GopherCon UK 2025 - Unleashing the Go Toolchain

`Unleashing the Go Toolchain`

`GopherCon UK '25`

`Kemal Akkoyun | @kakkoyun`
:::

`$whoami`

notes:

- A software engineer at Datadog working on APM and observability
- A father, husband, and a dog owner (she passed away last year)
- I'm a geek, a nerd (D&D, Custom keyboards, rasperry pi cluster, etc.)
- Recently, I'm into personal knowledge management
- Experience in **performance engineering** and **observability**.
- Focus on **instrumenting applications** for **continuous profiling** and **runtime insights**.
- Proficient in **memory management**, **concurrency**, and **runtime internals**, especially in **Go**.
- **Maintainership**:
  - **Prometheus**, **Thanos**, **Prometheus Operator**, and **Parca** team member.
  - One of the maintainers of the **Prometheus Go Client Library (client_golang)**.
- Built **eBPF-based whole-system performance profiler**: parca-agent.
- Contributor to foundational **observability tools** under CNCF.
- A member in **OpenTelemetry Profiling** and **OpenTelemetry Go Compilte-time Instrumentation** SIG and projects.

- *Past:* **CNCF TAG Observability**, and **Kubernetes SIG Instrumentation**

---

notes:

- I work at datadog on APM. We want folks to be able to catch logs/metrics/traces in their code to know what's up in their code.
- Datadog serves over 30,000 customers including 8 of the top 10 leading AI companies
- We monitor billions of containers per day and collect over a hundred trillion events per day
- Our engineering org has over 2,500 people - and we're always hiring great Go developers!
- Our team is one the most prolific contributors to the Go runtime and toolchain outside of Google
- Do you know this mascot has a name? It's called `Bits`. You know Datadog, bits?? 🤣
- Pun intended. There are a lot of dog puns internally. Pun dog meme is real!

`What makes Go great?`

notes:

I know everyone here is passionate about Go—that's why we're all at GopherCon! So instead of searching for a unique answer, I'll just share what makes Go great to me.

Simplicity

Programs must be written for people to read, and only incidentally for machines to execute.

- Hal Abelson

notes:

Why is it so important that Go is easy to read? It's because when we write code, we are primarily writing it so that someone else can understand it later. As Hal Abelson, the legendary CS professor from MIT said, "programs must be written for people to read, and only incidentally for machines to execute".

- Simple to understand.
- Simple to troubleshoot.
- Simple to operate.

notes:

For me, it is simplicity.

- Code is easy to read
- No hidden complexity
- Clear function call chains
- No method/function/operator overloading
- What you see is what you get
- Native binary

Very closely related to Go's readability is that Go code doesn't hide things. It's pretty easy to figure out what function is invoked by what function in what order. That's one of the reasons why there's no method, function, or operator overloading.

The code is easy to read

When you read the code, there's nothing hidden, you can see everything that executes

And when you compile, you get a native binary with no dependencies

---

No magic

notes:

It's a non-magical language.

What do I mean by non-magical?

notes:

Magic in programs often seems like a great idea while you are working on it,
but when you go back to the code later or have to debug a problem,
it's always ten times harder to figure out what's going on and what went wrong.

And these three things are pretty great, they've helped me avoid a lot of pain whenever I'm working in Go.

Why This Matters?

Magic seems great while coding...

...but debugging the magical code is 10x harder

notes:

I used to be a Ruby on Rails developer. I've seen the magic of Rails.
It's a great framework. It's a great language. It's a great community.
It's a great ecosystem. It's a great tool. It's a great everything.

But, and yeah, there's always a but, when you have to debug a problem,
it's always ten times harder to figure out what's going on and what went wrong.

Hence I evolved into a Go developer.

`There's always a "but"...`

notes:

But, and yeah, there's always a but, there are some downsides to the things that make Go great.

Before I go into those downsides, let's change topics for a moment. Let's talk about distributed tracing and observability. I promise this will all make sense in a couple of minutes.

The Three Pillars of Observability

notes:

Let's talk about observability, for a moment.

Pillar	Purpose
Logs	What happened?
Metrics	How much and how fast?
Traces	Where did the time go? (fancy logs)

notes:

For observability to work, we need these three pillars working together.
But the challenge is how to collect this data without making developers' lives miserable.

