Best Title in the Universe

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Abstract. stuff

1 Introduction

The majority of version control systems handle patches in a non-structured way. They see a file as a list of lines that can be inserted, deleted or modified, with no regard to the semantics of that specific file. The immediate consequence of such design decision is that we, humans, have to solve a large number of conflicts that arise from, in fact, no conflicting edits, yet, the tools fail to see such edits as non-conflicting as they are not aware of the file's semantics. Implementing a tool that knows the semantics of any file we happen to need, however, is clearly not an easy task, specially given the plethora of file formats we see nowadays.

Let us illustrate this with the following three CSV files:

– *show three different CSV files that conflict under diff3.*

It is not hard to see that Alice's and Bob's edits do *not* conflict. However, the diff3 [cite!] tool will flag them as such. Using generic programming techniques we can do a better job at identifying actual conflicts. The problem is twofold, however: (A) how to parse things generically and (B) how to diff over the results of these parsers and merge them properly.

We begin by explaining how we can write parsers in a very generic fashion, using type-level *grammar combinators*. This approach has lots of advantages, for instance, it is easily invertible to generate pretty-printers. The exposition of our library is guided by writing a CSV parser as an example.

Once we can solve the parsing problem in an elegant fashion, we address the diffing problem. Namelly, how can we take two values returned by a *grammar* parser and represent the differences between them.

To summarize our contributions,

– We present a generic parsing and pretty printing library built on Haskell's type-level, using a similar technique as in [1].
– We model the notion of *patch* generically, and prove it's correctness in Agda.

2 Grammar Combinators

Our parser combinator library seeks to generate a parser and a pretty printer from the same specification. It is similar to [3] and [2] in its idea, but drastically different in implementation. We achieve our generic parsers by encoding our combinators on the type-level, then having diffrent instances of a class *HasParser* for each of them. We were inpired by [1], who first used this technique to build API-driven web servers.

Sticking to CSV as our *to-go* example, we can write its grammar in BNF as shown in figure 1, it can be read as *A CSV file consists in many lines*. From this description, it is already expected that a CSV parser will return a $[Line]$, given an input file in the CSV format. But the converse should also be easy! Given a $[Line]$, knowing that it represents a CSV file, we should be able to print it as such.

The idea here lies in the fact that a BNF already looks like a Haskell type declaration, and at the same time, acts as the *type* of a language. We want to have (empty) types that mimick the BNF syntax and allow us to define instances by induction on their structure. The CSV grammar gives us the following datatype.

$$\begin{aligned} \mathit{CSV} &::= (\mathit{line}\ '\backslash n')^* \\ \mathit{line} &::= \mathit{string} \\ &\mid\ \mathit{string}\ ','\ \mathit{line} \end{aligned}$$

Fig. 1. CSV grammar

$$\begin{aligned} &\textbf{type}\ \mathit{CSV} = [\mathit{Line}] \\ &\textbf{data}\ \mathit{Line} = \mathit{One}\ \ \mathit{String} \\ &\qquad\qquad\mid\ \mathit{More}\ \mathit{String}\ \mathit{Line} \end{aligned}$$

Our parser combinators follow the applicative style, with some precedences swapped. With least precedense we have $a \mathbin{:\lll\ggg} b$, which will parse a then b, in sequence, and return $(\mathit{Result}\ a, \mathit{Result}\ b)$. Together with its forgetfull versions $a \mathbin{:\ast\ggg} b$ and $a \mathbin{:\lll\ast} b$, wich will ignore the result from the left, or right, respectively. These type combinators are right associative. Then we have the choice combinator $a \mathbin{:<|>} b$, which will try to parse a. If it fails, it proceeds by trying b, its result is $\mathit{Either}\ (\mathit{Result}\ a)\ (\mathit{Result}\ b)$. And last we have a *tagging* combinator $k \mathbin{:<\$>} a$ which injects the result of a into a datatype k. We will explain this combinator in more detail in section 2.1. We stress that a exhaustive description of the grammar combinators is beyond the scope of this paper. We refer the reader to the hackage documentation PUT IT ONLINE! for that.

A few high level combinators are also available, for example $\mathit{VMany}\ a$ and $\mathit{HMany}\ a$. The parsing behaviour of both is the same, they will parse as many a s as possible. On the pretty-printing side, however, one will concat it's arguments vertically whereas the other will concat it's arguments horizontally.

Henceforth, the CSV grammar written using our combinators looks like figure 2.

