

INJE08: Programming Paradigms
04IN1024: Programming Language Theory
Dry run WS 2015/16

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Studiengang	
ECTS (8 oder 6)	

Grading scheme

There are 9 questions with 0-2 points each: 2 points for a (mostly) correct and complete solution; 1 point for a somewhat reasonable solution with significant omissions or defects; 0 points otherwise. Points/grade: 0-8/5, 9/4, 10/3.7, 11/3.3, 12/3, 13/2.7, 14/2.3, 15/2, 16/1.7, 17/1.3, 18/1. Old exam rules: 0-10:5, 11:4, 12:3.7, 13:3.3, 14:3, 15:2.7, 16:2, 17:1.7, 18:1.

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The topics of the dry run are supposed to be representative of those to be expected from final and resit. Deviations would be announced. Of course, the topics are chosen to cover broad subjects areas. The actual questions are focused on specific competences that were emphasized in the lecture and exercised in the lab—in the edition of the course at hand.

1 Topic: *Syntax*

Define the concrete and abstract syntax of a language construct such that both syntaxes differ in a non-trivial way (i.e., other than by simply omitting terminals in abstract syntax). Add a comment about the assumed language and the reason for the difference.

2 Topic: *Interpreter*

Consider the data type *Set* and the demonstration of the *elementOf* function which is assumed to interpret terms of type *Set* in the sense of set membership:

```
> :i Set
data Set = Const [Int] | Union Set Set | Difference Set Set
> :t elementOf
elementOf :: Set -> Int -> Bool
> elementOf (Difference (Union (Const [])) (Const [1..100])) (Const [42]) 88
True
```

Define the *elementOf* function.

3 Topic: *Big-step operational semantics*

Consider the following rules of the big-step operational semantics for a fragment of the BTL language—it is obviously concerned with operations on natural numbers.

$$\text{zero} \rightarrow \text{zero} \quad \text{[ZERO]}$$

$$\frac{t \rightarrow n}{\text{succ}(t) \rightarrow \text{succ}(n)} \quad \text{[SUCC]}$$

$$\frac{t \rightarrow \text{zero}}{\text{pred}(t) \rightarrow \text{zero}} \quad \text{[PRED1]}$$

$$\frac{t \rightarrow \text{succ}(n)}{\text{pred}(t) \rightarrow n} \quad \text{[PRED2]}$$

Draw a derivation tree that uses each rule exactly once.

4 Topic: *Small-step operational semantics*

Consider the following rules of the small-step operational semantics for the basic functional programming language BFPL.

$$\frac{\phi \vdash e_{i+1} \Rightarrow e_{i+1}'}{\phi \vdash \mathbf{apply}(n, [v_1, \dots, v_i, e_{i+1}, \dots, e_k]) \Rightarrow \mathbf{apply}(n, [v_1, \dots, v_i, e_{i+1}', \dots, e_k])} \quad [\mathbf{apply1}]$$

$$\frac{\langle n, \mathit{sig}, \langle \langle n_1, \dots, n_k \rangle, e \rangle \rangle \in \phi}{\phi \vdash \mathbf{apply}(n, [v_1, \dots, v_k]) \Rightarrow e[n_1 \mapsto v_1, \dots, n_k \mapsto v_k]} \quad [\mathbf{apply2}]$$

Explain, in one concise sentence, how the semantics would need to change so that we switch from call-by-value (i.e., applying the function body to actual values) to call-by-name (i.e., passing unevaluated actual arguments).

5 Topic: *Lambda calculus*

Describe substitution $[N/x]M$, with M the term in which to replace all free occurrences of variable x by the term N , in a concise manner—formally or informally. (You would need to make a case discrimination over the forms of lambda terms.)

6 Topic: *Type systems*

Consider the following type system and big-step operational semantics. There are terms t , values v and types τ . A term can be of the forms a , b , and $c(t)$. There are two values: a and b . There are two types: q and r .

Type system

$a : q$ [type1]

$b : r$ [type2]

$$\frac{t : r}{c(t) : q}$$
 [type3]

Semantics

$a \rightarrow a$ [sem1]

$b \rightarrow b$ [sem2]

$$\frac{t \rightarrow v}{c(t) \rightarrow v}$$
 [sem3]

Explain, in one concise sentence, how the semantics fails to enforce a constraint put up by the type system.

7 Topic: *Polymorphism*

Please be reminded of the Haskell type of ‘(.)’:

```
Prelude> :t (.)
(.) :: (b -> c) -> (a -> b) -> a -> c
```

Here is an application of ‘(.)’:

```
Prelude> (.) not not True
True
```

What is the type of ‘(.)’ in System F ? How is the application represented in System F ? (Hint: You need to add type application.)

8 Topic: *Denotational semantics*

In an imperative language with a loop construct, compositionality dictates that the semantics of loops involves a fixed point construction. Explain, in a concise sentence, when (how, why) would fixed point construction be needed in the denotational semantics of a simple functional programming language (such as BFPL).

9 Topic: *Partial evaluation*

Consider this rule for binary expressions, as it is part of an inliner for the basic functional programming language BFPL:

```
pevaluate (Binary o e1 e2) env =  
  let  
    r1 = pevaluate e1 env  
    r2 = pevaluate e2 env  
  in  
    case (exprToValue r1, exprToValue r2) of  
      (Just v1, Just v2) -> valueToExpr (binOp o v1 v2)  
      _ -> Binary o r1 r2
```

Explain, in a concise sentence, how binary expressions are inlined.