`The Manual Way`

Let's see how manual instrumentation looks...

Manual Instrumentation

Go 🐹 - Setup (Simplified)

```
var tracer trace.Tracer

func main() {
    ctx := context.Background()
    exp, _ := newExporter(ctx)

    // Create tracer provider with batch span processor
    tp := newTraceProvider(exp)
    defer func() { _ = tp.Shutdown(ctx) }()
```

```
    otel.SetTracerProvider(tp)

    // Finally, set the tracer
    tracer = tp.Tracer("ExampleService")
}
```

notes:

In Go, first you need this setup code in every service. This is just the initialization - we haven't even started tracing actual functions yet.

Manual Instrumentation

Go 🐹 - Setup (Realistic)

```
package main

import (
    "context"
    "errors"
    "time"

    "go.opentelemetry.io/otel"
    "go.opentelemetry.io/otel/exporters/stdout/stdoutlog"
    "go.opentelemetry.io/otel/exporters/stdout/stdoutmetric"
    "go.opentelemetry.io/otel/exporters/stdout/stdouttrace"
    "go.opentelemetry.io/otel/log/global"
    "go.opentelemetry.io/otel/propagation"
```

```
    "go.opentelemetry.io/otel/sdk/log"
    "go.opentelemetry.io/otel/sdk/metric"
    "go.opentelemetry.io/otel/sdk/trace"
)

// setupOTelSDK bootstraps the OpenTelemetry pipeline.
// If it does not return an error, make sure to call shutdown for proper cleanup.
func setupOTelSDK(ctx context.Context) (shutdown func(context.Context) error, err error) {
    var shutdownFuncs []func(context.Context) error

    // shutdown calls cleanup functions registered via shutdownFuncs.
    // The errors from the calls are joined.
    // Each registered cleanup will be invoked once.
    shutdown = func(ctx context.Context) error {
        var err error
        for _, fn := range shutdownFuncs {
            err = errors.Join(err, fn(ctx))
        }
        shutdownFuncs = nil
        return err
    }

    // handleErr calls shutdown for cleanup and makes sure that all errors are returned.
    handleErr := func(inErr error) {
        err = errors.Join(inErr, shutdown(ctx))
    }

    // Set up propagator.
    prop := newPropagator()
    otel.SetTextMapPropagator(prop)

    // Set up trace provider.
    tracerProvider, err := newTracerProvider()
    if err != nil {
        handleErr(err)
```

```
        return
    }
    shutdownFuncs = append(shutdownFuncs, tracerProvider.Shutdown)
    otel.SetTracerProvider(tracerProvider)

    // Set up meter provider.
    meterProvider, err := newMeterProvider()
    if err != nil {
        handleErr(err)
        return
    }
    shutdownFuncs = append(shutdownFuncs, meterProvider.Shutdown)
    otel.SetMeterProvider(meterProvider)

    // Set up logger provider.
    loggerProvider, err := newLoggerProvider()
    if err != nil {
        handleErr(err)
        return
    }
    shutdownFuncs = append(shutdownFuncs, loggerProvider.Shutdown)
    global.SetLoggerProvider(loggerProvider)

    return
}

func newPropagator() propagation.TextMapPropagator {
    return propagation.NewCompositeTextMapPropagator(
        propagation.TraceContext{},
        propagation.Baggage{},
    )
}

func newTracerProvider() (*trace.TracerProvider, error) {
    traceExporter, err := stdouttrace.New(
```

```
        stdouttrace.WithPrettyPrint())
    if err != nil {
        return nil, err
    }

    tracerProvider := trace.NewTracerProvider(
        trace.WithBatcher(traceExporter,
            // Default is 5s. Set to 1s for demonstrative purposes.
            trace.WithBatchTimeout(time.Second)),
    )
    return tracerProvider, nil
}

func newMeterProvider() (*metric.MeterProvider, error) {
    metricExporter, err := stdoutmetric.New()
    if err != nil {
        return nil, err
    }

    meterProvider := metric.NewMeterProvider(
        metric.WithReader(metric.NewPeriodicReader(metricExporter,
            // Default is 1m. Set to 3s for demonstrative purposes.
            metric.WithInterval(3*time.Second))),
    )
    return meterProvider, nil
}

func newLoggerProvider() (*log.LoggerProvider, error) {
    logExporter, err := stdoutlog.New()
    if err != nil {
        return nil, err
    }

    loggerProvider := log.NewLoggerProvider(
        log.WithProcessor(log.NewBatchProcessor(logExporter)),
```

```
    )
    return loggerProvider, nil
}
```

