Programming Paradigms
Written Exam (6 CPs)

21.09.2016

First name		Last name	
Student number		Signature	

Instructions for Students

- Write your name and student number on the exam sheet and on every solution sheet you hand in and also sign them.
- This is a closed book exam: the only resources allowed are blank paper and pens (do not use pencils).
- Write neatly and clearly. The clarity of your explanations will affect your grade.
- The duration of the exam is 2 hours.

Good luck!

Do not write in this space

Question	Marks	Achieved
1	24	
2	8	
3	8	
4	16	
5	8	
6	12	
7	14	
8	10	
Total	100	

Exercise 1 (24 marks)

a. (4 marks) Briefly describe the main differences, advantages and disadvantages of static typing and dynamic typing.

b. (4 marks) Briefly describe the concept of tail recursion, and why it is desirable to write tail recursive functions.

c. (4 marks) Briefly describe the concept of mixins in Ruby.

d. (4 marks) The box model of Prolog execution is a simple way to show the control flow. Briefly sketch and describe the box model.

e. (4 marks) Erlang supports higher-order functions. Briefly explain this concept and give an example on how to use such functions.

f. (4 marks) What is the result of the following Haskell expression?
`[(x,y) | x <- [1..4], y <- [1..4]]`

Exercise 2 (8 marks) Write a Ruby function `timeseries(a)`, which takes as argument a time series (i.e., sequence of values) stored in an array and prints the minimum, the maximum and the average over the time series data. For instance, with `a = [1, 6, 7, 3, 3]` the function prints out `min = 1, max = 7, avg = 4`.

Exercise 3 (8 marks) Extend the Ruby class `Fixnum` with a method `square_root_times` that, if called for a number n and a code snippet, executes the code snippet $\lceil\sqrt{n}\rceil$ times. For example, `5.square_root_times{ puts 'hello world!' }` produces

```
hello world!
hello world!
hello world!
```

You are not allowed to use a built-in Ruby function to compute the square root of numbers.

Exercise 4 (16 marks) Write a Prolog program `rmdup(X,Y)` that removes all duplicates in list `X` and returns in `Y` the duplicate-free list. For instance, given the list `X = [a,b,a,c,a,a,b]`, the duplicate-free list is `Y = [c,a,b]`. The order of the elements in `Y` does not matter. Hint: Implement first a function `member(E,L)` to check whether `E` is a member in `L` and use it in `rmdup` (that is, you have to implement the built-in predicate `member/2` yourself).

Exercise 5 (8 marks) A well-known strategy for writing Prolog programs is "generate and test". That means, that one part of the program generates potential solutions, while another part of the program tests whether a potential solution is correct or not.

The predicate `between(L,U,X)` generates all integers between `L` and `U`. For example, calling `between(0,3,X)` generates the following output:

```
X = 0 ;
X = 1 ;
X = 2 ;
X = 3.
```

Using the `between(L,U,X)` generator, write a Prolog rule `square(S)` that tests whether a number `S` is the square of an integer (for example, `square(4)` would return true, `square(3)` would return false).

Exercise 6 (12 marks) Write an Erlang server that computes the Euclidean distance between two points in the plane, i.e., when it receives two coordinates, it computes the distance between the points and sends it back. The server process receives a tuple containing the ID of the process requesting the information and two coordinates. For example, a request may look like this: {`PID1, 3.5, 4.8, 2.0, 7.3`}, where `PID1` is the ID of the requesting process, while $x_1 = 3.5$, $y_1 = 4.8$ are the coordinates of the first point and $x_2 = 2.0$, $y_2 = 7.3$ are those of the second one. The Euclidean distance is computed as follows: $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$. Assume that you have access to a function `sqrt` that computes the square root of a number.

Show also how the server is started.

Exercise 7 (14 marks) Write a Haskell module that exports a function `subseq` that takes as input a list `x` and a list `y` and returns `true` if `x` is a subsequence of `y` and false otherwise. For instance, `subseq [1,2,3] [3,4,1,2,3,5]` returns `true`, whereas `subseq [1,2,3] [1,2]` returns `false`.

