Expand: Towards an extensible Pandoc system

An application of extensible compiler construction in Haskell

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Introduction

We can write documents using different markup languages:

- Latex (`.tex`)
- markdown (`.md`)
- Word (`.doc`)
- mediawiki
- ...

Usage might depend on syntactic preference, language features or purpose.

Introduction

All formats have their own way of describing document elements.

document element	HTML	Latex	Markdown
bold text	`<b>...</b>`	`\textbf{...}`	`**...**`
header	`<h2>...</h2>`	`\subsection{...}`	`##...`
paragraph	`<p>...</p>`	Blank lines	
url	`<a href="...">...</a>`	`\url{...}{...}`	`[...](...)`

Introduction

Problem: We have written a document in one language and would like to convert it to another, without doing all the formatting again.

Introduction (Pandoc)

Pandoc is open-source software that allows for automatic conversion between different types of markup formats.

- Supports many types of input and output formats
- Also provides its functionality as a Haskell library

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Pandoc is open-source software that allows for automatic conversion between different types of markup formats.

- Supports many types of input and output formats
- Also provides its functionality as a Haskell library
- Architecture:

  Readers that can parse specific markup file formats

  Abstract Syntax Tree an intermediate data structure to describe a general markup document

  Writers that can unparse (or write) to a target markup file format

Introduction (Problem)

Unfortunately, Pandoc's readers, intermediate type and writers are not extensible.

We propose `expand`, a Haskell library, in which all of the three components can be described in a modular way, with the possibility to extend and reuse different components.

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Extensibility

Implementing `expand`: Core Latex to HTML

- Abstract Syntax
- Grammar - Core Latex
- Semantics - HTML
- Composing the Tool

Extending components

- Numbered Headers
- Table of Contents

Conclusion

1. Extensibility

Extensibility

Suppose you want to extend the formatting of markdown.

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One should be able to

1. import an existing reader, writer or the definition of the intermediate data type
2. write extensions that build on these components
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Furthermore, the Haskell type system should verify that the composition is

Extensibility

We base our solution on the following Haskell libraries

- `murder` for defining parser using grammar fragments
- `AspectAG` for describing semantics using attribute grammars rules.

(Viera, M.: First Class Syntax, Semantics and Their Composition. Ph.D. thesis)

2. Implementing `expand`: Core Latex to HTML

Example input & output


```
\section{\plain{Introduction}}
\begin{paragraph}
    \plain{Iam id ipsum absurdum, \textbf{\plain{maximum}}
           malum neglegi. Ut id aliis narrare gestiant? }
\end{paragraph}

\subsection{\plain{subintroduction}}
\begin{paragraph}
    \plain{Sic enim censent, oportunitatis esse beate vivere. A primo,
           ut opinor, animantium ortu petitur origo summi boni. }
\end{paragraph}
```

Example input & output


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           ut opinor, animantium ortu petitur origo summi boni. }
\end{paragraph}
```

```
<h1>Introduction</h1>
<p>Iam id ipsum absurdum, <b>maximum</b>neglegi. Ut id
aliis narrare gestiant? </p>

<h2>subintroduction</h2>
<p>Sic enim censent, oportunitatis esse beate vivere. A
primo, ut opinor, animantium ortu petitur origo summi
boni. </p>
```

2.1 Abstract Syntax

```
module Declarations.CoreLatex where

data Document = Document { blocks :: BlockL } deriving Show
```

Figure: A datatype for the AS

```
module Declarations.CoreLatex where

data Document = Document { blocks :: BlockL } deriving Show

type BlockL = [Block]
data Block  = Header    { level_header  :: Int
                        , inlines_header :: InlineL }
            | Paragraph { inlines_par   :: InlineL }
    deriving (Show)
```

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data Document = Document {blocks :: BlockL} deriving Show

type BlockL = [Block]
data Block  = Header    {level_header   :: Int
                        ,inlines_header :: InlineL}
            | Paragraph {inlines_par    :: InlineL}
    deriving (Show)
type InlineL = [Inline]
data Inline = Plain     {str_plainInl   :: String}
            | Bold      {inlines_boldInl :: InlineL}
            | Italics   {inlines_italInl :: InlineL}
  deriving (Show)
```