Manual Instrumentation

Go 🐹 - Every function:

```
func httpHandler(w http.ResponseWriter, r *http.Request) {
    ctx, span := tracer.Start(r.Context(), "my_span")
    defer span.End()

    // YOUR BUSINESS LOGIC GOES HERE
}
```

notes:

Then, for every single function you want to trace, you need to add these two lines. Multiply this by hundreds of functions in a real service, and you can see the problem.

Python 🐍

```
from opentelemetry import trace
from opentelemetry.trace import Status, StatusCode

def process_order(order_id):
    tracer = trace.get_tracer(__name__)
    with tracer.start_as_current_span("process-order") as span:
```

```
        span.set_attribute("order.id", order_id)

        try:
            # Your business logic here
            validate_order(order_id)
            charge_payment(order_id)
            ship_order(order_id)
        except Exception as e:
            span.record_exception(e)
            span.set_status(Status(StatusCode.ERROR, str(e)))
            raise
        else:
            span.set_status(Status(StatusCode.OK))
```

Go 🐹

```
import (
    "go.opentelemetry.io/otel"
    "go.opentelemetry.io/otel/attribute"
)

func processOrder(ctx context.Context, orderID string) error {
    tracer := otel.Tracer("order-service")
    ctx, span := tracer.Start(ctx, "process-order")
    defer span.End()

    span.SetAttributes(attribute.String("order.id", orderID))

    if err := validateOrder(ctx, orderID); err != nil {
        span.RecordError(err)
        span.SetStatus(codes.Error, err.Error())
        return err
```

```
    }

    if err := chargePayment(ctx, orderID); err != nil {
        span.RecordError(err)
        span.SetStatus(codes.Error, err.Error())
        return err
    }

    return shipOrder(ctx, orderID)
}
```

The Semi-Automatic Way

Annotations and decorators...

Python 🐍

```
# This could exist but doesn't in OpenTelemetry AFAIK
from hypothetical_otel import trace

@trace.instrument("process-order")
def process_order(order_id: str):
    validate_order(order_id)
    charge_payment(order_id)
    ship_order(order_id)
```

Java ☕

```java
import io.opentelemetry.instrumentation.annotations.WithSpan;
import io.opentelemetry.instrumentation.annotations.SpanAttribute;

public class OrderService {
    @WithSpan("process-order")
    public void processOrder(@SpanAttribute("order.id") String orderId) {
        // Clean business logic
        validateOrder(orderId);
        chargePayment(orderId);
        shipOrder(orderId);
    }
}
```

Go 🐹

```go
// No annotation support in Go!
// 🎉 YAY! Simplicity! 🌮
func processOrder(ctx context.Context, orderID string) error {
    ctx, span := tracer.Start(ctx, "process-order")
    defer span.End()

    span.SetAttributes(attribute.String("order.id", orderID))
    // ... error handling boilerplate ...
}

// Every. Single. Function. 😭
```

`The Fully Automatic Way`

Zero code changes required...

Python 🐍

```
# Install and bootstrap
pip install opentelemetry-distro opentelemetry-exporter-otlp
opentelemetry-bootstrap -a install

# Run with zero code changes
opentelemetry-instrument python myapp.py
```

Works automatically with: Flask, Django, FastAPI, requests, psycopg2, redis...

Java ☕

```
# Download the agent
curl -L -o agent.jar https://github.com/.../opentelemetry-javaagent.jar

# Run with zero code changes
java -javaagent:agent.jar -jar myapp.jar
```

Works automatically with: Spring, Servlet, JDBC, HTTP clients, Kafka...

Go 🐹 - Still Manual...

```go
// 🎉 YAY! Simplicity! 🌮
func processOrder(ctx context.Context, orderID string) error {
    ctx, span := tracer.Start(ctx, "process-order")
    defer span.End()

    span.SetAttributes(attribute.String("order.id", orderID))
    // ... error handling boilerplate ...
}
```

No agent. No magic. Just ~~pain~~ boilerplate.

