

A TALE OF TWO MONIX STREAMS

Alexandru Nedelcu

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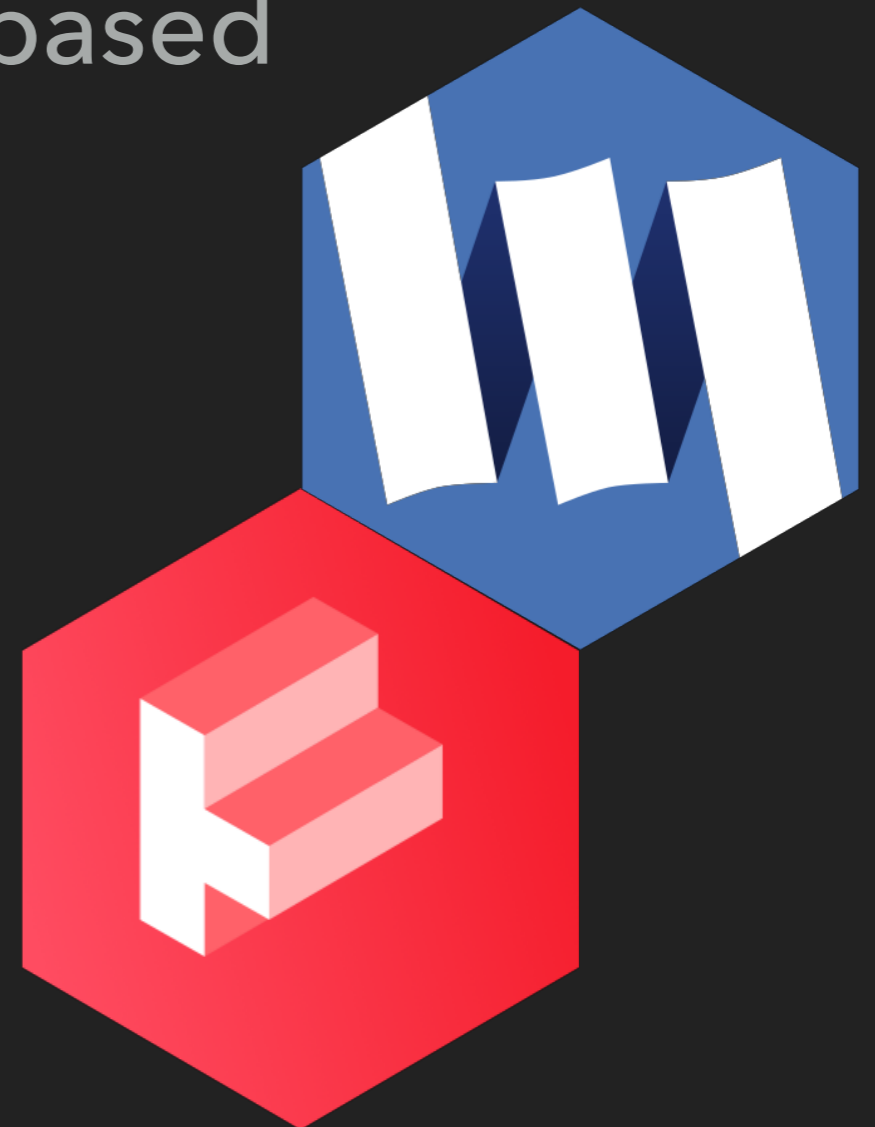
WHAT IS MONIX?

- ▶ Scala / Scala.js library
- ▶ For composing asynchronous programs
- ▶ Exposes Observable, Task, Coeval, Iterant and many concurrency primitives
- ▶ Typelevel (see typelevel.org)
- ▶ 3.0.0-RC1
- ▶ See: monix.io



3.0

- ▶ Deep integration with **Typelevel Cats**
- ▶ **Iterant** data type for lawful pull-based streaming
- ▶ major improvements to **Observable, Task, Coeval** and **CancelableFuture**



MONIFU

- ▶ Started on January 2, 2014, at 2:30 a.m.
- ▶ Developed for monitoring and controlling power plants
- ▶ Inspired by RxJava / ReactiveX ([link](#))
- ▶ Renamed to Monix on Dec 30, 2015 ([issue #91](#))
- ▶ Monix comes from: *Monads + Rx*



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I'M A DEVELOPER, I HAVE NO LIFE

```
commit 9c6ce3106c35de707b5d3f9d26cd63ed4b355c07
Author: Alexandru Nedelcu <noreply@alexn.org>
Date: Thu Jan 2 02:32:49 2014 +0200
```

Initial commit

(END)



+



=



STREAMS



PUSH - BASED STREAMING

○ OBSERVABLE[+A]

RX .NET - ORIGINS

- ▶ Reactive Extensions (also known as ReactiveX)
- ▶ The Observable pattern
- ▶ Built at Microsoft by
 - ▶ Jeffery Van Gogh
 - ▶ Wes Dyer
 - ▶ Erik Meijer
 - ▶ Bart De Smet

RX.NET - ORIGINS

```
trait Iterator[+A] {  
  def hasNext: Boolean  
  def next(): A  
}
```

