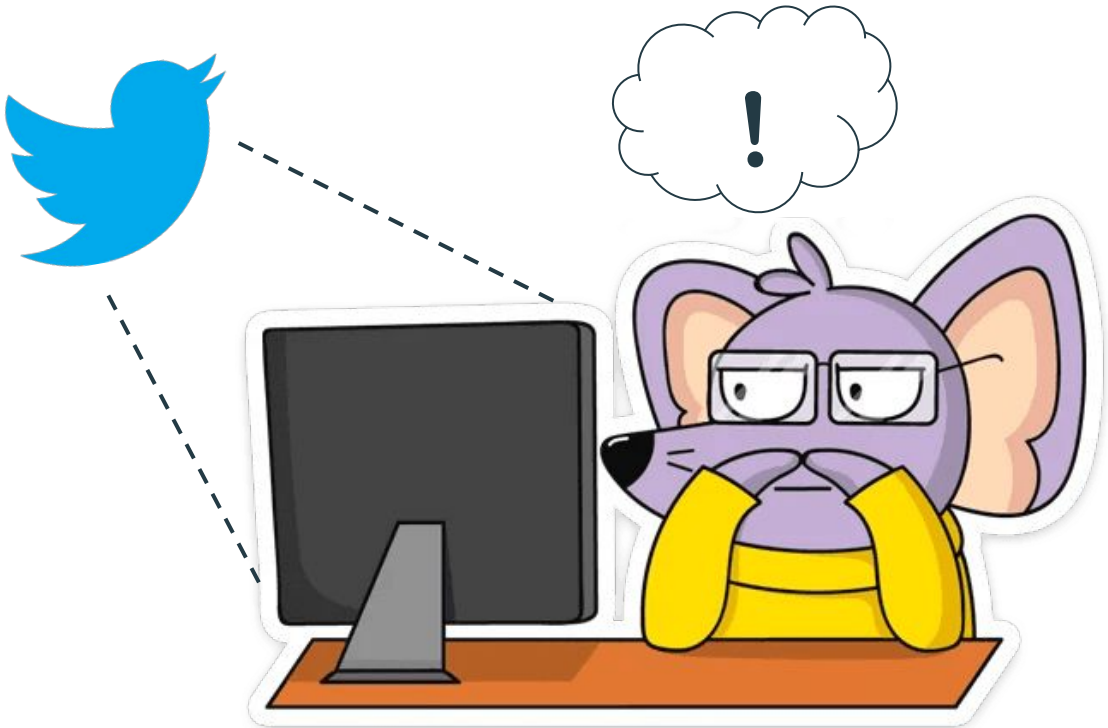

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Damian Gryski
@dgryski

New semgrep check:

Flag this construct:

io.WriteString(w, string(b))

Somewhere on Twitter...

```
  func f(w io.Writer, b []byte) {
-   io.WriteString(w, string(b))
+   w.Write(b)
  }
```

Bad code example

6 hours later...

No results on stackoverflow?!

WDYM AST type types are not “types”?!

How?!

Why?!

6 hours later...

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Let’s create our own linter!

We’ll use a fancy *go/analysis* framework

```go
var analyzer = &analysis.Analyzer{
  Name: "writestring",
  Doc:  "find sloppy io.WriteString() usages",
  Run:  run,
}

func run(pass *analysis.Pass) (interface{}, error) {
  // Analyzer implementation...
  return nil, nil
}
```

Analyzer definition

```go
for _, f := range pass.Files {
  ast.Inspect(f, func(n ast.Node) bool {
    // Check n node...
  })
}
```

Analyzer implementation

```go
// 1. Is it a call expression?
call, ok := n.(*ast.CallExpr)
if !ok || len(call.Args) != 2 {
  return true
}
```

Check n node: part 1

```go
// 2. Is it io.WriteString() call?
fn, ok := call.Fun.(*ast.SelectorExpr)
if !ok || fn.Sel.Name != "WriteString" {
  return true
}
pkg, ok := fn.X.(*ast.Ident)
if !ok || pkg.Name != "io" {
  return true
}
```

