CSCI 365 Module 1

due Wednesday, 26 Jan 2022

Specification

- To receive **Level 1** credit for this module:
  - You must complete Exercises 1–6.
  - Your code must adhere to the style guide linked from the course web page.
  - You must complete Quiz 1 for credit, which will test you on your ability to write simple recursive list processing functions in Haskell. January 28 in class is your first opportunity to take the quiz, but recall that if you do not get credit at that time, you may retake (a variant of) the quiz.
- To receive **Level 2** credit for this module:
  - Complete everything required for Level 1.
  - Complete exercise 7.
  - Read the Wikipedia article on Functional Programming and write a short response, as explained at the end of this document.

Advice

When solving the homework, strive to create not just code that works, but code that is stylish and concise. See the style guide on the website for some general guidelines. Try to write small functions which perform just a single task, and then combine those smaller pieces to create more complex functions. Don't repeat yourself: write one function for each logical task, and reuse functions as necessary.

Be sure to write functions with exactly the specified name and type signature for each exercise (to help in testing your code). You may create additional helper functions with whatever names and type signatures you wish.

Installing Haskell

You will need to install a Haskell toolchain on your computer. Follow the instructions found on the course website. Please try this early and come ask for help if you are stuck!

Getting started

Exercise 1 What is the largest possible value of type `Int` on the computer you are using? How do you know?

The value is architecture-dependent, so don't just Google it—find out empirically.

Exercise 2 The following code contains multiple syntax and type errors. Explain each of the errors and how to fix it. (You may want to save the code in a `.hs` file and try loading it in `ghci`.)

```
a, b, c :: Integer
a = 3
b = 99.3
c = b / a
c = 8

ints :: [Integer]
ints = [3,4] : [5,6,"seven"]

bar : Char
bar = 'xy'
```

Look and Say Sequence

The *Look and Say Sequence*[1], introduced by John Conway, begins as follows:

$$1, 11, 21, 1211, 111221, 312211, \ldots$$

where each sequence of digits "describes" the previous sequence; read the Wikipedia article for a full description.

[1] `https://en.wikipedia.org/wiki/Look-and-say_sequence`

Exercise 3 Write a Haskell function `getRun :: [Integer] -> ([Integer], [Integer])` which splits its input list into two pieces, a run of consecutive equal digits at the beginning, and the rest. For example,

```
getRun [1,1,1,2,3] = ([1,1,1], [2,3])
getRun [3,2,1]     = ([3], [2,1])
getRun [1]         = ([1],[])
```

If you find it helpful, you are welcome to write additional helper function(s).

Exercise 4 Now write a Haskell function `lookAndSay :: [Integer] -> [Integer]` which outputs the next digit sequence when given a digit sequence as input. For example,

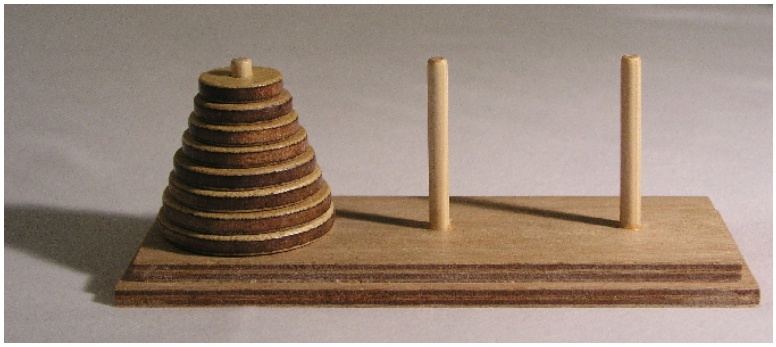
```
lookAndSay [1] = [1,1]
lookAndSay [1,1,1,2,2,1] = [3,1,2,2,1,1]
```

Of course, you should use your `getRun` function from the previous exercise.

