Haskell Macroprocessor

COMP40009 – Computing Practical 1

16th – 20th October 2023

Aims

- To provide experience with recursive list processing in Haskell.
- To provide an introduction to macroprocessors.

Introduction

A *macroprocessor*, or *preprocessor*, is a program that transforms a text file by replacing specially identified *keywords* within the file by a specified piece of text. The keyword replacement rules are provided in a separate information (`.info`) file. In this exercise, keywords are strings that begin with the character `'$'`, and an info file consists of one keyword definition per line. Furthermore, each definition can be assumed to comprise a keyword followed by a single space character and then the keyword's *definition*, which is a sequence of words, possibly including punctuation and whitespace characters. For example, given the info file[1]:

```
$name William Shakespeare
$birth-date 1564
$town Stratford upon Avon
```

and the text file:

```
Welcome to $town, where $name was born in $birth-date.
```

a macroprocessor will generate the output text: `Welcome to Stratford upon Avon, where William Shakespeare was born in 1564.` Note that both the text and info files may include arbitrary whitespace and punctuation characters. These must be faithfully preserved during the replacement process.

The same text file can be used to generate many "welcome" messages, simply by changing the info file. For example, given a similar info file for Thomas Hardy, we might instead generate:

```
Welcome to Stinsford, where Thomas Hardy was born in 1840.
```

Macroprocessors have many uses, for example in web programming, code generation and "mail merging" (an application we'll revisit in the extension).

[1]Note: Stratford upon Avon (the town) is not written with hyphens; see `https://www.telegraph.co.uk/style-book/places-and-people/`

This exercise requires you to implement a very simple macroprocessor in Haskell. In your repository, you have been provided with a skeleton file `src/MP.hs`, several info files in `info/`, and some template files in `templates/`.

Breaking up text

The main problem here is that the whitespace (e.g. `"␣"` (space)[2], `"\t"` (tab), `"\n"` (newline) etc.) and punctuation (e.g. `"."`, `";"`, `"\'"` etc.) characters must be preserved during the replacement. This means you have to be able to spot variable references embedded within arbitrary whitespace and punctuation, as in

```
Keywords (e.g. $x, $y, $z...) may appear anywhere, e.g. <$here>.
```

for example. Similarly, the layout of a keyword definition in an info file must be faithfully reproduced. For example, in

```
$rule␣Reproduce␣this␣precisely␣␣--␣␣or␣else!!
```

the spacing (there are seven space characters in the definition) and punctuation must be reproduced exactly.

To implement the replacement correctly, you therefore need to break up the text file into its component *words* and *separator* characters. The processing of the info file is a little simpler, in principle, as the variable name is guaranteed to be the first word on a line and is separated from its definition by a *single* space character.

In this exercise you're going to break up a piece of text using a `splitText` function that returns a pair comprising the separator characters, i.e. a `[Char]`, and the list of words, a `[String]`, in the order that they were encountered in the input. The arguments to `splitText` are the list of valid separator characters and the input text, which is a `String`:

```
splitText :: [Char] -> String -> ([Char], [String])
```

As an example, consider the string `"some␣words;␣some␣more."`. Given a list of separator characters, `['␣', ';', '.']`, we'd like `splitText` to break the text up to return:

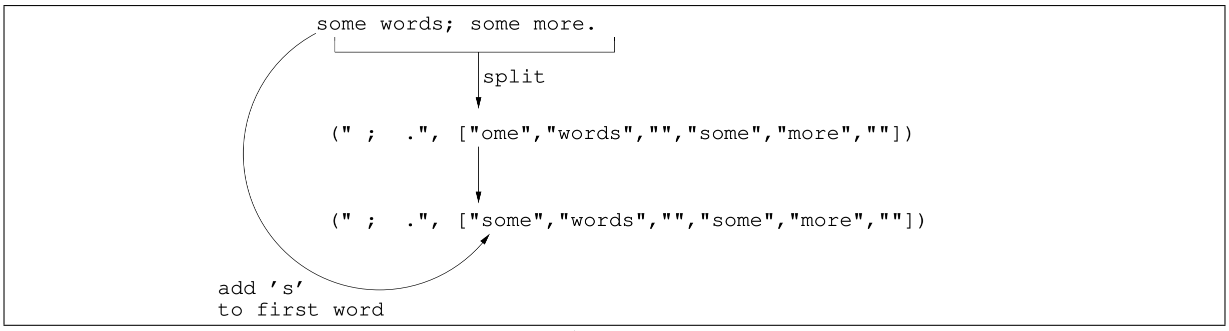
```
(['␣', ';', '␣', '␣', '.'],["some","words","","some","more",""])
```

The original text can be constructed from this, by interspersing the separators (first element of result pair) and the text words (second element).