Check n node: part 2

```go
// 3. Is second arg a string(b) expr?
stringCall, ok := call.Args[1].(*ast.CallExpr)
if !ok || len(stringCall.Args) != 1 {
  return true
}
stringFn, ok := stringCall.Fun.(*ast.Ident)
if !ok || stringFn.Name != "string" {
  return true
}
```

Check n node: part 3

```go
// 4. Does b has a type of []byte?
b := stringCall.Args[0]
if pass.TypesInfo.TypeOf(b).String() != "[]byte" {
  return true
}
```

Check n node: part 4

```go
// 5. Report the issue
msg := "io.WriteString(w, string(b)) -> w.Write(b)"
pass.Reportf(call.Pos(), msg)
```

Check n node: part 5

```go
func main() {
  singlechecker.Main(analyzer)
}
```

Main function definition

It works

But not without problems...

```go
func f(io InputController, b []byte) {
  io.WriteString(w, string(b))
}
```

io could be something else!

```go
func f(io InputController, b []byte) {
  io.WriteString(w, string(b))
}
```

Need to check that io is a package

io could be something else!

```go
import "github.com/quasilyte/io" // not stdlib!

func f(b []byte) {
  io.WriteString(w, string(b))
}
```

But even if it is a package we can get confused

io could be something else!

```
isharipov@lispbook:analysis-test$ go run main.go -c 1 -- test.go
/home/isharipov/CODE/go/analysis-test/test.go:6:2: io.WriteString(w, string(b)) -> w.Write(b)
5       func f(w io.Writer, x []byte, s string) {
6               io.WriteString(w, string(x))
7               io.WriteString(w, s)
```

The warning message is not perfect

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```
isharipov@lispbook:analysis-test$ go run main.go -c 1 -- test.go
/home/isharipov/CODE/go/analysis-test/test.go:6:2: io.WriteString(w, string(b)) -> w.Write(b)
5       func f(w io.Writer, x []byte, s string) {
6               io.WriteString(w, string(x))
7               io.WriteString(w, s)
```

[ ]byte variable is called “x”, not “b”

The warning message is not perfect

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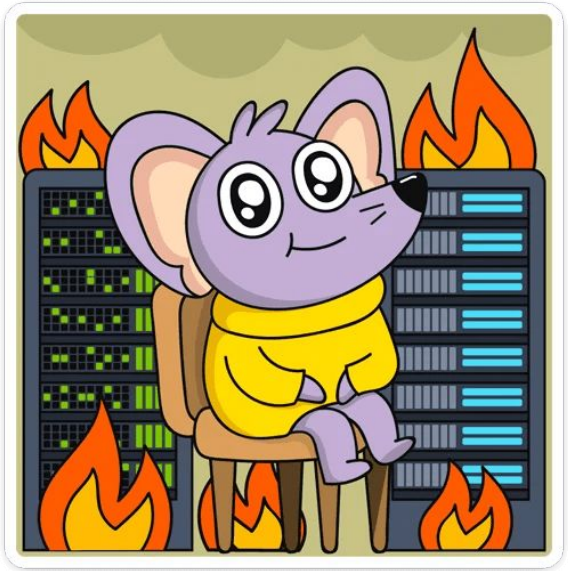
It could be worse



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Let’s try again

Now with ruleguard

```go
func writeString(m fluent.Matcher) {
  m.Match(`io.WriteString($w, string($b))`).
    Where(m["b"].Type.Is("[]byte")).
    Report("$$ -> $w.Write($b)")
}
```

writeString rule

```
func writeString(m fluent.Matcher) {
  m.Match(`io.WriteString($w, string($b))`).
    Where(m["b"].Type.Is("[]byte")).
    Report("$$ -> $w.Write($b)")
}
```

A rules group named writeString

(May include several rules)

writeString rule

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```
func writeString(m fluent.Matcher) {
  m.Match(`io.WriteString($w, string($b))`).
    Where(m["b"].Type.Is("[]byte")).
    Report("$$ -> $w.Write($b)")
}
```

AST pattern

writeString rule

```
func writeString(m fluent.Matcher) {
  m.Match(`io.WriteString($w, string($b))`).
   Where(m["b"].Type.Is("[]byte")).
   Report("$$ -> $w.Write($b)")
}
```

Result filter

writeString rule

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```
func writeString(m fluent.Matcher) {
  m.Match(`io.WriteString($w, string($b))`).
    Where(m["b"].Type.Is("[]byte")).
    Report("$$ -> $w.Write($b)")
}
```

Warning message template

writeString rule

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```
isharipov@lispbook:ruleguardtest$ ruleguard -c 1 -rules rules.go test.go
/home/isharipov/CODE/go/ruleguardtest/test.go:6:2: io.WriteString(w, string(x)) -> w.Write(x)
5       func f(w io.Writer, x []byte, s string) {
6               io.WriteString(w, string(x))
7               io.WriteString(w, s)
```

The warning message is perfect!