Figure: A datatype for the AS

```
module Declarations.CoreLatex where

data Document = Document {blocks :: BlockL} deriving Show


type BlockL = [Block]
data Block  = Header     {level_header   :: Int
                         ,inlines_header :: InlineL}
            | Paragraph  {inlines_par    :: InlineL}
    deriving (Show)
type InlineL = [Inline]
data Inline  = Plain      {str_plainInl    :: String}
             | Bold       {inlines_boldInl :: InlineL}
             | Italics    {inlines_italInl :: InlineL}
  deriving (Show)
$(deriveAG ''Document)
$(deriveLang "Doc" [''Document, ''BlockL, ''Block,
                    ''InlineL, ''Inline])
```

Figure: A datatype for the AS

```
$ (deriveAG ‘Document)
```

Generates the necessary labels and types to be used in the attribute grammar fragments.

```
$ (deriveLang "Doc" [‘Document, ‘BlockL, ‘Block,
                                ‘InlineL, ‘Inline])
```

Generates a record with the appropriate semantic function types, to be used by the parser.

2.2 Grammar - Core Latex

Core Latex (EBNF)

document ::= *block**
block ::= *paragraph*
| *header*
paragraph ::= "\begin" "{" "paragraph" "}" *inline**
"\end" "{" "paragraph" "}"
header ::= "\section" "{" *inline** "}"
| "\subsection" "{" *inline** "}"
| "\subsubsection" "{" *inline** "}"
inline ::= "\plain" "{" *text* "}"
| "\textbf" "{" *inline** "}"
| "\textit" "{" *inline** "}"

Figure: The EBNF for our input language

Core Latex (Haskell)


```
module Grammars.CoreLatex where

import Declarations.CoreLatex

gLatex sem = proc () → do
  rec
      doc    ← addNT ≺ ⟦ (pDocument sem) blocks ⟧
    blocks   ← addNT ≺ pFoldr (pBlockL_Cons sem, pBlockL_Nil sem)
                              ⟦ block ⟧
    block    ← addNT ≺ ⟦ head ⟧ <|> ⟦ par ⟧

      ...
```

Each production is expressed using the idiom brackets[1] ⟦ and ⟧
(`iI` and `Ii` in Haskell code)

[1] http://www.haskell.org/haskellwiki/Idiom_brackets

Core Latex (Haskell)


```
  ...
  par  ← addNT ≺ ⟦ (pParagraph sem)
                   "\\begin" "{" "paragraph" "}"
                   inls
                   "\\end" "{" "paragraph" "}" ⟧
  head ← addNT ≺ let h (x, name) = ⟦ (pHeader sem x) "\\" name
                                                     "{" inls
                                                     "}" ⟧
                     headers      = [(1, "section")
                                    ,(2, "subsection")
                                    ,(3, "subsubsection")]
                 in  foldr1 (<|>) (map h headers)
  ...
```

Figure: Our EBNF encoded as a series of grammar transformations

Core Latex (Haskell)


```
...
inls ← addNT ≺ pFoldr (pInlineL_Cons sem, pInlineL_Nil sem)
                      ||| inline |||
inl  ← addNT ≺ ||| (pBold sem)   "\\textbf" "{" inlineL "}" |||
           <|> ||| (pItalics sem) "\\textit" "{" inlineL "}" |||
           <|> ||| (pPlain sem)   "\\plain"  "{"
                                  (someExcept "\\&%$#_{}~^")
                                  "}" |||
exportNTs ≺ exportList document ( export cs_document doc
                                ∘ export cs_blockL    blocks
                                ∘ export cs_paragraph par
                                ∘ export cs_header    head
                                ∘ export cs_inline    inl
                                ∘ export cs_inlineL   inls)
```

