Grok: optimistic low-level parsing in Scala

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Outline

1. Why "easy" parsing is not easy (*psst, it's the errors*)

Part One
Parsing is Hard (?!)

Background

- I am a neuroscientist (studying aging in simple model organisms)

A typical day in research

- I wonder if older worms have defects in sequencing behavior?
- Let's compute transition probabilities for behaviors
- Let's read behavioral data
- Okay, parse the data, analyze...
- (wait, wait, wait)
- Stack trace? From the parser?! !*&%(*@&!%
- That's not supposed to be the hard part!!

Why is parsing *deceptively* hard?

It's easy:

- Input is complex **<- Want focus here!!**
- But it's like language, which we humans are specialized for!
- And we're good at explaining what we want, what the rules are.
- *We can do this!*

But it's not!

- Any rule can go wrong and needs handling.
- We are (Rex is) *not* so good at intuiting that.
- Need to focus on errors. **<- Argh!**

An example: head and last of a list.

```
def ht[A](xs: List[A]) = (xs.head, xs.last)
```

Easy *and wrong*.

```
def ht[A](xs: List[A]) = {
  for (h <- xs.headOption;
         t <- xs.lastOption)
  yield (h,t)
}
```

Correct *but not so easy*.
Parsing is like this, but a hundredfold worse.
What can we do?

Part Two
Crafting a solution to the parsing problems

What do we want when parsing?

- Focus on transformation, not on errors
- Capture errors for rapid debugging / resolution
- Reasonably fast: rare to need hand-rolling
- Make it hard to make a mistake

Testbed: the world's simplest* language

```
<item> := "y" | "n"
```

* Simplest non-degenerate language. The empty language is simpler.

The Java Way: what goes wrong?

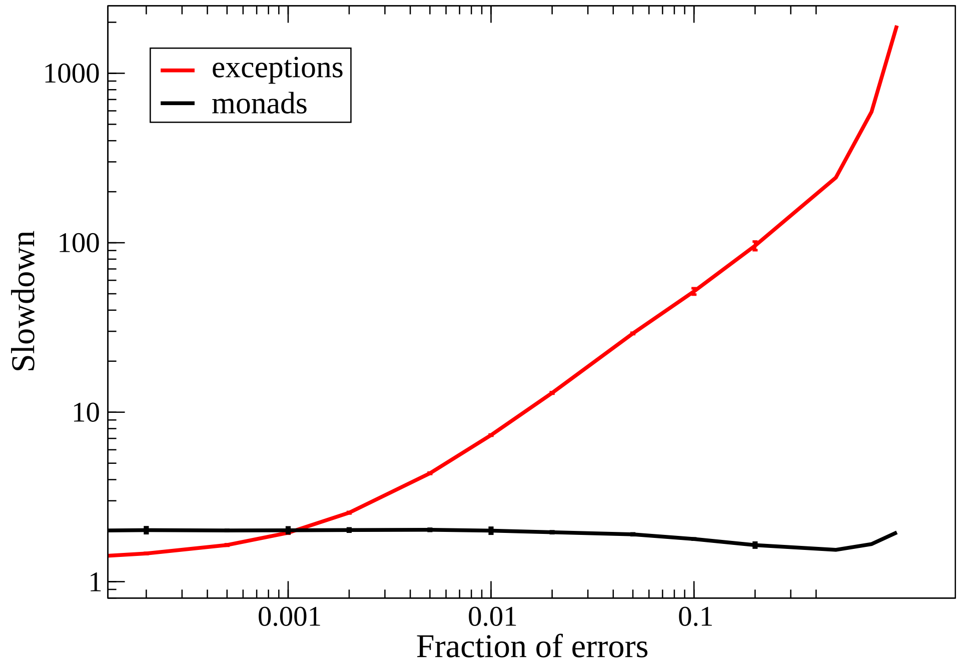
```
def parseEx(c: Char) =
  if (c == 'y') true
  else if (c == 'n') false
  else throw new IllegalArgumentException("Only y and n are allowed")
```

Unfortunately...

```
def countEx(s: String): Int = {
  var n, i = 0
  while (i < s.length) {
    n += (if (parseEx(s charAt i)) 2 else -1)
    i += 1
  }
  n
}
```

Did we forget to catch the exception? Will anyone ever remember?

