Building a Console Application in Haskell

Rebecca Skinner

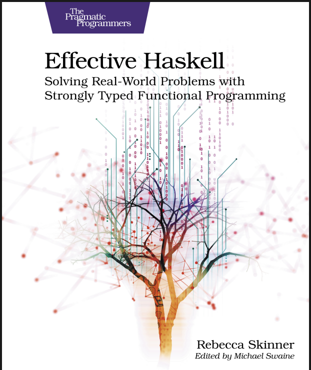
2022-12-07

Prelude

Hello, World

- About Me: Rebecca Skinner
  - Lead Software Engineer at Mercury
  - Author of Effective Haskell
- @cercerilla on Twitter and Cohost
- https://rebeccaskinner.net
- https://github.com/rebeccaskinner/

Effective Haskell



https://tinyurl.com/2744kfu7

Now in Beta!

About This Talk

During this talk we'll build basic command line tool in Haskell. As we go, you'll:

- Learn how Haskell programs use IO actions to deal with the real world
- Find out how to do simple terminal and file IO
- See examples of how to mix IO and pure functional code effectively
- Follow along with implementing pure functional code to work with text

Most importantly: You'll get an intuition for how to think about building Haskell programs that can serve as a basis for future learning.

HCat

HCat: A Haskell Pager

- Get a file name from the command line
- Print the contents of the file to the screen one page at a time
- After showing a page of text, wait for user input
- Format each page so it fits on the screen
- Allow the user to quit at any time

```
{-# LANGUAGE RecordWildCards #-}
{-# LANGUAGE OverloadedStrings #-}
{-# LANGUAGE LambdaCase #-}
{-# LANGUAGE TypeApplications #-}
module HCat where

import qualified System.IO.Error as IOError
import qualified Control.Exception as Exception

import qualified System.Environment as Environment
import qualified System.Exit as Exit
import qualified Data.List as List
import qualified Data.Maybe as Maybe
import qualified Data.Char as Char
import qualified Text.Printf as Printf
import qualified Data.Text as Text
import qualified Data.Text.IO as TextIO
import qualified Data.ByteString as BS
import System.IO ( openFile
                 , hPutStr
                 , hFlush
                 , hClose
                 , hFileSize
                 , hGetContents
                 , stdin
                 , stdout
                 , hGetChar
                 , hSetBuffering
                 , hGetBuffering
                 , hSetEcho
                 , BufferMode (..)
                 , Handle
                 , IOMode (..) )
import qualified System.Info
import qualified System.Process as Process
import Text.Read
import Control.Monad
import qualified Data.Time.Clock as Clock
import qualified Data.Time.Format as TimeFormat

-- import qualified System.Posix.User as PosixUser
import qualified System.Directory as Directory


--START:FileInfo
./src/HCat.hs | permissions: rw- | 19337 bytes | modified: 2022-01-25 04:15:03 | page: 1 of 15
```

Starting a New Project

Building HCat

Setting Up Your Development Environment

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Testing Test manually with `ghci` or use `hspec` but only test pure functions.

Linting Use `hlint`, but feel free to ignore anything you don't understand

Creating A New Project

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As a rule of thumb, each project should define:

- One library, named after the project. This is where most of your code will live
- One (or, occasionally, more than one) executable. These usually have very little code
- A test suite
- Optionally, benchmarks

Dependencies

You can browse available packages on hackage. To add a new dependency to your project, add it to your cabal file.

```
library
  hs-source-dirs:       src
  exposed-modules:      HCat
  build-depends:        base, directory, process
  ghc-options:          -Wall
  default-language:     Haskell2010
```

Executables and Libraries

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import HCat (runHCat)

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Why?

- Testability
- Easy Refactoring
- Low overhead to add additional executables

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- reads the contents of a file
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There's just one problem: Haskell is a pure functional language. Doesn't that mean no side effects?

