Go compile time instrumentation

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Agenda

1. Short bio
2. Observability domain
3. OpenTelemetry
4. History of OpenTelemetry go compile time instrumentation
5. Demo
6. Some code walkthrough
7. Current status and future
8. Questions

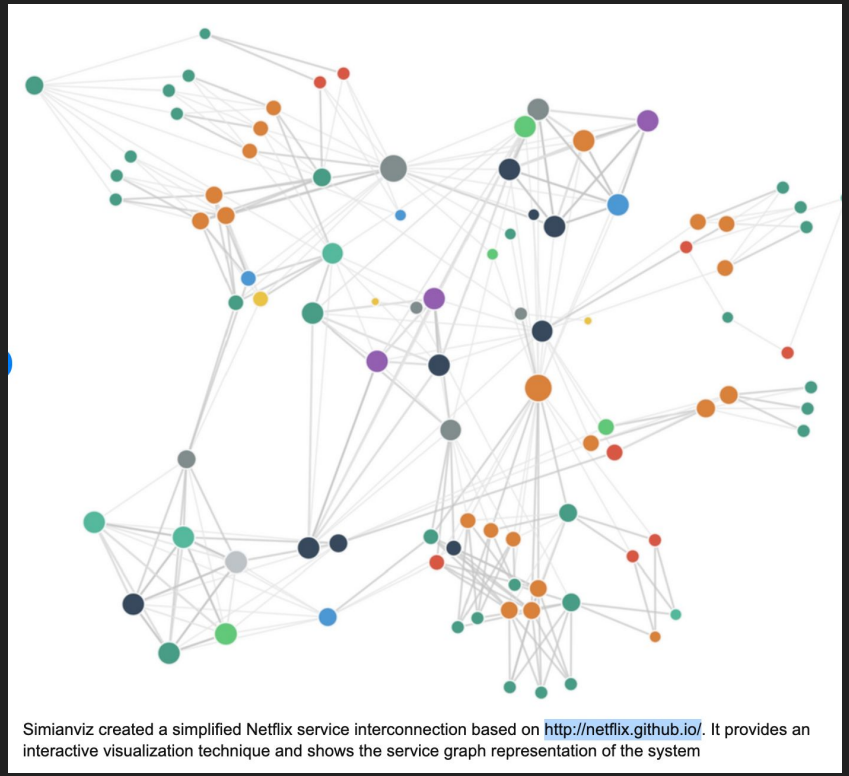
Short bio

I’m a founding engineer at Quesma, where we work on a data gateway. Before that, I spent over a decade working on observability at Sumo Logic and Dynatrace in different roles, with a short break in navigation software at TomTom where I had the opportunity to work on brand new navigation stack. I’m also founding member of the OpenTelemetry Go compile-time instrumentation project

https://github.com/open-telemetry/community/blob/main/projects/go-compile-instrumentation.md

Software complexity

Today's software, especially distributed systems, can be extremely complex. Understanding what is happening is crucial for solving problems.



Simianviz created a simplified Netflix service interconnection based on http://netflix.github.io/. It provides an interactive visualization technique and shows the service graph representation of the system

Observability - tool for complexity

Observability is the ability to understand the internal state of a system by examining its outputs. In the context of software, this means being able to understand the internal state of a system by examining its telemetry data, which includes traces, metrics, and logs.

To make a system observable, it must be instrumented. That is, the code must emit traces, metrics, or logs. The instrumented data must then be sent to an observability backend.

