

Creating an Emacs Diary Parser with Haskell and Parsec

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Chapter 1

“Brian Beckman: Don’t Fear the Monad”

Available on Youtube [3].

Dr. Beckman, astrophysicist and senior software engineer, begins with a basic introduction to functional programming as a concept. Most notably, he focuses on the concept of functions as being **replaceable** by table-lookups.

1.1 Outline (7:50)

1. Functions
2. Monoids
3. Functions
4. Monads

1.2 Notation (8:25)

ONAL NOTATION :

- $int\ x = x \in int$
- `x :: int`
- $int\ f(int\ x)$
- `f :: int → int`

PE VARIABLE $a : \forall a$

- `A x`
- `x :: a`
- `static A f<A>(A x)`
- `f :: a → a`

1.2.1 Composition

Given:

```
x :: a
f :: a → a
g :: a → a
```

in imperative style function composition might appear as: `f(g(a))` or in reverse: `g(f(a))`.

In functional style, function application appears as: `g a` and composition can be shown as: `f(g a)`. Parenthesis are necessary due to partial application being left associative. For example, `f h g` is applied as though `(f h) g`.

It is also possible to use a composition operator, `o`, to imply composition: `(f o g) a`. So, given the above 1.2.1, we can deduce:

```
h = (f o g) a = f o g
h :: a → a
```

This does confuse the concepts of `a` as argument and `a` as type, but the point remains clear, I think.

1.3 Monoids (20:40)

In abstract algebra, a branch of mathematics, a monoid is an algebraic structure with a single associative binary operation and an identity element.

Monoids are studied in semigroup theory, because they are semigroups with identity.
^a.

^aWikipedia

A *Monoid* is a *Set* with:

1. an associative binary operator (generally composition)
2. an identity value

The operator need not be commutative.

In a programming context, a *Monoid* guarantees type-consistency over function composition.

1.4 Monads (30:39)

Given:

```
x :: a
f :: a → M a
g :: a → M a
g :: a → M a
```

`M` is described as a “Type Constructor.”

Again, Dr. Beckman is using `a` to represent both a value of type `a` as well as the type itself `a`. Here he introduced the *Monad* “bind” operator: `>>=`, which he likes to call “shove”:

```
f :: a → M a
g :: a → M a
-- the right hand side is g, but written with
-- a lambda to preserve symmetry
λa → (f a) >>= λa → (g a)
```

The reason to preserve symmetry in the above expression is that the desired expression is “bracketed” as: $\lambda a \rightarrow [(fa) >>= \lambda a \rightarrow (ga)]$ because the bind operator has type:

```
(>>=) :: Monad m => m a -> (a -> m b) -> m b
```

That is, `>>=` accepts a *Monad* $(M\ a)$ and returns a function from $a \rightarrow M\ a$.

The functions f , and g live in a *Monoid*. $M\ a$ (the *data*) lives in a *Monad*.

`(>>=)` is the analog of function composition and, therefore, obeys the rules of a *Monoid*. Including associativity and identity.

In a *Monad*, identity is—in Haskell—written as:

```
return :: Monad m => a -> m a
```

Extended to non-uniform types:

```
g :: a -> Mb
f :: b -> Mc
λa -> (g a) >>= λb -> (f b) :: a -> Mc
g >>= λb -> (f b)
```

Chapter 2

The Maybe Monad

2.1 As Described by Computerphile [2]

```
-- Type and 2 type constructors: Val and Div
data Expr = Val Int | Div Expr Expr

-- Val 1
-- Div (Val 6) (Val 2)

unsafe_eval :: Expr → Int
unsafe_eval (Val n) = n
unsafe_eval (Div x y) = div (eval x) (eval y)

-- eval (Div (Val 6) (Val 2))
```