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```
func writeString(m fluent.Matcher) {
  m.Match(`io.WriteString($w, string($b))`).
    Where(m["b"].Type.Is("[]byte")).
    Suggest("$w.Write($b)")
}
```

Auto fix replacement template
(can be combined with Report)

writeString rule

```
isharipov@lispbook:ruleguardtest$ cat test.go
package test

import "io"

func f(w io.Writer, x []byte, s string) {
        io.WriteString(w, string(x))
        io.WriteString(w, s)
        io.WriteString(w, string(s))
}
isharipov@lispbook:ruleguardtest$ ruleguard -c 1 -rules rules.go -fix test.go
isharipov@lispbook:ruleguardtest$ cat test.go
package test

import "io"

func f(w io.Writer, x []byte, s string) {
        w.Write(x)
        io.WriteString(w, s)
        io.WriteString(w, string(s))
}
```

With -fix, suggestions are applied automagically

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Let’s try semgrep

```yaml
rules:
  - id: writestring
    patterns:
      - pattern: io.WriteString($W, string($B))
    message: "use $W.Write($B)"
    languages: [go]
    severity: ERROR
```

writestring.yml

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```
isharipov@lispbook:semgreptest$ semgrep -f writestring.yml test.go
running 1 rules...
test.go
severity:error rule:writestring: use w.Write(x)
6:      io.WriteString(w, string(x))
severity:error rule:writestring: use w.Write(s)
8:      io.WriteString(w, string(s))
ran 1 rules on 1 files: 2 findings
```

Something went wrong...

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```
isharipov@lispbook:semgreptest$ semgrep -f writestring.yml test.go
running 1 rules...
test.go
severity:error rule:writestring: use w.Write(x)
6:      io.WriteString(w, string(x))
severity:error rule:writestring: use w.Write(s)
8:      io.WriteString(w, string(s))
ran 1 rules on 1 files: 2 findings
```

False positive!

Something went wrong...

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```yaml
rules:
  - id: writestring
    patterns:
      - pattern: io.WriteString($W, string($B))
    message: "use $W.Write($B)"
    languages: [go]
    severity: ERROR
```

TODO: type filters

writestring.yml

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By the way…

Have you heard of *YAML5*?

```
{
  rules: [
    {
      id: 'writestring',
      patterns: [
        {pattern: 'io.WriteString($W, string($B))'},
      ],
      message: 'use $W.Write($B)',
      languages: ['go'],
      severity: 'ERROR',
    },
  ],
}
```

Using YAML5 format for semgrep rules

Let’s try CodeQL

QL language reference

Learn all about QL, the powerful query language that underlies the code scanning tool CodeQL.

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- Queries
- Types
- Modules
- Aliases
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- Defining the results of a query: You can control how analysis results are displayed in source code by modifying a query's `select` statement.
- Providing locations in CodeQL queries: CodeQL includes mechanisms for extracting the location of elements in a codebase. Use these mechanisms when writing custom CodeQL queries and libraries to help display information to users.
- About data flow analysis: Data flow analysis is used to compute the possible values that a variable can hold at various points in a program, determining how those values propagate through the program and where they are used.
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```
 *
 * ```go
 * f(x)
 * g(a, b...)
 * ```
 */
class CallExpr extends CallOrConversionExpr {
  CallExpr() {
    exists(Expr callee | callee = getChildExpr(0) | not isTypeExprBottomUp(callee))
    or
    // only calls can have an ellipsis after their last argument
    has_ellipsis(this)
  }
```

