BATCHING MONADS

COMBINING FREE MONAD AND FREE APPLICATIVE FTW

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PROBLEM

We need to integrate with Google Calendar

However, we project that we will be rate limited.

SOLUTION

Google provides a batch API, let's just use that!

RESTRICTIONS

The Google batch API only permits 50 requests per batch request.

THE PROBLEM WITH MONADS

```scala
for {
  x <- process1
  y <- process2
  z <- process3
} yield (x, y, z)

// Desugars to

process1.flatMap(x =>
  process2.flatMap(y =>
    process3.map(z =>
      (x, y, z)
    )
  )
)
```

APPLICATIVE TO THE RESCUE

```
(process1, process2, process3).tupled

// Rougly equivalent to

val ff = ((a: A) => (b: B) => (c: C) => (a, b, c)).pure[F]
// ff: F[A => B => C => (A, B, C)]

val f1 = ff.ap(process1)
// f1: F[B => C => (A, B, C)]

val f2 = f1.ap(process2)
// f2: F[C => (A, B, C)]

val f3 = f2.ap(process3)
// f3: F[(A, B, C)]
```

THE FREE MONAD

```
sealed abstract class Free[S[_], A]

final case class Pure[S[_], A](a: A)       extends Free[S, A]

final case class Suspend[S[_], A](a: S[A]) extends Free[S, A]

final case class FlatMapped[S[_], B, C](
  c: Free[S, C], f: C => Free[S, B]
) extends Free[S, B]
```

FREE APPLICATIVE

```scala
sealed abstract class FreeApplicative[F[_], A]

final case class Pure[F[_], A](a: A)     extends FreeApplicative[F, A]

final case class Lift[F[_], A](fa: F[A]) extends FreeApplicative[F, A]

final case class Ap[F[_], P, A](
  fn: FreeApplicative[F, P => A], fp: FreeApplicative[F, P]
) extends FreeApplicative[F, A]
```

A TALE OF TWO ALGEBRAS

```
object GoogleCalendarClient {
  sealed trait Action[A]
  final case class CalendarsGet(...) extends Action[Option[GCalendar]]
  final case class EventsGet(...)    extends Action[Option[GCalendarEvent]]
  final case class EventsInsert(...) extends Action[GCalendarEvent]
  final case class EventsUpdate(...) extends Action[GCalendarEvent]
  final case class EventsDelete(...) extends Action[Unit]
}
```

A TALE OF TWO ALGEBRAS

```
object ExternalCalendarClient {
  sealed trait Action[A]
  final case class AddEvent(...)    extends Action[Unit]
  final case class DeleteEvent(...) extends Action[Unit]
  final case class EventExists(...) extends Action[Boolean]
  final case class UpdateEvent(...) extends Action[Unit]
}
```

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APPLICATIVE REQUESTS

```
import GoogleCalendarClient.{Methods => G}

val request: Request[(Option[GCalendar], GCalendarEvent)] =
  (G.calendars.get(...), G.events.insert(...))).tupled

val response: F[(Option[GCalendar], GCalendarEvent)] =
  client.run(request)
```

COMMANDS AND REQUESTS

```
// We need to follow this pattern for ExternalCalendarClient as well.
object GoogleCalendarClient {
  sealed trait Command[A]
  final case class Pure[A](value: A)          extends Command[A]
  final case class Exec[A](action: Action[A]) extends Command[A]

  type Request[A] = FreeApplicative[Command, A]

  def exec[A](action: Action[A]): Request[A] =
    FreeApplicative.lift(Command.Exec(action))
}
```

COMMANDS AND REQUESTS

```
// We need to follow this pattern for ExternalCalendarClient as well.
object GoogleCalendarClient {
  object Methods {
    object calendars {
      def get(...):    Request[Option[GCalendar]]      = exec(CalendarsGet(...))
    }
    object events {
      def insert(...): Request[GCalendarEvent]         = exec(EventsInsert(...))
      def update(...): Request[GCalendarEvent]         = exec(EventsUpdate(...))
      def delete(...): Request[Unit]                   = exec(EventsDelete(...))
      def get(...):    Request[Option[GCalendarEvent]] = exec(EventsGet(...))
    }
  }
}
```

COMMANDS AND REQUESTS

```scala
import GoogleCalendarClient.{Methods => G}

val request: Request[Option[GCalendar]] = G.calendars.get(...)

val response: F[Option[GCalendar]] = client.run(request)
```