What if `Div` is passed zero? The program will crash. So, error-checking is necessary.

```
safediv :: Int → Int → Maybe Int
safediv n m = if m == 0 then Nothing else Just (div n m)

eval :: Expr → Maybe Int
eval (Val n) = Just n
eval (Div x y) = case eval' x of
    Nothing → Nothing
    Just n → case eval y of
        Nothing → Nothing
        Just m → safediv n m

eval' :: Expr → Int
```

Abstracting the pattern of `case` checking `Maybe` values can be represented as:

Without 'do' notation	With 'do' notation
<pre>eval' :: Expr → Maybe Int eval' (Val n) = return n eval' (Div x y) = eval' x >>= (λn → eval' y >>= (λm → safediv n m))</pre>	<pre>eval'' :: Expr → Maybe Int eval'' (Val n) = return n eval'' (Div x y) = do n ← eval'' x m ← eval'' y safediv n m</pre>

Chapter 3

Other Monads

The *Monad* type[4, p. 402]:

```
class Monad m where
  (>>=) :: m a → (a → m b) → m b
  return :: a → m a
  (>>)  :: m a → m b → m b
  fail  :: String → m a
```

Monad comes with some default definitions:

```
m >> k = m >>= λ_ → k
fail s = error s
```

From this definition it can be seen that `>>` acts like `>>=`, except that the value returned by the first argument is discarded rather than being passed to the second argument. [4, p. 403]

3.1 The Identity Monad [4, p. 404]

The identity monad takes a type to itself with definitions:

```
m >>= f = f m
return = id
```

3.2 Definition of Maybe

```
instance Monad Maybe where
  (Just x) >>= k = k x
  Nothing >>= k = Nothing
  return      = Just
  fail s      = Nothing
```

3.3 The List *Monad*

```
instance Monad [] where
  xs >>= f = concat (map f xs)
  return x = [x]
  fail s = []
```

Lists are, in fact, themselves instances of *Monad*.

```
fmap :: Functor f => (a -> b) -> f a -> f b
(<>>=) :: Monad m => m a -> (a -> m b) -> m b
map    :: (a -> b) -> [a] -> [b]
```


Chapter 4

Using Parsec

4.1 Parsing CSV

```
import Text.ParserCombinators.Parsec
```

[5, Ch. 16]

Input type is a sequence of characters, i.e., a Haskell *String*. *String* is the same as *[Char]*. The return value is *[[String]]*; a list of a list of Strings. We'll ignore *st* for now.

The *do* block implies a *Monad*. *GenParser* is a parsing monad.

many is a higher-order function that passes input repeatedly to the function passed as its argument. It collects the return values and returns them in a list.

```
csvFile :: GenParser Char st [[String]]
csvFile =
  do result <- many line
  eof
  return result
```

A *line* is a list of *cells* followed by *eol*.

```
line :: GenParser Char st [String]
line =
  do result <- cells
  eol
  return result
```

```
cells :: GenParser Char st [String]
cells =
  do first <- cellContent
  next <- remainingCells
  return (first : next)
```

The choice operator, (*<|>*), tries the parser on the left and tries The parser on the right if the left consumes no input.

```
remainingCells :: GenParser Char st [String]
remainingCells =
  (char ',' >> cells) <|> (return [])
```

```
cellContent :: GenParser Char st String
cellContent =
  many (noneOf ",\n")
```

```
eol :: GenParser Char st Char
eol = char '\n'
```

```
parseCSV :: String → Either ParseError [[String]]
parseCSV input = parse csvFile "(unknown)" input
```

4.2 sepBy and endBy Combinators

```
import Text.ParserCombinators.Parsec
```

```
csvFile = endBy line eol
line    = sepBy cell (char ',')
cell    = quotedCell <|> many (noneOf ",\n\r")
```

A CSV cell may be either a bare cell or a quoted cell. Since a quoted cell may, itself, contain quotes (doubled for escape) a `quotedCell` is `many quotedChar`.

```
quotedCell =
  do char '"'
  \content ← many quotedChar
  \char ← "<?> \"quote_at_end_of_cell\" -- see eol below
  return content
```

The function `quotedChar` begins by consuming any character that is *not* itself a quote. If it is a quoted character, the stream must be checked for a second consecutive quote. If so, a single quote mark is returned to the result string.