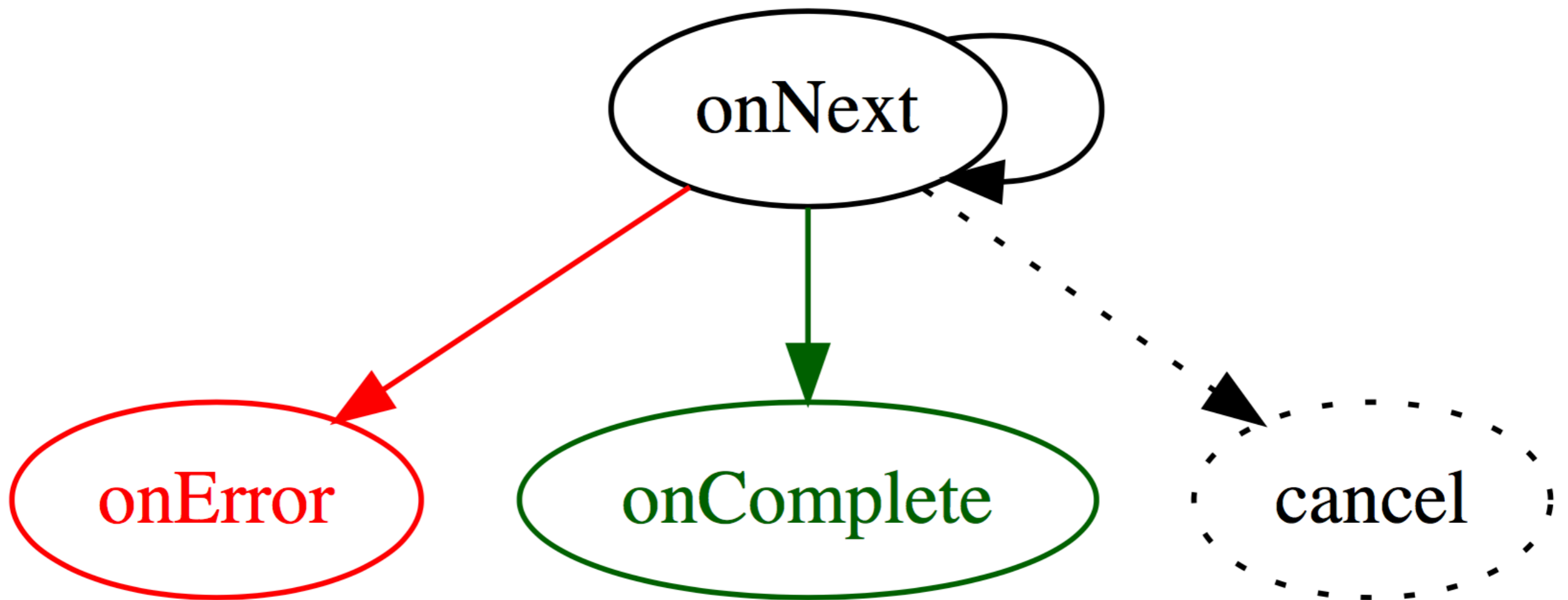
```
trait Iterable[+A] {  
  def iterator: Iterator[A]  
}
```

RX .NET - ORIGINS

```
trait Observable[+A] {  
  def subscribe(o: Observer[A]): Cancelable  
}
```

```
trait Observer[-A] {  
  def onNext(elem: A): Unit  
  def onComplete(): Unit  
  def onError(e: Throwable): Unit  
}
```

RX.NET - ORIGINS



**OBSERVABLE IS THE DUAL OF
ITERABLE**

Erik Meijer

RX.NET - PROBLEMS

- ▶ Pure push - based
- ▶ No protections against slow consumers
- ▶ Unbounded buffers / throttling
- ▶ Trivia: **flatMap** is aliased to **mergeMap** because **concatMap** is unsafe

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REACTIVE-STREAMS.ORG

```
trait Subscription {  
  def request(n: Long): Unit  
  def cancel(): Unit  
}
```

```
trait Subscriber[A] {  
  def onSubscribe(s: Subscription): Unit  
  
  def onNext(elem: A): Unit  
  def onComplete(): Unit  
  def onError(e: Throwable): Unit  
}
```

TOWARD THE FUTURE[A]



IDEA 1: BACK-PRESURE WITH FUTURE

```
import scala.concurrent.Future

trait Observer[-A] {
  def onNext(elem: A): Future[Unit]

  def onComplete(): Unit

  def onError(e: Throwable): Unit
}
```

IDEA 2: CONSUMER DRIVEN CANCELATION

```
import monix.execution.Ack
import scala.concurrent.Future

trait Observer[-A] {
  def onNext(elem: A): Future[Ack]

  def onComplete(): Unit

  def onError(e: Throwable): Unit
}
```

IDEA 2: CONSUMER DRIVEN CANCELATION

```
sealed trait Ack extends Future[Ack] {  
  // ...  
}
```

```
object Ack {  
  /** Signals demand for more. */  
  case object Continue extends Ack  
  
  /** Signals demand for early termination. */  
  case object Stop extends Ack  
}
```


SIDE EFFECTS, WOOT!

```
class SumObserver(take: Int) extends Observer[Int] {  
    private var count = 0  
    private var sum    = 0  
  
    def onNext(elem: Int): Ack = {  
        count += 1  
        sum += elem  
        if (count < take) Continue else {  
            onComplete()  
            Stop  
        }  
    }  
  
    def onComplete() =  
        println(s"Sum: $sum")  
    def onError(e: Throwable) =  
        e.printStackTrace()  
}
```

OBSERVABLE IS HIGH-LEVEL

```
val sum: Observable[Long] =
  Observable.range(0, 1000)
    .take(100)
    .map(_ * 2)
    .foldF

// Actual execution
sum.subscribe(result => {
  println(s"Sum: $result")
  Stop
})
```

OBSERVABLE IS HIGH-LEVEL

```
val sum: Task[Long] =  
    Observable.range(0, 1000)  
        .take(100)  
        .map(_ * 2)  
        .foldL  
  
// Actual execution  
val f: CancelableFuture[Long] =  
    sum.runAsync
```

OBSERVABLE IS A MONADIC TYPE

```
observable.flatMap { i ⇒ Observable.range(0, i) }
```

```
observable.mapTask { key ⇒ Task(f(key)) }
```

```
observable.mapEval { key ⇒ IO(f(key)) }
```

SUSPENDING SIDE EFFECTS

```
def readFile(path: String): Observable[String] =  
  Observable.suspend {  
    // The side effect  
    val lines = Source.fromFile(path).getLines  
    Observable.fromIterator(lines)  
  }
```

SUSPENDING SIDE EFFECTS

- ▶ Does not need IO / Task for *evaluation* or *suspending* effects
- ▶ **Observable** is **IO-ish**

REACTIVE WOOT!

```
observable.mergeMap { key => eventsSeq(key) }
```

```
observable.switchMap { key => eventsSeq(key) }
```

REACTIVE WOOT!

```
observable.throttleFirst(1.second)
```

```
observable.sample(1.second)
```

```
observable.debounce(1.second)
```

```
observable.echoOnce(1.second)
```