APPLICATIVE REQUESTS REVISITED

```
import GoogleCalendarClient.{Methods => G}

val request: Request[(Option[GCalendar], GCalendarEvent)] =
  (G.calendars.get(...), G.events.insert(...)).tupled

val response: F[(Option[GCalendar], GCalendarEvent)] =
  client.run(request)
```

HTTP CLIENT INTERFACE

```
trait GoogleCalendarClient[F[_]] {
  def run[A](r: GoogleCalendarClient.Request[A]): F[A]
}
```

IMPLEMENTING THE INTERFACE

```
final class BatchingGoogleCalendarClient[F[_]](
  implicit F: MonadError[F, Throwable]
) extends GoogleCalendarClient[F] {
  override def run[A](r: GoogleCalendarClient.Request[A]): F[A] = ???
}
```

FUNCTIONK

```
trait FunctionK[F[_], G[_]] {
  def apply[A](fa: F[A]): G[A]
}

type ~>[F[_], G[_]] = FunctionK[F, G]
```

FUNCTIONK

```scala
val optionToList = new (Option ~> List) {
  override def apply[A](fa: Option[A]): List[A] = fa match {
    case None    => Nil
    case Some(x) => List(x)
  }
}

// Using kind-projector

val optionToList = λ[Option ~> List] {
  case None    => Nil
  case Some(x) => List(x)
}
```

FREEAPPLICATIVE#COMPILE

```
sealed abstract class FreeApplicative[F[_], A] {
  ...
  /**
    * Interpret this algebra into another algebra.
    * Stack-safe.
    */
  def compile[G[_]](f: F ~> G): FreeApplicative[G, A] = ...
}
```

BABY'S FIRST INTERPRETER

```
type CommandWithId[A] = (UUID, Command[A])

val idGenCompiler = λ[Command ~> CommandWithId] {
  (c: Command[A]) => (UUID.randomUUID(), c)
}

r: Request[A] = ...
r: FreeApplicative[Command, A] = ...
val commandsWithIds: FreeApplicative[CommandWithId, A] = r.compile(idGenCompiler)
```

FREEAPPLICATIVE#ANALYZE

```
sealed abstract class FreeApplicative[F[_], A] {
  ...
  /** Interpret this algebra into a Monoid. */
  def analyze[M: Monoid](f: F ~> λ[α => M]): M = ...
}
```

ACCUMULATING INTERPRETER

```scala
type Requests[_] = Vector[(UUID, Exec[_])]

val requestsBuilder = λ[CommandWithId ~> Requests] {
  case   (_, _: Pure[_]) => Vector.empty
  case x@(_, _: Exec[_]) => Vector(x)
}


val commandsWithIds: FreeApplicative[CommandWithId, A] = ...
val requests: Vector[(UUID, Exec[_])] = commandsWithIds.analyze(requestsBuilder)
```

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FREEAPPLICATIVE#FOLDMAP

```
sealed abstract class FreeApplicative[F[_], A] {
  ...
  /**
    * Interprets/Runs the sequence of operations using the semantics of
    * `Applicative` G[_]. Tail recursive.
    */
  def foldMap[G[_]](f: F ~> G)(implicit G: Applicative[G]): G[A] = ...
}
```

READER INTERPRETER

```scala
type Env       = Map[UUID, EncodedResponse]
type Reader[A] = Kleisli[Either[Throwable, ?], Env, A]

val readerInterpreter = λ[CommandWithId ~> Reader] {
  case (_, Pure(v)) => Kleisli.pure(v)
  case (id, Exec(action)) =>
    Kleisli[Either[Throwable, ?], Env, A](
      _.get(id) match {
        case Some(response) => decode[A](action, response)
        case None => Left(new NoSuchElementException(...))
      }
    )
}
val commandsWithIds: FreeApplicative[CommandWithId, A] = ...
val reader: Reader[A] = commandsWithIds.foldMap(readerInterpreter)
```

PUTTING IT ALL TOGETHER

```
// Remember: Request[A] =:= FreeApplicative[Command, A]
override def run[A](r: GoogleCalendarClient.Request[A]): F[A] = {
  val commandsWithIds: FreeApplicative[CommandWithId, A] = r.compile(idGenCompiler)
  val requests: Vector[(UUID, Exec[_])] = commandsWithIds.analyze(requestsBuilder)
  val reader: Reader[A] = commandsWithIds.foldMap(readerInterpreter)
  val batches: Vector[Vector[(UUID, Exec[_])]] = requests.grouped(batchLimit).toVector
  val responsesF: Vector[F[Env]] = batches.map(runBatch)
  val sequenced: F[Vector[Env]] = responsesF.sequence
  val envF: F[Env] = sequenced.map(_.foldLeft(Map.empty: Env)(_ ++ _))
  envF.flatMap(env => eitherToF(reader(env)))
}

def runBatch(rs: Vector[(UUID, Exec[_])]): F[Env] = ...
def eitherToF[A](either: Either[Throwable, A]): F[A] = ...
```