The Java Way: what goes wrong?



Failure cases are really, *really* slow!

The Monadic Way: what goes wrong?

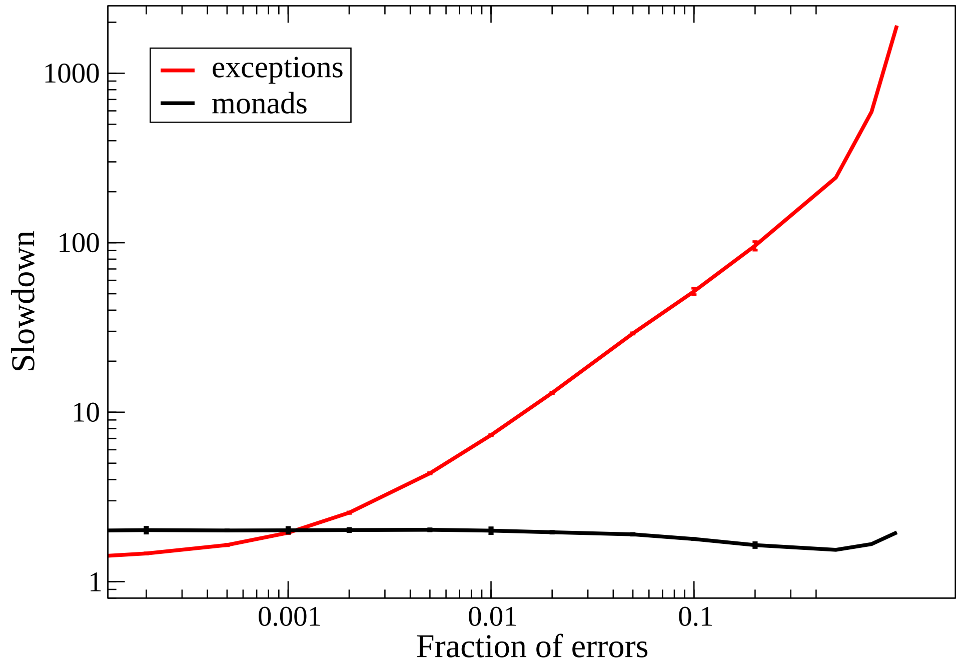
```
def parseOpt(c: Char) =
  if (c == 'y') Some(true)
  else if (c == 'n') Some(false)
  else None
```

Unfortunately...

```
def countOpt(s: String): Int = {
  var n, i = 0
  while (i < s.length) {
    parseOpt(s charAt i) match {
      case Some(x) => n += (if (x) 2 else -1)
      case _ =>
    }
    i += 1
  }
  n
}
```

Boilerplate grows *linearly with number of options*!

The Monadic Way: what goes wrong?



Success cases are slow!

Can we rescue the Monadic Way?

```
class Wiggle(src: Dance, id: Int, i0: Int, iN: Int, dist: Double, phase: Option[Double])
```

What we want:

```
new Wiggle(parseDance, parseInt, parseInt, parseInt, parseDouble, parseDoubleOption)
```

What we've got:

```
for {
  src <- parseDance; id: <- parseInt;
  i0: <- parseInt; iN: <- parseInt; dist: <- parseDouble
} yield new Wiggle(src, id, i0, iN, dist, parseDouble)
```

- Detailed option/error types infect entire call stack
- Loads of nuisance variables

Can we rescue the Monadic Way?