REACTIVE WOOT!

```
observable.sampleRepeated(1.second)
```

```
observable.debounceRepeated(1.second)
```

```
observable.echoRepeated(1.second)
```

REACTIVE WOOT!

observable

- `distinctUntilChanged`
- `sample(1.second)`
- `echoRepeated(5.seconds)`

REACTIVE WOOT!

```
observable.publishSelector { hot =>
    val a = hot.filter(_ % 2 == 0).map(_ * 2)
    val b = hot.filter(_ % 2 == 1).map(_ * 3)

    Observable.merge(a, b)
}
```

OBSERVABLE OPTIMISATIONS

OBSERVABLE OPTIMISATIONS FOR FLAT-MAP

- ▶ Models complex state machine for eliminating **asynchronous boundaries**
- ▶ Deals with **Concurrency** by means of one **Atomic**
 - ▶ Cache-line padding for avoiding *false sharing*
 - ▶ Uses **getAndSet** platform intrinsics
- ▶ **monix-execution** ftw

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OBSERVABLE OPTIMISATIONS FOR MERGE-MAP / BUFFERING

- ▶ Using [JCTools.org](https://jctools.org) for non-blocking queues
 - ▶ MPSC scenarios
 - ▶ Consumer does not contend with producers

CONSEQUENCES

- ▶ **Best in class performance**
(synchronous ops have ~zero overhead,
can optimise synchronous pipelines)
- ▶ Referential Transparency
(subscribe <-> unsafePerformIO)
- ▶ Pure API, Dirty Internals

CONSEQUENCES

- ▶ Best in class performance
(synchronous ops have ~zero overhead,
can optimise synchronous pipelines)
- ▶ **Referential Transparency**
(`subscribe <-> unsafePerformIO`)
- ▶ **Pure API, Dirty Internals**

PULL-BASED STREAMING

ITERANT[F,A]

**ARCHITECTURE IS FROZEN
MUSIC**

Johann Wolfgang Von Goethe

**DATA STRUCTURES ARE
FROZEN ALGORITHMS**

Jon Bentley

FP DESIGN – KEY INSIGHTS

1. Freeze Algorithms into *Data-Structures*
(*Immutable*)
2. Think *State Machines*
3. Be *Lazy*

FP DESIGN – KEY INSIGHTS

1. Freeze Algorithms into *Data-Structures*
2. Think *State Machines*
(most of the time)
3. Be *Lazy*

FP DESIGN – KEY INSIGHTS

1. Freeze Algorithms into *Data-Structures*
2. Think *State Machines*

3. Be *Lazy*

(Strict Values => Functions ;-))



Finite State Machine Cat

LINKED LISTS

```
sealed trait List[+A]
```

```
case class Cons[+A](  
  head: A,  
  tail: List[A])  
extends List[A]
```

```
case object Nil  
extends List[Nothing]
```

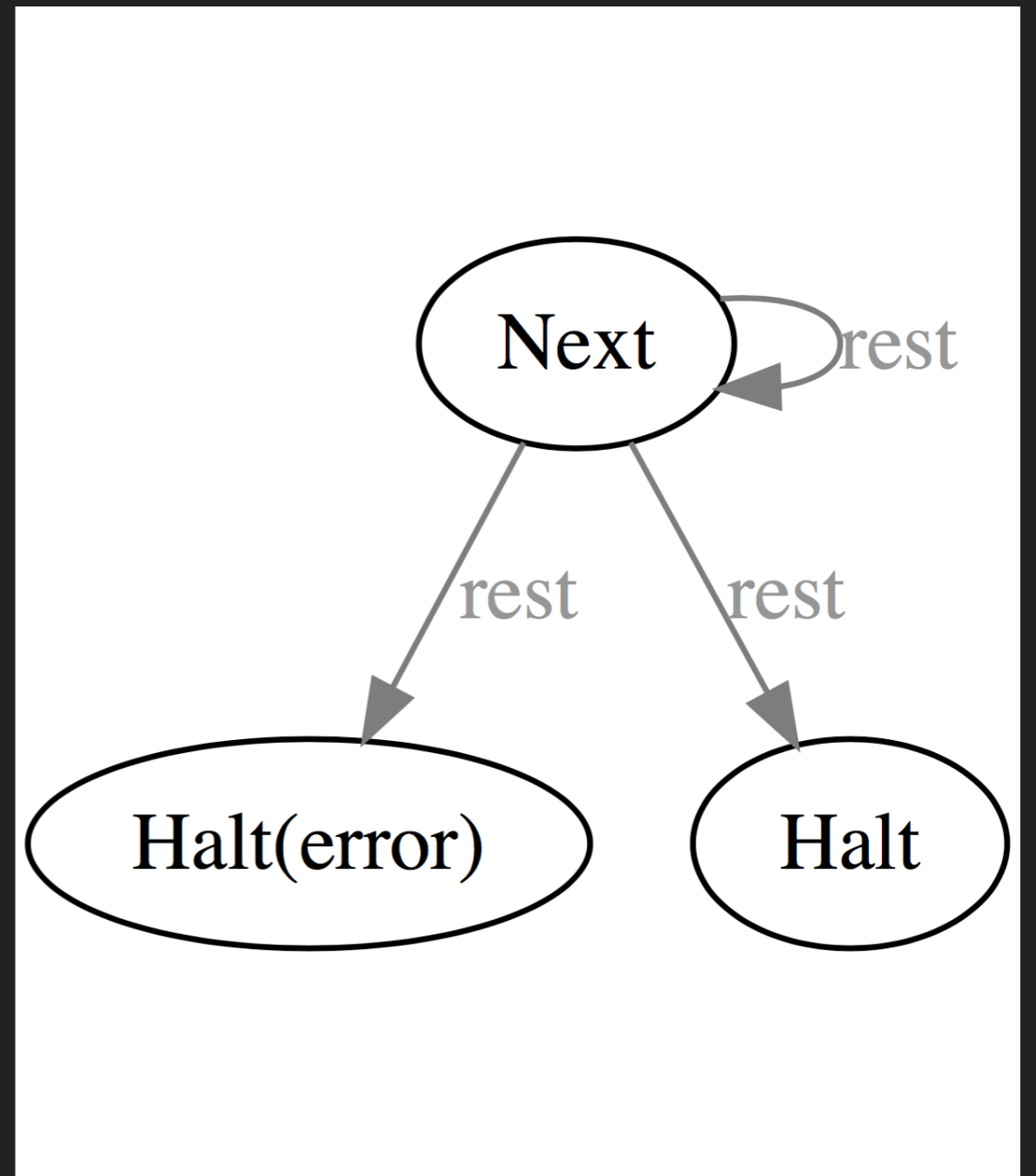


LAZY EVALUATION

```
sealed trait Iterant[A]
```

```
case class Next[A](  
  item: A,  
  rest: () => Iterant[A])  
extends Iterant[A]
```

```
case class Halt[A](  
  e: Option[Throwable])  
extends Iterant[A]
```