Let's now work out how to define the function recursively. The input text begins with a non-separator (`'s'`) so if we recursively split the remainder of the string[3] then we will get back a pair comprising the separators (`['␣', ';', '␣', '␣', '.']`) and words (`["ome", "words", "", "some", "more",""]`). Importantly, note the `""`. This appears in the list of words because there are two consecutive separators (`';'` and `'␣'`) in the string, so there must be a null word between them. This is almost the answer we want, but it is missing the `'s'` on the front of the first `'some'`, so to patch up, we just add it (with `(:)`)

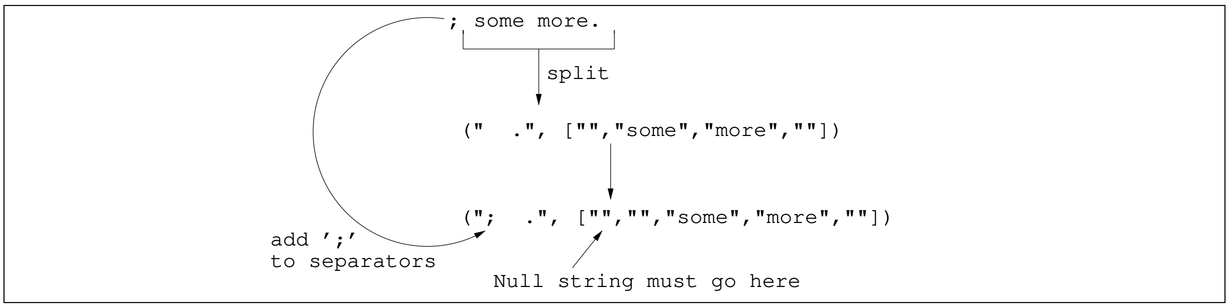
[2]It is difficult to see `" "`, so, for clarity, they are often rendered as a visible space character (␣) instead.

[3]Recall that, in Haskell, `String` and `[Char]` are **the same**: we can deconstruct a `String` by pattern matching using `(:)` the same as we would for a list.



some words; some more.
split
(" ; .", ["ome","words","","some","more",""])
(" ; .", ["some","words","","some","more",""])
add 's'
to first word

Figure 1: Text splitting at a non-separator



; some more.
split
(" .", ["","some","more",""])
("; .", ["","","some","more",""])
add ';'
to separators
Null string must go here

Figure 2: Text splitting at a separator

to the first word in the list returned. This is shown in Figure 1 – note that strings are used for the separators there instead of lists.

What happens if the first character in the input string is a separator? To get this right we need to think about how the original text will be rebuilt from its constituents. Given the pair `(['<', '␣', '>'], ["", "bracketed", "text", ""])`, for example, the rule is that the first *word* appears before the first *separator* in the rebuilt string, so the above will be rebuilt as `"<bracketed␣text>"`, not `"<␣bracketed>text"`. Note that the `""` at the end of the list arises because the string ends with a separator. Thus, when we encounter a separator at the head of the input string the first word in the list of resulting words must be `""`. This is shown in Figure 2 – note that strings are used for the separators there instead of lists.

What's the base case? If the input string is null then `([ ],[ ])` would appear to work, and it can, although it's a little messier. To keep it simple we'll instead return `([ ],[""])`. When we use `splitText` to process keyword definitions you'll see that this is tantamount to imposing a *precondition* that each definition contains at least one word.

Preamble

This project is split into two different components: a library you will develop called `macro`, and an executable program called `macroprocessor` that has been implemented for you. You will be working, like last time, within the `src/` folder, in the `MP.hs` file. The skeleton contains the following type aliases:

```
type FileContents = String

type Keyword      = String
type KeywordValue = String
type KeywordDefs  = [(Keyword, KeywordValue)]
```

The app/ folder contains the code for performing the file input/output (I/O). Haskell I/O will be covered later in the course, so you don't need to worry about what is happening in that code. The main function defined by the application requires three arguments: the template and info files, as well as the place to output the result. This can be ran using cabal run, which if provided no arguments looks like this:

```
$ cabal run macroprocessor
Usage: cabal run macroprocessor <template> <info> <output>
```

Once you have everything working, you can generate your own output, by running the above command with the required arguments. For example, in the top-level directory, running:

```
$ cabal run macroprocessor templates/welcome.txt info/shakespeare.info out.txt
```

Results in a file containing the result of expanding the template welcome.txt with Shakespeare's information (this was the first example of this specification).

