IO and Instructions

Original by Koen Claessen

Apple Pie

Mumsig äppelpaj

Värm upp ugnen till 225 grader, blanda ingredienserna nedan och se till att fatet är både ugnsäkert och insmort med margarin. Lägg på äpplena som du tärnar först och sen kanel och socker ovanpå. Häll på resten av smulpajen och låt stå i ugnen i ca 25 minuter. Servera med massor av vaniljsås!

2.5 dl mjöl

100 gram margarin

5-6 äpplen, gärna riktigt stora

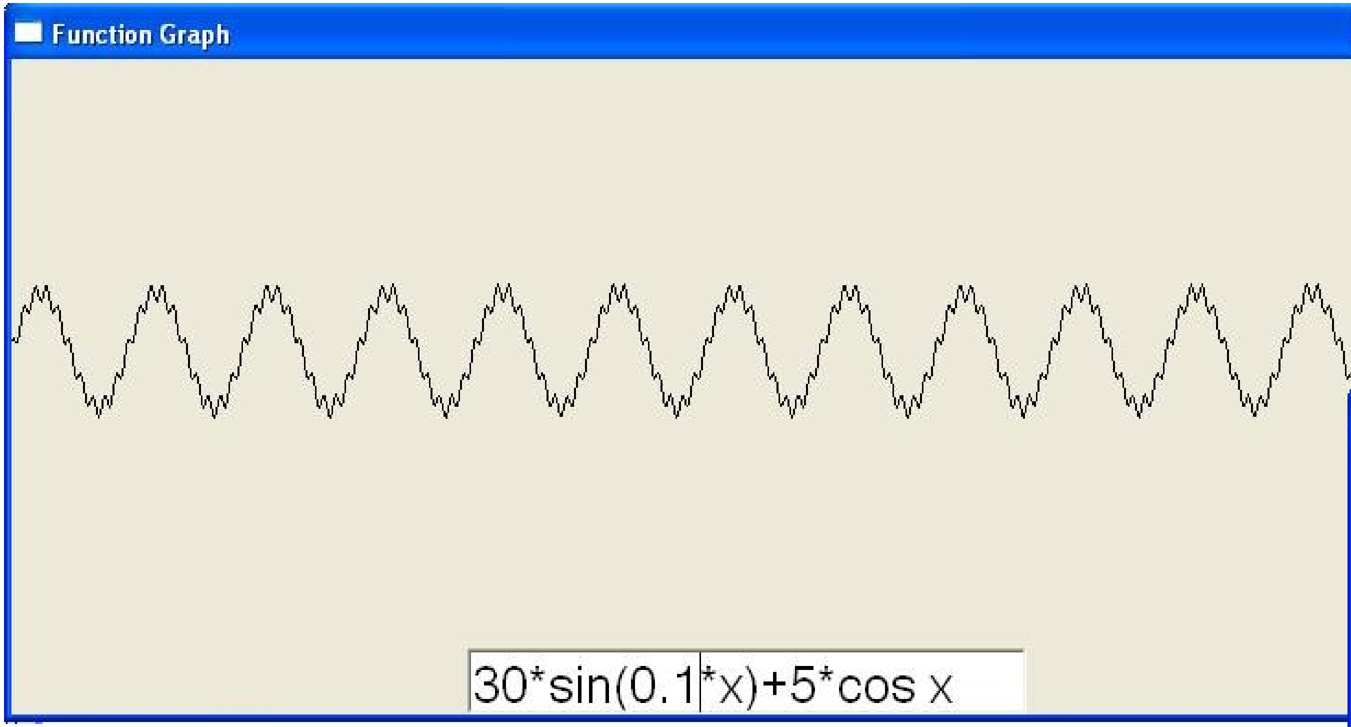
1 dl socker

1 msk kanel

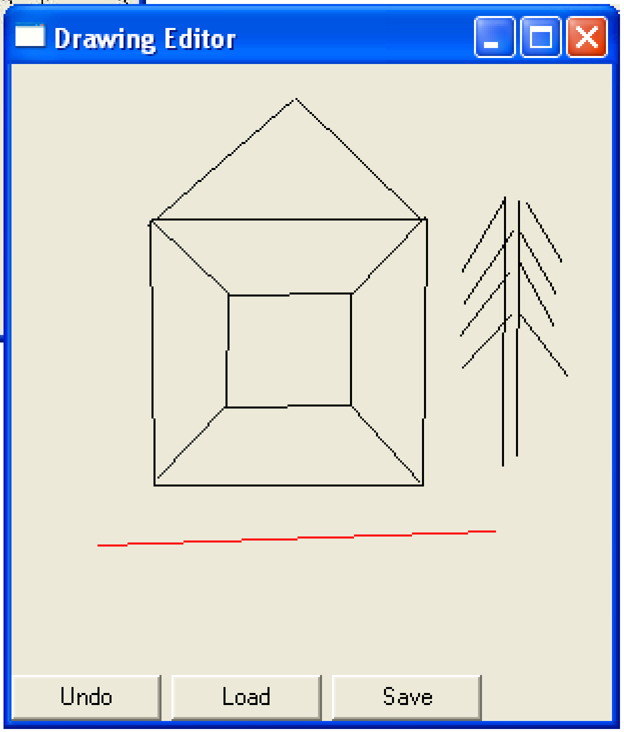
Mycket vaniljsås, gärna Marzan

Difference?