Notice that `try` in `quotedChar` on the right side of `<|>`. Recall that I said that `try` only has an effect if it is on the left side of `<|>`. This `try` does occur on the left side of a `<|>`, but on the left of one that must be within the implementation of `many`.

This `try` is important. Let's say we are parsing a quoted cell, and are getting towards the end of it. There will be another cell following. So we will expect to see a quote to end the current cell, followed by a comma. When we hit `quotedChar`, we will fail the `noneOf` test and proceed to the test that looks for two quotes in a row. We'll also fail that one because we'll have a quote, then a comma. If we hadn't used `try`, we'd crash with an error at this point, saying that it was expecting the second quote, because the first quote was already consumed. Since we use `try`, this is properly recognized as not a character that's part of the cell, so it terminates the `many quotedChar` expression as expected. Lookahead has once again proven very useful, and the fact that it is so easy to add makes it a remarkable tool in `Parsec`.

```
quotedChar =
  noneOf "\""
  \<|> try (string "\n\r") >> return ''
```

`Parsec` also includes combinators for error handling and reporting. A first attempt at an `eol` implementation that handles multiple line-ending styles might appear as:

```
eol' = try (string "\n\r")
      <|> try (string "\r\n")
      <|> string "\n"
      <|> string "\r"
```

```
> parseCSV "line1"
Left "(unknown)" (line 1, column 6):
unexpected end of input
expecting ",", "\n\r", "\r\n", "\n" or "\r"
```

The failure above is unclear and requires knowledge of the parser implementation to debug fully. The monad `fail` function can be used to add messaging:

```
eol' = try (string "\n\r")
      <|> try (string "\r\n")
      <|> string "\n"
      <|> string "\r"
      <|> fail "Couldn't find EOL"
```

This adds messaging to the result, but is still noisy and unclear:

```
> parseCSV "line1"
Left "(unknown)" (line 1, column 6):
unexpected end of input
expecting ",", "\n\r", "\r\n", "\n" or "\r"
Couldn't find EOL
```

The Parsec `<?>` operator is designed to help here.

It is similar to `<|>` in that it first tries the parser on its left. Instead of trying another parser in the event of a failure, it presents an error message. Here's how we'd use it:

```
eol = try (string "\n\r")
      <|> try (string "\r\n")
      <|> string "\n"
      <|> string "\r"
      <?> "end of line"
```

This has a more pleasing result:

```
> parseCSV "line1"
Left "(unknown)" (line 1, column 6):
unexpected end of input
expecting "," or end of line
```

The general rule of thumb is that you put a human description of what you're looking for to the right of `<?>`.

```
parseCSV :: String -> Either ParseError [[String]]
parseCSV input = parse csvFile "(unknown)" input
```

Chapter 5

Using HUnit to test the Parser

5.1 Helper Functions

```
module SpecHelpers where
import Test.HUnit

import Text.Printf

import Data.Time.Clock
import Data.Time.Calendar
import Data.Time.Format

import Text.Parsec
import Text.Parsec.String
```

5.1.1 Date Helpers

Create a date-parser via partial application of `parseTimeOrError`:

```
acceptOuterWhitespace = True

parseDateF :: String → String → Either String Day
parseDateF fmt s =
  case parseTimeM acceptOuterWhitespace defaultTimeLocale fmt s :: Maybe UTCTime of
    Nothing → Left $ printf "Failed to parse '%s' with '%s'" s fmt
    (Just x) → Right $ utctDay x

parseTimeF :: String → String → Either String UTCTime
parseTimeF fmt s =
  case parseTimeM acceptOuterWhitespace defaultTimeLocale fmt s :: Maybe UTCTime of
    Nothing → Left $ printf "Failed to parse '%s' with '%s'" s fmt
    (Just x) → Right x

showTime :: UTCTime → String
showTime = formatTime defaultTimeLocale "%e %b %Y %R"
```

