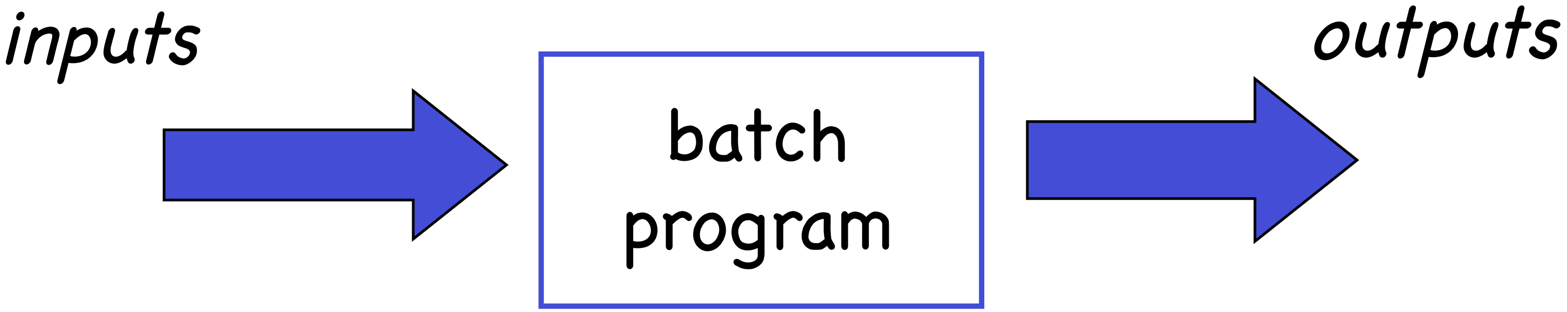
CSCE 314
Programming Languages

Interactive Programming: I/O

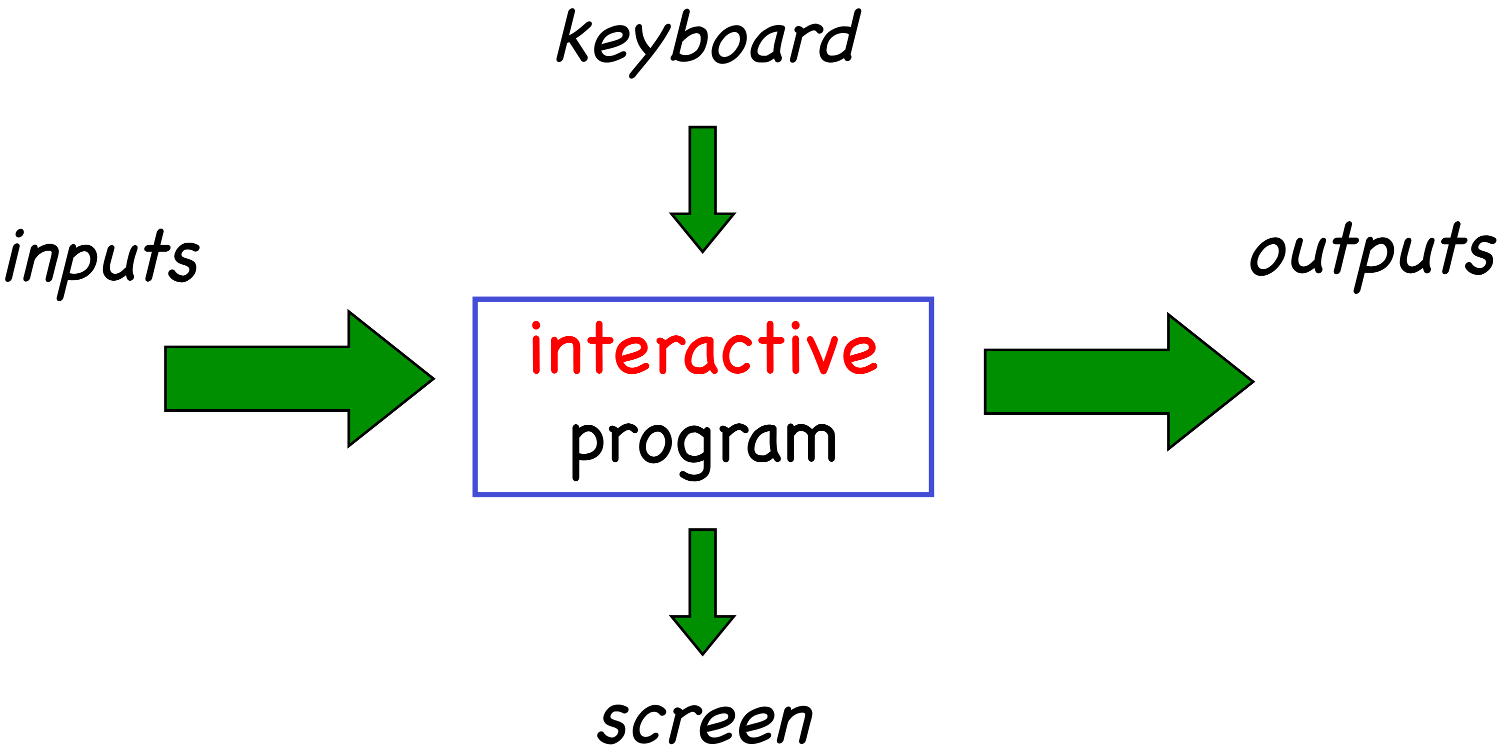
Dr. Hyunyoung Lee

Introduction

To date, we have seen how Haskell can be used to write batch programs that take all their inputs at the start and give all their outputs at the end (e.g., a compiler).