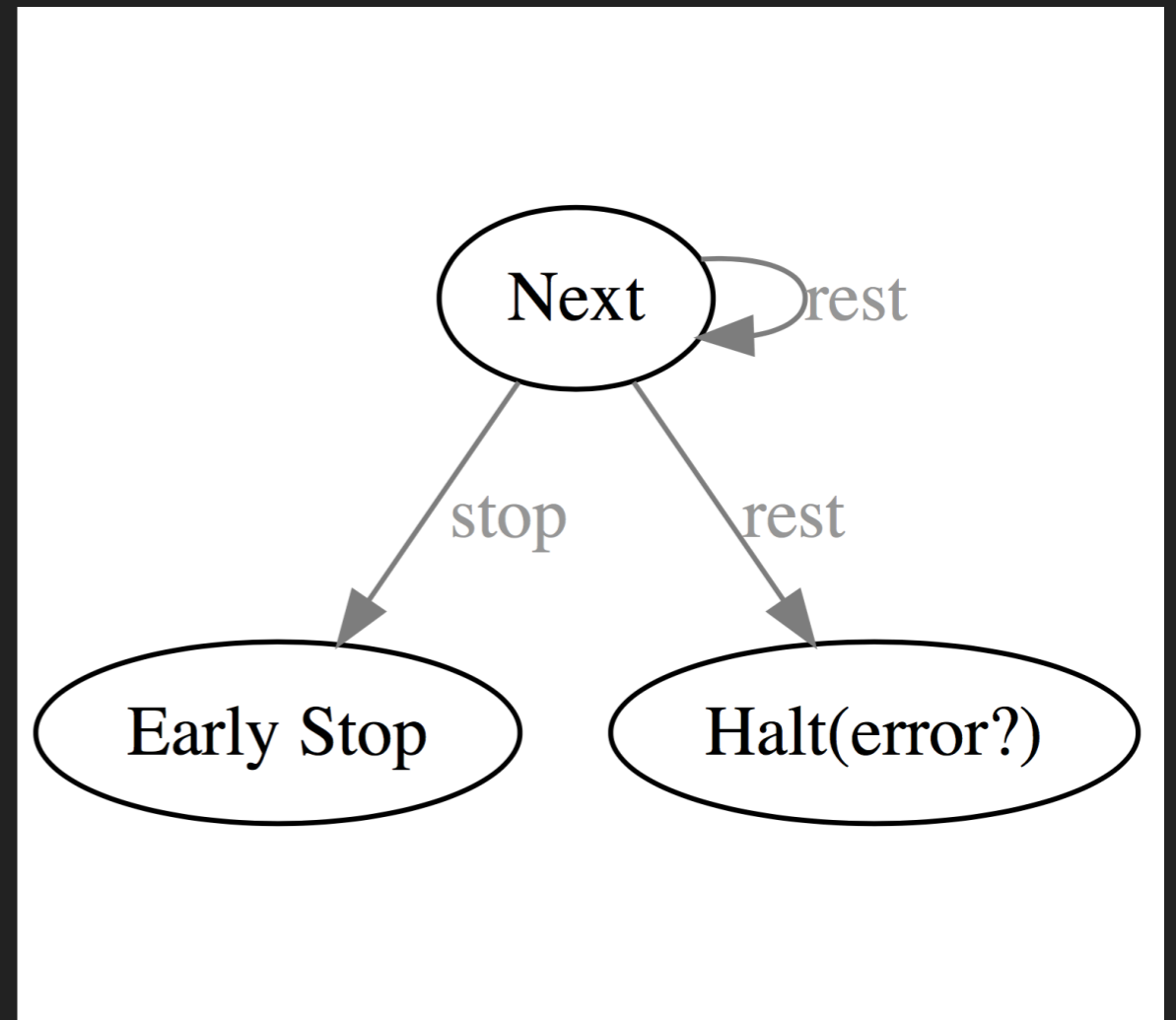


RESOURCE MANAGEMENT

```
sealed trait Iterant[A]
```

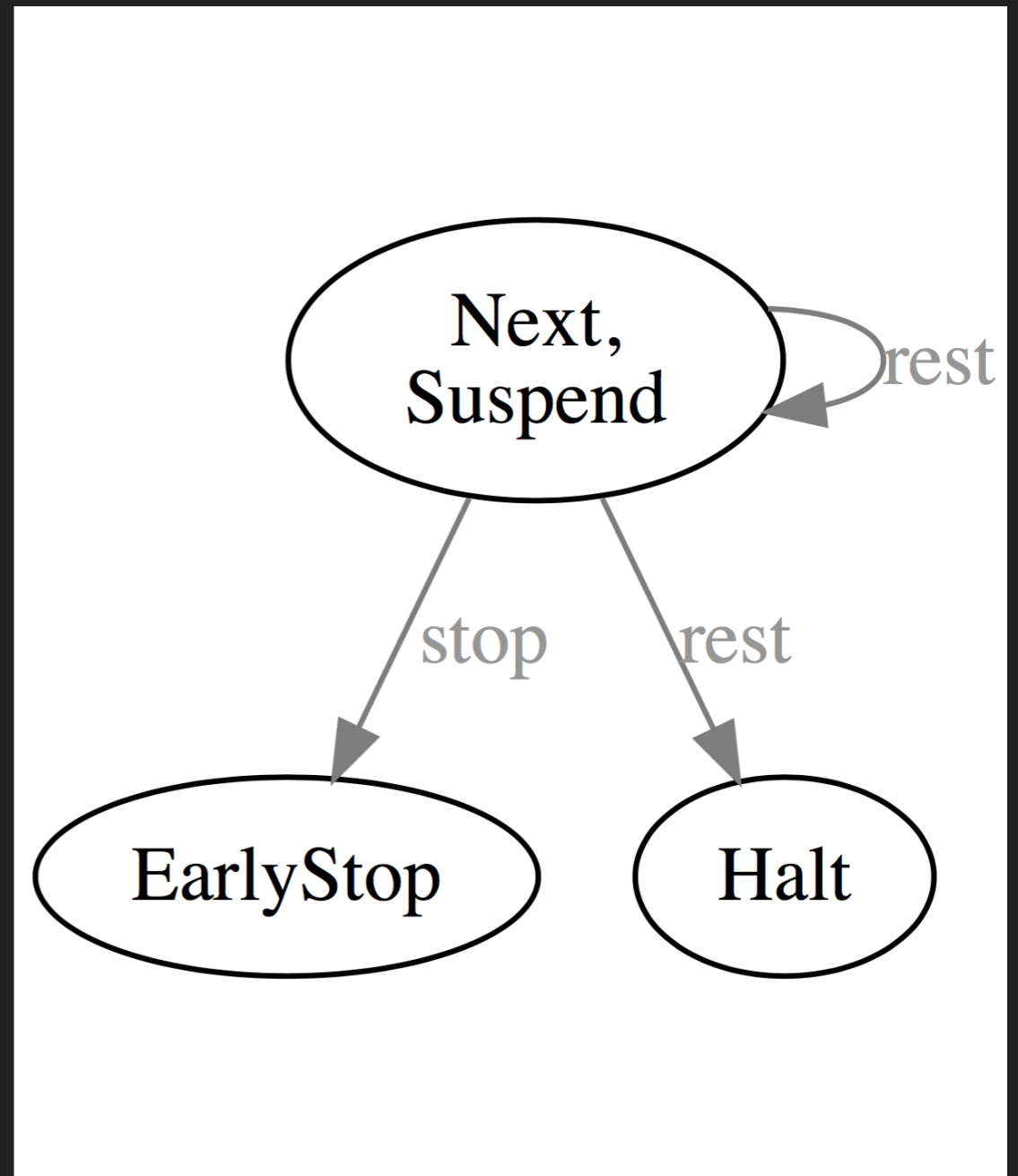
```
case class Next[A](  
  item: A,  
  rest: () => Iterant[A],  
  stop: () => Unit)  
extends Iterant[A]
```

```
case class Halt[A](  
  e: Option[Throwable])  
extends Iterant[A]
```



DEFERRING

```
sealed trait Iterant[A]  
  
// ...  
case class Suspend[A](  
  rest: () => Iterant[A],  
  stop: () => Unit)  
extends Iterant[A]
```



FILTER

```
def filter[A](fa: Iterant[A])(p: A  $\Rightarrow$  Boolean): Iterant[A] =  
  fa match {  
    case halt @ Halt(_)  $\Rightarrow$  halt  
    // ...  
  }
```

FILTER

```
def filter[A](fa: Iterant[A])(p: A ⇒ Boolean): Iterant[A] =  
  fa match {  
    // ...  
    case Suspend(rest, stop) ⇒  
      Suspend(() ⇒ filter(rest))(p), stop)  
    // ...  
  }
```

FILTER

```
def filter[A](fa: Iterant[A])(p: A ⇒ Boolean): Iterant[A] =  
  fa match {  
    // ...  
    case Next(a, rest, stop) ⇒  
      if (p(a)) Next(a, () ⇒ filter(rest)(p), stop)  
      else Suspend(() ⇒ filter(rest)(p), stop)  
  }
```


TRAMPOLINES



CAN WE DO THIS ?

```
case class Next[A](  
  item: A,  
  rest: Future[Iterant[F, A]],  
  stop: Future[Unit])  
extends Iterant[A]
```

CAN WE DO THIS ?

```
type Task[+A] = () => Future[A]
```

```
case class Next[A](  
  item: A,  
  rest: Task[Iterant[F, A]],  
  stop: Task[Unit])  
extends Iterant[A]
```

CAN WE DO THIS ?

```
import monix.eval.Task

case class Next[A](
  item: A,
  rest: Task[Iterant[F, A]],
  stop: Task[Unit])
extends Iterant[A]
```

CAN WE DO THIS ?

```
import monix.eval.Coeval

case class Next[A](
  item: A,