OpenTelemetry

What is OpenTelemetry

1. Open source implementation of observability concepts
2. Framework and toolkit (set of libraries) designed to create, manage and consume telemetry signals

OpenTelemetry was officially introduced in **2019** as a **merger** of two existing observability projects:

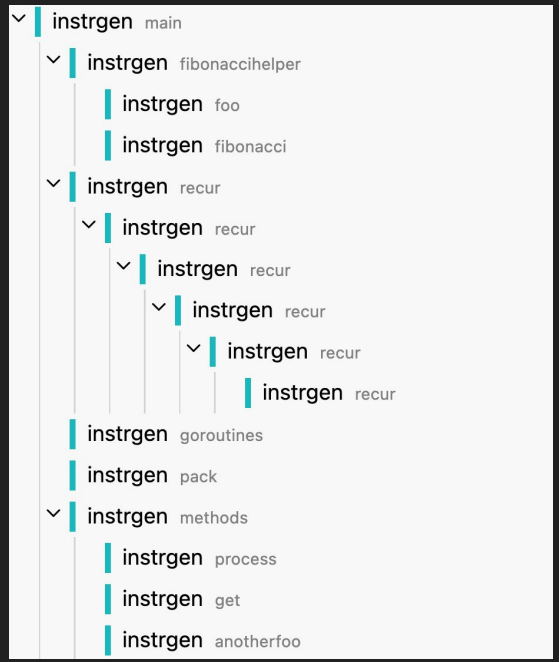
1. **OpenTracing** (by the Cloud Native Computing Foundation - CNCF)
2. **OpenCensus** (originally developed by Google)

Telemetry signals

- Logs (additonal info about behaviour)
- Metrics (measuring)
- Traces

Trace

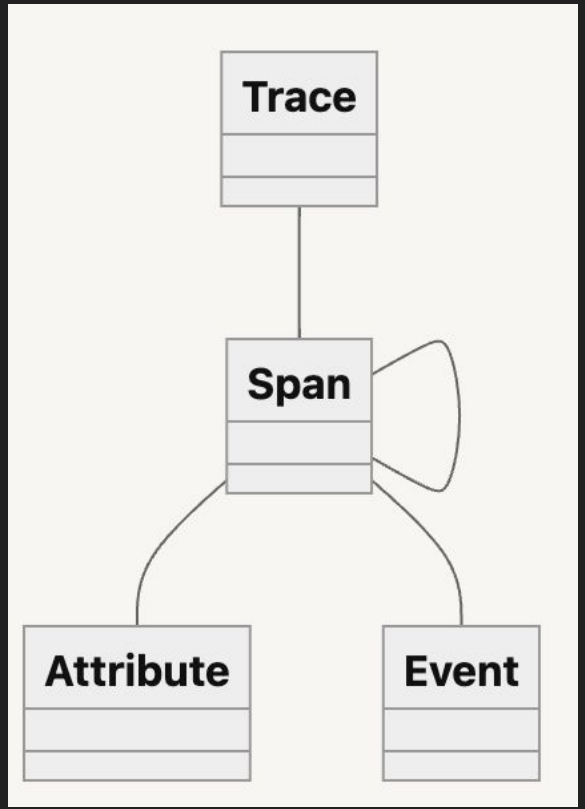
A trace represents the execution path of a request across multiple services.




```
{
  "name": "hello",
  "context": {
    "trace_id": "5b8aa5a2d2c872e8321cf37308d69df2",
    "span_id": "051581bf3cb55c13"
  },
  "parent_id": null,
  "start_time": "2022-04-29T18:52:58.114201Z",
  "end_time": "2022-04-29T18:52:58.114687Z",
  "attributes": {
    "http.route": "some_route1"
  },
  "events": [
    {
      "name": "Guten Tag!",
      "timestamp": "2022-04-29T18:52:58.114561Z",
      "attributes": {
        "event_attributes": 1
      }
    }
  ]
}
```

Tracing concepts

- Trace represents an execution path
- Span represents step in an execution path
- Attribute and Event represents additional metadata information carried together with span



