TIME-WARPING WITH CATS EFFECT

Jacob Wang

Hello

- Software Developer at 

- @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

In the beginning, we have `java.lang.Thread`

```
trait Runnable {
  def run(): Unit
}

val t = new Thread(new Runnable {
  def run() = {
    Thread.sleep(1000)
    println("hi!") }
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  - `thread.run()` executes the Runnable initially assigned to the thread
- `Thread.sleep()` suspends the current thread's execution, and OS schedules other threads to run

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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)

Thread Pools (ExecutorService)

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  def submit(runnable: Runnable): Unit
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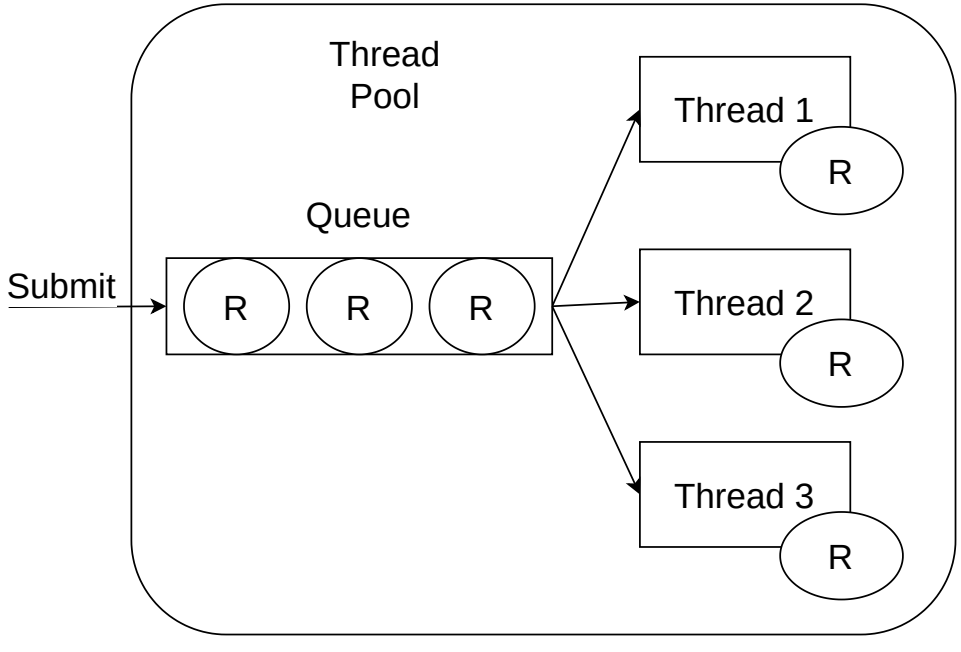

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  // Simplified, delay in nanoseconds
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  - See `java.util.concurrent.ScheduledThreadPoolExecutor`

One Simple Idea

Can we write a `ScheduledExecutorService` that doesn't use sleep nor run anything, but instead just record the **Runnables** 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
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  override def schedule(runnable: Runnable, delay: Long): Unit = // ...

  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)
    }
  }
}
```

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- Evaluation depends on "what task is in the queue, and when should they be run", which means there's no difference between running 100 **Runnable** scheduled all within 1 millis or 1000 years!
- "Great, but only cavemen use Runnables"

It’s Runnables all the way down

Almost all effect libraries / Futures ultimately ends up as **Runnables** being executed un by a thread pool.

```
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
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- So the technique covered thus far can be applied everywhere!

cats.effect TestContext

`TestContext` is one implementation of controlled thread pool / scheduler

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

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

// execute our IO in the TestContext
ctxShift.evalOn(testCtx)(io).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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- You can find it in `cats-effect-laws` library dependency

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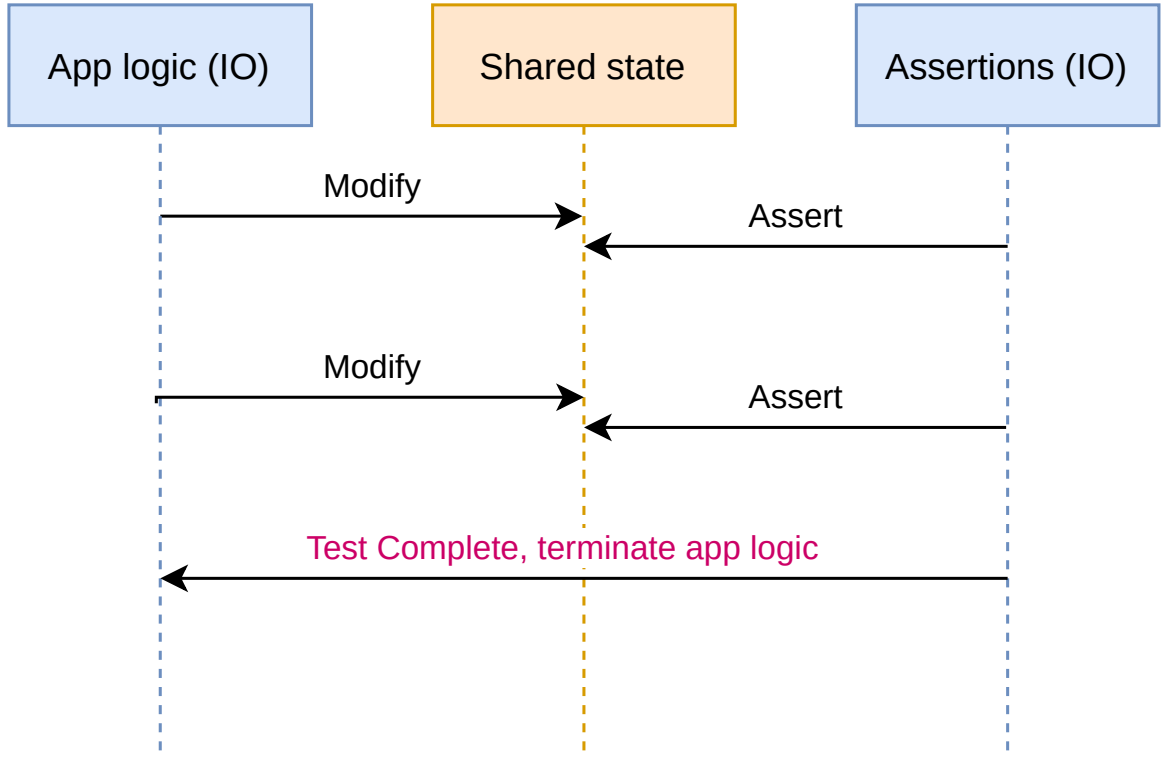

```scala
val appLogic: IO[Unit] = ???      // Step 1: Define Logic and Assertions
val assertions: IO[Unit] = for {
  _ <- IO.sleep(5.seconds)
  _ <- assertState(state1)
  _ <- IO.sleep(5.seconds)
  _ <- assertState(state2)
} yield succeed

// Step 2: Run it with test "framework" (reusable across test suites)
val testContext = TestContext()
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] = 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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- 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

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