Running a Program



30*sin(0.1*x)+5*cos x



How do you write this as a function?

What is the type of the result?

A Simple Example

```
Prelude> writeFile “myfile.txt” “Anna+Kalle=sant”
Prelude>
```

- Writes the text “Anna+Kalle=sant” to the file called “myfile.txt”
- No result displayed – why not?

What is the Type of writeFile?

```
Prelude> :i writeFile
writeFile :: FilePath -> String -> IO ()
```

Just a String

INSTRUCTIONS to the operating system to write the file

- When you give GHCi an expression of type IO, it *obeys the instructions* (instead of printing the result)
- Note: The function writeFile does *not* write the file
- It only computes the instruction to write

The type ()

- The type () is called the *unit type*
- It only has one value, namely ()
- We can see () as the “empty tuple”
- It means that there is no interesting result

The type FilePath

- Is a *type synonym...*
- *...*which is a way to give an additional name to a type that already exists

```
type FilePath = String
```

- for convenience and/or documentation
- Remember: **data** creates a *new type,* which is different

```
data Shape = Circle Float | ...
```

Instructions with a result value

```
Prelude> :i readFile
readFile :: FilePath -> IO String
```

INSTRUCTIONS for computing a String

Instructions vs. values – an analogy

- Instructions:

1. Take this card
2. Put the card into the ATM
3. Enter the code "1437"
4. Select "500kr"
5. Take the money

- Value:

Which would you rather have?

Instructions vs. values – an analogy

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Instructions with a result value

```
Prelude> :i readFile
readFile :: FilePath -> IO String
```

INSTRUCTIONS for computing a String

We cannot extract 500kr from the list of instructions either...

- readFile “myfile.txt” is not a String
- no String can be extracted from it...
- ...but we can combine it with other instructions that use the result

Putting Instructions Together

```
writeTwoFiles :: FilePath -> String -> IO ()
writeTwoFiles file s =
   do writeFile (file ++ “1”) s
      writeFile (file ++ ”2”) s
```

Use **do** to combine instructions into larger ones

```
copyFile :: FilePath -> FilePath -> IO ()
copyFile file1 file2 =
   do s <- readFile file1
      writeFile file2 s
```

Putting Instructions Together

```
catFiles :: FilePath -> FilePath -> IO String
catFiles file1 file2 =
  do s1 <- readFile file1
     s2 <- readFile file2
     return (s1++s2)
```

Use **do** to combine instructions into larger ones

Use **return** to create an instruction with just a result

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

Instructions vs. Functions

- **Functions** always give the same result for the same arguments
- **Instructions** can behave differently on different occasions
- Confusing them is a major source of bugs
  - Most programming languages do so...
  - ...understanding the difference is important!

The IO type

```
data IO a  -- a built-in type

putStr    :: String -> IO ()
putStrLn  :: String -> IO ()
readFile  :: FilePath -> IO String
writeFile :: FilePath -> String -> IO ()
...
```

Look in the standard modules:
System.IO, System.*

Some Examples

- doTwice :: IO a -> IO (a,a)
- dont :: IO a -> IO ()
- second :: [IO a] -> IO a

- (see file ExampleIO.hs)

Evaluating & Executing

- IO actions of result type ()
  - are just executed in GHCi

```
Prelude> writeFile “emails.txt” “anna@gmail.com”
```

- IO actions of other result types
  - are executed, and then the result is printed

```
Prelude> readFile “emails.txt”
“anna@gmail.com”
```

Quiz

- Define the following function:

```
sortFile :: FilePath -> FilePath -> IO ()
```

- “sortFile file1 file2” reads the lines of file1, sorts them, and writes the result to file2
- You may use the following standard functions:

```
sort    :: Ord a => [a] -> [a]
lines   :: String -> [String]
unlines :: [String] -> String
```

Answer

```
sortFile :: FilePath -> FilePath -> IO ()
sortFile file1 file2 =
  do s <- readFile file1
     writeFile file2 (unlines (sort (lines s)))
```

General guideline:
Do as much as possible using pure functions.
Only use IO when you *have to*.

