COMPUTER SCIENCE TRIPOS Part IB – 2024 – Paper 6

9 Semantics of Programming Languages (nk480)

(a) Suppose the types $\mathsf{InputChannel}(\tau)$, $\mathsf{OutputChannel}(\tau)$, and $\mathsf{IOChannel}(\tau)$ have the following API:

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\begin{array}{lll} {\rm read} & : & {\rm InputChannel}(\tau) \to \tau \\ \\ {\rm write} & : & {\rm OutputChannel}(\tau) \times \tau \to {\rm unit} \\ \\ {\rm read} & : & {\rm IOChannel}(\tau) \to \tau \\ \\ {\rm write} & : & {\rm IOChannel}(\tau) \times \tau \to {\rm unit} \end{array}
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Note that read and write are overloaded functions. Define a suitable subtyping relation over the channel types. [5 marks]

(b) Consider the following two concurrent L1 programs:

Program 1: r := !r + 1; r := !r + 1Program 2: r := !r + 2

Are these two programs semantically equivalent in a concurrent setting? Give an informal but precise argument if they are, or give a counterexample if not. [2 marks]

- (c) Suppose we try to introduce a safe file-handling API in a language with higher-order functions and state (such as L3) by introducing the function withFile : (File \rightarrow unit) \rightarrow unit. This function creates a file, passes the file to its callback, and then closes the file after the callback returns. Is there any way for a File object to outlive the callback invocation and leak into the environment? Either argue that the API is safe, or give a counterexample. [3 marks]
- (d) We can define the prefix relation $xs \sqsubseteq ys$ on lists as follows:

$$\frac{xs \sqsubseteq ys}{x :: xs \sqsubseteq x :: ys}$$

- (*i*) Prove that the prefix relation is reflexive. [3 marks]
- (*ii*) Prove that the prefix relation is transitive. Inversion properties may be used without proof, as long as they are explicitly indicated. [7 marks]