Exercise 8 (10 marks) Write a Haskell module that exports a function `noOfElem` that takes as input an element `x` and a list and returns the number of occurences of `x` in the list. For instance, `NoOfElem 1 [1,2,3,1]` returns `2`.

Solution 1

a. Static typing:

- types and their constraints are checked before executing a program
- pro: less error-prone
- con: sometimes too restrictive

Dynamic typing:

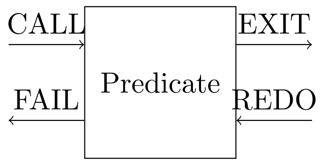
- type checking is done dring program execution
- pro: more flexible
- con: more difficult to debug

b. A function is tail-recursive if there is no operation after the recursive call, that is, no operations are executed after the recursive call terminates. As a consequence, no data need to be stored on the stack that is needed when the recursive call terminates. Hence, different from non-tail-recursive function, for tail-recursive functions the stack does not grow with each recursive call.

c. A mixin in Ruby is a combination of modules and classes. More specifically, a module can be included in a class definition. By doing so, all methods of the module are added and available to the class. Mixins have some similarity to the concept of multiple inheritance.

d. The box model provides a simple way to show the control flow of a Prolog program. A box represents the invocation of a single predicate. The box has four ports (with associated events):

- CALL: The first call of a predicate; control enters into the box
- EXIT: The goal has been proven
- REDO: The system comes back to a goal, trying ot re-satisfy it, i.e., backtracking
- FAIL: The goal/predicate fails



e. A higher-order function is a function that accepts another function as input or returns a function in output. For example, the following expression increments the elements of a list by 1 using an anonymous function:
`lists:map(fun(X) -> X+1 end, [1,2,3,4])` returns `[2,3,4,5]`

f. `[(1,1), (1,2), (1,3), (1,4), (2,1), (2,2), ..., (4,4)]`

Solution 2

```
def timeseries( a )
  min = max = a[0]
  sum = 0
  a.each{ |v|
    max = v if v > max
    min = v if v < min
    sum += v
  }
  puts "min = #{min}"
  puts "max = #{max}"
  puts "avg = #{sum/a.length}"
end
```

Solution 3

```
class Fixnum
  def square_root_times
    i = 0
    while i * i < self
      i += 1
      yield
    end
  end
end
```

Solution 4

```
member( X, [X|_] ).
member( X, [_|Xs] ) :- member(X, Xs).

rmdup( [], [] ).
rmdup( [H|T], R ):-
  member( H, T ),
  !,
  rmdup(T,R).
rmdup( [H|T], [H|Rest] ):-
  rmdup( T, Rest ).
```

Solution 5

```
square( S ) :-
  between( 0, S, X ),
  S is X * X,
  !.
```

Solution 6

```
-module(euclidserver).
-export([loop/0]).

loop() ->
  receive
    {PID,X1,Y1,X2,Y2} ->
      XD = X1 - X2,
      YD = Y1 - Y2,
      PID ! sqrt(XD * XD + YD * YD),
      loop()
  end.

Pid = spawn(fun euclidserver:loop/0).
```

Solution 7

```
module Subseq (
       subseq
) where

-- Verify whether x occurs at the beginning of y
sseq :: Eq a => [a] -> [a] -> Bool
sseq x [] = False
sseq [] y = True
sseq (x:xs) (y:ys) = if x == y then sseq xs ys else False

-- Verify whether x occurs somewhere in y
subseq :: Eq a => [a] -> [a] -> Bool
subseq x [] = False
subseq x y =
   if sseq x y then
       True
   else
      subseq x (tail y)
```

Solution 8

```
module NoOfElem (noOfElem) where

noOfElem ::  Eq a => a -> [a] -> Int
noOfElem x [] = 0
noOfElem x (h:t) = (if h == x then 1 else 0) + noOfElem x t
```