APPLICATIVE REQUESTS REVISITED AGAIN

```scala
import GoogleCalendarClient.{Methods => G}

val request: Request[(Option[GCalendar], GCalendarEvent)] =
  (G.calendars.get(...), G.events.insert(...)).tupled

val response: F[(Option[GCalendar], GCalendarEvent)] =
  client.run(request)
```

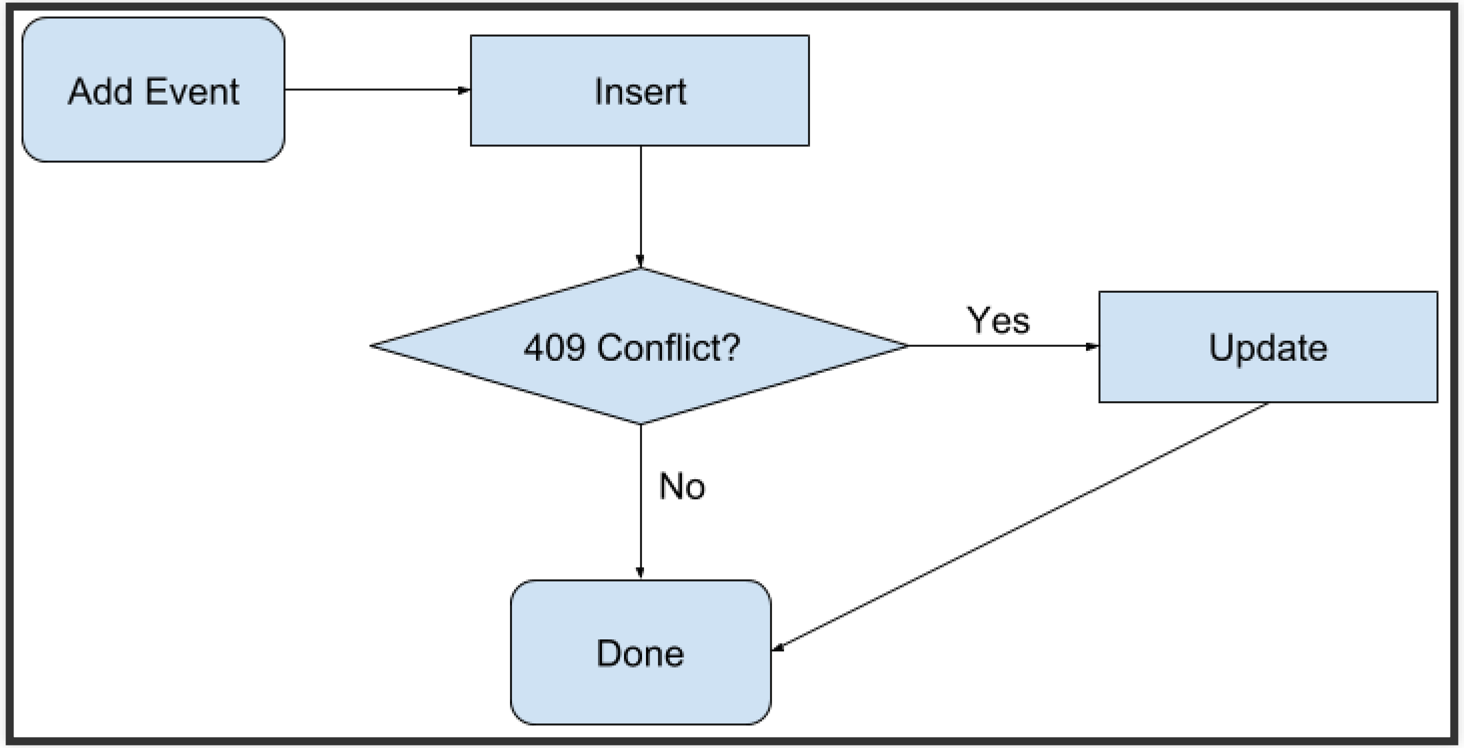
BUT WAIT...

What does this have to do with batching Monads?