Maybe we can abstract away the boilerplate?

```
((A,B) => Z) => ((E[A],E[B]) => E[Z])
```

This is *possible*, but we must write builders:

```
object Foo {
  def apply[A,B](a: A, b: B) = new Foo(a, b)
}
```

And we must abstract over arity:

```
((A,B,C) => Z) => ((E[A],E[B],E[C]) => E[Z])
((A,B,C,D) => Z) => ((E[A],E[B],E[C],E[D]) => E[Z])
((A,B,C,D,F) => Z) => ((E[A],E[B],E[C],E[D],E[F]) => E[Z])
```

Can we rescue the Monadic Way?

And (at least with implicit conversions) over certainty:

```
((A,B,C) => Z) => ((E[A],E[B],C) => E[Z])
((A,B,C) => Z) => ((E[A],B,E[C]) => E[Z])
((A,B,C) => Z) => ((A,E[B],E[C]) => E[Z])
```

And then finally you can:

```
magic(Foo.apply _)(parseDance, parseInt, parseInt, parseInt, parseDouble, parseDouble)
```

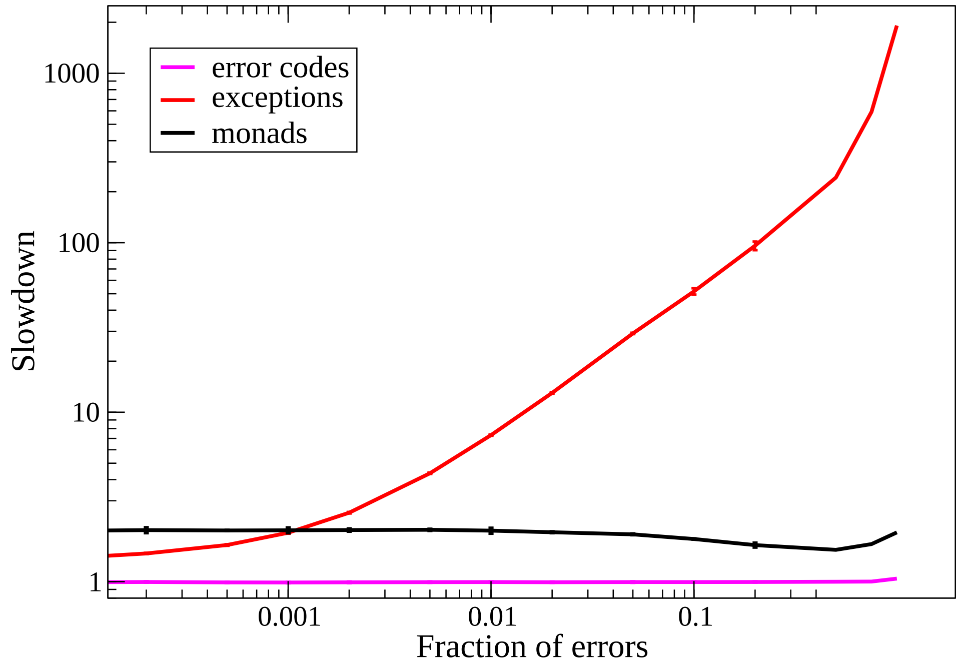
And after all that work you *still* have sizable performance penalties.

Let's back up.

What ways do we have to deal with error conditions?

- Return values (incl. monads).
  Slow on success, boilerplate, error logic mixed in everywhere.
- Exceptions.
  Slow on failure, can escape, records *code* context not *data* context.
- Error codes.
  You will forget to check the error code. **Seriously, you will forget.**
- Goto.
  Just…no.

Well, okay. What about error codes?



They're fast, just like we thought. But we will forget to check them.

What about goto?

- C has a frightfully dangerous setjmp/lngjmp library call.
- C++ has exceptions.

Operation	Clock cycles
Exception setup	0
Exception invoked	6800
setjmp (setup)	18
lngjmp (invoked)	47

But the JVM doesn't have setjmp/lngmp. *Whew!*

How close can we get?