Figure: Our EBNF encoded as a series of grammar transformations

2.3 Semantics - HTML

Rules

We want to compute a *String* from the abstract syntax tree: the HTML text. Therefore we introduce a synthesized attribute *html*.

```
module Semantics.HTML where
import Declarations.CoreLatex
$ (attLabels ["html"])
```

Using *AspectAG*, we can now define a rule per data constructor, describing how to compute this *String*.

```
document_html  = ...
blockLnil_html  = ...
blockLcons_html = ...
header_html    = syn html $
                   do level ← at ch_level_header
                      inls  ← at ch_inlines_header
                      return $ "<h" ++ show level ++ ">"
                               ++ inls # html
                               ++ "</h" ++ show level ++ ">"
                               ++ "\n"
bold_html      = syn html $
                   do inls ← at ch_inlines_boldInl
                      return $ "<b>"
                               ++ inls # html
                               ++ "</b>"
        ...
```

We can now generate the record of semantic functions

```
semHtml = mkDoc blockLcons_html
                blockLnil_html
                ...
                paragraph_html
                plain_html
```

to be used by the parsers:

```
module Grammars.CoreLatex where

gLatex sem = proc () → do
  rec
    doc    ← addNT ≺ ⟦ (pDocument sem) blocks ⟧
    blocks ← addNT ≺ pFoldr (pBlockL_Cons sem, pBlockL_Nil sem)
                            ⟦ block ⟧
    block  ← addNT ≺ ⟦ head ⟧ <|> ⟦ par ⟧
    par    ← addNT ≺ ⟦ (pParagraph sem)
                       "\\begin" "{" "paragraph" "}"
    ...
```

- We use a deforestated approach, i.e. the Tree never comes into existence

2.4 Composing the Tool

Composing the tool


```
module Converter where

import Grammars.CoreLatex (gLatex)
import Semantics.HTML (semHTML, html)
import Expand.Utils (buildConverter)

latex2html :: String → String
latex2html = buildConverter (gLatex semHtml) html
```

3. Extending components

3.1 Numbered Headers

Numbered Headers

§3.1

We want to extend the HTML generation in a way that headers are numbered.

Numbered Headers

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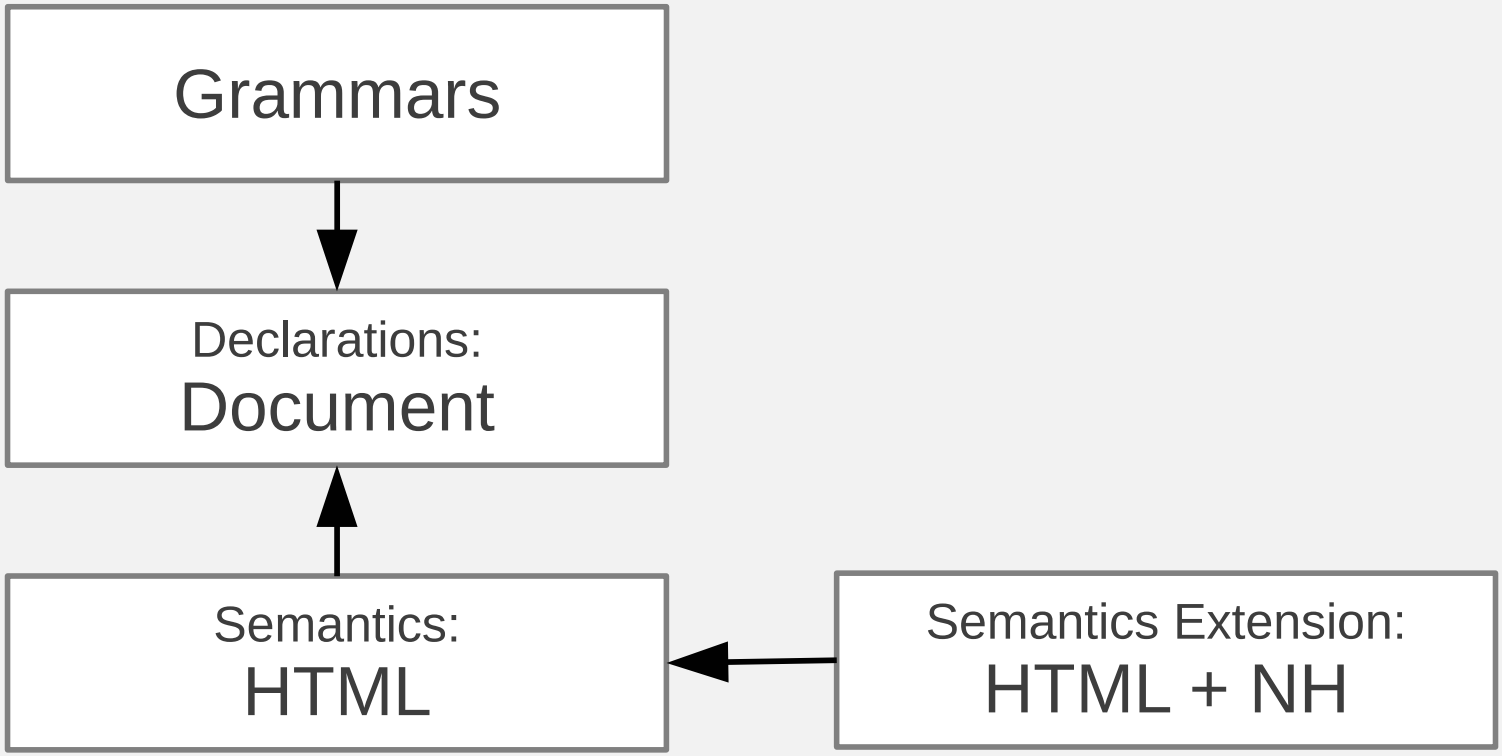