ALGEBRA SHMALGEBRA

```scala
object ExternalCalendarClient {
  sealed trait Action[A]
  final case class AddEvent(...)    extends Action[Unit]
  final case class DeleteEvent(...) extends Action[Unit]
  final case class EventExists(...) extends Action[Boolean]
  final case class UpdateEvent(...) extends Action[Unit]
}
```

BUSINESS LOGIC



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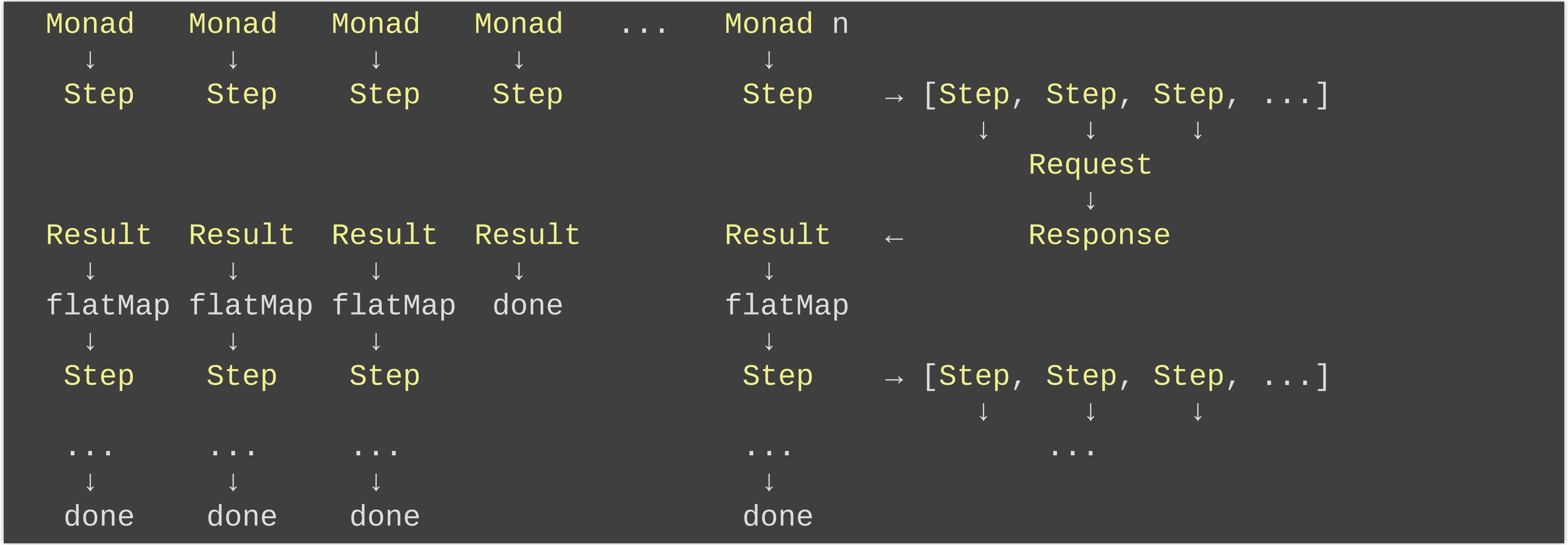
BUSINESS LOGIC MAKES FP CRY 😫

```
def addEvent =
  insert.flatMap(res =>
    if (res.conflict) update
    else res
  )
```

WHAT IF...



```
Monad   Monad   Monad   Monad   ...   Monad n
  ↓       ↓       ↓       ↓             ↓
 Step    Step    Step    Step          Step    → [Step, Step, Step, ...]
                                                    ↓     ↓     ↓
                                                       Request
                                                          ↓
Result  Result  Result  Result        Result   ←       Response
  ↓       ↓       ↓       ↓             ↓
flatMap flatMap flatMap  done         flatMap
  ↓       ↓       ↓                     ↓
 Step    Step    Step                  Step    → [Step, Step, Step, ...]
                                                    ↓     ↓     ↓
 ...     ...     ...                   ...              ...
  ↓       ↓       ↓                     ↓
 done    done    done                  done
```

BATCHED MONADS EXEMPLIFIED

```
addEvent eventExists updateEvent
   ↓         ↓            ↓
 insert    exists       update  → [insert, exists, update]
                                     ↓       ↓       ↓
                                          Request
                                             ↓
 Conflict Pure(true)  Not Found ←         Response
   ↓                     ↓
flatMap               flatMap
   ↓                     ↓
 update                insert   →    [update, insert]
                                             ↓
                                          Request
                                             ↓
Pure(())              Pure(())  ←        Response
```