  rest: Coeval[Iterant[F, A]],
  stop: Coeval[Unit])
extends Iterant[A]
```

CAN WE DO THIS ?

```
import cats.effect.IO

case class Next[A](
  item: A,
  rest: IO[Iterant[F, A]],
  stop: IO[Unit])
extends Iterant[A]
```

PARAMETRIC POLYMORPHISM

```
sealed trait Iterant[F[_], A]
```

```
case class Next[F[_], A](  
  item: A,  
  rest: F[Iterant[F, A]],  
  stop: F[Unit])
```

```
extends Iterant[F, A]
```

PARAMETRIC POLYMORPHISM

```
import cats.syntax.all._
import cats.effect.Sync

def filter[F[_], A](p: A ⇒ Boolean)(fa: Iterant[F, A])
  (implicit F: Sync[F]): Iterant[F, A] = {

  fa match {
    // ...
    case Suspend(rest, stop) ⇒
      Suspend(rest.map(filter(p)), stop)
    // ...
  }
}
```


BRING YOUR OWN BOOZE

```
import monix.eval.Task
```

```
val sum: Task[Int] =  
  Iterant[Task].range(0, 1000)  
    .filter(_ % 2 == 0)  
    .map(_ * 2)  
    .foldL
```

BRING YOUR OWN BOOZE

```
import cats.effect.IO

val sum: IO[Int] =
  Iterant[IO].range(0, 1000)
    .filter(_ % 2 == 0)
    .map(_ * 2)
    .foldL
```

BRING YOUR OWN BOOZE

```
import monix.eval.Coeval

val sum: Coeval[Int] =
  Iterant[Coeval].range(0, 1000)
    .filter(_ % 2 == 0)
    .map(_ * 2)
    .foldL
```

PERFORMANCE PROBLEMS

- ▶ Linked Lists are everywhere in FP
- ▶ Linked Lists are terrible
- ▶ Async or Lazy Boundaries are terrible
- ▶ Find Ways to work with Arrays and
- ▶ ... to avoid lazy/async boundaries

PERFORMANCE SOLUTIONS

- ▶ Linked Lists are everywhere in FP
- ▶ Linked Lists are terrible
- ▶ Async or Lazy Boundaries are terrible
- ▶ Find Ways to work with Arrays and
- ▶ ... to avoid lazy/async boundaries

WHAT CAN ITERATE OVER ARRAYS?