Understanding IO

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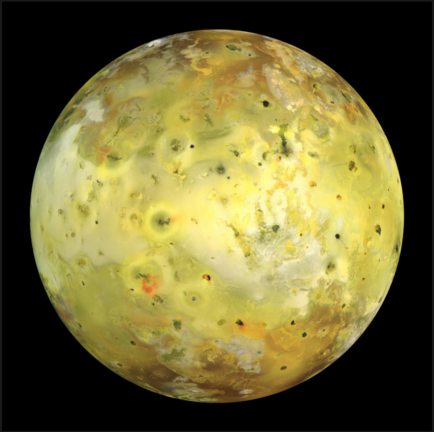
- Reading and writing files
- Printing text to the screen
- Handling user input

A True Color Photo of Side Effects



A side effect in its natural environment.

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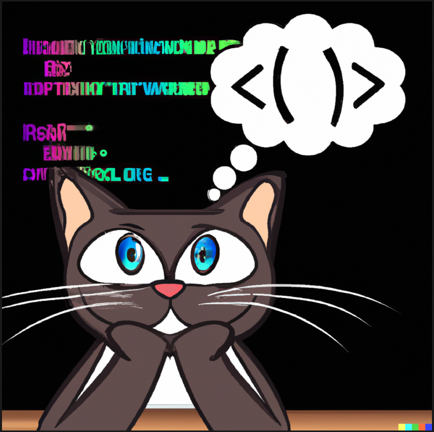
- Nothing will happen until we evaluate `writeReadFile`
- When we evaluate `writeReadFile` we'll get whatever random contents were in `example.txt`
- We won't ever write "Hello, Haskell" to the file, because we're not using result of `writeFile`!

Let’s Dream of a Better Way



Let’s dream up a better way

IO, the Lazy Way

If we want to be lazy, we need to work for it by making sure every new side effect must depend on the previous one.

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More often, there isn't an obvious dependency:

- Writing a log message before opening a file
- Writing data to a file, then reading the contents
- Printing a message to the screen then waiting on user input

A Pointer To The Real World

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```
data RealWorld
```

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writeReadFile world0 =
  let
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```

But it sucks.

Typing IO Operations

Let's make a type!

Typing IO Operations

```
data SideEffect a =
  SideEffect { runSideEffects :: RealWorld -> (RealWorld, a) }
```

Side Effects Are Programs

Think of `SideEffect a` as a program that returns a value of type a.

`SideEffect String` : A program that runs and outputs a `String`

`SideEffect Int` : A program that runs and outputs an `Int`

`SideEffect` programs are not pure functional programs. They rely on, and change, the `RealWorld`.

Side Effect Examples

Let's look at some examples of `SideEffect` programs. We'll imagine some internal helper functions that will do the unsafe low level IO operations:

```
readFile :: FilePath -> SideEffect String
readFile filename = SideEffect $ \realWorld ->
  let (realWorld', contents) = internalReadFile filename realWorld
  in (realWorld', contents)

writeFile :: FilePath -> String -> SideEffect ()
writeFile filename contents = SideEffect $ \realWorld ->
  let realWorld' = internalWriteFile filename contents realWorld
  in (realWorld', ())

print :: String -> SideEffect ()
print message = SideEffect $ \realWorld ->
  let realWorld' = internalPrint message realWorld
  in (realWorld', ())
```

Combining Side Effects

A `SideEffect` program can do things that have side effects, like reading from and writing to files, but that's pretty limiting. We can do a lot more if we can have a `SideEffect` program that executes other `SideEffect` programs and uses the results.

```
data SideEffect a =
  SideEffect { runSideEffects :: RealWorld -> (RealWorld, a) }

joinSideEffects :: SideEffect (SideEffect a) -> SideEffect a
joinSideEffects outerSideEffect = SideEffect $ \world ->
  let (world', innerSideEffect) = runSideEffects outerSideEffect world
  in runSideEffects innerSideEffect world'
```

First One, Then The Other

Most of the time, we want to write a SideEffect program that does one side effect and then does another one. It turns out that this is just another way of saying that we have one SideEffect program that calls the first effect, and uses it's value to call the second one:

```
data SideEffect a =
  SideEffect { runSideEffects :: RealWorld -> (RealWorld, a) }

sequenceSideEffects :: SideEffect a -> (a -> SideEffect b) -> SideEffect b
sequenceSideEffects sideEffect makeNextSideEffect =
  joinSideEffects $ SideEffect $ \world ->
    let (world', val) = runSideEffects sideEffect world
    in (world', makeNextSideEffect val)
```

Write, Read, Print

Let's to to write our program again, using the things we've just built:

```
writeReadFile :: SideEffect ()
writeReadFile =
  writeFile "example.txt" "Hello, Haskell"
  `sequenceSideEffects` (\_ -> readFile "example.txt")
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How does this version compare?