History of OpenTelemetry go instrumentation

Beginnings of go instrumentation

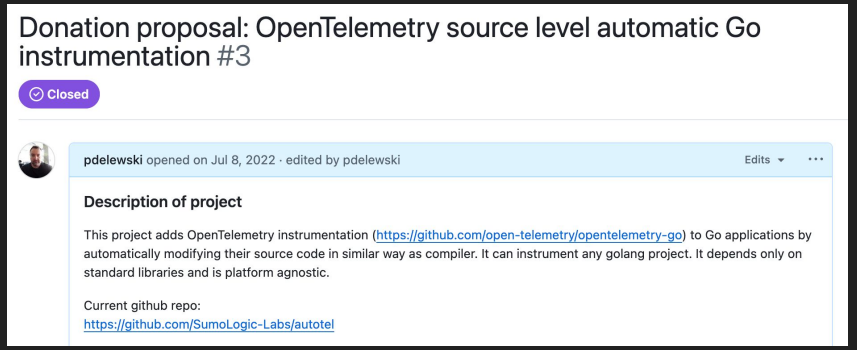
Everything started with two proposals:

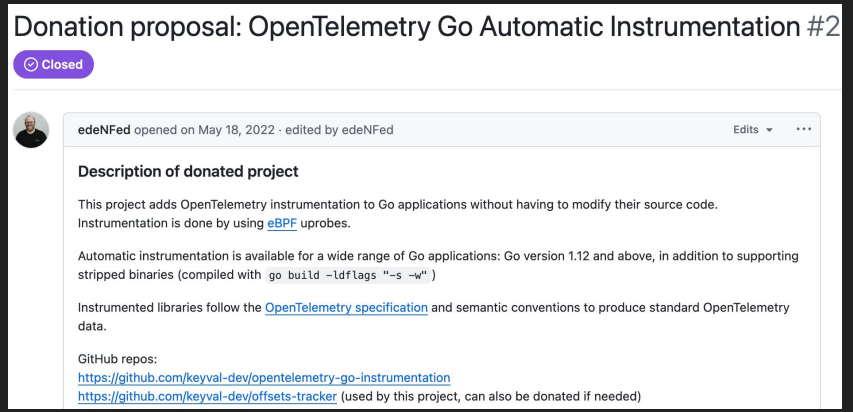
- https://github.com/open-telemetry/opentelemetry-go-instrumentation/issues/3
- https://github.com/open-telemetry/opentelemetry-go-instrumentation/issues/2

Presented on the same GO SIG

Two repos:

- https://github.com/open-telemetry/opentelemetry-go-contrib/
- https://github.com/open-telemetry/opentelemetry-go-instrumentation

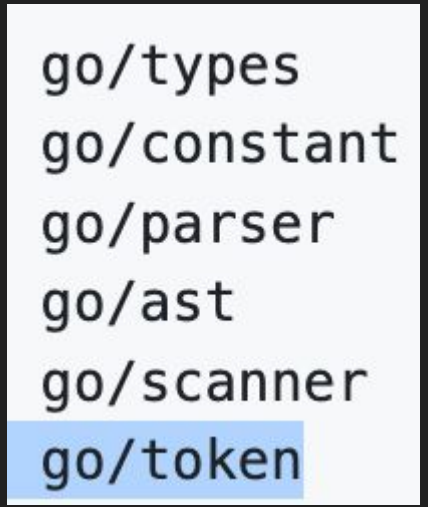




Go features

Go provides excellent tooling for code analysis and manipulation

- All tools needed for source level manipulation are part of standard library



Go AST Traversal

```go
func main() {
    // parse file
    fset := token.NewFileSet()
    node, err := parser.ParseFile(fset, filename: "main.go", src: nil, parser.ParseComments)
    if err != nil {
        log.Fatal(err)
    }

    ast.Inspect(node, func(n ast.Node) bool {
        fn, ok := n.(*ast.FuncDecl)
        if ok {
            fmt.Printf(format: "function declaration found on line %d: \n\t%s\n",
                fset.Position(fn.Pos()).Line, fn.Name.Name)
            fmt.Println()
        }
        return true
    })
}
```