Using `-XDataKinds` GHC extension we can have type-level strings, which are suitable for defining combinators such as Sym `","`, that parses the symbol `","`. Here, *genParser* and *Result* are definitions provided by the class *HasParser*, which is defined for all grammar combinators,

```haskell
type CSVParser = VMany LineParser
type LineParser = Line :<$> Iden
                       :<|> Iden :<*> Sym "," :*> LineParser
csvParser :: Parser (Result CSVParser)
csvParser = genParser (Proxy :: Proxy CSVParser)
```

Fig. 2. CSV Parser

```haskell
class HasParser a where
  type Result a :: *
  genParser     :: Proxy a -> Parser (Result a)
```

And, for illustration purposes, the instance for *VMany* is defined as:

```haskell
instance (HasParser a) => HasParser (VMany a) where
  type Result (VMany a) = [Result a]
  genParser _ = many (genParser (Proxy :: Proxy a))
```

Note that we need to keep using these proxies (from `Data.Proxy`) around so GHC can choose the correct instance to fetch *genParser* from.

The attentive reader might have noticed a few problems with the CSV parser presented in figure 2. If we try to compile that code GHC will complain about a recursive type synonym. That is very easy to fix, however. We just wrap the recursive calls in a newtype and provide a cannonical instance[1] for it.

```haskell
type LineParserA = Line :<$> Iden
                        :<|> Iden :<*> Sym "," :*> LineParser
newtype LineParser = LP LineParserA
instance HasParser LineParser where
  type Result LineParser = Result LineParserA
  genParser _ = genParser (Proxy :: Proxy LineParserA)
```

2.1 The Tagging Combinator

Tagging is the least intuitive of the combinators, for it deserves its own section. The reason for including it in the library is to provide the user with a way to generate hiw own datatypes instead of standard[2] ones. The important observation is that any Haskell type is isomorphic to a sum-of-products, which can be expressed using standard types.

The parser instance for a :<$> b is defined as:

```haskell
instance (HasParser a, HasIso k (Result a)) => HasParser (k :<$> a) where
  type Result (k :<$> a) = k
  genParser _ = genParser (P a) >>= return . og
```

[1] In fact, we provide Template Haskell code to do exactly that. The user should just call $(*deriveRec* '' *LineParser* '' *LineParserA*).

[2] We call standard types any type built using () , *Either* , (,) , [] and atomic types such as *Integer*, *String*, *Double*, ...

Where the $HasIso\ a\ b$ class defines two functions $go :: a \rightarrow b$ and $og :: b \rightarrow a$ to convert values from one type to another. In our CSV example, we have the following instance:

$$
\begin{array}{l}
\textbf{instance}\ \mathit{HasIso}\ \mathit{Line}\ (\mathit{Either}\ \mathit{String}\ (\mathit{String}, \mathit{Line}))\ \textbf{where} \\
\quad go\ (\mathit{One}\ s) \qquad\quad = \mathit{Left}\ s \\
\quad go\ (\mathit{More}\ s\ l) \quad\ \ = \mathit{Right}\ (s, l) \\
\quad og\ (\mathit{Right}\ (s, l)) = \mathit{More}\ s\ l \\
\quad og\ (\mathit{Left}\ s) \qquad\quad = \mathit{Left}\ s
\end{array}
$$

The calculation below shows that *LineParser* indeed has the expected result type. Here we use $a{\sim}b$ to denote an isomorphism between a and b meaning that we parse a value of type b and inject it into something of type a through $og :: b \rightarrow a$.

$$
\begin{aligned}
\mathit{Result}\ \mathit{LineParser} &= \mathit{Line}{\sim}\mathit{Result}\ (\mathit{Iden} :<|> \mathit{Iden} :\lessdot\!\!> \mathit{Sym}\ \texttt{","} :\!\!\gtrdot \mathit{LineParser}) \\
&= \mathit{Line}{\sim}\mathit{Either}\ (\mathit{Result}\ \mathit{Iden})\ (\mathit{Result}\ (\mathit{Iden} :\lessdot\!\!> \mathit{Sym}\ \texttt{","} :\!\!\gtrdot \mathit{LineParser})) \\
&= \mathit{Line}{\sim}\mathit{Either}\ \mathit{String}\ (\mathit{Result}\ \mathit{Iden}, \mathit{Result}\ (\mathit{Sym}\ \texttt{","} :\!\!\gtrdot \mathit{LineParser})) \\
&= \mathit{Line}{\sim}\mathit{Either}\ \mathit{String}\ (\mathit{String}, \mathit{Result}\ \mathit{LineParser}) \\
&= \mathit{Line}{\sim}\mathit{Either}\ \mathit{String}\ (\mathit{String}, \mathit{Line})
\end{aligned}
$$

And the result is precisely the *HasIso* instance that we have for the type *Line*. In fact, we provide Template Haskell code to generate these mechanical isomorphisms automatically, the user would just call $\$(\mathit{deriveIso}\ \text{''}\ \mathit{Line})$.