Recursive instructions

- Let's define the following function:

```
getLine :: IO String
```

```
Prelude> getLine
apa
“apa”
```

- We may use the following standard function:

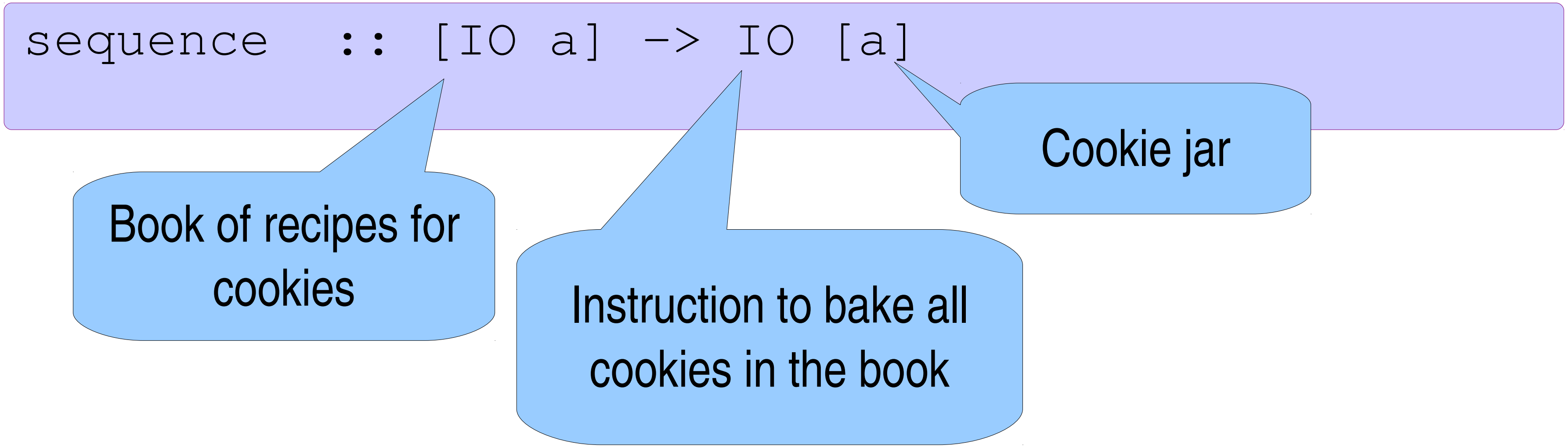
```
getChar :: IO Char
```

Two useful functions

```
sequence_ :: [IO ()] -> IO ()
sequence  :: [IO a] -> IO [a]
```

Can be used to *combine* lists of instructions into one instruction

Analogy for sequence



```
sequence  :: [IO a] -> IO [a]
```

Book of recipes for cookies

Instruction to bake all cookies in the book

Cookie jar

An Example

- Let's define the following function:

```
writeFiles :: FilePath -> [String] -> IO ()
```

```
Prelude> writeFiles “file” [“apa”,”bepa”,”cepa”]

Prelude> readFile “file1”
“apa”

Prelude> readFile “file3”
“cepa”
```

- We may use the following standard functions:

```
show      :: Show a => a -> String
zip       :: [a] -> [b] -> [(a,b)]
```

A possible definition

```
writeFiles :: FilePath -> [String] -> IO ()
writeFiles file xs =
  sequence_ [ writeFile (file++show i) x
            | (x,i) <- zip xs [1..length xs]
            ]
```

We create complex instructions by combining simple instructions

Definitions?

```
sequence_ :: [IO ()] -> IO ()
```

```
sequence  :: [IO a] -> IO [a]
```

Functions vs. Instructions

- **Functions** always produce the same results for the same arguments
- **Instructions** can have varying results for each time they are executed
- Are these functions?

```
putStrLn :: String -> IO ()
readFile :: FilePath -> IO String
sequence :: [IO a] -> IO [a]
```

YES! They deliver
the same instructions for the
same arguments

(but executing these
instructions can have
different results)

What is the Type of doTwice?

```
Prelude> :i doTwice
doTwice :: Monad m => m a -> m (a,a)
```

Monad = Instructions

There are several different kinds of instructions!

- We will see other kinds of instructions (than IO) in the next lecture

Reading

Chapter 9 of Learn You a Haskell:

http://learnyouahaskell.com/input-and-output
(“Instructions” are called “actions”)

Do’s and Don’ts

```
isBig :: Integer → Bool
isBig n | n > 9999  = True
        | otherwise = False
```

guards and
boolean results

```
isBig :: Integer → Bool
isBig n = n > 9999
```

Do’s and Don’ts

```
resultIsSmall :: Integer → Bool
resultIsSmall n = isSmall (f n) == True
```

comparison with a boolean constant

```
resultIsSmall :: Integer → Bool
resultIsSmall n = isSmall (f n)
```

Do’s and Don’ts

```
resultIsBig :: Integer → Bool
resultIsBig n = isSmall (f n) == False
```

comparison with a boolean constant

```
resultIsBig :: Integer → Bool
resultIsBig n = not (isSmall (f n))
```

nd Don’ts

Do not make unnecessary case distinctions

```
fun1 :: [Integer] → Bool
fun1 []       = False
fun1 (x:xs) = length (x:xs) == 10
```

necessary case distinction?

repeated code

```
fun1 :: [Integer] → Bool
fun1 xs = length xs == 10
```

s and Don’ts

Make the base case as simple as possible

right base case ?

```
fun2 :: [Integer] → Integer
fun2 [x]      = calc x
fun2 (x:xs) = calc x + fun2 xs
```

repeated code

```
fun2 :: [Integer] → Integer
fun2 []       = 0
fun2 (x:xs) = calc x + fun2 xs
```