TRACING

~~TOKIO-TRACE~~

scoped, structured, **async-aware** diagnostics

I know on the program it says this talk is about "tokio-trace". That's a lie,
this talk is not actually about tokio-trace.

We renamed the library, and it's called "tracing" now.

"tracing" is a set of libraries for instrumenting Rust programs with scoped, structured, and async-aware diagnostics.

Why I Am The Most Important LOGGING Thought Leader

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If you know anything about me, you'll know that I love DevOps LOGS and that I'm perhaps the most perfect and important thought leader on the subject. It is a heavy crown to wear sometimes, but I do it gladly. I am almost solely responsible for discovering a number of computing concepts, which is what makes me so good at DevOps LOGGING. When people ask for my business card I simply write "DevOps" INFO on something and give it to them.

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you're probably wondering, who am I, and why am I an important logging thought
leader? my name is Eliza Weisman; I'm a systems software engineer at
Buoyant in San Francisco.

I've been writing Rust since 2015, and I've been doing it professionally for
over two years now.

I contribute to the tokio, tower, and linkerd 2 open source projects.

Some of you have probably seen my twitter where I post bad programming jokes
and pictures of my cats...

WHY I MADE ANOTHER LOGGING LIBRARY

A lot of you are probably wondering why we made another logging library. We already have a pretty robust ecosystem for logging.

WHY I MADE ANOTHER LOGGING LIBRARY

Well first of all, I don't like to call it "logging". I prefer to call it "GNU
slash logging".

Yes, that was a joke. But what I really prefer to call it is "in-process
tracing". We'll talk about what that actually means a little later.

To answer this question, I'm going to start by asking some questions of my
own.

HOW MANY OF YOU ARE USING FUTURES?

alright, show of hands...how many of you are using futures (or async-await)?

AND DOES YOUR LOGGING MAKE ANY SENSE?

great. do your logs make any sense? like at all?

ASYNC IS HARD

Yeah. Async is hard, right? *pause for laughter*

If you're writing a high-performance network application, you probably need to use asynchronous programming. Async presents some unique challenges to
diagnostics.

Execution is multiplexed between tasks. When a task requires something from IO or
another task, instead of blocking, it yields. Then, we start executing another
task. The task will wake back up when IO is ready.

Because of this, log messages can end up interleaved, or we can't tell what
context a message happened in.

HOW DO WE GET USABLE DIAGNOSTICS FROM ASYNC SYSTEMS?

What do we need in order to get usable diagnostics from async software?

The way I see it, there are three main things we want our diagnostics to capture: context, causality, and structure.

CONTEXT

Context. When we record that an event occurred, we don't just want to know
where in the *source code* it happened, but in what *runtime context* as well.

For example, if we have a server that's processing requests, the context might
include: what client did this request come from? what where the request's
method, path, and headers?

In synchronous code, we can infer context from the order that log records appear in. But in async code, we switch between contexts, so our diagnostics
need to track them.

CAUSALITY

Second, we want to capture *causality*. What other events caused this event to occur?

If some task is running in the background, say, a DNS resolution, or a database connection, what caused that task to start? Which request required that DNS resolution?

In async systems we can't rely on ordering to determine causality. So again, we need to record it.

STRUCTURE

Traditional logging is based on human-readable text messages. We'd prefer our diagnostics to record machine-readable structured data.

This lets us interact with our diagnostic data programmatically. You can record typed values and interact with them as numbers, booleans, and so on.

TRACING

```
→ formerly tokio-trace
→ part of the Tokio project
→ doesn't require the Tokio runtime
→ works with no-std
```

Enter tracing. Tracing is a framework for instrumenting rust programs, with contextual, causal, strucutred diagnostics.

As I said before, this used to be called tokio-trace. Tracing is part of the Tokio project, but it doesn't require the Tokio runtime.

TRACING

→ formerly tokio-trace

→ part of the Tokio project

→ doesn't require the Tokio runtime

→ works with no-std*

With some caveats.

TIME FOR A

DEMO

HOW TRACING ACTUALLY WORKS

So how does `tracing` actually *work*?

SO WHAT DID I MEAN BY IN-PROCESS TRACING?

