

Programming Languages

29 June 2020

Rules

Time at disposal: 4 h.

Read carefully the following questions. For every questions, provide an answer in English. Please remember to justify why the results hold by writing the logical flow that lead you to the answers.

Note that your full name and SDU username must be in the header of every page in your answer.

Exercises

1. Please provide an answer to the following questions.

- (a) Define in your own words the notions of overriding and overloading.
- (b) What are the main differences between overriding and overloading?
- (c) Consider the following pseudocode in a language Java-like where if a class A extends B then A is a subtype of B.

```
class A { ... }  
class B extends A { ... }  
class C extends B { ... }
```

```
class F {  
    B fie (B x) {...}  
}
```

Now consider the following classes.

```
class Q1 extends F {  
    A fie (A p) {...}  
}
```

```
class Q2 extends F {  
    C fie (C p) {...}  
}
```

```

class Q3 extends F {
    A fie (C p) {...}
}

class Q4 extends F {
    C fie (A p) {...}
}

```

For each of these 4 classes, state if they present or not a threat to type security (i.e., if it is possible to have type errors at runtime by allowing writing such a class)? Motivate your answer.

- (d) Consider the previous 4 classes. Which ones will you be able to write in Java without having a compiler error? Motivate your answer.
2. Given $I_{L_1}^{L_2}$ an interpreter of L_2 written in L_1 , $C_{L_1}^{L_2, L_3}$ a compiler written in L_1 that compiles a language written in L_2 into L_3 , $\llbracket P \rrbracket$ the function computed by the program P . Consider the expression $\llbracket I_{L_0}^{L_1} \rrbracket (\llbracket I_{L_0}^{L_2} \rrbracket (C_{L_2}^{L_2, L_1}, C_{L_2}^{L_3, L_0}), I_{L_3}^{L_1})$.
- (a) Are the compilers, and interpreters applied to the correct languages? Motivate your answer.
- (b) If so, what does the evaluation produce?

3. Please provide an answer to the following questions.

- (a) Define in your own words the notion of side effects?
- (b) Why are side effects important? What are their pros and cons?
- (c) By reading the specification of the C++ language, you notice that it guarantees that arguments will be evaluated linearly and will not interleave, but that there are not guarantee of evaluation of parameters or expressions in any specific order. Consider the following C-like program.

```

v = 0
write(v++ + v, v)

```

What will this program print? If there are more possibilities list all of them. Motivate your answer.

4. Please provide an answer to the following questions.

- (a) What does the term cast and coercion mean?
- (b) Write two pseudocode programs showing an example of cast and an example of coercion (max 3 lines each). Explain what an interpreter would do when processing your pseudocode programs.
- (c) Discuss the pros and cons of cast and coercion.
- (d) Assuming you would like to design a language to develop mission critical software, would you chose to support in your language a cast or coercion mechanism? Motivate your answer.

5. Please provide an answer to the following questions.

- (a) Consider the following program with call by reference and static scoping

```

int x = 2;
void foo(reference int y){
    x = x+1;
    y = y+10;
    x = x+y;
    write(x);
}
{ int x = 10;
  foo(x);
  write(x);
}

```

What does it print? Motivate your answer.

- (b) What does the program print if dynamic scoping is used instead of static scoping? Motivate your answer.
- (c) What does the program print if static scoping is used but the parameter of the function `foo` is passed by value? Motivate your answer.
- (d) Consider the following program with static scoping, deep binding and evaluations of expressions from right to left. For the parameter passing mechanisms: **name** means that the parameter is passed by name, **valueresult** by value-result, **reference** by reference.

```

int x = 5 , y = 7 ;
int foo( name int v , valueresult int z ) {
    z = z + v ;
    write( x , y , z ) ;
    z = z + x--;
    write( x , z ) ;
    return z--;
}
{
    int y = 3 , x = 1 ;
    int bar( reference int v , name int x ) {
        int w = x ;
        v = v - foo( y + v--, w ) ;
        write( ++v ) ;
        return ( w + ++y ) ;
    }
    write( bar( y , foo( x++, y ) + y++ ) ) ;
}
write (x , y ) ;

```

What does it print? Motivate your answer.

Remark: do not forget that pass by value-result copies back the last value of the formal parameter when the procedure has ended! This exercises can take a while and it is better to leave it for last.

6. Please provide an answer to the following questions.

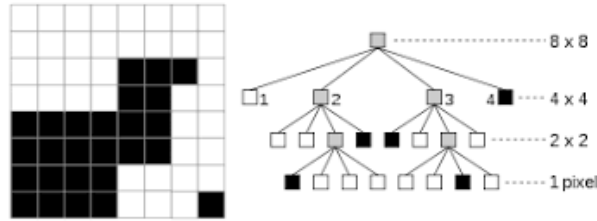


Figure 1: Graphical representation of a Quad Tree.

- (a) A list data type in Haskell can be defined as follows.

```
data [] a = [] | (:) a ([] a)
```

The symbol `[]` in this definition is used three times. Does it represent always the same thing? If so, what is it? If not, what does every occurrence of `[]` stand for?

- (b) Can `Either` be made as a Monad? Specifically, can you complete the definition of the following instance?

```
instance Monad Either where
  x >>= f = ...
  return x = ...
```

If this is possible, please complete the definition of the `>>=` and `return` function. If not, explain what is the problem and propose a possible fix?

7. A lot of techniques for the compression of images are based on a tree data structure called “Quad Tree”. Assume that the image is square and the size of the square is a power of 2. If the image is homogeneous (same color) it is encoded, regardless of its dimension, as a leaf containing its color (see Figure 1 for a graphical representation). If the image is not homogeneous, then it is encoded as a node whose child encode i) the upper left square, ii) the upper right square, iii) the bottom right square, and iv) the bottom left square using the data type

```
data QT a = C a | Q (QT a) (QT a) (QT a) (QT a)
```

Write a function in Haskell named `myframe` that given a color `c` and a QuadTrees `q` gives back `Just c` if the external border of the image encoded by `q` is composed only by pixel of color `c`, `Nothing` otherwise.

Example. Let suppose that

```
z = C 0
q0 = C 2
q1 = Q q0 q0 z q0
q2 = Q q0 z q0 q0
```

then `myframe (Q q1 q0 q0 q2)` returns `Just 2`

Write the type signature of all the functions that you define.

Motivate your choices briefly describing your code.

8. Please provide an answer to the following questions.

(a) Consider the following Haskell program

```
mymess = do
  f <- (2*)
  (return f) . (\x -> x+1)
```

Give the type signature of `mymess`. What Monad is used in this case?

(b) Unfold the do syntactic sugar notation of `mymess`.

(c) What is the result of the evaluation of the expression `mymess 1`. Show the steps that Haskell is performing to arrive at the result.