Numbered Headers

We introduce a chained attribute *cHeaderNum*, which is threaded through the tree in a *State Monad* like fashion. We keep a local copy of the value in every header by introducing the *headerNum* attribute (so that it is available for future extension).

```
module Semantics.General.NumberedHeaders where

import Declarations.CoreLatex

$ (attLabels ["cHeaderNum", "headerNum"])
```

Numbered Headers

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```
module Semantics.General.NumberedHeaders where

import Declarations.CoreLatex

$ (attLabels ["cHeaderNum", "headerNum"])
```

We will model the header number as a $[Int]$, and introduce two utility functions.

```
updateHeaderNum :: Int → [Int] → [Int]
updateHeaderNum level par = zipWith (+) par' (zeros ++ [1])
  where par'  = par ++ repeat 0
        zeros = replicate (level − 1) 0

formatHeaderNum :: [Int] → String
formatHeaderNum = intercalate "." ∘ map show
```

Numbered Headers


```
cHeaderNum_NTs = nt_BlockL .*. nt_Block .*. hNil

default_cHeaderNum     = chain cHeaderNum cHeaderNum_NTs

document_cHeaderNum = inh cHeaderNum cHeaderNum_NTs $
  do return (ch_blocks .=. ([] :: [Int]) .*. emptyRecord)

header_headerNum       = loc headerNum $
  do lhs     ← at lhs
     level   ← at ch_level_header
     return $ updateHeaderNum level (lhs # cHeaderNum)

header_cHeaderNum      = syn cHeaderNum $
  do loc     ← at loc
     return $ loc # headerNum
```

Note that the attribute rules are independent of the target language.

Numbered Headers

We still have to change the HTML output. We use the *synmodM* function to define a modification of a rule.