Stackless exceptions

- Worse than exceptions: *no idea* where an uncaught one came from.

```
import scala.util.control.Breaks._
def test() = {
  var n = 0
  for (i <- Iterator.from(1)) {
    if (n > 10) break
    n += i
  }
  println(n)
}
test()
```

What is the output in the REPL?

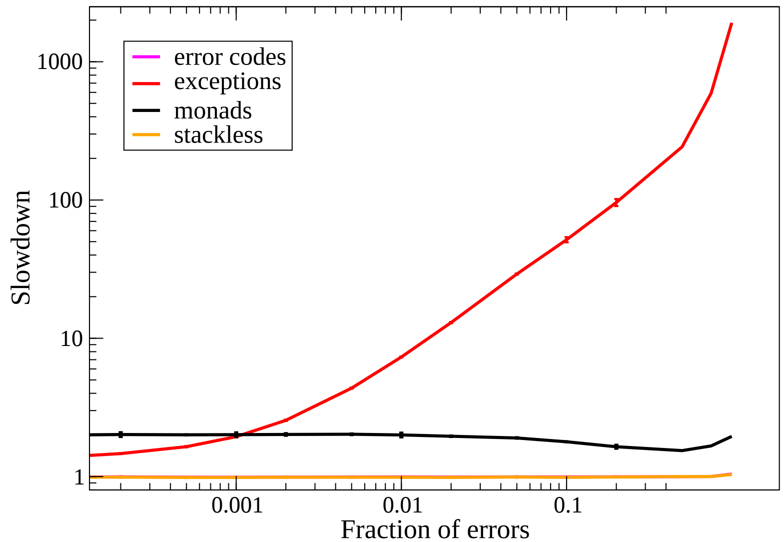
```
scala.util.control.BreakControl
```

sigh

- But compiler already inserts these to `return` from inside closures, and you don't notice.

How close can we get?

Stackless exceptions



Wow! Fast in all use cases!

Note: this is only because JVM can inline and convert to a jump. If it actually has to be thrown, it's still 10x faster than a real exception.

Now we have a glimmer of a solution.

- Internal to library: use error codes (fastest)
- External API: use stackless exceptions
- *How do we make them safe?*
- *How do we manage mutability?*

Manage safety with the *key pattern*

```
class Foo {
  def safeBar = ???
  def supervise[A](f: Key[this.type] => A): A = ???
  def unsafeBaz(implicit unlock: Key[this.type]) = ???
}
```

```
def useUnsafeFoo(foo: Foo)(implicit unlock: Key[foo.type]) = ???
```

- Just like checked exceptions: you must handle them.
- Inversion of control allows precise requirements.

```
val foo, other = new Foo
foo.supervise{ implicit key =>
  useUnsafeFoo(foo)   // Works
  foo.unsafeBaz       // Works
  otherFoo.unsafeBaz  // Compile-time error, no key!
}
```

How does the CPU manage mutability?

```
PUSHA
CALL sub
POPA
```

So if we like our mutable state:

```
class WillMutate {
  var state: State
  def saveOnStack[A](f: => A): A = {
    val temp = state
    try { f } finally { state = temp }
  }
}
```

```
val m = new WillMutate
...  // I like my state!  But I need to change it for a bit.
m.saveOnStack {
  m.mutate    // Just use the same m!
}
// Now my old state is back
```

Part Three

Grokking: simple, low-level, fast, optimistic

Grok

Grok is like an Iterator for parseable data.

This is not new. Everything from PrintReader to IntBuffer does this.

