Principles of software composition 2017/18
Exam – September 11, 2018

[**Ex. 1**] Suppose we replace the **while-do** command of IMP with the command **for** a **do** c whose operational semantics is defined by the rules:

$$\frac{\langle a, \sigma\rangle \to 0}{\langle \mathbf{for}\ a\ \mathbf{do}\ c, \sigma\rangle \to \sigma} \qquad \frac{\langle a, \sigma\rangle \to n \neq 0 \quad \langle c, \sigma\rangle \to \sigma'' \quad \langle \mathbf{for}\ a-1\ \mathbf{do}\ c, \sigma''\rangle \to \sigma'}{\langle \mathbf{for}\ a\ \mathbf{do}\ c, \sigma\rangle \to \sigma'}$$

1. Show a **for-do** program that diverges.
2. Extend the proof of determinacy taking into account the new construct.

[**Ex. 2**] Consider the HOFL term

$$t \stackrel{\text{def}}{=} \mathbf{rec}\ f.\ \lambda x.\ \mathbf{if}\ x \times x\ \mathbf{then}\ x\ \mathbf{else}\ (f\ x)$$

1. Find the principal type of t.
2. Find the canonical form of the term $t\ 1$, if any.
3. Compute the (lazy) denotational semantics of t.

[**Ex. 3**] Let us consider the CCS processes

$$p \stackrel{\text{def}}{=} \mathbf{rec}\ x.(\alpha.x + \overline{\alpha}.\mathbf{nil}) \qquad r \stackrel{\text{def}}{=} (p|q)\backslash\alpha$$
$$q \stackrel{\text{def}}{=} \mathbf{rec}\ y.(\overline{\alpha}.y + \alpha.\mathbf{nil}) \qquad s \stackrel{\text{def}}{=} \mathbf{rec}\ z.(\tau.\tau.z + \tau.z + \tau.\mathbf{nil})$$

1. Draw the LTSs of the processes r and s.
2. Which of the HM-formulas below can be used to distinguish r from s?

$$F_0 \stackrel{\text{def}}{=} \Box_\tau \mathit{false} \qquad F_1 \stackrel{\text{def}}{=} \Diamond_\tau \Box_\tau \mathit{false} \quad F_2 \stackrel{\text{def}}{=} \Diamond_\tau \Diamond_\tau \mathit{true}$$
$$F_3 \stackrel{\text{def}}{=} \Diamond_\tau \Box_\tau \Diamond_\tau \mathit{true} \quad F_4 \stackrel{\text{def}}{=} \Diamond_\tau(\Diamond_\tau \mathit{true} \wedge \Box_\tau \Diamond_\tau \mathit{true})$$

[**Ex. 4**] A vessel serves three harbours A, B and C. When it is in A it can move to B and C with equal probability or it can stay in A with probability 20%. When it is in B it can move to either A or C with equal probability and it cannot stay in B. When it is in C it can move to A with probability 20% and to B with probability 80%.

1. Model the system as a DTMC.
2. Where it is more likely to find the vessel on the long run?
3. If the vessel is in A on sunday, what is the probability that it is found in A also on tuesday?