```
module Semantics.HTML.NumberedHeaders where

import Declarations.HTML
import Semantics.HTML

header_html' = synmodM html $
  do level ← at ch_level_header
     inls  ← at ch_inlines_header
     loc← at loc
     let num = loc # headerNum
     return $ "<h" ++ show level ++ ">"
              ++formatNH num ++ "  "
              ++ inls # html
              ++ "</h" ++ show level ++ ">" ++ "\n"
```

Numbered Headers

We can now construct a new semantic record for *html* generation by combining both the *html* and the *cHeaderNum* aspects:

```
semHtml' = mkDoc
  (default_cHeaderNum     `ext` blockLcons_html)
  (default_cHeaderNum     `ext` blockLnil_html)
  bold_html
  (document_cHeaderNum `ext` document_html)
  (header_headerNum       `ext` header_cHeaderNum
                          `ext` header_html'
                          `ext` header_html)
  inlineLcons_html
  inlineLnil_html
  italics_html
  (default_cHeaderNum     `ext` paragraph_html)
  plain_html
```

Numbered Headers

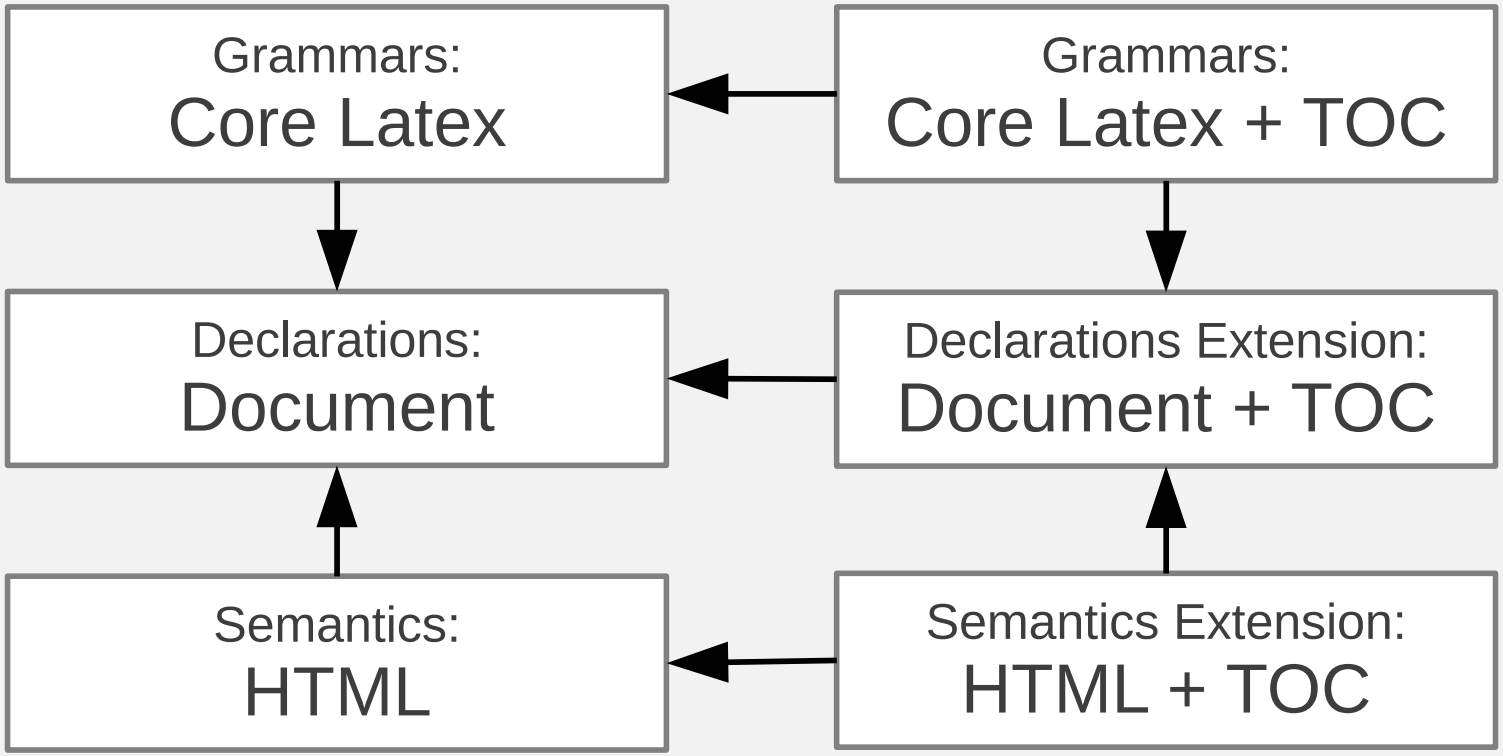
Our alternative converter now becomes:

$$latex2html' :: String \to String$$
$$latex2html' = buildConverter\ (gLatex\ semHtml')\ html$$

3.2 Table of Contents

Table of Contents

A table of contents requires extensions in all three components.



The abstract syntax needs support for a TOC node.