2.2 Lexing Remarks

In the example we gave in figure 2 we use a few atomic grammar combinators that were left unexplained, such as *Iden* and *Sym* ",". The reason for this is that the semantics of these combinators depends on the underlying lexer being used.

We provide a class *HasLexer lang* which ties this knot. It is fairly straight forward to use. The full, correct code, of the CSV example is shown below (where $a :<!> b$ means parse a but only if it is *not* followed by b).

$$
\begin{array}{l}
\textbf{data}\ \mathit{CSV} \\
\textbf{instance}\ \mathit{HasLexer}\ \mathit{CSV}\ \textbf{where} \\
\quad \mathit{identStart}\ \_\ \ \texttt{','}\ \ = \mathit{False} \\
\quad \mathit{identStart}\ \_\ \ \texttt{'\textbackslash n'} = \mathit{False} \\
\quad \mathit{identStart}\ \_\ \ \_\ \qquad = \mathit{True} \\
\quad \mathit{identLetter}\ p \qquad\ = \mathit{identStart}\ p \\
\quad \mathit{reservedList}\ \_ \qquad = [\,] \\
\textbf{type}\ \mathit{CSVParser} = \mathit{VMany}\ \mathit{LineParser} \\
\textbf{type}\ \mathit{LineParser}'
\end{array}
$$

$$= \mathit{Line} \mathrel{:<\$>} \mathit{Ident}\ \mathit{CSV} \mathrel{:<!>} \mathit{Sym}\ \mathit{CSV}\ \texttt{","}$$
$$\mathrel{:<|>} \mathit{Ident}\ \mathit{CSV} \mathrel{:\lll} \mathit{Sym}\ \mathit{CSV}\ \texttt{","} \mathrel{:\ggg} \mathit{LineParser}$$

newtype *LineParser* = *LP LineParser′*

data *Line* = *One String* | *More String Line*
  deriving (*Eq*, *Show*, *Ord*)

$ (*deriveRec* '' *LineParser* '' *LineParser′*)
$ (*deriveIso* '' *Line*)

The *HasLexer lang* class defines lexing primitives for a language, which is specified through an empty data constructor. The type signature for *identStart*, for instance, is:

$$\mathit{identStart} :: \mathit{Proxy}\ \mathit{lang} \to \mathit{Char} \to \mathit{Bool}$$

And it decides which characters start an identifier. For the readers familiar with `Text.Parsec`, our HasLexer is just a lifting from Parsec's lexing primitives to a typeclass.

2.3 Pretty Printing

- *show the HasPrinter class.*
- *Mention the comments problem, and say that this is left as future work.*
- *Explain that deriveRec also devires a HasPrinter instance for the encapsulated recursive type.*

2.4 Summary

On this section we presented our *grammar combinators* library with a simple use case. The important points the reader whould take are:

- Having type-level combinators to specify a language's grammar gives us an easy way to generate both a parser and a pretty-printer.
- Handling user defined types or mutually recursive grammars is not a problem.
- The type of the elements of a grammar is very regular, in fact, it is built using products, coproducts, units and lists (minus isomorphism for user defined types).

[Find a name for our library! : How about "Grammar Combinators"?]

3 Diffing the results

- *Explain the patching problem.*
- *We want a type-safe approach.*
- *Argue that the types resulting from our parser are in a sub-language of what we treated next.*

4 Context Free Datatypes

- *Explain the universe we're using.*
- *Explain the intuition behing our D datatype.*
- *Mention that it is correct.*

```
data U : ℕ → Set where
  u1  : {n : ℕ} → U n
  _⊕_ : {n : ℕ} → U n → U n → U n
  _⊗_ : {n : ℕ} → U n → U n → U n
  β   : {n : ℕ} → U (suc n) → U n → U n
  μ   : {n : ℕ} → U (suc n) → U n
  vl  : {n : ℕ} → U (suc n)
  wk  : {n : ℕ} → U n → U (suc n)
```

5 Related Work

- People have done similar things... or not.

6 Conclusion

- This is what we take out of it.

References

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2. Tillmann Rendel and Klaus Ostermann. Invertible syntax descriptions: Unifying parsing and pretty printing. *SIGPLAN Not.*, 45(11):1–12, 2010.
3. Jeremy Shaw. boomerang. http://hackage.haskell.org/package/boomerang. Acessed: November 2015.