WHAT CAN ITERATE OVER ARRAYS?

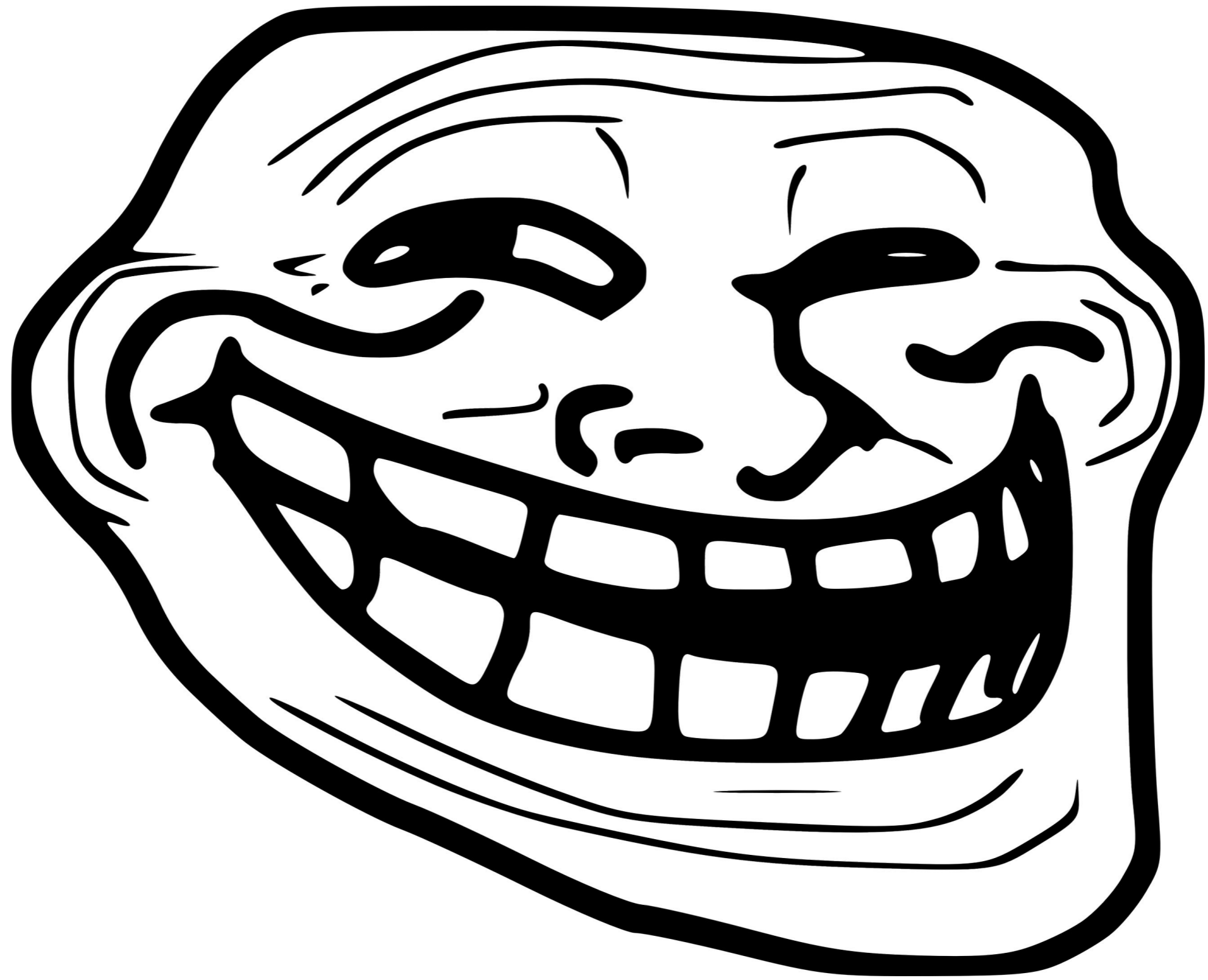
```
trait Iterator[+A] {  
  def hasNext: Boolean  
  def next(): A  
}
```

```
trait Iterable[+A] {  
  def iterator: Iterator[A]  
}
```

WHAT CAN ITERATE OVER ARRAYS?

```
case class NextBatch[F[_], A](  
  batch: Iterable[A],  
  rest: F[Iterant[F, A]],  
  stop: F[Unit])  
extends Iterant[F, A]
```

```
case class NextCursor[F[_], A](  
  cursor: Iterator[A],  
  rest: F[Iterant[F, A]],  
  stop: F[Unit])  
extends Iterant[F, A]
```

○OBSERVABLE[+A]

VS

ITERANT[F,A]

Case Study: `scanEval`

<https://github.com/monix/monix/pull/412>

Case Study: `scanEval`

```
import cats.effect.Sync

sealed abstract class Iterant[F[_], A] {
  // ...
  def scanEval[S](seed: F[S])(op: (S, A) => F[S])
    (implicit F: Sync[F]): Iterant[F, S] = ???
}
```