```
module Declarations.CoreLatex.Toc

import Declarations.CoreLatex

data EXT_Block = Toc

$(extendAG '' EXT_Block [])
$(deriveLang "DocToc" ['' EXT_Block])
```

The function *deriveLang* will also produce a new record type containing the semantic function of the *Toc* production.

Table of Contents

Our latex language needs an additional construct:

$$
\begin{array}{lll}
\textit{document} & ::= & \textit{block} * \\
\textit{block} & ::= & \textit{paragraph} \\
 & | & \textit{header} \\
 & & \\
\textit{paragraph} & ::= & \texttt{"\textbackslash begin"}\ \ \texttt{"\{"}\ \texttt{"paragraph"}\ \texttt{"\}"}\ \textit{inline} * \\
 & & \texttt{"\textbackslash end"}\ \texttt{"\{"}\ \texttt{"paragraph"}\ \texttt{"\}"} \\
\textit{header} & ::= & \texttt{"\textbackslash section"}\ \ \ \ \ \ \texttt{"\{"}\ \textit{inline} * \ \texttt{"\}"} \\
 & | & \texttt{"\textbackslash subsection"}\ \ \ \texttt{"\{"}\ \textit{inline} * \ \texttt{"\}"} \\
 & | & \texttt{"\textbackslash subsubsection"}\ \texttt{"\{"}\ \textit{inline} * \ \texttt{"\}"} \\
\textit{inline} & ::= & \texttt{"\textbackslash plain"}\ \ \texttt{"\{"}\ \textit{text}\ \ \ \texttt{"\}"} \\
 & | & \texttt{"\textbackslash textbf"}\ \texttt{"\{"}\ \textit{inline} * \ \texttt{"\}"} \\
 & | & \texttt{"\textbackslash textit"}\ \texttt{"\{"}\ \textit{inline} * \ \texttt{"\}"}
\end{array}
$$

Table of Contents

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$$
\begin{array}{lll}
\textit{document} & ::= & \textit{block} * \\
\textit{block} & ::= & \textit{paragraph} \\
 & | & \textit{header} \\
 & | & \texttt{"\textbackslash tableofcontents"} \\
\textit{paragraph} & ::= & \texttt{"\textbackslash begin"}\ \ \texttt{"\{"}\ \texttt{"paragraph"}\ \texttt{"\}"}\ \textit{inline} * \\
 & & \texttt{"\textbackslash end"}\ \texttt{"\{"}\ \texttt{"paragraph"}\ \texttt{"\}"} \\
\textit{header} & ::= & \texttt{"\textbackslash section"}\ \ \ \ \ \ \texttt{"\{"}\ \textit{inline} *\ \texttt{"\}"} \\
 & | & \texttt{"\textbackslash subsection"}\ \ \ \texttt{"\{"}\ \textit{inline} *\ \texttt{"\}"} \\
 & | & \texttt{"\textbackslash subsubsection"}\ \texttt{"\{"}\ \textit{inline} *\ \texttt{"\}"} \\
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 & | & \texttt{"\textbackslash textbf"}\ \texttt{"\{"}\ \textit{inline} *\ \texttt{"\}"} \\
 & | & \texttt{"\textbackslash textit"}\ \texttt{"\{"}\ \textit{inline} *\ \texttt{"\}"}
\end{array}
$$

Table of Contents

Since the abstract syntax tree now supports a table of contents, we can extend the grammar for the latex-like language:

