


TIME-WARPING WITH CATS EFFECT

Jacob Wang

Hello

- Software Developer at  medidata
- @jatcwang
- Talk to me about types, FP, libraries and tools :)

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- But how do you test it?

The Problem

Tests involving time and delays are difficult to write

- Using `Thread.sleep` (or any kind of real clock) leads to long-running and flaky tests
- but what else can we do?

In this talk

- Threads, thread pools and schedulers from the ground up
- How to build a “controlled” thread pool / scheduler
- How to write tests with cats-effect’s TestContext

Back to the basics

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 - `thread.run()` executes the Runnable
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```
// java.lang.Runnable
trait Runnable {
  def run(): Unit
}

val t = new Thread(new Runnable {
  def run() = {
    Thread.sleep(1000)
    println("hi!")
  }
})
t.run() // "hi!" after a delay of ~1 second
```

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- Clunky API
- Overhead both in processing time and memory
 - Memory overhead (each thread has its own stack)
 - “Context Switching” cost from one thread to another
 - In many use cases it limits scalability
(e.g. Backend services serving a lot of requests all hitting the DB)

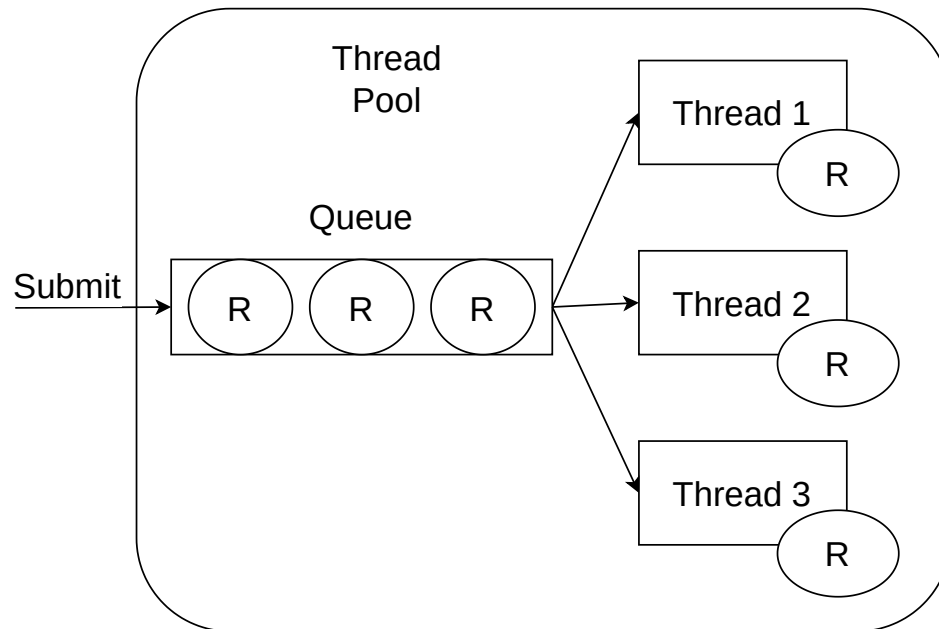
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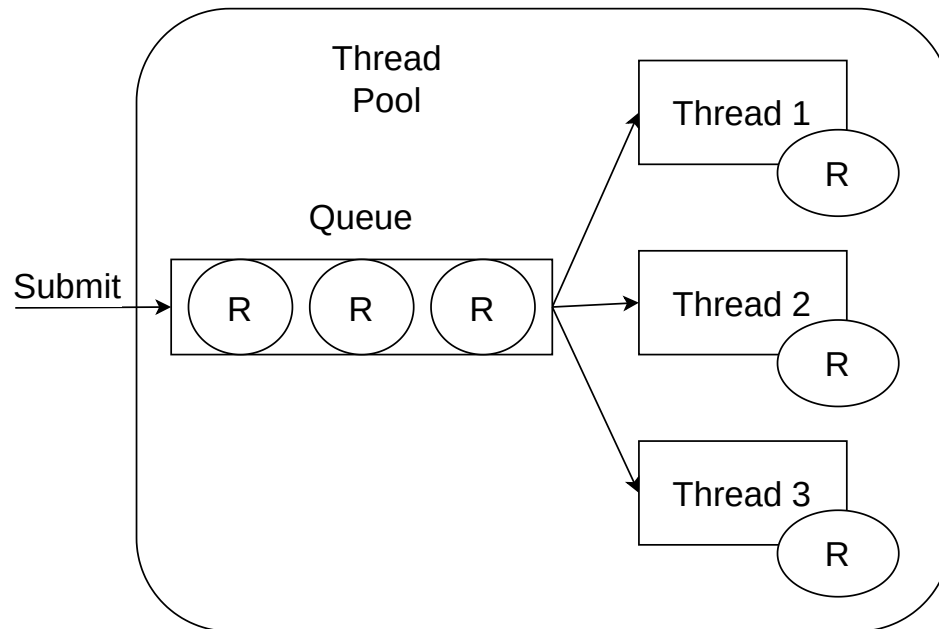
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ExecutionContext is Scala's own simpler interface for the same idea

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  // Simplified, delay in nanoseconds  
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`Thread.sleep` continuously

- See `java.util.concurrent.ScheduledThreadPoolExecutor`

One Simple Idea

Can we write a `ScheduledExecutorService` that doesn't use sleep nor run anything, but instead just record the **Runnable**s and when it should be run?

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```
final case class Task(runnable: Runnable, runAt: Long)

class ControlledScheduledExecutorService extends ScheduledExecutorService {
  private var currentTime: Long = 0
  private var allTasks: SortedSet[Task] = SortedSet.empty // sorted by runAt

  override def schedule(runnable: Runnable, delay: Long): Unit = {
    allTasks = allTasks :+ Task(runnable, currentTime + delay)
  }
}
```