Case Study: `scanEval`

```
def loop(state: S)(source: Iterant[F, A]): Iterant[F, S] =
  try source match {
    case Next(head, tail, stop) =>
      protectedF(state, head, tail, stop)
    case ref @ NextCursor(cursor, rest, stop) =>
      evalNextCursor(state, ref, cursor, rest, stop)
    case NextBatch(gen, rest, stop) =>
      val cursor = gen.cursor()
      val ref = NextCursor(cursor, rest, stop)
      evalNextCursor(state, ref, cursor, rest, stop)
    case Suspend(rest, stop) =>
      Suspend[F, S](rest.map(loop(state)), stop)
    case Last(item) =>
      val fa = ff(state, item)
      Suspend(fa.map(s => lastS[F, S](s)), F.unit)
    case halt @ Halt(_) =>
      halt.asInstanceOf[Iterant[F, S]]
  } catch {
    case NonFatal(ex) => signalError(source, ex)
  }
```

Case Study: `scanEval`

```
import cats.effect.Effect
```

```
abstract class Observable[+A] {
```

```
  //...
```

```
  def scanEval[F[_], S](seed: F[S])(op: (S, A) => F[S])
```

```
    (implicit F: Effect[F]): Observable[S] = ???
```

```
}
```

Case Study: `scanEval`

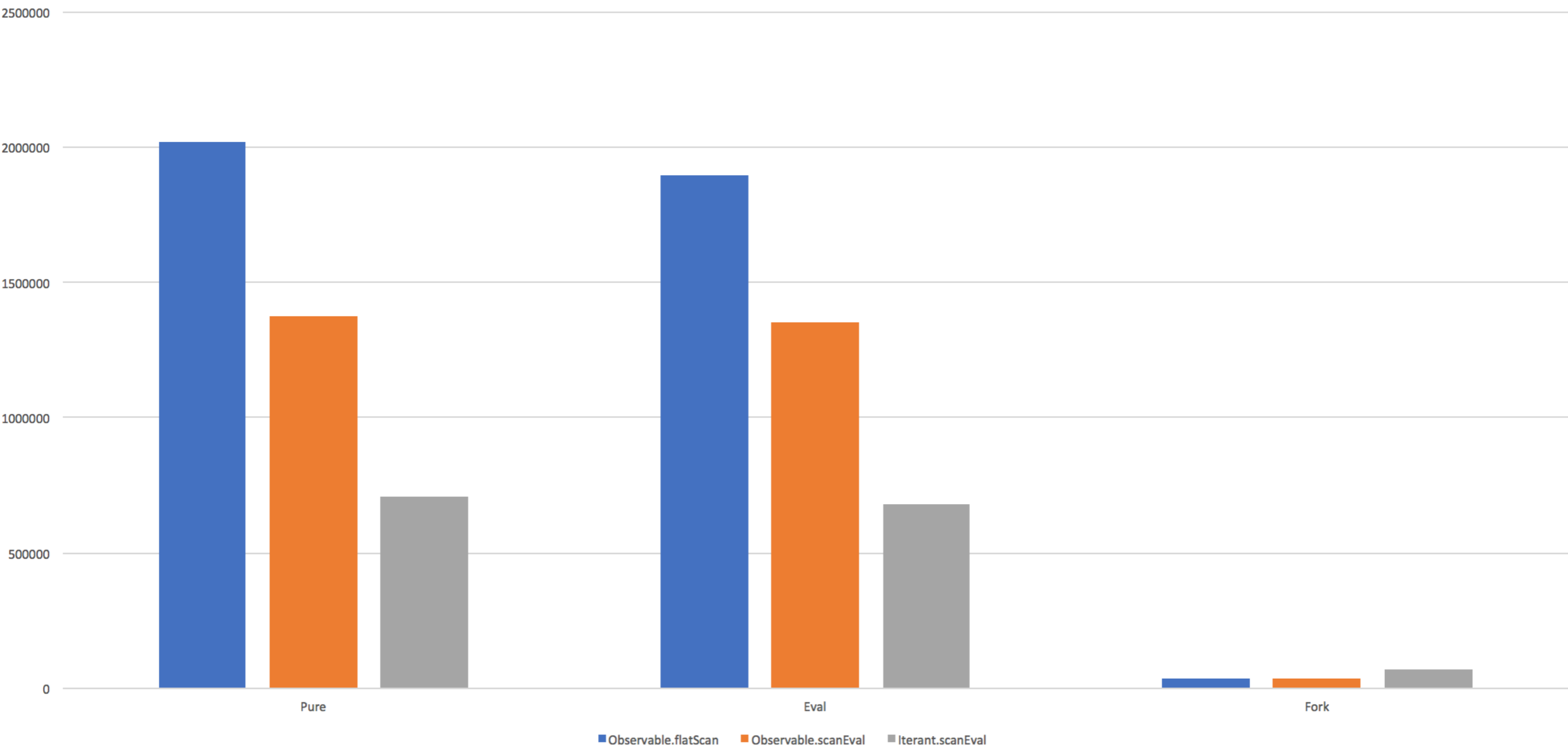
```
abstract class Observable[+A] {  
  // ...  
  def scanEval[F[_], S](seed: F[S])(op: (S, A) => F[S])  
    (implicit F: Effect[F]): Observable[S] =  
    scanTask(Task.fromEffect(seed))((a, e) => Task.fromEffect(op(a, e)))  
  
  def scanTask[S](seed: Task[S])(op: (S, A) => Task[S]): Observable[S] =  
    ???  
}
```

Case Study: `scanEval`

- ▶ **Observable's `scanTask` is `flatMap`**
- ▶ **With the aforementioned implementation**