Is anyone here familiar with distributed tracing systems? Like OpenTracing,
OpenCensus or Zipkin?

Okay, great. These are diagnostic tools for distributed systems. They're designed for tracking contexts as they move from node to node, so that you can
correlate events on one node with events on another.

A key insight behind `tracing` is that asynchronous programs are kind of like distributed systems writ small. You have concurrently running tasks that
communicate through fallible message passing. The only difference is that
everything lives in one address space.

CORE PRIMITIVES SPANS AND

Our core primitives instrumentation primitives are *spans* and *events*

SPANS

PERIODS OF TIME

A span represents a period of time where the program is executing in a
context.

Spans have beginnings and ends, and we can *enter* and *exit* them as we
switch between contexts. A program can enter and exit a span multiple times over
its lifespan. This is especially important for asynchronous code. In particular,
it gives us the ability to record both how long a task existed for, *and* how
long we were actively executing it.

```rust
let span = span!(Level::TRACE, "my_great_span");
```

So here is how you use spans. You create a span with the `span!` macro, and you get back this span object. Here's a span called "my great span".

```rust
let span = span!(Level::TRACE, "my_great_span");
let _guard = span.enter();
```

Then you can *enter* the span. You get back a RAII guard, so you can enter the span in a scope.

```rust
let span = span!(Level::TRACE, "my_great_span");
let _guard = span.enter();
// do some stuff *inside* the span...
```

Anything that happens while that guard is held is considered inside the span.

```rust
#[tracing::instrument]
fn my_function(question: &str) -> Option<usize> {
    // ...
}
```

We also have this instrument attribute. You can put it on a function & it will automatically create and enter a span when the function is called.

```rust
#[tracing::instrument]
async fn my_function(question: &str) -> Option<usize> {
    // ...
}
```

And this works with async functions too.

EVENTS

MOMENTS IN TIME

```
event!(Level::INFO, "something happened!");
```

Events, on the other hand, represent singular instants in time where something happened.

They're analagous to log records in conventional logging. But unlike log records, they exist in a span context.

FIELDS

ADD STRUCTURED DATA

```
event!(Level::INFO, foo = 3, bar = false);
```

Fields are how we attach typed, structured data to spans and events. A field
is a key-value pair.

Tracing subscribers can consume field values as a subset of Rust primitive types.

SUBSCRIBERS

COLLECT TRACE

Finally, we have a component called a `Subscriber`. Subscribers are the
component that actually collects and records the trace data generated by our
instrumentation.

You can think of a subscriber as being kind of like a logger. And like loggers, `Subscribers` are pluggable. This is tracing's main extension point.

Libraries can provide subscribers that implement different behavior. One might
print traces to standard out, another might record metrics, and third might send
events to some distributed tracing system.

BUT HOW DO I USE IT?

To put it all together, here's a little example.

```
for yak in yaks {
    shave_yak(yak);
}
```

We're shaving some yaks.

```
for yak in yaks {
    tokio::spawn(shave_yak(yak));
}
```

...asynchronously. So this shave_yak function is asynchronous, it's returning a future.

```rust
let span = span!(Level::INFO, "shaving_yaks");

for yak in yaks {
    tokio::spawn(shave_yak(yak));
}
```

So we create a span called "shaving yaks". We're going to do all the work in there.

```rust
let span = span!(Level::INFO, "shaving_yaks", yak_count = yaks.len());

for yak in yaks {
    tokio::spawn(shave_yak(yak));
}
```

We annotate that span with the number of yaks we're shaving.

```rust
let span = span!(Level::INFO, "shaving_yaks", yak_count = yaks.len());
let _enter = span.enter();

for yak in yaks {
    tokio::spawn(shave_yak(yak));
}
```

We enter the span, indicating we're executing in that context. This returns a RAII guard that indicates we're inside the span until it's dropped.

```rust
let span = span!(Level::INFO, "shaving_yaks", yak_count = yaks.len());
let _enter = span.enter();

for yak in yaks {
    let span = span!(Level::DEBUG, "shave", current_yak = yak);
    tokio::spawn(shave_yak(yak));
}
```