However, we would also like to use Haskell to write interactive programs that read from the keyboard and write to the screen, as they are running (e.g., an interpreter).



The Problem: Haskell functions are pure mathematical functions

Haskell programs have no side effects.

referential transparency: called with the same arguments, a function always returns the same value

However, reading from the keyboard and writing to the screen are side effects:

Interactive programs have side effects.

The Solution - The IO Type

Interactive programs can be viewed as a pure function whose domain and codomain are the current *state of the world*:

```
type IO = World -> World
```

However, an interactive program may return a result value in addition to performing side effects:

```
type IO a = World -> (a, World)
```

What if we need an interactive program that takes an argument of type b? `b -> IO a`

```
b -> World -> (a, World)
```

The Solution (Cont.)

Now, interactive programs (impure actions) can be defined using the IO type:

```
IO a
```

The type of actions that return a value of type a

For example:

```
IO Char
```

The type of actions that return a character

```
IO ()
```

The type of actions that return the empty tuple (a dummy value); purely side-effecting actions

Basic Actions (built into the GHC system)

1. The action getChar reads a character from the keyboard, echoes it to the screen, and returns the character as its result value:

```
getChar :: IO Char
```

2. The action putChar c writes the character c to the screen, and returns no result value:

```
putChar :: Char -> IO ()
```

3. The action return v simply returns the value v, without performing any interaction with the user:

```
return :: a -> IO a
```

Sequencing – do notation

A sequence of IO actions can be combined into a single composite action using the do notation:

```
do v1 <- a1
   v2 <- a2
   a3
   . . .
   vn <- an
   return (f v1 v2 ... vn)
```

First perform action a1 and call its result value v1, ..., and finally, apply the function f to combine all the results into a single value, and return it as the result value from the expression as a whole.

The layout rule applies

If the value vi is not used, simply write ai

Called "generator" because ai generates value for vi

Sequencing Example

Deafine an action (act1) that reads three characters, discards the second, and returns the first and third as a pair.

```
act1 :: IO (Char,Char)
act1 = do x <- getChar
          getChar
          y <- getChar
          return (x,y)
```

The character read by the second getChar is not used

Derived Primitives

- Reading a string from the keyboard:

```
getLine :: IO String
getLine  = do x <- getChar
              if x == ‘\n’ then return []
              else do xs <- getLine
                      return (x:xs)
```

- Writing a string to the screen:

```
putStr        :: String -> IO ()
putStr []      = return ()
putStr (x:xs) = do putChar x
                   putStr xs
```

- Writing a string and moving to a new line:

```
putStrLn    :: String -> IO ()
putStrLn xs = do putStr xs
                 putChar '\n'
```

Building More Complex IO Actions

We can now define an action that prompts for a string to be entered and displays its length:

```
strlen :: IO ()
strlen  = do putStr “Enter a string: ”
             xs <- getLine
             putStr “The string has ”
             putStr (show (length xs))
             putStrLn “ characters.”
```

Now, try:

```
> strlen
Enter a string: Haskell Rocks!
The string has 14 characters.
```

The Type of main

A complete Haskell program is a single IO action. For example:

```
main :: IO ()
main = getLine >>= \cs ->
       putLine (reverse cs)
```

Typically, IO “contaminates” a small part of the program (outermost part), and a larger portion of a Haskell program does not perform any IO. For example, in the above definition of main, reverse is a non-IO function.

Hangman

Consider the following version of hangman:

1. One player secretly types in a word.
2. The other player tries to deduce the word, by entering a sequence of guesses.
3. For each guess, the computer indicates which letters in the secret word occur in the guess.
4. The game ends when the guess is correct.

Hangman (Cont.)

We adopt a top down approach to implementing hangman in Haskell, starting as follows:

```
hangman :: IO ()
hangman  =
   do putStrLn "Think of a word: "
      word <- sgetLine
      putStrLn "Try to guess it:"
      guess word
```

Hangman (Cont.)

The action sgetLine reads a line of text from the keyboard, echoing each character as a dash:

```
sgetLine :: IO String
sgetLine  = do x <- getCh
               if x == '\n' then
                  do putChar x
                     return []
               else
                  do putChar '-'
                     xs <- sgetLine
                     return (x:xs)
```

Hangman (Cont.)

The action getCh reads a single character from the keyboard, without echoing it to the screen:

```
import System.IO

getCh :: IO Char
getCh  = do hSetEcho stdin False -- echo off
            c <- getChar
            hSetEcho stdin True  -- echo on
            return c
```

Hangman (Cont.)

The function guess is the main loop, which requests and processes guesses until the game ends.

```
guess :: String -> IO ()
guess word =
   do putStr "> "
      xs <- getLine
      if xs == word then
         putStrLn "You got it!"
      else
         do putStrLn (diff word xs)
            guess word
```

Hangman (Cont.)

The function diff indicates which characters in one string occur in the second string:

```
diff :: String -> String -> String
diff xs ys =
   [if elem x ys then x else '-' | x <- xs]
```

For example:

```
> diff "haskell" "pascal"

"-as--ll"
```