Benchmark: scanEval

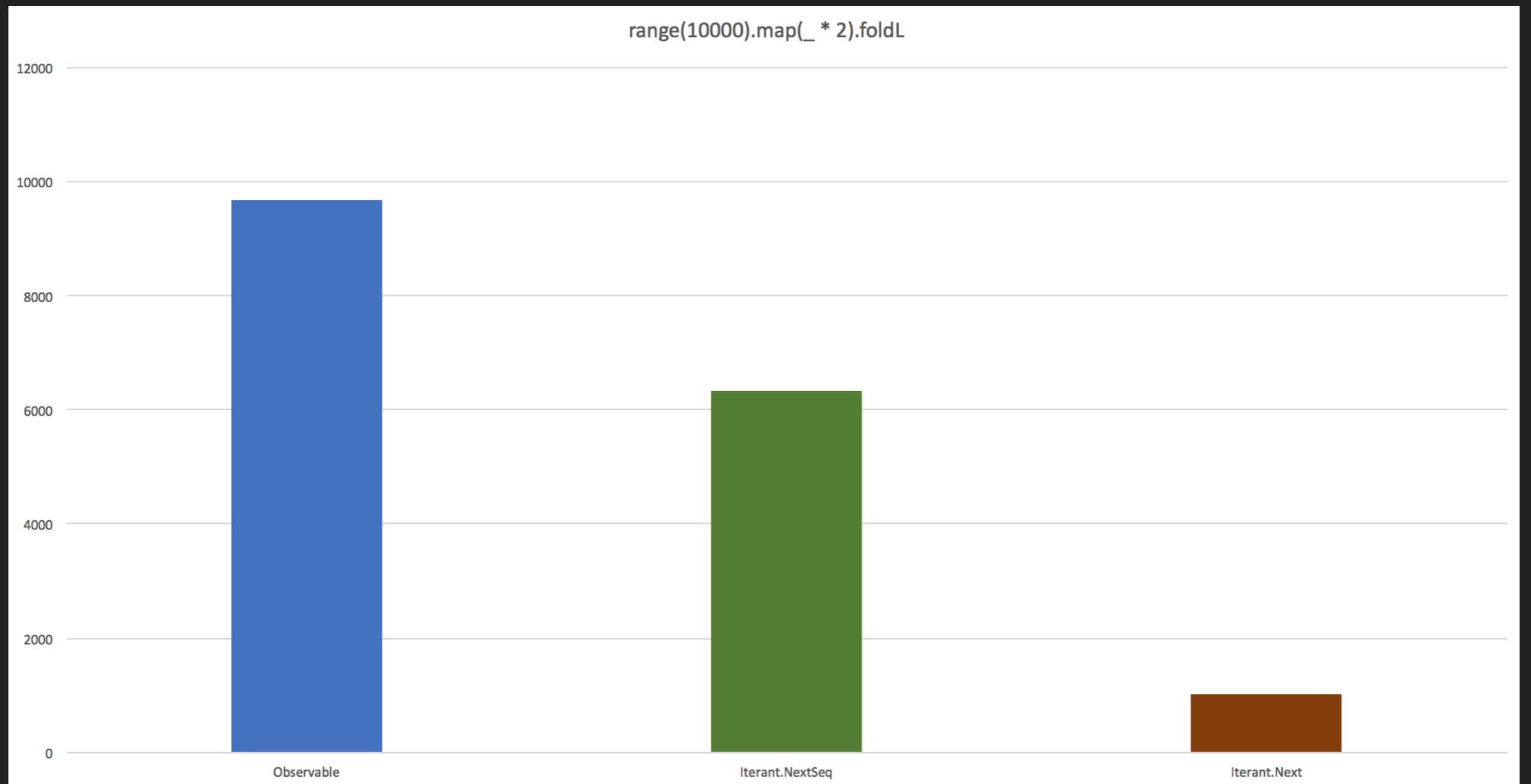
Observable's flatScan vs scanEval vs Iterant's scanEval



Case Study: **scanEval**

- ▶ **Observable** has performance
- ▶ **Iterant** has reason

Benchmark: `map(f).foldL`



OBSERVABLE FOLD-RIGHT

- ▶ Cannot express **foldRight** for **Observable**
- ▶ But can work with substitutes, e.g. **foldWhileLeftL ...**

```
abstract class Observable[+A] {  
  // ...  
  def foldWhileLeftL[S](seed:  $\Rightarrow$  S)  
    (op: (S, A)  $\Rightarrow$  Either[S, S]): Task[S]  
}
```

ITERANT FOLD-RIGHT

```
sealed abstract class Iterable[F[_], A] {  
  // ...  
  def foldRightL[B](b: F[B])  
    (f: (A, F[B], F[Unit]) => F[B])  
    (implicit F: Sync[F]): F[B]  
}
```

ITERANT FOLD-RIGHT

```
def exists[F[_], A](ref: Iterant[F, A], p: A ⇒ Boolean)
  (implicit F: Sync[F]): F[Boolean] =
  ref.foldRightL(F.pure(false)) { (e, next, stop) ⇒
    if (p(e)) stop followedBy F.pure(true)
    else next
  }
```

ITERANT FOLD-RIGHT

```
def forall[F[_], A](ref: Iterant[F, A], p: A => Boolean)
  (implicit F: Sync[F]): F[Boolean] =
  ref.foldRightL(F.pure(true)) { (e, next, stop) =>
    if (!p(e)) stop followedBy F.pure(false)
    else next
  }
```

ITERANT FOLD-RIGHT

```
def concat[F[_], A](lh: Iterant[F, A], rh: Iterant[F, A])
  (implicit F: Sync[F]): Iterant[F, A] =
  Iterant.suspend[F, A] {
    lh.foldRightL(F.pure(rh)) { (a, rest, stop) =>
      F.pure(Iterant.nextS(a, rest, stop))
    }
  }
```


ITERANT FOLD-RIGHT



Alex Nedelcu

@alexelcu



Finally understood what's going on: foldRight reflects the shape of the data constructor for lists perfectly. No match, no implementation.

Alex Nedelcu @alexelcu

foldRight sucks:

1. wants head/tail decomposition (no push-based protocols)
2. incompatible w/ finalizers...

6:37 PM - 7 Aug 2017

Conclusions

▶ **Observable** is best for

- ▶ Reactive operations
- ▶ Shared data sources
- ▶ Throttling
- ▶ Buffering
- ▶ Performance

▶ **Iterant** is best for

- ▶ Easier implementation reasoning
- ▶ Converting Task / IO calls into streams

Conclusions

▶ Both

- ▶ Implement [reactive-streams.org](https://reactivestreams.org/)
- ▶ Can express asynchronous streams
- ▶ Do back-pressuring & safe resource handling

One more thing ...



VS



QUESTIONS?



monix.io



@monix



@monix



alexn.org



@alexelcu



@alexandru