But Grok lets you be optimistic and just grab what you want.

```
import kse.flow._, kse.eio._
val g = Grok("4 and 20 blackbirds")
g{ implicit fail => (g.I, g.tok, g.I, g.tok) }
```

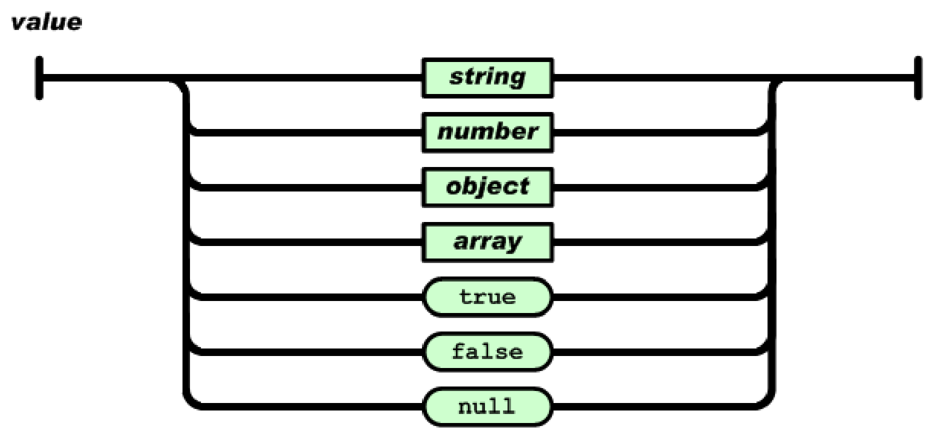
```
res0: kse.flow.Ok[kse.eio.GrokError,(Int, String, Int, String)] =
  Yes((4,and,20,blackbirds))
```

```
val g = Grok("4 and twenty blackbirds")
g{ implicit fail => (g.I, g.tok, g.I, g.tok) }
```

```
res1: kse.flow.Ok[kse.eio.GrokError,(Int, String, Int, String)] = No(
Error in integer: improper format                          v
  token 3, position 6 :                              4 and twenty blackbirds
)
```

Grokking JSON

Specification

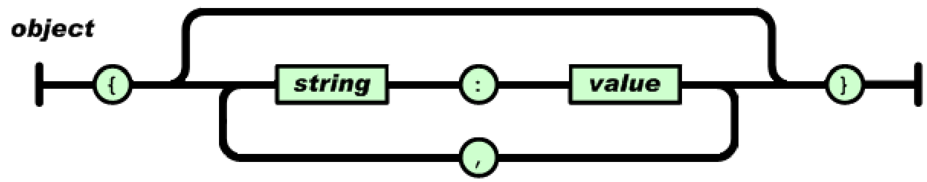


Implementation

```
def parseJany(g: Grok)(implicit fail: GrokHop[g.type]): Any = g.peek match {
  case '{' => parseJob(g)
  case '[' => parseJarr(g)
  case '"' => g.quoted
  case c if (c >= '0' && c <= '9') || c == '-' => g.D
  case 't' | 'f' => g.Z
  case _ => fail(g.customError)
}
```

Grokking JSON

Specification

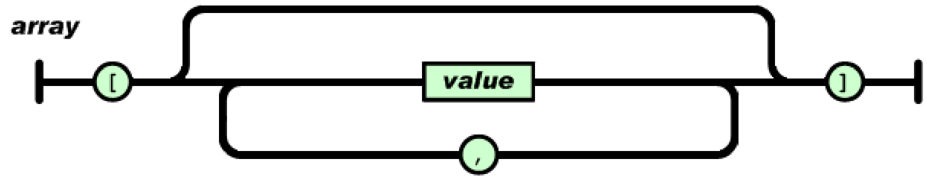


Implementation

```
def parseJob(g: Grok)(implicit fail: GrokHop[g.type]): Map[String, Any] = {
  val m = new AnyRefMap[String, Any]
  g exact '{'
  while (g.peek != '}') {
    if (!m.isEmpty) g exact ','
    val key = g.quoted
    g exact ':'
    m += (key, parseJany(g))
  }
  g exact '}'
  m
}
```