Exercise 5 Finally, write a function `lookAndSaySeq :: Integer -> [[Integer]]`, where `lookAndSaySeq n` produces the first `n` terms of the look and say sequence. For example,

```
lookAndSaySeq 4 = [[1], [1,1], [2,1], [1,2,1,1]]
```

The Towers of Hanoi



Adapted from an assignment given in UPenn CIS 552, taught by Benjamin Pierce

Exercise 6 The *Towers of Hanoi* is a classic puzzle with a solution that can be described recursively. Disks of different sizes are stacked on three pegs; the goal is to get from a starting configuration with all disks stacked on the first peg to an ending configuration with all disks stacked on the last peg, as shown in Figure 1.

The only rules are

- you may only move one disk at a time, and
- a larger disk may never be stacked on top of a smaller one.

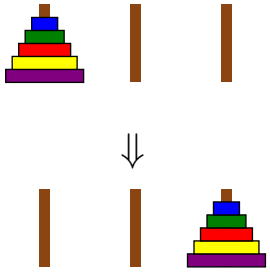


Figure 1: The Towers of Hanoi

For example, as the first move all you can do is move the topmost, smallest disk onto a different peg, since only one disk may be moved at a time.

From this point, it is *illegal* to move to the configuration shown in Figure 3, because you are not allowed to put the green disk on top of the smaller blue one.

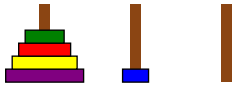


Figure 2: A valid first move.

For this exercise, define a function `hanoi` with the following type:

```
type Peg  = String
type Move = (Peg, Peg)
hanoi :: Integer -> Peg -> Peg -> Peg -> [Move]
```

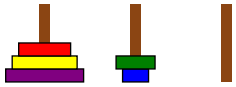


Figure 3: An illegal configuration.

Given the number of discs and names for the three pegs, `hanoi` should return a list of moves to be performed to move the stack of discs from the first peg to the last.

Note that a `type` declaration, like `type Peg = String` above, makes a *type synonym*. In this case `Peg` is declared as a synonym for `String`, and the two names `Peg` and `String` can now be used interchangeably. Giving more descriptive names to types in this way can be used to give shorter names to complicated types, or (as here) simply to help with documentation.

Example: `hanoi 2 "a" "b" "c" == [("a","b"), ("a","c"), ("b","c")]`

Exercise 7 (Level 2) What if there are four pegs instead of three? That is, the goal is still to move a stack of discs from the first peg to the last peg, without ever placing a larger disc on top of a smaller one, but now there are two extra pegs that can be used as "temporary" storage instead of only one. Write a function similar to `hanoi` which solves this problem.

It should be possible to do it in far fewer moves than with three pegs. For example, with three pegs it takes $2^{15} - 1 = 32767$ moves to transfer 15 discs. With four pegs it can be done in only 129 moves! However, you need not worry about making your function as efficient as possible, as long as it does significantly better than with three pegs.

If you are stuck, feel free to search for more information on the Internet; be sure to cite any sources you use.

See Exercise 1.17 in Graham, Knuth, and Patashnik, *Concrete Mathematics*, second ed., Addison-Wesley, 1994.

Reading (Level 2) Read the Wikipedia page on Functional Programming: `https://en.wikipedia.org/wiki/Functional_programming`. You don't necessarily have to read every single word, but you should read at least some parts of it carefully (pick whatever seems most interesting to you) and skim the rest. Then write some short (a few sentences each) responses to the following questions.

Important: To avoid simply copying your answers from Wikipedia (and to help your brain learn and retain more), I suggest making some brief notes while you read, then later (after at least 15 minutes) coming back and writing your responses without looking at the Wikipedia page, referring only to your notes.

1. When was the first functional programming language created?
2. In your own words, what are a few of the defining characteristics of functional programming?
3. What is one way in which functional programming seems like it might be different than other programming languages you know? How do you think this might affect the way you write programs?