`The Reality Check`

The developer experience gap is real...

The Pain is Real

Manual instrumentation means

	Challenge
❌	Writing boilerplate in every function
❌	Remembering to add spans for new code
❌	Inconsistent coverage across teams
❌	Maintenance burden when requirements change

What Go developers want:

> "The same zero-friction experience other languages have..."

	Goal
✅	Automatic instrumentation
✅	No runtime performance overhead
✅	No manual code changes

`The Question`

How can Go compete with runtime magic?

notes:

This is the key question. Go doesn't have annotations, runtime bytecode manipulation, or monkey patching. So how can it possibly compete with languages that do?

The Challenge

Go's constraints:

Constraint	Why It Matters
❌ No annotations	Can't use `@WithSpan`
❌ No runtime code injection	Can't modify behavior at runtime
✅ Must compile instrumentation	Everything baked into binary

notes:

Go has some fundamental constraints that make traditional automatic instrumentation approaches impossible. But there's a key insight here - Go's philosophy has always been to put the magic in the build tools, not in the runtime.

`The Solution?`

Go has a hidden superpower...
The toolchain is just another Go program

`Go Puts its Magic in Tools, not the Language`

Show of Hands 🙋

Who has ever heard about `toolexec`?

notes:

Before we dive deeper, let's see where everyone stands. This will help me gauge how deep to go into certain topics.

Now that we understand the why and the how, let's get practical. I'm going to show you exactly how to build a toolexec wrapper that can automatically instrument Go code. We'll start simple and build up to production-ready solutions.

Introducing: `-toolexec`

Go's best kept secret

```
go help build | grep -A6 toolexec

-toolexec 'cmd args'
 a program to use to invoke toolchain programs like vet and asm.
 For example, instead of running asm, the go command will run
 'cmd args /path/to/asm <arguments for asm>'.
 The TOOLEXEC_IMPORTPATH environment variable will be set,
 matching 'go list -f {{.ImportPath}}' for the package being built.
```

notes:

Let's look at what toolexec actually is. According to the Go documentation, toolexec lets you specify a program to invoke toolchain programs. So instead of running the compiler directly, Go will run your wrapper program with the compiler as an argument.

With `-toolexec`, We Intercept Everything

Simple Wrapper

First, let's just intercept the build process

notes:

Let's start by building the simplest possible toolexec wrapper. This will help us understand how the toolchain calls tools and what information we have access to.

The Basic Wrapper

```
package main

import (
    "fmt"
    "os"
    "os/exec"
    "strings"
    "time"
)

func main() {
    if len(os.Args) < 2 {
        fmt.Fprintf(os.Stderr, "TOOLEXEC: error: no tool specified\n")
        os.Exit(1)
    }

    tool := os.Args[1]
    args := os.Args[2:]

    fmt.Fprintf(os.Stderr, "TOOLEXEC: %s %s\n", tool, strings.Join(args, " "))

    start := time.Now()
    cmd := exec.Command(tool, args...)
    cmd.Stdout = os.Stdout
    cmd.Stderr = os.Stderr
```

```
    err := cmd.Run()

    duration := time.Since(start)
    fmt.Fprintf(os.Stderr, "TOOLEXEC: completed in %v\n", duration)

    if err != nil {
        os.Exit(1)
    }
}
```

notes:

Here's our basic wrapper. It validates arguments, logs what tool is being called, times the execution, and forwards everything to the real tool. This gives us visibility into the build process without changing anything.

Usage & Output

```
go build -toolexec='./toolexec-wrapper' ./demo
```

What you see:

```
TOOLEXEC: compile -o /tmp/go-build.../main.a main.go
TOOLEXEC: completed in 23.5ms
TOOLEXEC: link -o /tmp/go-build.../demo main.a
TOOLEXEC: completed in 15.2ms
```

Every tool call is intercepted!