Grokking JSON

Specification

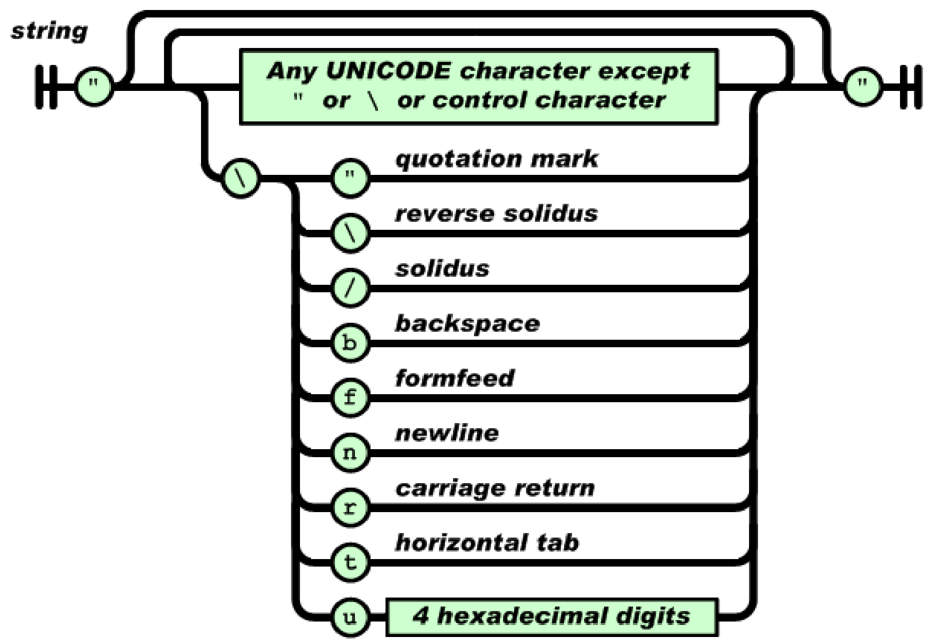


Implementation

```
def parseJarr(g: Grok)(implicit fail: GrokHop[g.type]): Array[Any] = {
  val ab = Array.newBuilder[Any]
  var index = 0
  g exact '['
  while (g.peek != ']') {
    if (index > 0) g exact ','
    ab += parseJany(g)
    index += 1
  }
  g exact ']'
  ab.result
}
```

Grokking JSON

Specification

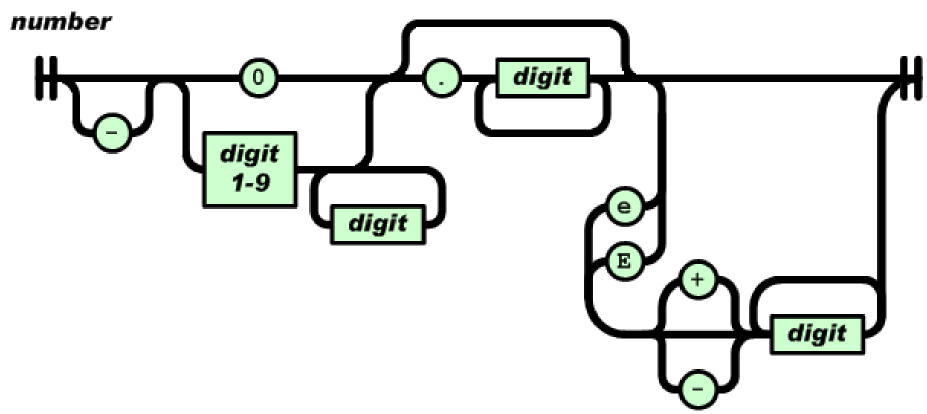


Implementation

```
g.quoted
```

Grokking JSON

Specification



Implementation (if you're happy with Double)

```
g.D
```

Grokking JSON

Boilerplate

```
import collection.Map
import collection.mutable.AnyRefMap
import kse.flow._
import kse.eio._

object pJson {
  ...

  def parse(g: Grok): Ok[GrokError, Map[String, Any]] =
    g.delimit(0){ implicit fail => parseJob(g.trim) }

  def apply(ab: Array[Byte]) = parse(Grok text ab)
  def apply(s: String) = parse(Grok(s))
}
```

Yes, but anyone can parse JSON.