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- Every side effect depends on its predecessor, so they all happen in the right order
- Our code is focused on the work it needs to do, without having to explicitly pass around references to the real world
- Our code program is still a pure functional program. Instead of doing side effects directly, we generate a program that would have side effects if it were run. The programs themselves are still pure values.

That's Not All

Before we get back to HCat

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One more thing

That's No Side Effect

```haskell
sayHello :: IO ()
sayHello =
  putStrLn "Hello, World!"
```

```
U:@**-  Hello.hs      18% L5     (Haskell +8 FlyC ivy ElDoc) 12:02AM 0.36
```

Ceci n'est pas une side effect.

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```
writeReadFile :: IO ()
writeReadFile =
  writeFile "example.txt" "Hello, Haskell"
  >>= (\_ -> readFile "example.txt")
  >>= print
```

To do List

Writing a long chain of calls to »= gets tiresome. Instead we can use do notation:

```
writeReadFile :: IO ()
writeReadFile = do
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- The <- arrow names the output of an IO action
- When we run a Haskell program, the initial state of the real world is used to run an IO action named `main`.

HCat

Return of the HCat

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Now that we understand how to write code that has side effects and interacts with the real world, let's put it to practice with an MVP:

```
module Main where

runHCat :: IO ()
main = readFile "example.txt" >>= putStrLn
```

The M-est of MVPs

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Let's take one problem at a time

Getting Into Arguments

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```
module HCat where
import System.Environment

targetFileName :: IO FilePath
targetFileName = do
  args <- getArgs
  case args of
    [filename] ->
      pure filename
    _otherwise ->
      ioError $ userError "please provide a single filename"

runHCat :: IO ()
runHCat = do
  contents <- readFile =<< targetFileName
  putStrLn contents
```

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Opinion: Getting too fancy too early will cause more problems than it solves. Start with the simplest thing that can possibly work.

What About Libraries?

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Why parse arguments directly instead of using a library?

- Handling arguments yourself is good practice while learning
- Some good libraries use language features you probably haven't learned yet

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```haskell
module HCat where
import System.Process
data TerminalDimension = TerminalLines | TerminalCols
data ScreenDimensions =
  ScreenDimensions {screenRows :: Int, screenColumns :: Int}

getTerminalSize :: IO ScreenDimensions
getTerminalSize = do
  termLines <- tput TerminalLines
  termCols <- tput TerminalCols
  pure ScreenDimensions
    { screenRows = termLines
    , screenColumns = termCols }

tput :: TerminalDimension -> IO Int
tput dimension = do
  outputData <- readProcess "tput" [cmd] ""
  pure . read . head . lines $ outputData
  where
    cmd = case dimension of
      TerminalLines -> "lines"
      TerminalCols -> "cols"
```

Word Wrapping

Given the size of our terminal, we can wrap the text to fit.

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```haskell
wordWrap :: Int -> String -> [String]
wordWrap lineLength lineText =
  case splitAt lineLength lineText of
    (fullLine, "") -> [fullLine]
    (hardwrappedLine, rest) ->
      let (nextLine, remainder) = softWrap hardwrappedLine
       in nextLine : wordWrap lineLength (remainder <> rest)
  where
    softWrap hardWrapped =
      let (rest, wrappedText) = break isSpace $ reverse hardWrapped
       in (reverse wrappedText, reverse rest)

