

## Homework 9

1. Describe what is meant by *eliminating tail recursion*? When can this optimization be applied and why is it of benefit?
2. A programming language has arithmetic expression. For an arithmetic expression the compiler of this language produces the following snippet of JVM code.

```
ldc 1  
ldc 2  
ldc 3  
imul  
ldc 4  
ldc 3  
isub  
iadd  
iadd
```

Give the arithmetic expression that produced this code. Make sure you give all necessary parentheses.

3. Describe what the following JVM instructions do!

```
ldc 3  
iload 3  
istore 1  
ifeq label  
if_icmpge label
```

4. What does the following JVM function calculate?

```

.method public static bar(I)I
.limit locals 1
.limit stack 9
    iload 0
    ldc 0
    if_icmpne If_else_8
    ldc 0
    goto If_end_9
If_else_8:
    iload 0
    ldc 1
    if_icmpne If_else_10
    ldc 1
    goto If_end_11
If_else_10:
    iload 0
    ldc 1
    isub
    invokestatic bar(I)I
    iload 0
    ldc 2
    isub
    invokestatic bar(I)I
    iadd
If_end_11:
If_end_9:
    ireturn
.end method

```

5. What does the following LLVM function calculate? Give the corresponding arithmetic expression .

```

define i32 @foo(i32 %a, i32 %b) {
    %1 = mul i32 %a, %a
    %2 = mul i32 %a, 2
    %3 = mul i32 %2, %b
    %4 = add i32 %1, %3
    %5 = mul i32 %b, %b
    %6 = add i32 %5, %4
    ret i32 %6
}

```

6. As an optimisation technique, a compiler might want to detect 'dead code' and not generate anything for this code. Why does this optimisation technique have the potential of speeding up the run-time of a program? (Hint:

On what kind of CPUs are programs run nowadays?)

7. In an earlier question, we analysed the advantages of having a lexer-phase before running the parser (having a lexer is definitely a good thing to have). But you might wonder if a lexer can also be implemented by a parser and some simple grammar rules. Consider for example:

$$S ::= (Kw \mid Id \mid Ws) \cdot S \mid \epsilon$$
$$Kw ::= \text{if} \mid \text{then} \mid \dots$$
$$Id ::= (a \mid \dots \mid z) \cdot Id \mid \epsilon$$
$$Ws ::= \dots$$

What is wrong with implementing a lexer in this way?

8. What is the difference between a parse tree and an abstract syntax tree? Give some simple examples for each of them.
9. What are the two main features of code in static single assignment form (SSA)?
10. **(Optional)** This question is for you to provide regular feedback to me: for example what were the most interesting, least interesting, or confusing parts in this lecture? Any problems with my Scala code? Please feel free to share any other questions or concerns. Also, all my material is ~~err~~ imperfect. If you have any suggestions for improvement, I am very grateful to hear.

If *\*you\** want to share anything (code, videos, links), you are encouraged to do so. Just drop me an email or send a message to the Forum.