```

/** A byte slice type */
class ByteSliceType extends SliceType {
  ByteSliceType() { this.getElementType() instanceof Uint8Type }
}
```

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```
onversionExpr {
  CallExpr() {
    exists(Expr callee | callee = getChildExpr(0) | not isTypeExprBottomUp(callee))
    or
    // only calls can have an ellipsis after their last argument
    has_ellipsis(this)
  }
```

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```
import go
from CallExpr c,
     Expr w,
     ConversionExpr conv,
     SelectorExpr fn
where w = c.getArgument(0)
  and conv = c.getArgument(1)
  and fn = c.getCalleeExpr()
  and fn.getSelector().getName() = "WriteString"
  and fn.getBase().toString() = "io"
  and conv.getOperand().getType() instanceof ByteSliceType
  and conv.getType() instanceof StringType
select c, "use " + w + ".Write(" + conv.getOperand() + ")"
```

CodeQL query

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How to run?

- Use the *online query console*
- Select *quasilyte/codeql-test* project
- Copy/paste query from the previous slide

Query ran on 1 project Run 3 minutes ago Order query runs by... Share

quasilyte/codeql-test 3123a59 1 result View as: Alert

c	message
call to WriteString test.go:6	use w.Write(x)

CodeQL pros

- SSA support

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- Taint analysis (source-sink)

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- SSA support
- Taint analysis (source-sink)
- Not limited by (Go) syntax rules
- Real declarative programming language
- Backed by ~~GitHub~~ Microsoft
- 1st class GitHub integration

CodeQL

Ruleguard
and
Semgrep

Truth be told...

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CodeQL cons

The main points that I want to cover:

1. Steep learning curve
2. Simple things are not simple
3. Non-trivial QL may look alien for many people

Why Ruleguard then?

- Very easy to get started (just “go get” it)

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Why Ruleguard then?

- Very easy to get started (just “go get” it)
- Rules are written in pure Go
- Integrated in *golangci-lint* and *go-critic*
- Simple things are simple
- Very Go-centric (both pro and con)

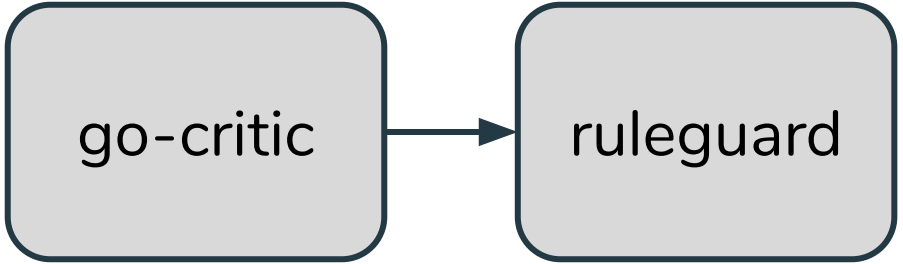
Using ruleguard from golangci

Enabling Ruleguard

1. Install golangci-lint on your pipeline (if not yet)
2. Prepare a rules file (a Go file with ruleguard rules)
3. Enable ruleguard in golangci-lint config

You can also use Ruleguard directly or via go-critic.

ruleguard



```yaml
linters:
  enable:
    - gocritic
linters-settings:
  gocritic:
    enabled-checks:
      - ruleguard
    settings:
      ruleguard:
        rules: "rules.go"
```

.golangci.yml checklist

```yaml
linters:
  enable:
    - gocritic
linters-settings:
  gocritic:
    enabled-checks:
      - ruleguard
    settings:
      ruleguard:
        rules: "rules.go"
```

go-critic linter should be enabled

.golangci.yml checklist

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```yaml
linters:
  enable:
    - gocritic
linters-settings:
  gocritic:
    enabled-checks:
      - ruleguard
    settings:
      ruleguard:
        rules: "rules.go"
```

ruleguard checker should be enabled

.golangci.yml checklist

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```yaml
linters:
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      - ruleguard
    settings:
      ruleguard:
        rules: "rules.go"
```

rules param should be set

.golangci.yml checklist

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Ruleguard guide

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```
m.Match(`pattern1`, `pattern2`)
```

Match() does the syntax matching

```
m.Match(`pattern1`, `pattern2`)
```

Matching alternations:

pattern1|pattern2

Match() does the syntax matching

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`$x = $x` pattern string

`$x = $x` pattern string

⇩

Parsed AST

`$x = $x` pattern string

Parsed AST

Modified AST (with meta nodes)