Getting started

As per the previous exercise, you will use the git version control system to get the repository with the skeleton files for this exercise and its (incomplete) test suite. You can get your repository with the following (remember to replace the *username* with your own username).

```
git clone https://gitlab.doc.ic.ac.uk/lab2324_autumn/haskellmacroprocessor_username.git
```

What to do

- Write a Haskell function `lookUp :: String -> [(String, a)] -> [a]` that, given a search string and a list of string/item pairs, returns the list of items whose associated string matches the search string. For example,

  ```
  *MP> lookUp "A" [("A",8),("B",9),("C",5),("A",7)]
  [8,7]
  ```

  Hint: try doing this with a list comprehension as it is much easier this way.

- Define the splitText function that will break up a string as described above. For example:

  ```
  *MP> splitText ['␣', '.', ','] "A comma, then some words."
  (['␣',',','␣','␣','␣','.'],["A","comma","","then","some","words",""])
  ```

  (The list of separators returned in the example comprises one space, a comma, then three spaces and the full stop.) Note that the empty strings ("") are important as they correspond to the locations of the separator characters , and . in the example.

- Define a function `combine :: [Char] -> [String] -> [String]` that will combine the components of a string from its constituent separator characters and words, as generated by a call to splitText. To do this follow the rules outlined above but note that the result is a *list* of strings that, when concatenated (concat) will rebuild the original string. Note that this means the function should satisfy the *axiom*[4]

[4]Optional note (you can ignore this if you wish): You will notice that splitText returns a pair, but that the "inverse" function, combine consumes its two arguments separately. It would be really nice to be able to compose the two directly, but

```
let (ts, ws) = splitText seps s in concat (combine ts ws) ≡ s
```

- Define a function `getKeywordDefs :: [String] -> KeywordDefs` that takes the contents of an information file in the form of a list of lines (each line is a string), and which returns a list of keyword/definition pairs. For example,

  ```
  *MP> getKeywordDefs ["$x Define x", "$y 55"]
  [("$x","Define x"),("$y","55")]
  ```

  Hint: You may find it easier to use `splitText` to turn each line into space-separated words; the keyword will then be the first word in the line and its definition the concatenation (`concat`) of the remaining words. If you do it this way, you do not need to worry about punctuation and other whitespace characters in the definition; it's only the first space that's important.

- Define a function `expand :: FileContents -> FileContents -> FileContents` that takes the contents of a text file and an info file and combines them using the above functions to build a string representing the output file. For example:

  ```
  *MP> expand "The capital of $1 is $2" "$1 Peru\n$2 Lima."
  "The capital of Peru is Lima."
  ```

  Note that this is function that is called by the `macroprocessor` application we provided.

  Hint: You first need to split the text file into its component words and separators. To do this, you may assume that the only separators in the text file will be one of the characters in the string `"␣\n\t.,:;!\"'()<>/\\"`; a predefined variable, `separators`, containing these characters has been declared in the skeleton file for you. You might also find it useful to define a helper function to replace the words of the template file one-by-one. Recall that the word may be empty (`""`), so you will need to check this first. If the word is non-empty and begins with a `'$'`, then it is a keyword and should be replaced by looking it up in the list of `keywordDefs` generated from the info file; otherwise, the word is returned intact.

Testing your Solution

Like in the previous exercise, there is more than one test-suite provided. As you implement the required functions, you should run one of the following commands:

```
cabal test macro-test
cabal test macro-test --test-options="--color always"
cabal test macro-test --test-options="-p /lookUp/"
cabal test macro-test --test-options="--color always -p /lookUp/"
```

The first will just run the test-suite, the second will ensure it is colourised, the third will run the tests for `lookUp` specifically, and the fourth will both colour the output and only run the `lookUp` tests.

---

unfortunately the types do not match. A beautiful way to fix this is to use Haskell's *uncurry* function. If `f` is a function of type `a -> b -> c` then `uncurry` turns it into a function of type `(a, b) -> c`. This is an example of a *higher-order* function, i.e. a function that takes another function as an argument and/or returns a function as its result. Using `uncurry` we can write the above axiom as:

```
  concat (uncurry combine (splitText seps s)) ≡ s
```

You may find `uncurry` useful in defining your `expand` function below, but it is up to you whether you use it.

As before, there is also a test suite `macro-properties`, which tests the property that relates `split` and `combine` as outlined above. This can be invoked with one of the following:

```
cabal test macro-properties
cabal test macro-properties --test-options="--color always"
cabal test macro-test macro-properties --test-options="--color always"
```

The first will just run the properties test-suite, the second will ensure it is coloured, and the third will run *both* the regular test suite and the property-based tests colourised.