Instrumentation

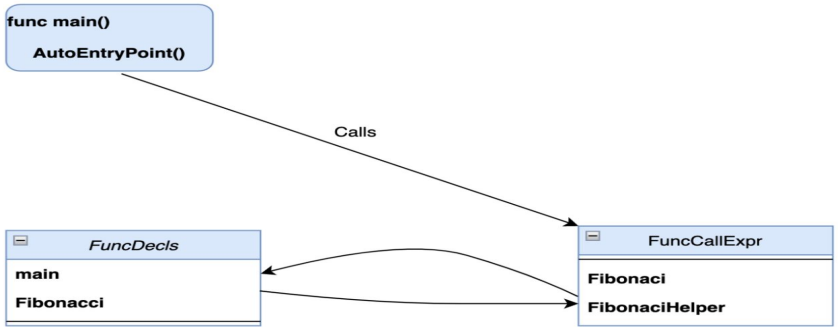
Instrgen first instrumentation approach

OpenTelemetry Go Source Automatic Instrumentation – How it works

`instrgen` adds OpenTelemetry instrumentation to source code by directly modifying it. It uses the AST (Abstract Syntax Tree) representation of the code to determine its operational flow and injects necessary OpenTelemetry functionality into the AST.

The AST modification algorithm is the following:

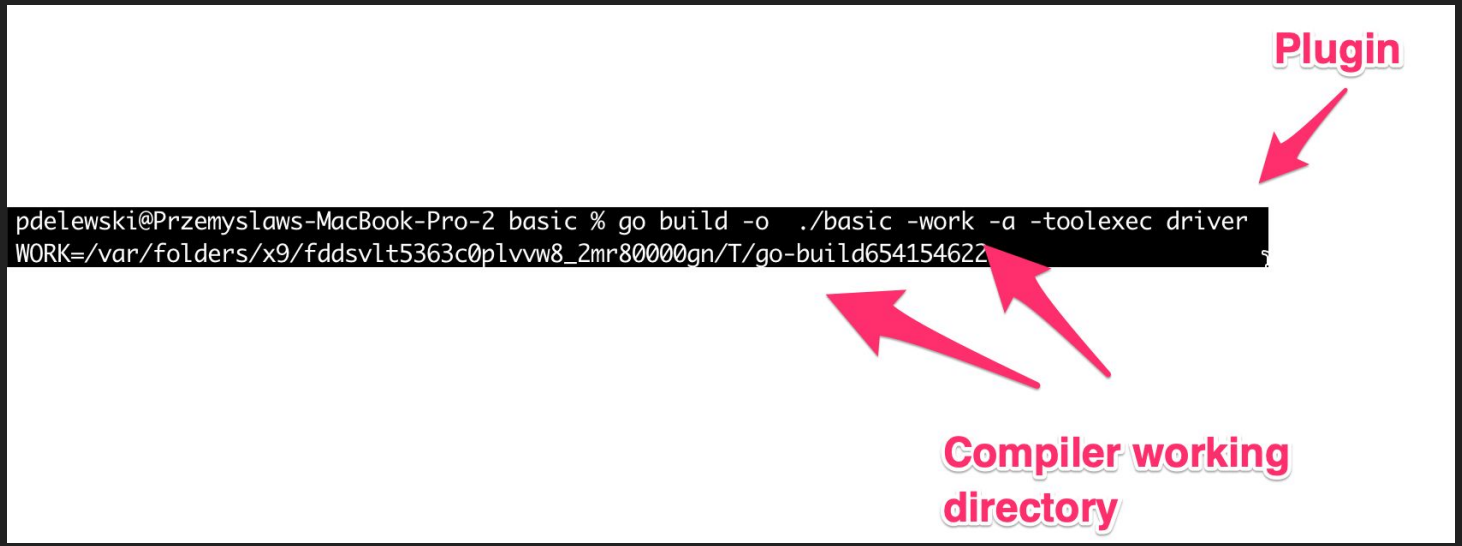
1. Search for the entry point: a function definition with `AutotelEntryPoint()`.
2. Build the call graph. Traverse all calls from the entry point through all function definitions.
3. Inject OpenTelemetry instrumentation into functions bodies.
4. Context propagation. Adding an additional context parameter to all function declarations and function call expressions that are visible (it will not add a context argument to call expressions if they are not reachable from the entry point).