Preparing to time-warp...

Since no OS thread nor scheduling are involved, we have total control over what to run and when to run it

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  private var currentTime: Long = 0  
  private var allTasks: SortedSet[Task] = SortedSet.empty // sorted by runAt  
  
  override def schedule(runnable: Runnable, delay: Long): Unit = // ...  
  
  // Move clock forward and run any Runnables that should happen during this period  
  def tick(elapseTime: Long) = {  
    currentTime = currentTime + elapseTime  
    var nextTask = allTasks.findAndRemove(_.runAt <= currentTime)  
    while (nextTask.nonEmpty) {  
      nextTask.get.runnable.run()  
      nextTask = allTasks.findAndRemove(_.runAt <= currentTime)  
    }  
  }  
}
```

It's warp time!

```
val ctx = new ControlledScheduledExecutorService

ctx.schedule(
  new Runnable { def run() = println("Warped!") },
  1000
)

// Nothing happens until we "tick" to the right time
ctx.tick(200)
ctx.tick(300)
ctx.tick(500) // "Warped!"
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“Great, but only cavemen use raw **Runnable**s”

It's Runnables all the way down

Almost all effect libraries / Futures ultimately ends up as **Runnables** being submitted to thread pools.

```
implicit val ec: ExecutionContext = ...
Future {
  1 + 1 // 1
}.map { res =>
  println(res) // 2
}

// Eventually translates to something like...
ec.execute(new Runnable {
  def run() = {

    val res = 1 + 1 // 1

    ec.execute(new Runnable { // submit the "next step" back to the EC
      def run() = {

        println(res) // 2

      }
    })
  }
})
})
```


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```
val testCtx = cats.effect.laws.util.TestContext() // TestContext <: ExecutionContext
implicit val ctxShift: ContextShift[IO] = testCtx.ioContextShift
implicit val timer: Timer[IO] = testCtx.ioTimer

val appLogic = for {
  _ <- IO { println("hi!") }
  _ <- IO.sleep(100.days)
  _ <- IO { println("I have awakened!") }
} // Step 1 Define the IO