FREE INCEPTION

```
type GStep[A] = GoogleCalendarClient.Request[A]
// FreeApplicative[GoogleCalendarClient.Command, A]

type GLogic[A] = Free[GStep, A]
// Free[λ[a => FreeApplicative[GoogleCalendarClient.Command[a]], A]
object GLogic {
  def pure[A](a: A): GLogic[A]            = Free.pure(a)
  def suspend[A](fa: GStep[A]): GLogic[A] = Free.liftF(fa)
}
```

FREE INCEPTION

```
def actionToGRequest[A](action: ExternalCalendarClient.Action[A]): GLogic[A] = {
  action match {
    case e: Action.AddEvent    => addEvent(e)
    case e: Action.DeleteEvent => deleteEvent(e)
    case e: Action.EventExists => eventExists(e)
    case e: Action.UpdateEvent => updateEvent(e)
  }
}
```

FREE INCEPTION

```scala
def addEvent(e: Action.AddEvent): GLogic[Unit] = {
  GLogic.suspend(G.events.insert(...)).flatMap { res =>
    if (res.isConflict) GLogic.suspend(G.events.update(...))
    else GLogic.pure(())
  }
}
```

ANOTHER CLIENT INTERFACE

```
trait ExternalCalendarClient[F[_]] {
  def run[A](r: ExternalCalendarClient.Request[A]): F[A]
}

class GoogleExternalCalendarClient[F[_]](
  implicit F: MonadError[F, Throwable]
) extends ExternalCalendarClient[F] {
```

FREE#RESUME

```scala
sealed abstract class Free[S[_], A] {
  ...
  /** Evaluate a single layer of the free monad. */
  def resume(implicit S: Functor[S]): Either[S[Free[S, A]], A] = ...
}
```

INTERPRETER INPUTS

```
type Inputs = Map[UUID, Either[GStep[GLogic[_]], Any]]

def getInitialInputs(actions: Vector[(UUID, Action[_])]): Inputs =
  actions.iterator.map { case (id, a) => (id, actionToGRequest(a).resume) }.toMap
```

INTERPRETER EVALUATION

```
type ResultMap = Map[UUID, Any]

/** Monadic recursive function for building our ResultsMap. */
def buildResultsRec(inputs: Inputs): F[Either[Inputs, ResultMap]] = {
  val completed = inputs.collect { case (cmdId, Right(x)) => (cmdId, x) }
  // If all of our steps are completed, we're done.
  if (completed.size == inputs.size) {
    F.pure(Either.right(completed))
  } else {
    // Obtain the next set of steps and their indices so we can run them and
    // bind the results to the next set of inputs.
    val steps: Vector[GStep[(CmdId, GLogic[_])]] = collectSteps(inputs)
    runSteps(steps).map(rs => Either.left(rebuildInputs(rs, inputs)))
  }
}
```

FREE#FOLD

```scala
sealed abstract class Free[S[_], A] {
  /**
   * Catamorphism. Run the first given function if Pure, otherwise,
   * the second given function.
   */
  def fold[B](r: A => B, s: S[Free[S, A]] => B)(implicit S: Functor[S]): B = ...
}
```

INTERPRETER EVALUATION

```
type Inputs = Map[UUID, Either[GStep[GLogic[_]], Any]]

def rebuildInputs(
  responses: Vector[(CmdId, GLogic[_])],
  inputs: Inputs
): Inputs = responses.foldLeft(inputs) { case (accInputs, (cmdId, gLogic)) =>
  val newValue = gLogic.fold(Either.right, Either.left)
  accInputs.updated(index, newValue)
}
```

DYNAMIC EXTRACTOR

```scala
type ResultMap = Map[UUID, Any]

def extractor(results: ResultMap) = λ[CommandWithId ~> F] {
  case (_,     Command.Pure(a))       => F.pure(a)
  case (cmdId, Command.Exec(action)) =>

    def extractDynamic[B](implicit ct: ClassTag[B]): F[B] = ...

    action match {
      case _: Action.AddEvent     => extractDynamic
      case _: Action.UpdateEvent => extractDynamic
      case _: Action.EventExists => extractDynamic
      case _: Action.DeleteEvent => extractDynamic
    }
}
```

PUTTING IT ALL TOGETHER...AGAIN

```scala
override def run[A](request: ExternalCalendarClient.Request[A]): F[A] = {
  val requestWithIds: RequestWithIds[A] = request.compile(idGenCompiler)
  val actions: Vector[(UUID, Action[_])] = requestWithIds.analyze(actionAccumulator)
  F.tailRecM(getInitialInputs(actions))(buildResultsRec).flatMap { resultMap =>
    requestWithIds.foldMap(extractor(resultMap))
  }
}
```

WHEW 😅

Questions?