And we can see what is going on!

notes:

When you run this, you'll see every single tool invocation that happens during the build. The compiler, linker, everything goes through our wrapper. Now we have a window into the build process.

```
go build -toolexec='./my-wrapper' ./...
```

What it does:

- Intercepts every tool call in the build process
- Lets you wrap `compile`, `link`, `asm`, etc.
- Gives you access to source code before compilation

notes:

Here's Go's secret weapon: toolexec. It's a flag that lets you intercept and wrap every tool call during the build process. Most Go developers have never heard of it, but it's the key to everything we're going to show you today.

`The Go Build Process (simplified)`

```
go build
- compile runtime
- compile [...]
- compile main
- link main
```

TODO: Add a link to daniel marti's talk

Target the Compiler

Focus on `compile` - that's where the source code is

```
func main() {
    tool := os.Args[1]
    args := os.Args[2:]

    // Only intercept compile operations
    if strings.Contains(tool, "compile") {
        return handleCompile(tool, args)
    }

    // Pass through other tools unchanged
    return runTool(tool, args)
}
```

notes:

The key insight is that we only care about the compiler - that's the only tool that has access to Go source code. The linker, assembler, and other tools work with compiled artifacts, so we let them pass through unchanged.

Access the Source Code

Extract Go files from compiler arguments

```
func handleCompile(tool string, args []string) error {
    // Find Go source files in args
    var goFiles []string
    for _, arg := range args {
```

```
        if strings.HasSuffix(arg, ".go") {
            goFiles = append(goFiles, arg)
        }
    }

    // Parse and analyze each Go file
    for _, file := range goFiles {
        if err := analyzeGoFile(file); err != nil {
            return err
        }
    }

    // Continue with normal compilation
    return runTool(tool, args)
}
```

notes:

Now we're getting to the interesting part. The compiler arguments contain the paths to all Go source files being compiled. We extract those files, analyze them (we'll see how in the next slide), and then let the normal compilation proceed.

Show of Hands 🙋

Who has written linters for Go?

notes:

So the big question is: how can Go compete with this? Go doesn't have runtime magic, annotations, or bytecode manipulation. But Go has something else - something that's been hiding in plain sight.

Great! And how about building Go tools and linters? This experience will be really valuable as we explore how toolexec works.

AST Manipulation Magic ✨

Parse, transform, and rewrite Go source

```go
import (
    "go/ast"
    "go/parser"
    "go/token"
)

func analyzeGoFile(filename string) error {
    fset := token.NewFileSet()
    node, err := parser.ParseFile(fset, filename, nil, parser.ParseComments)
    if err != nil {
        return err
    }

    // Walk the AST and find functions to instrument
    ast.Inspect(node, func(n ast.Node) bool {
        if fn, ok := n.(*ast.FuncDecl); ok {
            instrumentFunction(fn)
        }
        return true
    })

}
```

notes:

Now we're using Go's built-in AST tools to parse the source code into a syntax tree. We walk through every node in the tree, and when we find function declarations, we can modify them. This is where the real magic happens!

The Plan: Build-time Transformation

Instead of runtime magic, we transform at compile-time:

1. **Intercept** the build process with `-toolexec`
2. **Analyze** source code before compilation
3. **Transform** AST to add instrumentation
4. **Compile** the modified code

Result: Zero-overhead (runtime) instrumentation baked into your binary

notes:

The approach is elegant: instead of trying to modify behavior at runtime, we modify the source code during the build process. This way, all the instrumentation gets compiled directly into your binary with zero runtime overhead.

`One more thing...`

Cross-cutting concerns made simple <!-- element class="fragment" --

---

Show of Hands 🙋

Who *doesn't* like YAML?

(Be honest!)

notes:

This one always gets interesting reactions! Don't worry, by the end of this talk, you might have a different perspective on YAML - at least when it comes to Go tooling.

notes:

Now that we've seen how toolexec works at a technical level, let's step back and look at the bigger picture. What we've built is actually a form of Aspect-Oriented Programming for Go. Let me explain what that means and why it's so powerful.

Aspect-Oriented Programming

Cross-cutting concerns made simple

What is AOP?

Aspect-Oriented Programming separates cross-cutting concerns from business logic

Concern	Examples
Observability	Tracing, metrics, logging
Security	Authentication, authorization, input validation
Reliability	Circuit breakers, retries, health checks
Performance	Caching, rate limiting, profiling

notes:

AOP is about separating concerns that cut across your entire application - things like logging, security, and monitoring - from your core business logic. Instead of mixing them together, you define these concerns separately and apply them automatically.