AST matching engine

```
func match(pat, n ast.Node) bool
```

pat is a compiled pattern

n is a node being matched

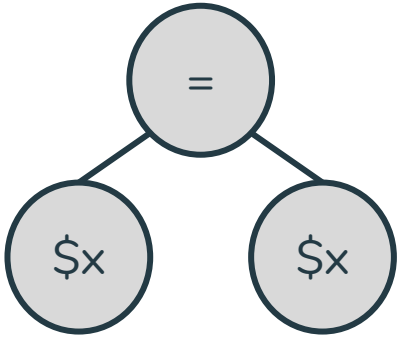
Algorithm

- Both pat and n are traversed
- Non-meta nodes are compared normally
- pat meta nodes are separate cases
- Named matches are collected (capture)
- Some patterns may involve backtracking

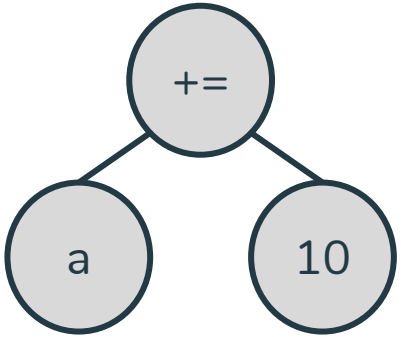
Meta node examples

- $x is a simple “match any” named match
- $_ is a “match any” unnamed match
- $*_ matches zero or more nodes