Every iteration of the loop, we create a new span "shave", annotated with the yak we're shaving.

```rust
let span = span!(Level::INFO, "shaving_yaks", yak_count = yaks.len());
let _enter = span.enter();

for yak in yaks {
    let span = span!(Level::DEBUG, "shave", current_yak = yak);
    tokio::spawn(shave_yak(yak).instrument(span));
}
```

This instrument combinator attaches a span to a future so that it's entered whenever we poll the future.

```rust
let span = span!(Level::INFO, "shaving_yaks", yak_count = yaks.len());
let _enter = span.enter();

for yak in yaks {
    let span = span!(Level::DEBUG, "shave", current_yak = yak);
    let future = async move {
        shave_yak(yak).await;
        debug!("yak shaved!");
        Ok(())
    };
    tokio::spawn(future.instrument(span));
}
```

We record an event after the yak is shaved. Since this is inside the async block that's implemented with the shave span, we don't need to record which yak
we're shaving --- the span does that for us.

```rust
let span = span!(Level::INFO, "shaving_yaks", yak_count = yaks.len());
let _enter = span.enter();

for yak in yaks {
    let span = span!(Level::DEBUG, "shave", current_yak = yak);
    let future = async move {
        match shave_yak(yak).await {
            Ok(()) => debug!("yak shaved successfully"),
            Err(error) => warn!(error, "yak shaving failed!"),
        };
        Ok(())
    };
}
```

Let's say shaving the yak is fallible. Here we can record an event depending on the return value. And here we're recording that error as a structured field on this span, so the subscriber can record it as a typed value.

Again, we don't need to record what yak we were shaving --- that's added by the span.

WORKS WITH LOG

this compiles

```
use log::info;

info!("log-style logging! foo={}; bar={}", 42, true);
```

We also have drop in compatibility with the `log` crate. Here I'm importing log and using its `info` macro to log a message. If I want to switch to tracing...

...and so does this

```
use tracing::info;

info!("log-style logging! foo={}; bar={}", 42, true);
```

All I have to do is change which crate I'm importing.

tracing has macros that are a superset of log's macros. They can do more stuff than log, but they support all the same syntax.

We also have adapters to let you convert between log records and trace events.

ONLY **PAY** FOR WHAT YOU **USE**

Any runtime instrumentation has performance costs.

Tracing's goal is to ensure you don't pay any costs you don't *have* to.

What does that mean?

DISABLED INSTRUMENTATION IS (NEARLY)

First of all, we've made sure that a subscriber filters
out spans or events you don't want to record, the overhead is basically a single
load and a branch --- under one nanosecond.

We cache filter evaluations when possible --- if something is always
disabled, we never need to re-filter it.