Traditional AOP Solutions

Runtime Magic:

Java/C#: Annotations + bytecode weaving
JavaScript: Proxies + decorators
Python: Decorators + metaclasses

Go's Answer:

Compile-time transformation

- No runtime overhead
- No reflection needed
- Zero cognitive load for developers

notes:

Most languages solve this with runtime magic - annotations, decorators, proxies. But Go's approach is different and better: we do the transformation at compile time, so there's zero runtime overhead and no mysterious behavior.

Real-World Example: Manual Implementation

Before AOP - A typical Go function:

```
func ProcessOrder(ctx context.Context, order Order) error {
    // Authentication
    if !auth.IsAuthorized(ctx, "orders:write") {
        span.SetStatus(codes.Error, "unauthorized")
        return ErrUnauthorized
```

```
    }

    // Tracing
    ctx, span := tracer.Start(ctx, "ProcessOrder")
    defer span.End()

    // Logging
    log.InfoContext(ctx, "processing order", "orderID", order.ID)

    // Circuit breaker
    err := circuitBreaker.Execute(func() error {
        return processOrderInternal(ctx, order)
    })

    // Error handling & metrics
    if err != nil {
        span.SetStatus(codes.Error, err.Error())
        metrics.Counter("orders.failed").Inc()
        return err
    }

    return nil
}
```

notes:

Look at this typical Go function. The business logic is buried under layers of cross-cutting concerns. This is what we want to eliminate.

After AOP: Clean Business Logic

With toolexec transformation:

```
func ProcessOrder(ctx context.Context, order Order) error {
    // Pure business logic!
    return processOrderInternal(ctx, order)
}
```

All the cross-cutting concerns applied automatically via directives:

```
//dd:auth scope:orders:write
//dd:trace
//dd:log level:info
//dd:circuit-breaker
//dd:metrics counter:orders.processed
func ProcessOrder(ctx context.Context, order Order) error {
    return processOrderInternal(ctx, order)
}
```

notes:

With our AOP approach, the function becomes incredibly clean. All the cross-cutting concerns are declared as directives at the top, and the actual business logic is uncluttered. The toolexec transformation handles everything automatically.

Aspect Definitions

```
# aspects.yaml
aspects:
  - name: "tracing"
    target: "func.*Context"
    template: |
      ctx, span := tracer.Start(ctx, "{{.FuncName}}")
      defer span.End()
```

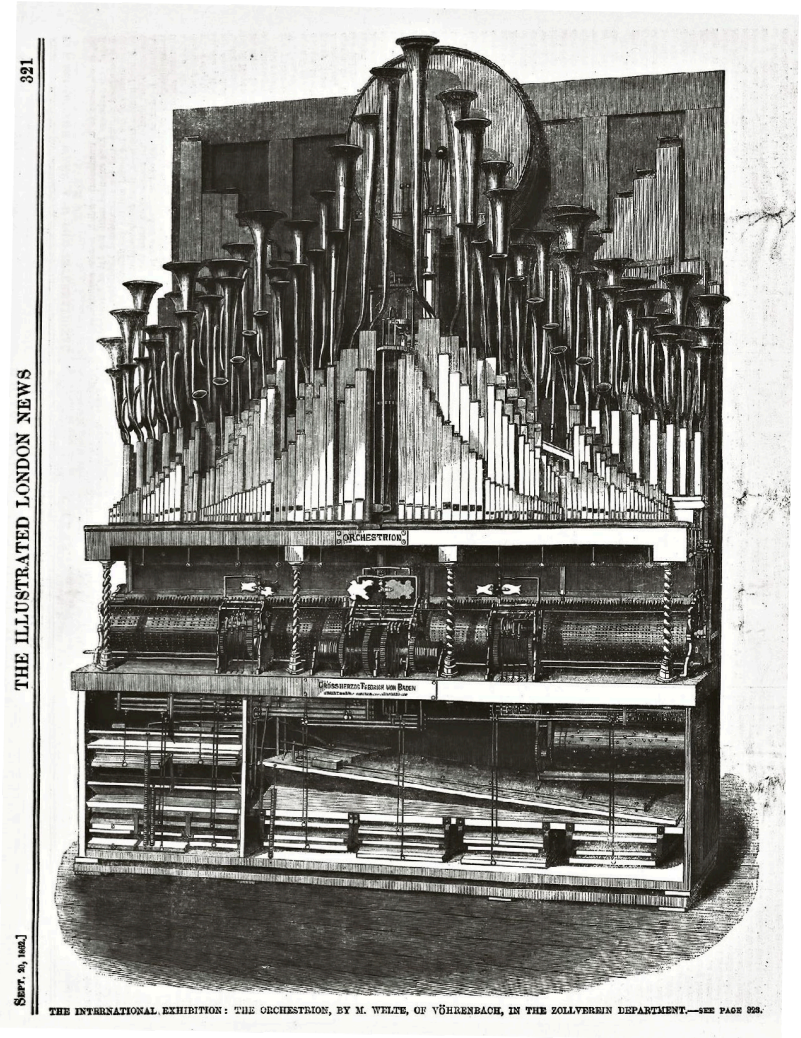
```yaml
- name: "auth"
  target: "func.*Order.*"
  template: |
    if !auth.IsAuthorized(ctx, "{{.Permission}}") {
        return ErrUnauthorized
    }

- name: "logging"
  target: "func.*"
  template: |
    log.InfoContext(ctx, "{{.FuncName}} started")
    defer log.InfoContext(ctx, "{{.FuncName}} completed")
```