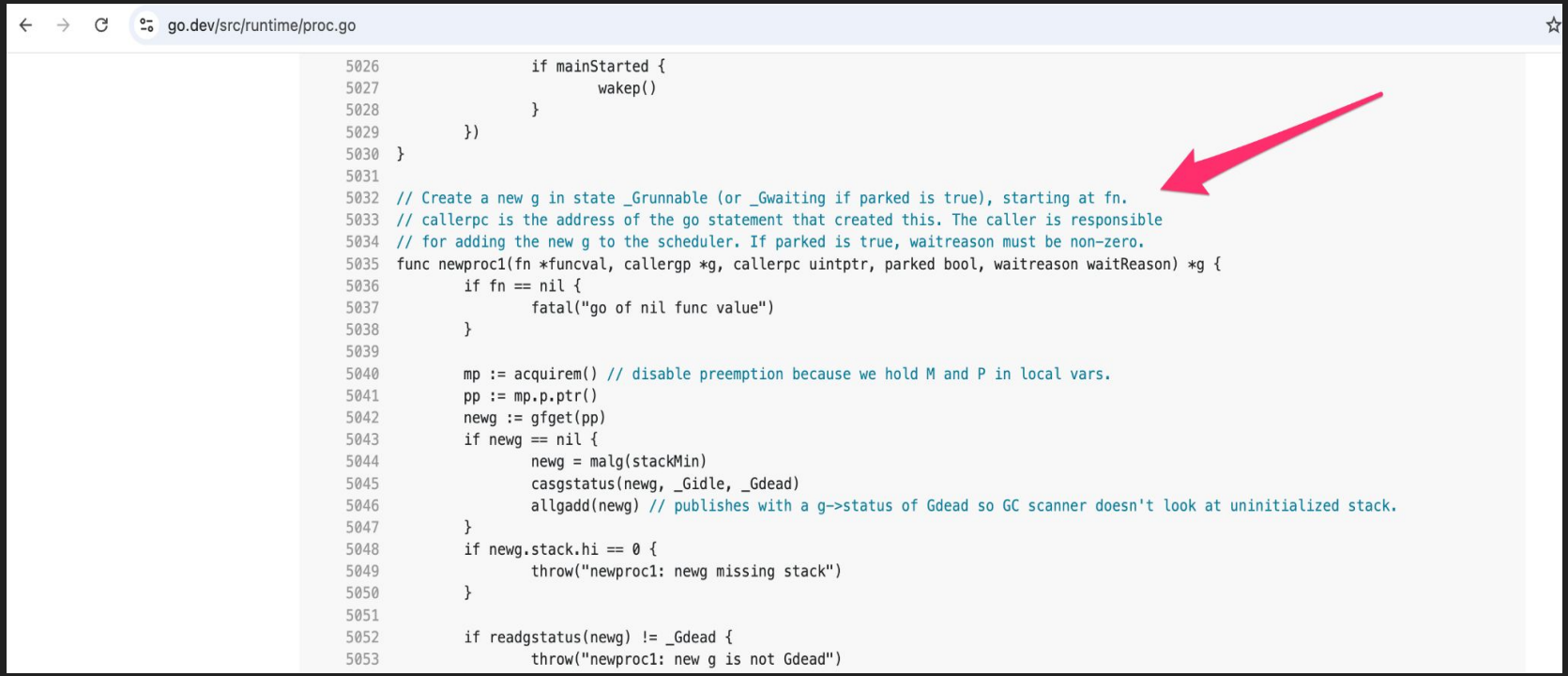
! Problematic from context propagation perspective, might give incorrect results and compilation failures.