Pattern $x=$x

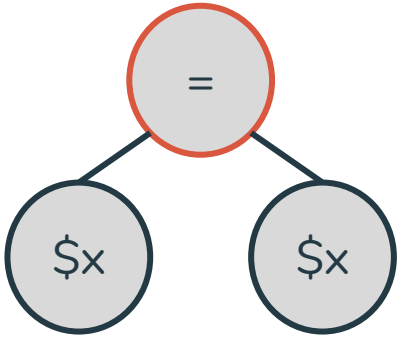


Target a+=10

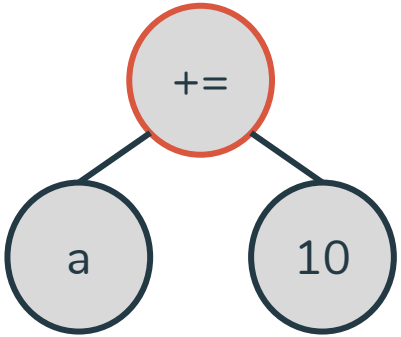


Pattern matching

Pattern $x=$x

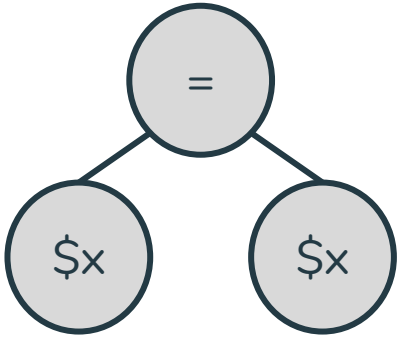


Target a+=10

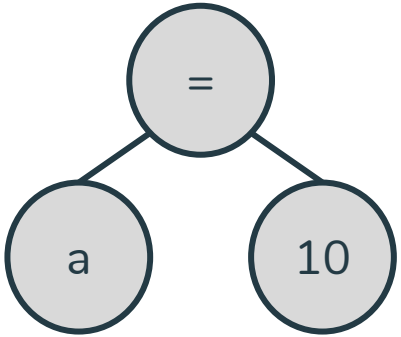


Pattern matching

Pattern $x=$x

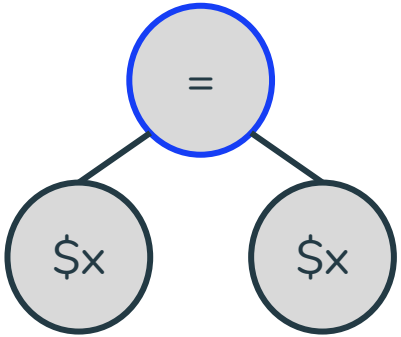


Target a=10

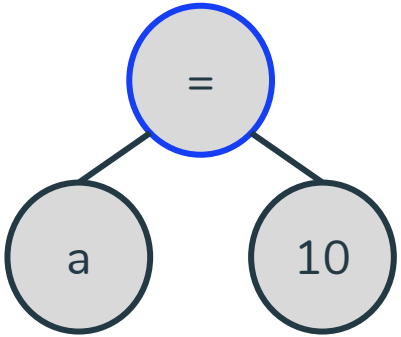


Pattern matching

Pattern $x=$x

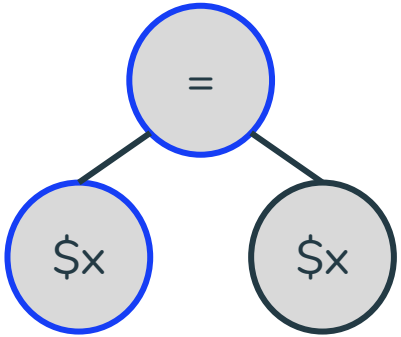


Target a=10

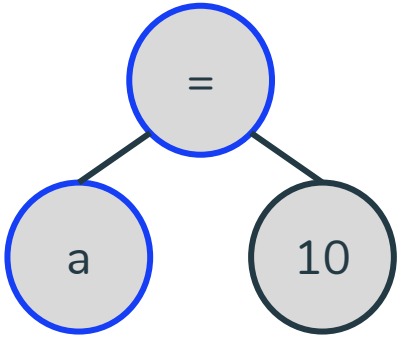


Pattern matching

Pattern $x=$x



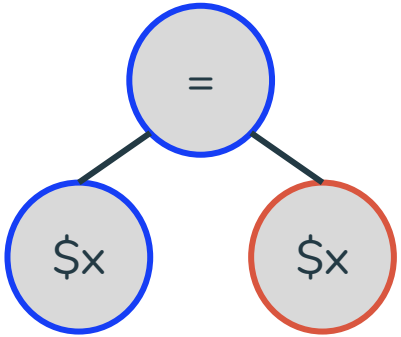
Target a=10



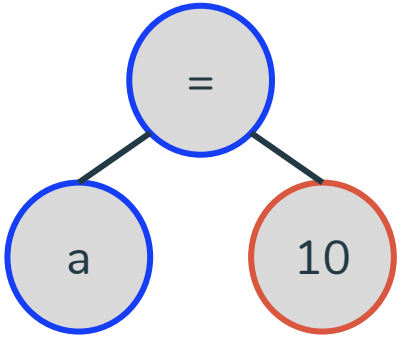
$x is bound to a

Pattern matching

Pattern $x=$x



Target a=10



a != 10

Pattern matching

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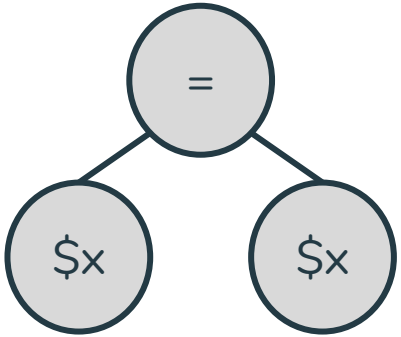
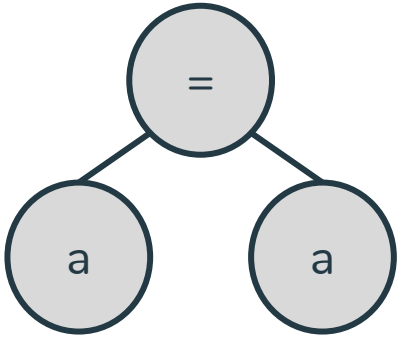
Pattern $x=$x