Production Validation: Orchestrion

The YAML vision, realized in production

Datadog's proof that this approach works at scale



"If YAML + toolexec can work, this is how"

What is Orchestrion?

Compile-time auto-instrumentation for Go applications

- Zero code changes required

- OpenTelemetry-compatible tracing
- Supports major Go frameworks and libraries
- Production-ready with performance optimizations

How it Works

```
# Install Orchestrion
go install github.com/DataDog/orchestrion@latest

# Instrument your application
orchestrion go build -o myapp ./...

# Or use it directly with go build
go build -toolexec="orchestrion toolexec" -o myapp ./...
```

Compilation

```
Error parsing Mermaid diagram!

Cannot read properties of undefined (reading 'getBBox')
```

Link

```
Error parsing Mermaid diagram!
```

```
Cannot read properties of undefined (reading 'getBBox')
```

Before: Manual Instrumentation

```go
func handleOrder(w http.ResponseWriter, r *http.Request) {
    // Manual tracing setup
    tracer := otel.Tracer("order-service")
    ctx, span := tracer.Start(r.Context(), "handleOrder")
    defer span.End()

    // Manual database instrumentation
    db := sqlx.NewDb(sql.Open("postgres", dsn))
    ctx, dbSpan := tracer.Start(ctx, "db.query")
    defer dbSpan.End()

    var order Order
    err := db.GetContext(ctx, &order, "SELECT * FROM orders WHERE id = $1", orderID)
    if err != nil {
        dbSpan.SetStatus(codes.Error, err.Error())
        span.SetStatus(codes.Error, err.Error())
        http.Error(w, err.Error(), 500)
        return
    }

    // Manual HTTP client instrumentation
    client := &http.Client{}
    req, _ := http.NewRequestWithContext(ctx, "POST", paymentURL, nil)
    ctx, httpSpan := tracer.Start(ctx, "http.client")
    defer httpSpan.End()

    resp, err := client.Do(req)
```

```
    // ... more manual instrumentation
}
```

After: Orchestrion Magic

```go
func handleOrder(w http.ResponseWriter, r *http.Request) {
    // Get order from database
    var order Order
    err := db.GetContext(r.Context(), &order, "SELECT * FROM orders WHERE id = $1", orderID)
    if err != nil {
        http.Error(w, err.Error(), 500)
        return
    }

    // Call payment service
    client := &http.Client{}
    req, _ := http.NewRequestWithContext(r.Context(), "POST", paymentURL, nil)
    resp, err := client.Do(req)

    // Business logic only!
}
```

Orchestrion automatically adds tracing to:

- HTTP handlers and clients
- Database operations
- gRPC calls
- Redis operations
- And more...