runHCat :: IO ()
runHCat = do
  contents <- readFile =<< targetFileName
  termSize <- getTerminalSize
  let wrapped = wordWrap (screenColumns termSize) contents
  putStrLn $ unlines wrapped
```

Architecture

A Lesson On Building Things

Let's talk about Architecture

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wordWrap lineText = do
  lineLength <- tput TerminalCols
  case splitAt lineLength lineText of
    (fullLine, "") ->
      pure [fullLine]
    (hardwrappedLine, rest) -> do
      let (nextLine, remainder) = softWrap hardwrappedLine
      wrappedRemainder <- wordWrap (remainder <> rest)
      pure (nextLine : wrappedRemainder)
  where
    softWrap hardWrapped =
      let (rest, wrappedText) = break isSpace $ reverse hardWrapped
       in (reverse wrappedText, reverse rest)
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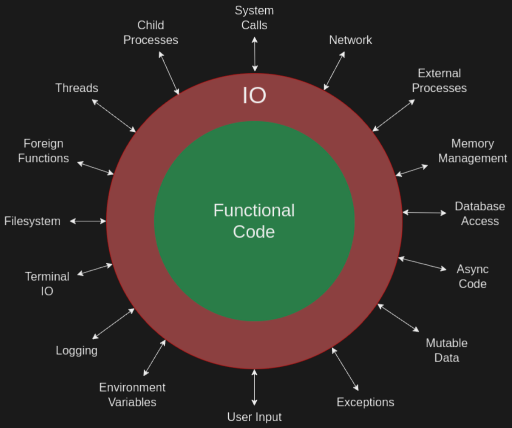
Unfortunately...

- It can only be called by other IO actions
- We don't know what it might do. Perhaps it makes a network request to a word wrap server?
- We'll have a harder time testing it

The Lesson

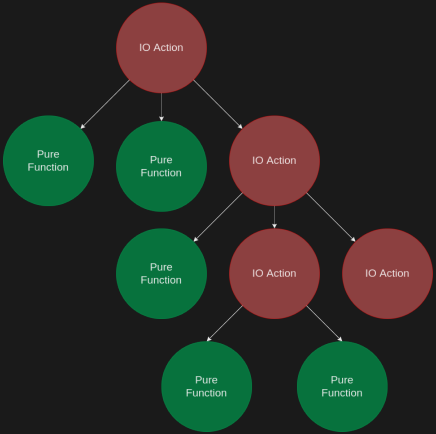
As much as possible, have IO actions gather data then pass it into pure functions for computation.

Procedural Shell, Functional Core



The "procedural shell, functional core" model is an over-simplification of a good guideline

Happy Little Trees



IO Actions and pure functions more closely resemble a tree

Back to HCat

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Back to our regularly scheduled HCat Presentation

Pagination

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```
paginate :: ScreenDimensions -> String -> [String]
paginate dimensions text = pages
  where
    rows = screenRows dimensions
    cols = screenColumns dimensions
    wrappedLines = concatMap (wordWrap cols) (lines text)
    pages = map (unlines . padTo rows) $ groupsOf rows wrappedLines
    padTo lineCount rowsToPad =
      take lineCount $ rowsToPad <> repeat ""
    groupsOf n elems
      | null elems = []
      | otherwise =
        let (hd, tl) = splitAt n elems
        in hd : groupsOf n tl
```

The Event Loop

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- Get some user input
- Loop over each page, displaying them
- Exit cleanly if the user wants to quit

Getting User Input

```haskell
data ContinueCancel
  = Continue
  | Cancel
  deriving stock (Eq, Show)

getContinue :: IO ContinueCancel
getContinue = do
  hSetBuffering stdin NoBuffering
  hSetEcho stdin False
  input <- getChar
  case input of
    ' ' -> return Continue
    'q' -> return Cancel
    _ -> getContinue
```

Taking User Input for a Loop

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showPages :: [String] -> IO ()
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Unfortunately, this can make things more difficult instead of easier.

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This is a good starting spot for implementing the effectful logic in your programs.

Continued Action

As your programs grow, it's a good idea to think about making your IO actions compose. This can make your code a bit more verbose at first, but it buys you flexibility later.

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Putting It All Together

```haskell
runHCat :: IO ()
runHCat = do
  contents <- readFile =<< targetFileName
  termSize <- getTerminalSize
  showPages $ paginate termSize contents
```

Questions?

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Want to know more?

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