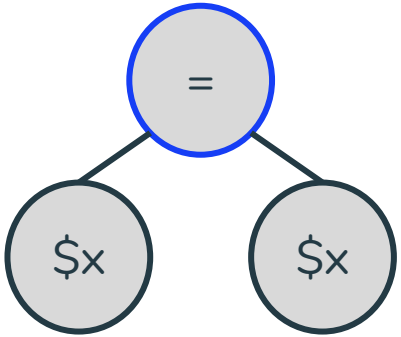


Target a=a

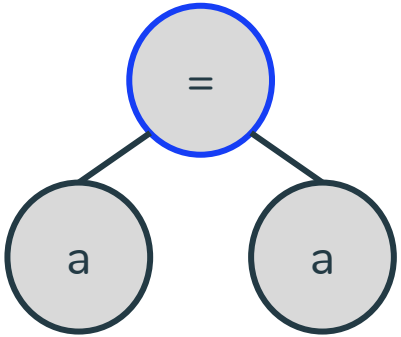


Pattern matching

Pattern $x=$x

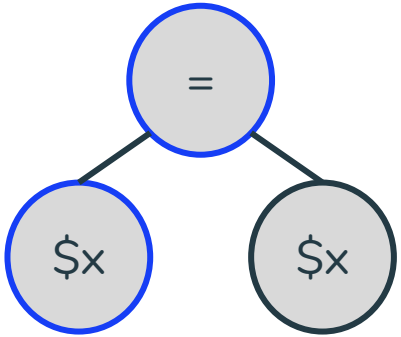


Target a=a

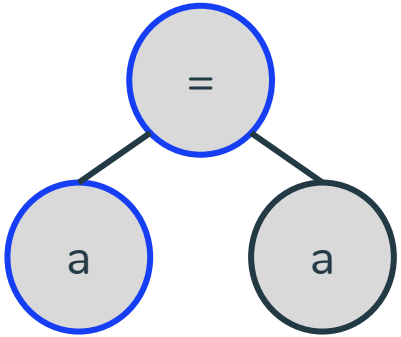


Pattern matching

Pattern $x=$x



Target a=a



$x is bound to a

Pattern matching

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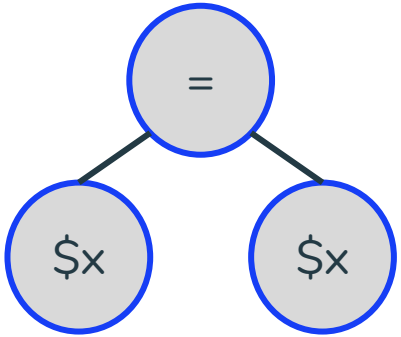
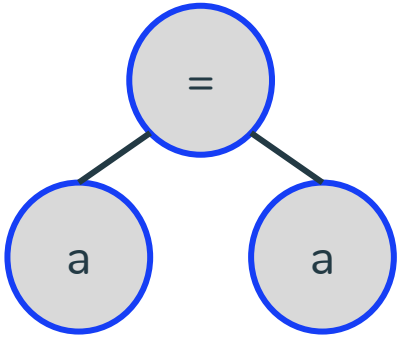
Pattern $x=$x



Target a=a



a = a, pattern matched

Pattern matching

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```
m.Where(cond1 && cond2)
```

Where() is for the match filtering

```
m.Where(cond1 && cond2)
```

Where expression

Where() is for the match filtering

```
m.Where(cond1 && cond2)
```

Where expression operands

Where() is for the match filtering

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Where() expression operands

- Matched text predicates

Where() expression operands

- Matched text predicates
- Properties like AssignableTo/ConvertibleTo/Pure

Where() expression operands

- Matched text predicates
- Properties like AssignableTo/ConvertibleTo/Pure
- Check whether a value implements interface

Where() expression operands

- Matched text predicates
- Properties like AssignableTo/ConvertibleTo/Pure
- Check whether a value implements interface
- Type matching expressions

Where() expression operands

- Matched text predicates
- Properties like AssignableTo/ConvertibleTo/Pure
- Check whether a value implements interface
- Type matching expressions
- File-related filters (like “file imports X”)

Type matching examples

`$t`	Arbitrary type
`[]byte`	Byte slice type
`[]$t`	Arbitrary slice type
`map[$t]$t`	Map with $t key and value types
`map[$t]struct{}`	Any set-like map
`func($_) $_`	Any T1->T2 function type

Type matching examples (cont.)

`struct{$*_}`	Arbitrary struct
`struct{$x; $x}`	Struct of 2 $x-typed fields
`struct{$_; $_}`	Struct with any 2 fields
`struct{$x; $*_}`	Struct that starts with $x field
`struct{$*_; $x}`	Struct that ends with $x field
`struct{$*_; $x; $*_}`	Struct that contains $x field