5.1.2 Parser Testing Helpers

```

nullState = ()
testParse :: Parser a → String → String → Either ParseError a
testParse p src = runParser p nullState src

-- assertParsesTo expected p input = do
--   let result = testParse p input
--   case result of
--     (Right actual) → expected @=? show actual
--     (Left error)   → assertFailure
--     (printf "Failed to parse input '%s': %s" input (show error))

```

A Type for expressing parser assertions

```

data ParserContext a =
  ParserContext { parser    :: Parser a
                 , input    :: String
                 , expected :: String
                 }

parses :: (Show a) ⇒ ParserContext a → Assertion
parses pa =
  case testParse (parser pa) ("expected:␣" ++ (show expected pa)) (input pa) of
    (Right actual) → assertEquals "" (show expected pa) (show actual)
    (Left error)   → assertFailure (show error)

instance (Show a) ⇒ Testable (ParserContext a)
  where
    test = TestCase ∘ parses

assertParser message expected parser input =
  parses pa
  where
    pa = ParserContext parser input expected

```

5.1.3 Writing the Tests

Table 5.1: Test Types

<code>recordTests :: Test</code>	
<code>test :: Testable t ⇒ t → Test</code>	Provides a way to convert data into a <i>Test</i> or set of <i>Test</i> .
<code>(~:) :: Testable t ⇒ String → t → Test</code>	Creates a test from the specified <i>Testable</i> , with the specified label attached to it. Since <i>Test</i> is <i>Testable</i> , this can be used as a shorthand way of attaching a <i>STestLabel</i> to one or more tests.
<code>assertEquals :: (Show a, Eq a) ⇒ String → a → a → Assertion</code>	
<code>(@=? :: (Show a, Eq a) ⇒ a → a → Assertion</code>	Asserts that the specified actual value is equal to the expected value (with the actual value on the left-hand side).

5.1.4 The Preamble

Declare the test module and export its tests.

```

module EmacsDiary.RecordSpec (recordTests) where

import Test.HUnit
import Text.Parsec
import Text.Parsec.String
import Data.Time.Clock
import Data.Time.Format

import SpecHelpers

import EmacsDiary.Record

recordTests = test [
  "create_a_DiaryEntry" ~: do
    let (Right d) = parseTimeF "%e_%b_%Y" "7_July_2008"
    "7_July_2008_Chicago,_IL" @=? show (DiaryEntry d "Chicago,_IL")
]

```

5.2 Testing the Parser

```

module EmacsDiary.ParserSpec (tests) where

import Test.HUnit
import SpecHelpers

import EmacsDiary.Parser (diary)

tests = test [
  "parse_empty_date-line:_7_July_2008'" ~: do
    assertParser "!!!" "2008-07-07" diary "7_July_2008"
]

```

Chapter 6

The Emacs Diary Parser

6.1 Parsing Dates and Times

```
module EmacsDiary.Parser.Interval where

import qualified EmacsDiary.Parser.Tokens as T

import Text.Parsec (
    many, string, count, spaces, digit, many1, choice, (<|>), try, sepBy1, unexpected)
import Text.Parsec.String (Parser)
import Data.Time.Clock (
    addUTCTime,
    NominalDiffTime,
    utctDayTime,
    utctDay,
    UTCTime)
import Data.Time.Calendar (fromGregorian, showGregorian, Day)
import Data.Time.Format (iso8601DateFormat, formatTime, parseTimeM, defaultTimeLocale)
import Text.Printf (printf)

import Control.Monad (void)

showTimeFormat = "%H:%M:%S%z"
locale = defaultTimeLocale
```