```
module Grammars.CoreLatex.Toc

import Grammars.CoreLatex
import Declarations.CoreLatex
import Declarations.CoreLatex.Toc

gLatexToc sem = proc imported →
  do
    let block = getNT cs_block imported
    addProds ≺ (block, ⟦ (pToc sem) "\\tableofcontents" ⟧)
    exportNTs ≺ imported
```

Table of Contents

We model the table of contents as a [([Int], String)]

```
module Semantics.General.Toc where
import Declarations.CoreLatex
$ (attLabels ["sToc","toc"])
sToc_NTs = nt_Document .*. nt_Block .*. nt_BlockL .*. HNil
default_sToc = use sToc sToc_NTs (++) []
header_sToc = syn sToc $ do loc <- at loc
                            inls <- at ch_inlines_header
                            return [(loc # headerNum,
                                     inls # sInlStr)]
```

Table of Contents

Using the inherited attribute *toc* we can now format it using an appropriate *html* rule.

```
module Semantics.HTML.Toc where

import Semantics.General.Toc

toc_html = syn html $ do lhs ← at lhs
                         return $ formatToc (lhs # toc)

formatToc :: [([Int], String)] → String
formatToc = foldr f ""
  where f (x, section) table = "<a href=#" ++ show x ++ ">"
                             ++ (formatNH x) ++ "  " ++ section
                             ++ "</a><br />\n" ++ table
```

The *html* formatting of a header is changed so that it contains an `id` attribute (omitted)

We now have all the building blocks to create the new conversion tool:

```
latex2html'' :: String → String
latex2html'' = buildConverter   (  gLatex      semHtml''
                                +>> gLatexToc  semHtmlToc) html
```

Example input


```
\tableofcontents
\section{\plain{Introduction}}
\begin{paragraph}
    \plain{Iam id ipsum absurdum, \textbf{\plain{maximum}}
           malum neglegi. Ut id aliis narrare gestiant? }
\end{paragraph}

\subsection{\plain{subintroduction}}
\begin{paragraph} ...
```

Example input


```
\tableofcontents
\section{\plain{Introduction}}
\begin{paragraph}
    \plain{Iam id ipsum absurdum, \textbf{\plain{maximum}}
           malum neglegi. Ut id aliis narrare gestiant? }
\end{paragraph}

\subsection{\plain{subintroduction}}
\begin{paragraph} ...
```

```
<a href=#[1]>1 Introduction</a><br />
<a href=#[1,1]>1.1 subintroduction</a><br />
<a href=#[2]>2 Conclusion</a><br />

<h1 id="[1]">1 Introduction</h1>
<p>Iam id ipsum absurdum, <b>maximum</b>neglegi. Ut id
aliis narrare gestiant? </p>

<h2 id="[1,1]">1.1 subintroduction</h2>
<p> ...
```

4. Conclusion

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- We have shown how to build an extensible document formatting system using the `murder` and `AspectAG` libraries.
- The Haskell type system validates the composition of all the extensions
  - Grammar fragments state in their type which non terminals they require and expose
  - All usages of non-terminals are guaranteed to point to valid productions
  - AG rules state in their type which attributes should be present and which attribute they define

Conclusion

- We have shown how to build an extensible document formatting system using the `murder` and `AspectAG` libraries.
- The Haskell type system validates the composition of all the extensions
  - Grammar fragments state in their type which non terminals they require and expose
  - All usages of non-terminals are guaranteed to point to valid productions
  - AG rules state in their type which attributes should be present and which attribute they define
- By the modular nature of the components we can reuse aspects, like the Table of Contents.

All code can be found at `http://hackage.haskell.org/package/expand`.

```
header_sToc
  :: (HasField (Proxy (Ch_inlines_header, [Inline])) chi r,
      HasField (Proxy Att_headerNum) l t,
      HasField (Proxy Att_sInlStr) r t1,
      HExtend (Att (Proxy Att_sToc) [(t, t1)]) sp sp') ⇒
      Rule l ho chi par l1 ho1 ic sp l1 ho1 ic sp'

header_sToc = syn sToc $
  do loc ← at loc
     inls ← at ch_inlines_header
     return [(loc # headerNum, inls # sInlStr)]
```