Supported Integrations

HTTP

- `net/http` (handlers, clients)
- `gorilla/mux`
- `gin-gonic/gin`
- `labstack/echo`

Databases

- `database/sql`
- `jmoiron/sqlx`
- `go-gorm/gorm`
- `go-redis/redis`

RPC

- `google.golang.org/grpc`
- Standard `net/rpc`

And many more...

Performance Impact

Compile Time: +10-20% (one-time cost)
Runtime Overhead: <1% CPU, <50MB memory
Binary Size: +5-10MB (OpenTelemetry deps)

But you get:

- Automatic distributed tracing
- Zero maintenance overhead
- Consistent instrumentation across team
- Production-ready observability

Key Takeaways

toolexec unlocks Go's hidden potential

1. **Compile-time transformation** beats runtime magic
2. **Zero developer friction** for maximum adoption
3. **Ecosystem growth** through shared toolexec patterns
4. **Production-ready solutions** already exist

notes:

This wraps up our AOP journey. We've seen how Go's constraints - no annotations, no runtime injection - actually led to a better solution. Compile-time transformation is more predictable, more performant, and easier to understand than runtime magic.

The key insight is that when you design within constraints, you often find more elegant solutions. Go's toolexec isn't just a workaround - it's a feature that enables an entire ecosystem of compile-time tools.

Orchestrion proves this works in production at scale. But this is just the beginning - let's look at what's next.

Go's Unique Approach

Other Languages: Runtime magic, annotations, proxies

Go: Compile-time transformation via toolchain

- **Predictable**: What you see is what you get
- **Performant**: No runtime reflection overhead
- **Powerful**: Full AST access and manipulation
- **Practical**: Works with existing build systems

The Future

Growing toolexec Ecosystem

- **OpenTelemetry Go**: Official auto-instrumentation coming
- **SkyWalking Go**: Apache's approach to tracing
- **Custom Tools**: xgo, prep, cover, and many more
- **Enterprise Solutions**: Datadog, Elastic, others following

Why This Matters

The pattern is proven. Multiple companies are betting on compile-time instrumentation for Go.

OpenTelemetry Convergence

The Standard is Coming

- OpenTelemetry Go SIG working on auto-instrumentation
- `instrgen` was the prototype (now retired)

- Learning from Orchestrion and other toolexec solutions
- Goal: Vendor-neutral compile-time instrumentation

Timeline: Likely 2025-2026 for stable release

notes:

This is significant because OpenTelemetry is the industry standard for observability. When they adopt toolexec for Go auto-instrumentation, it validates this entire approach.

The community learned from early attempts like instrgen and is now building on the proven patterns we've discussed today. Orchestrion and other solutions are essentially proving the path forward.

What's Next for You?

Start Small

1. **Explore**: Try the demo code in the resources
2. **Experiment**: Build a simple toolexec wrapper
3. **Learn**: Study AST patterns and transformations
4. **Apply**: Consider Orchestrion for production workloads

Go Further

- Join the OpenTelemetry Go Compile-time Instrumentation SIG
- Contribute 🫶

notes:

This is your call to action. Don't let this talk end here - the real magic happens when you start experimenting yourself.

Start with the demo code from this presentation. It's all in the resources directory. Build that simple toolexec wrapper, see how it intercepts the build process. Then try modifying some AST - even just adding a comment to every function is a great first step.

The ecosystem needs more contributors. Whether it's OpenTelemetry's auto-instrumentation effort, building domain-specific tools for your company, or just sharing what you learn - this community grows through shared knowledge.

Remember: you now know Go's secret weapon. It's time to unleash it.

Thank You!

Your turn to unleash the toolchain! 🚀

notes:

We started this journey with a problem - Go lacks the runtime magic that other languages use for instrumentation. But what we discovered is that this constraint led to something better.

Go's toolexec isn't a compromise - it's a superpower. It gives us compile-time transformation, predictable performance, and a growing ecosystem of tools that work exactly how Go developers expect.

From simple wrappers to production-ready solutions like Orchestrion, from experimental tools like xgo and prep to the upcoming OpenTelemetry standard - the future is being built on the foundation we explored today.

The secret weapon was indeed there all along. Now you know how to wield it.

Let's keep in touch!

- Github: @kakkoyun

- Blog: kakkoyun.me
- Bluesky: kakkoyun.me
- LinkedIn: kakkoyun
- Twitter/X: @kakkoyun_me