Golden tests For this exercise, there is a *third* category of tests available, called "golden tests". These can be used to test your `expand` function on the provided template and info files, comparing the result of your program with the expanded files generated by the model solution. Since this will write files to your system, you should probably run it with `--delete-output onpass` option, which will not work with the other two test-suites:

```
cabal test macro-golden --test-options="--delete-output onpass"
cabal test macro-golden --test-options="--color always --delete-output onpass"
```

This will ensure that if your tests pass, any generated files are cleaned up properly. By default, the golden tests have been configured to try and make use of the command `diff`. If this is installed on your system, your test failures will be more descriptive than if it is not. If you don't have `diff`, a test failure will be reported as `the contents of the files differ`, and you will need to look manually yourself. Otherwise, you may get output that looks like the following:

```
--- test/golden/welcomeShakespeare.golden 2023-08-07 17:53:13.114869531 +0100
+++ test/out/welcomeShakespeare.txt       2023-08-08 14:10:02.991250522 +0100
@@ -1 +1 @@
-Welcome to Stratford upon Avon, where William Shakespeare was born in 1564.
+Welcome to $town, where $name was born in $birth-date.
```

This output resulted from running the tests without `expand` actually replacing the keywords. How should you interpret it? The first two lines are just telling you what two files have been compared, and their timestamps: you can ignore these. The next line tells you the number of removals and additions there have been from the original file. In this case, 1 line was removed and 1 line was added: this may indicate that a single line was modified, which is the case here. You may see several of these `@@` lines if the file is long and there are changes in multiple places – the `diff` tool tries to trim away as much of the matching text as possible.

Within each block of changes started by the `@@`, there will be lines starting with `-` normally close to lines starting with `+`: these denote lines that were removed from one file and added by the other (or a modification!). In the above example, you can see two such lines, pointing out that the first line should have been seen, but the second one was found instead: that isn't right! It is then up to you to inspect the two lines to figure out what the difference is and go fix it.

There is one commented out test in `test/Golden.hs`: you may wish to uncomment this for the extension. Note that a valid extension may actually break the other tests!

Note that the code at the bottom of `test/Golden.hs` is quite involved, with a lot of I/O code, it is recommended that you don't worry about how this testing works at this stage.

Extension: an enhanced `expander`

Now assume that an info file can contain multiple sets of keyword definitions, each separated by a `'#'` character. Modify your implementation of `expand` so that it expands the input file once for each set of definitions. For example, given the info file:

```
$name William Shakespeare
$birth-date 1564
$town Stratford upon Avon
#
$birth-date 1840
$town Stinsford
$name Thomas Hardy
#
$name Charles Dickens
$town Landport
$birth-date 1812
```

your program should now expand the given text file *three* times. The three pieces of expanded text should be separated by a line of five `'-'` characters. Thus, expanding the "welcome" text file with the above info file should generate (precisely):

```
Welcome to Stratford upon Avon, where William Shakespeare was born in 1564.
-----
Welcome to Stinsford, where Thomas Hardy was born in 1840.
-----
Welcome to Landport, where Charles Dickens was born in 1812.
-----
```

Note that this functionality is similar to that of a "mail merger", which generates multiple instances of a letter template given a file of names, addresses and other information about the target recipients. In that case each letter instance is separated by "page break" characters so that, when printed, each letter starts on a separate sheet of paper. Here, we've used `"-----"` as the separator, but the principle is the same.

Submission

As with all previous exercises, you will need to use the commands `git add`, `git commit` and `git push` to send your work to the GitLab server. Then, as always, log into the LabTS server, `https://teaching.doc.ic.ac.uk/labts`, click through to your `HaskellMacroprocessor` exercise `https://gitlab.doc.ic.ac.uk/lab2324_autumn/haskellmacroprocessor_username` and request an auto-test of your submission.

IMPORTANT: Make sure that you submit the correct commit to Scientia.

Assessment

In general, the assessment for laboratory exercises uses the following scheme:

```
F - E: Very little to no attempt made.
       Submissions that fail to compile cannot score above an E.

D - C: Implementations of most functions attempted;
       solutions may not be correct, or may not have a good style.

B:     Implementations of all functions attempted, and solutions
       are mostly correct. Code style is generally good.

A:     There are no obvious deficiencies in the solution or
       the student's coding style. In addition, there is
       evidence of productive testing.

A*:    As for an A -- plus the student has done additional work
       beyond the basic spec, e.g. by considering (and clearly
       commenting) interesting variations or extensions to the
       given functions; e.g. based on their own research.
```