```go
// Just report a message
m.Report("warning message")

// Report + do an auto fix in -fix mode
m.Suggest("autofix template")
```

Report() and Suggest() handle a match

More ruleguard examples

```go
func printFmt(m fluent.Matcher) {
  m.Match(`fmt.Println($s, $*_)`).
    Where(m["s"].Text.Matches(`%[sdv]`)).
    Report("found formatting directives")
}
```

Find formatting directives in a non-formatting fmt calls

```go
func badLock(m fluent.Matcher) {
  m.Match(`$mu.Lock(); $mu.Unlock()`).
    Report(`$mu unlocked immediately`)

  m.Match(`$mu.Lock(); defer $mu.RUnlock()`).
    Report(`maybe $mu.RLock() is intended?`)
}
```

Find mutex usage issues

(*real-world example*)

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```go
func sprintErr(m fluent.Matcher) {
  m.Match(`fmt.Sprint($err)`,
          `fmt.Sprintf("%s", $err)`,
          `fmt.Sprintf("%v", $err)`).
    Where(m["err"].Type.Is(`error`)).
    Suggest(`$err.Error()`)
}
```

Suggest error.Error() instead

```
func arrayDeref(m fluent.Matcher) {
  m.Match(`(*$arr)[$i]`).
    Where(m["arr"].Type.Is(`*[$_]$_`)).
    Suggest(`$arr[$i]`)
}
```

Find redundant explicit array dereference expressions

```go
func osFilepath(m fluent.Matcher) {
  m.Match(`os.PathSeparator`).
    Where(m.File().Imports("path/filepath")).
    Suggest(`filepath.Separator`)
}
```

Suggest filepath.Separator instead of os.PathSeparator

```
# -e runs a single inline rule
ruleguard -e 'm.Match(`!($x != $y)`)' file.go
```

Running ruleguard with -e

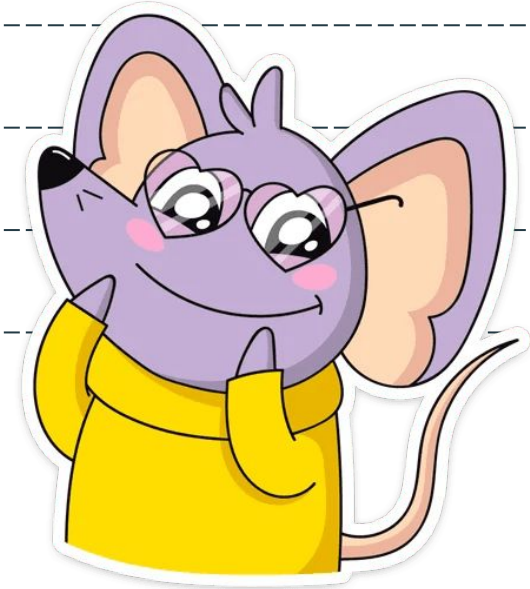
Side-by-side comparison

Written in

go-ruleguard	Go
Semgrep	Mostly OCaml
CodeQL	??? (Compler+Runtime are closed source)

Written in

go-ruleguard	Go
Semgrep	Not Go
CodeQL	Probably not Go



Ruleguard vs Semgrep vs CodeQL

Matching mechanism

go-ruleguard	AST patterns
Semgrep	AST patterns
CodeQL	Dedicated query language

Type matching mechanism

go-ruleguard	Typematch patterns + predicates
Semgrep	N/A (planned, but not implemented yet)
CodeQL	Type assertion-like API

DSL

go-ruleguard	Go
Semgrep	YAML files
CodeQL	Dedicated query language

Supported languages

go-ruleguard	Go
Semgrep	Go + other languages
CodeQL	Go + other languages

How much you can do

go-ruleguard	Simple-medium diagnostics
Semgrep	Simple-medium diagnostics
CodeQL	Almost whatever you want

Links

- Ruleguard quickstart: *EN*, *RU*
- *Ruleguard DSL documentation*
- Ruleguard examples: *one*, *two*
- *gogrep* - AST patterns matching library for Go
- A list of *similar tools*
- *.golangci.yml* from go-critic (uses ruleguard)

Ruleguard
vs
CodeQL
vs
Semgrep

Искандер (Alex) Шарипов @quasilyte

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