SUBSCRIBERS DON'T PAY COSTS BY DEFAULT

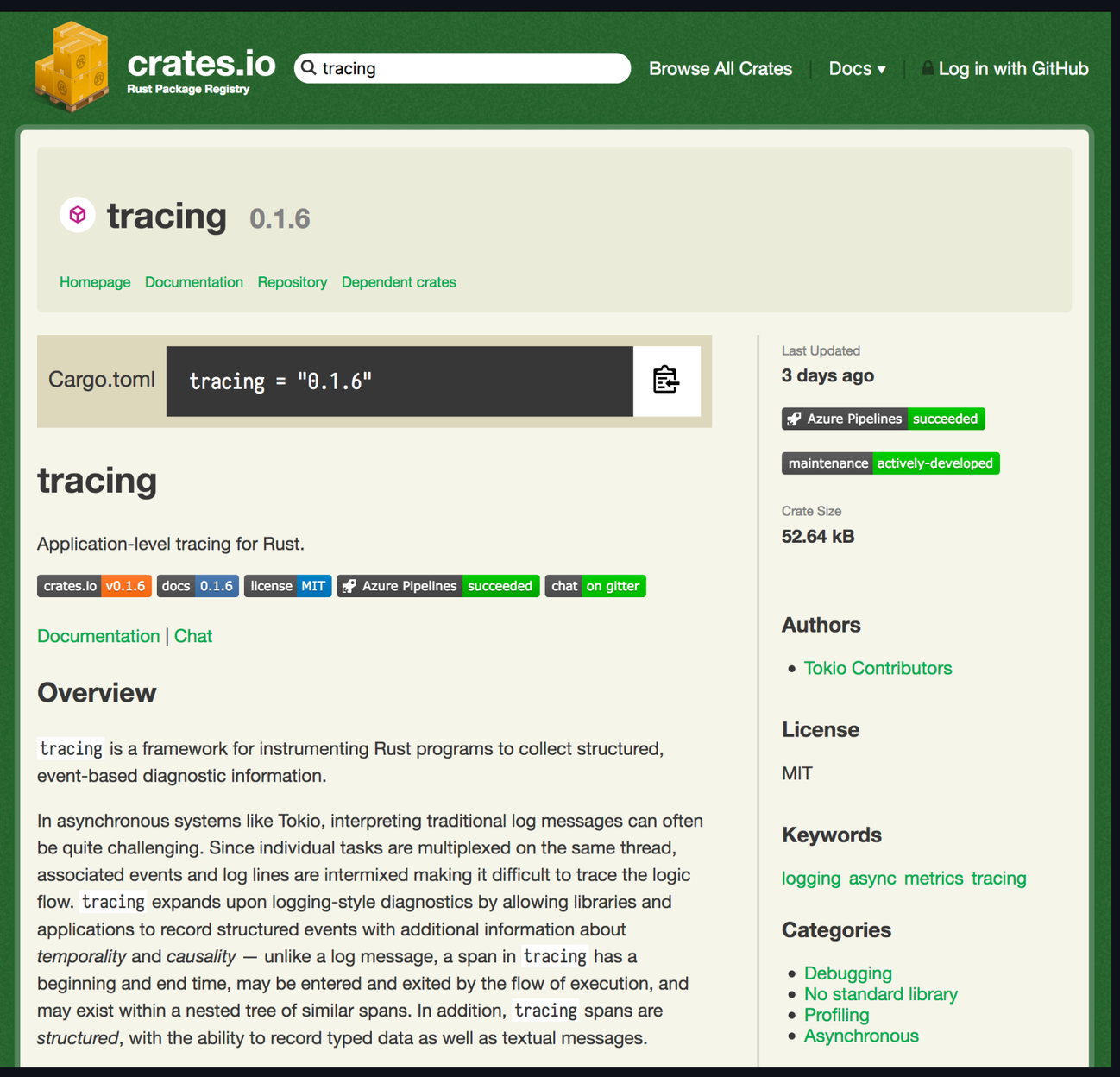
Furthermore, we've left all the real overhead up to subscriber implementations.
Since different use-cases have different requirements --- some have to allocate to track data, others need to make syscalls to get timestamps --- `tracing` doesn't require that *all* subscribers pay those costs.

BOOTSTRAPPING AN ECOSYSTEM

It's worth noting that we're trying to bootstrap a whole ecosystem here. Tracing consists of two core libraries, tracing and tracing-core, that provide the instrumentation APIs and the plumbing that makes everything work.

But this doesn't do a whole lot on it's own. There are so many different ways to consume the data that tracing exposes, and we have some other libraries
providing subscriber implementations. For example, the one I used in the demo is
from the "tracing-fmt" crate, which logs tracing events to standard out. Jon Gjengset is working on a "tracing-timing" crate that uses tracing spans for time
profiling.

There's a whole lot of neat stuff we can build on top of tracing together. I'm sure I haven't even thought of all of it yet.



→ crates.io/crates/tracing

→ github.com/tokio-rs/tracing

So here's how you can get involved. The first thing you can do is just try it
out. I love bug reports and feature requests, and I love PRs even more.

Second, if there's anything you want to see in the ecosystem, maybe you want a
subscriber for your favorite metrics lib, or a different way of formatting trace
logs, please share it! I can't wait to see what people build using `tracing`.

The core crates live in the `tokio-rs/tracing` repo

QUESTIONS?

→ email: eliza@buoyant.io
→ twitter: @mycoliza
→ slides: elizas.website/slides/
→ blog post: tokio.rs/blog/2019-08-tracing/
→ ...or, see me after class!

Before I open the floor for questions, here's how you can contact me if you want to chat about tracing, tokio or linkerd.

Also, you can find the slides (and a recording of this talk) at elizas.website/slides. Feel free to take a picture of this slide if you want to.