// execute our IO in the TestContext
ctxShift.evalOn(testCtx)(appLogic).unsafeRunAsyncAndForget() // Step 2 "run" the IO

println("Ticking 50 days..") // Step 3 time-warp!
testCtx.tick(50.days) // "hi!" printed here

println("Ticking another 50 days..")
testCtx.tick(50.days) // "I have awakened!" is printed
```

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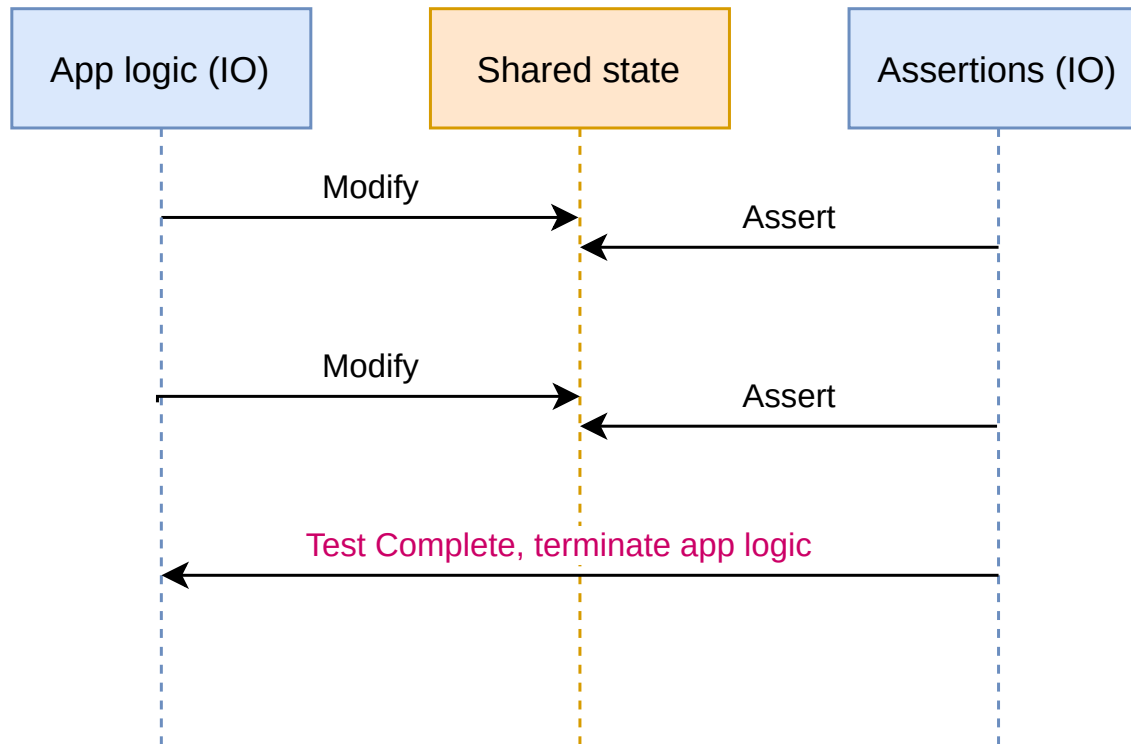
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```

val testContext = TestContext()
implicit val contextShift: ContextShift[IO] = testContext.ioContextShift
implicit val timer = testContext.ioTimer

val appLogic: IO[Unit] = ???           // Step 1: Define Logic and Assertions
val assertions: IO[Unit] = for {
  _ <- IO.sleep(5.seconds)
  _ <- assertState(state1)
  _ <- IO.sleep(5.seconds)
  _ <- assertState(state2)
} yield succeed

// Step 2: Run it with test "framework" (reusable across test suites)
val test = for {
  fibre <- appLogic.start // forks the app logic into the background
  _ <- IO.sleep(1.nanos) // very small delay to ensure assertions
                        // always run after app logic has happened
  _ <- assertions.guarantee(fibre.cancel)
} yield succeed

// Step 3: "Execute" the test
val f: Future[Assertion] = contextShift.evalOn(testContext)(test).unsafeToFuture()

// Actually execute all the app logic and assertions
// Note that assertions will terminate the appLogic when it is done
// so that this works for infinitely repeating app logic too
testContext.tick(1000.days)

```


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 - Good for catching race conditions
- Since only TestContext is controlled, **ALL** your Runnables need to be submitted to it
 - Doobie Transactor, any `Future{..}/future.map`, etc etc
 - External libraries should allow you to specify a thread pool
- The underlying mechanism is based on simple primitives , you can time-warp with Scala Future, Monix, ZIO, and Java `CompletableFuture` too ;)

Acknowledgements

- People on cats-effect gitter chat who helped me setup TestContext tests
 - Daniel Spiewak (@djspiewak)
 - Fabio Labella (aka SystemFw)
 - Gavin Bisesi (@Daenyth)

Thank you!

// reveal.js plugins