Of course! Parboiled2, for instance.

```
def Json = rule { WhiteSpace ~ Value ~ EOI }

def JsonObject: Rule1[JsObject] = rule {
  ws('{') ~ zeroOrMore(Pair).separatedBy(ws(',')) ~ ws('}') ~>
    ((fields: Seq[JsField]) => JsObject(fields :_*))
}

def Pair = rule { JsonStringUnwrapped ~ ws(':') ~ Value ~> ((_, _)) }

def JsonArray = rule {
  ws('[') ~ zeroOrMore(Value).separatedBy(ws(',')) ~ ws(']') ~>
    (JsArray(_ :_*))
}

def Value: Rule1[JsValue] = rule {
  run {
    (cursorChar: @switch) match {
      case '"' => JsonString
      case '0'|'1'|'2'|'3'|'4'|'5'|'6'|'7'|'8'|'9'|'-' => JsonNumber
      case '{' => JsonObject
      ...
```

(From Parboiled2 examples directory.)

How fast is it?

Setting expectations.

Parser combinators

```
Speed (MB/s)
"a": "b"     [1, 2, 3]
0.50         0.75
```

Jackson

```
Speed (MB/s)
"a": "b"     [1, 2, 3]
236          53
```

How fast is it?

Parser combinators

```
Speed (MB/s)
             "a": "b"      [1, 2, 3]
Par. Comb.  0.50          0.75
Jackson     236           53
Grok        220           89
```

Wait, *what??*

From parboiled2 mailing list thread, "Quick JSON parsing benchmark"

```
[info]            benchmark      ms linear runtime
[info]    ParserCombinators 2931.64 ===========================/.../===================
[info] Parboiled1JsonParser  117.15 ==============================
[info] Parboiled2JsonParser   12.79 ===
[info]          Json4SNative    8.62 ==
[info]             Argonaut    7.06 =
[info]         Json4SJackson    4.19 =
```

What's the trick?

- Direct parsing: don't talk about it *do it*
- Custom Double-parsing code

What about errors?

Adding context that matters

```
def parseJarr(g: Grok)(implicit fail: GrokHop[g.type]): Array[Any] = {
  val ab = Array.newBuilder[Any]
  var index = 0
  g.context("index " + index) {
    g exact '['
    while (g.peek != ']') {
      if (index > 0) g exact ','
      ab += parseJany(g)
      index += 1
    }
    g exact ']'
  }
  ab.result
}
```

Adding context that matters

```
Error in subset of data: improper format
  token 1, position 0 :                         {"web-app": {\n  "servlet": [
  parsing key web-app                           ^
  in subset of data: improper format
    token 4, position 12 :               {"web-app": {\n  "servlet": [
    parsing key servlet                             ^
    in subset of data: improper format
      token 7, position 27 :               "servlet": [   \n    {
      parsing index 0                               ^
      in subset of data: improper format
        token 8, position 36 :         let": [   \n    {\n      "servle
        parsing key init-param                      ^
        in subset of data: improper format
          token 19, position 143 :       "init-param": {\n        "conf
          parsing key configGlossary:installationAt    ^
          in expected string: improper format          v
            token 21, position 184 :    installationAt"; "Philadelphia
```

Conclusions

- Non-local error handling is simple
- Non-local error handling can be fast
- With Grok, parsing is only as hard as it should be
- Grok is not ready to use. It's alpha, full of bugs. But it's getting close.
- For more: ichoran@gmail.com
- And I never tweet anything, but follow @_ichoran_ and I will announce when Grok is really ready.

Thanks for listening!