Instrgen second approach

- Utilizing toolexec (https://github.com/open-telemetry/opentelemetry-go-contrib/pull/4058)



Runtime hooking



Compilation process internals

https://raw.githubusercontent.com/pdelewski/toolexec/refs/heads/dump-args/main.go

```
/opt/homebrew/Cellar/go/1.22.5/libexec/pkg/tool/darwin_arm64/compile
-o
/var/folders/x9/fddsvlt5363c0plvvw8_2mr80000gn/T/go-build2085540145/b001/_pkg_.a
-trimpath
/var/folders/x9/fddsvlt5363c0plvvw8_2mr80000gn/T/go-build2085540145/b001=>
-p
main
-lang=go1.19
-complete
-buildid
1ho7jWjcAkI15K5xGJoi/1ho7jWjcAkI15K5xGJoi
-goversion
go1.22.5
-c=4
-shared
-nolocalimports
-importcfg
/var/folders/x9/fddsvlt5363c0plvvw8_2mr80000gn/T/go-build2085540145/b001/importcfg
-pack
/Users/pdelewski/Projects/toolexec/main.go
```

Working directory

Package name

Source files

```go
package main

import (
    "fmt"
    "golang.org/x/sys/unix"
    "os"
    "os/exec"
)

func executePass(args []string) {  1 usage
    path := args[0]
    args = args[1:]
    cmd := exec.Command(path, args...)
    cmd.Stdin = os.Stdin
    cmd.Stdout = os.Stdout
    cmd.Stderr = os.Stderr
    if e := cmd.Run(); e != nil {
        fmt.Println(e)
    }
}

func lockFile(file *os.File) error {  1 usage
    return unix.Flock(int(file.Fd()), unix.LOCK_EX) // Exclusive lock
}

func unlockFile(file *os.File) error {  1 usage
    return unix.Flock(int(file.Fd()), unix.LOCK_UN) // Unlock
}

func compile(args []string, f *os.File) {  1 usage
    for _, a := range args {
        lockFile(f)
        f.WriteString(a)
        f.WriteString( s: "\n")
        unlockFile(f)
    }
    executePass(args[0:])

}

func main() {
    f, _ := os.OpenFile( name: "args", os.O_APPEND|os.O_CREATE|os.O_WRONLY,  perm: 0644)
    args := os.Args[1:]
    compile(args, f)
}
```

Demo

Code walkthrough (PackageRewriter)

```go
// PackageRewriter interface does actual input package
// rewriting according to specific criteria.
type PackageRewriter interface {  1 usage
    // ID Dumps rewriter id.
    Id() string
    // Inject tells whether package should be rewritten.
    Inject(pkg string, filepath string) bool
    // ReplaceSource decides whether input sources should be replaced
    // or all rewriting work should be done in temporary location.
    ReplaceSource(pkg string, filePath string) bool
    // Rewrite does actual package rewriting.
    Rewrite(pkg string, file *ast.File, fset *token.FileSet, trace *os.File)
    // WriteExtraFiles generate additional files that will be linked
    // together to input package.
    // Additional files have to be returned as array of file names.
    WriteExtraFiles(pkg string, destPath string) []string
}
```

Current status and future

Current status and future

Two new donations from alibaba and datadog:

- https://github.com/open-telemetry/community/issues/1961
- https://github.com/open-telemetry/community/issues/2497

For documentation look:

- https://www.datadoghq.com/blog/go-instrumentation-orchestrion/
- https://github.com/alibaba/opentelemetry-go-auto-instrumentation

New SIG (Special Interests Group)

- https://github.com/open-telemetry/community/pull/2490

  New repo

  https://github.com/open-telemetry/opentelemetry-go-compile-instrumentation/

  Blog post

  https://opentelemetry.io/blog/2025/go-compile-time-instrumentation/

Thank you!
Go compile time instrumentation

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Questions