6.1.1 Type Definitions

A newtype declaration creates a new type in much the same way as data. The syntax and usage of newtypes is virtually identical to that of data declarations - in fact, you can replace the newtype keyword with data and it'll still compile, indeed there's even a good chance your program will still work. The converse is not true, however - data can only be replaced with newtype if the type has exactly one constructor with exactly one field inside it. ([1, /NewType])

```
newtype Date = Date Day deriving (Eq)
```

Ill `show Date` using the ISO-8601 format:

```
instance Show Date where
    show (Date d) = showGregorian d
```

`Time` will represent instances of UTC times.

```
data Time = Time { timeHour    :: Integer
                  , timeMinute :: Integer
                  } deriving (Eq)

instance Show Time where
    show t = iso8601DateFormat (Just showTimeFormat)

instance Num Time where
    a + b = fromInteger $ (seconds a) + (seconds b)
    a * b = fromInteger $ (seconds a) * (seconds b)
    abs   = fromInteger o abs o seconds
    signum = fromInteger o signum o seconds
    negate = fromInteger o negate o seconds
    fromInteger a = Time h m
        where
            i = fromInteger a
            h = quot i 3600
            m = div s 60
            s = rem i 3600

timeFromList :: [Integer] → Time
timeFromList (h:m:_) = Time h m

seconds :: Time → Integer
seconds (Time h m) = 3600*h + 60*m

timeToNDiff :: Time → NominalDiffTime
timeToNDiff (Time h m) = fromInteger (3600*h + 60*m)

addTime :: UTCTime → Time → UTCTime
addTime a t = addUTCTime (timeToNDiff t) a
```

6.1.2 Parsers

```
decided :: Parser (Either String a) → Parser a
decided p = do
    e ← p
    case e of
        (Left s)  → unexpected s
        (Right r) → return r

timeS :: Parser Time
timeS = timeFromList <$> sepBy1 T.numeric (T.symbol ":")

dateFormats = [
    "%d_%b_%Y",
    "%d_%B_%Y",
    "%e_%b_%Y",
    "%e_%B_%Y",
    "%F"]

--date :: Parser UTCTime
--date = decided p
--  where
--    p = asUTC <$> dateS
```



```

-- dateString :: Parser String
-- dateString = do
--   void spaces
--   d ← digits
--   m ← word
--   y ← digits
--   return (d:(m:y))
--   -- $ parseDateS (printf "%s %s %s" d m y)

dayP :: Parser Int
dayP = fromIntegral <$> T.numeric

yearP :: Parser Integer
yearP = T.numeric

months = [
  ("January", 1), ("Jan", 1),
  ("February", 2), ("Feb", 2),
  ("March", 3), ("Mar", 3),
  ("April", 4), ("Apr", 4),
  ("May", 5),
  ("June", 6), ("Jun", 6),
  ("July", 7), ("Jul", 7),
  ("August", 8), ("Aug", 8),
  ("September", 9), ("Sep", 9),
  ("October", 10), ("Oct", 10),
  ("November", 11), ("Nov", 11),
  ("December", 12), ("Dec", 12)
]

keyValueParser :: (String, Int) → Parser Int
keyValueParser (m,n) = try (string m) >> return n

monthP :: Parser Int
monthP = choice $ map keyValueParser months

-- date :: Parser Date
date :: Parser Day
date = do
  d ← dayP
  m ← T.lexeme monthP
  y ← yearP
  return $ fromGregorian y m d

time :: UTCTime → Parser UTCTime
time datetime = addTime datetime <$> timeS

```

Bibliography

- [1] *The Haskell Wiki* April 2018
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- [4] Simon Thompson, *The Craft of Functional Programming*, Pearson, Edinburgh Gate, England, Second Edition, 1999.
- [5] Bryan O'Sullivan, Don Stewart, and John Goerzen *Real World Haskell* O'Reilly Media 2008.