CSc 520

Principles of Programming Languages

13: Haskell — Patterns

Christian Collberg

collberg@cs.arizona.edu

Department of Computer Science

University of Arizona

Pattern Matching

- Haskell has a notation (called patterns) for defining functions that is more convenient than conditional (`if-then-else`) expressions.
- Patterns are particularly useful when the function has more than two cases.

Pattern Syntax:

```
function_name pattern_1 = expression_1
function_name pattern_2 = expression_2
      ...
function_name pattern_n = expression_n
```


Pattern Matching...

```
fact n = if n == 0 then
      1
   else
      n * fact (n-1)
```

fact Revisited:

```
fact ::  Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```


Pattern Matching...

- Pattern matching allows us to have alternative definitions for a function, depending on the format of the actual parameter. Example:

```
isNice "Jenny" = "Definitely"
isNice "Johanna" = "Maybe"
isNice "Chris" = "No Way"
```

Pattern Matching...

- We can use pattern matching as a design aid to help us make sure that we're considering all possible inputs.
- Pattern matching simplifies taking structured function arguments apart. Example:

```
fun (x:xs) = x ⊕ fun xs
     ⇔
fun xs = head xs ⊕ fun (tail xs)
```


Pattern Matching...

- When a function f is applied to an argument, Haskell looks at each definition of f until the argument matches one of the patterns.

```
not True = False
not False = True
```


Pattern Matching...

- In most cases a function definition will consist of a number of mutually exclusive patterns, followed by a default (or catch-all) pattern:

```
diary "Monday" = "Woke up"
diary "Sunday" = "Slept in"
diary anyday = "Did something else"

diary "Sunday" ⇒ "Slept in"
diary "Tuesday" ⇒ "Did something else"
```


Pattern Matching – Integer Patterns

- There are several kinds of integer patterns that can be used in a function definition.

Pattern	Syntax	Example	Description
variable	var_name	fact n = $\cdots$	n matches any argument
constant	literal	fact 0 = $\cdots$	matches the value
wildcard	_	five _ = 5	_ matches any argument
(n+k) pat.	(n+k)	fact (n+1) = $\cdots$	(n+k) matches any integer $\geq k$

Pattern Matching – List Patterns

- There are also special patterns for matching and (taking apart) lists.

Pattern	Syntax	Example	Description
cons	(x:xs)	len (x:xs) = · · ·	matches non-empty list
empty	[ ]	len [ ] = 0	matches the empty list
one-elem	[x]	len [x] = 1	matches a list with exactly 1 element.
two-elem	[x,y]	len [x,y] = 2	matches a list with exactly 2 elements.

The sumlist Function

Using conditional expr:

```
sumlist ::  [Int] -> Int
sumlist xs = if xs == [ ] then 0
             else head xs + sumlist(tail xs)
```

Using patterns:

```
sumlist ::  [Int] -> Int
sumlist [ ] = 0
sumlist (x:xs) = x + sumlist xs
```

- Note that patterns are checked top-down! The ordering of patterns is therefore important.

The length Function Revisited

Using conditional expr:

```
n ::  [Int] -> Int
n s =  if s == [ ] then 0 else 1 + len (tail s)
```

Using patterns:

```
n ::  [Int] -> Int
n [ ] = 0
n (_:xs) = 1 + len xs
```

Note how similar `len` and `sumlist` are. Many recursive functions on lists will have this structure.

The fact Function Revisited

Using conditional expr:

```
fact n = if n == 0 then 1 else n * fact (n-1)
```

Using patterns:

```
fact' ::  Int -> Int
fact' 0 = 1
fact' (n+1) = (n+1) * fact' n
```

- Are `fact` and `fact'` identical?

  `fact (-1)` ⇒ `Stack overflow`
  `fact' (-1)` ⇒ `Program Error`

- The second pattern in `fact'` only matches positive integers (≥ 1).

Summary

- Functional languages use recursion rather than iteration to express repetition.
- We have seen two ways of defining a recursive function: using conditional expressions (`if-then-else`) or pattern matching.
- A pattern can be used to take lists apart without having to explicitly invoke `head` and `tail`.
- Patterns are checked from top to bottom. They should therefore be ordered from specific (at the top) to general (at the bottom).

Homework

- Define a recursive function `addints` that returns the sum of the integers from 1 up to a given upper limit.
- Simulate the execution of `addints 4`.

```
addints ::  Int -> Int
addints a = ···

?  addints 5
   15

?  addints 2
   3
```


Homework. . .

- Define a recursive function `member` that takes two arguments – an integer `x` and a list of integers `L` – and returns `True` if `x` is an element in `L`.
- Simulate the execution of `member 3 [1,4,3,2]`.

```
member ::  Int -> [Int] -> Bool
member x L = ···

?  member 1 [1,2,3]
   True
?  member 4 [1,2,3]
   False
```


Homework. . .

- Write a recursive function `memberNum x L` which returns the number of times `x` occurs in `L`.
- Use `memberNum` to write a function `unique L` which returns a list of elements from `L` that occurs exactly once.

```
memberNum ::  Int -> [Int] -> Int
unique ::  [Int] -> Int

?  memberNum 5 [1,5,2,3,5,5]
   3
?  unique [2,4,2,1,4]
   1
```

Homework...

- Ackerman's function is defined for nonnegative integers:

$$\begin{aligned} A(0,n) &= n+1 \\ A(m,0) &= A(m-1,1) \\ A(m,n) &= A(m-1,A(m,n-1)) \end{aligned}$$

- Use pattern matching to implement Ackerman's function.
- Flag all illegal inputs using the built-in function `error S` which terminates the program and prints the string `S`.

```
ackerman ::  Int -> Int -> Int
ackerman 0 5 ⇒ 6
ackerman (-1) 5 ⇒ ERROR
```