1 Propositions as Types

Task 1 (L14.1, 15 points) One proposition is more general than another if we can instantiate the propositional variables in the first to obtain the second. For example, $A \supset (B \supset A)$ is more general than $A \supset (\bot \supset A)$ (with $\bot/B$), $(C \land D) \supset (B \supset (C \land D))$ (with $C \land D/A$), but not more general than $C \supset (D \supset E)$.

For each of the following proof terms, give the most general proposition proved by it. (We are justified in saying “the most general” because the most general proposition is unique up to the names of the propositional variables.)

1. $\lambda u. \lambda w. \lambda k. w (u k)$
2. $\lambda w. \{(\lambda u. w (\ell \cdot u)), (\lambda k. w (r \cdot k))\}$
3. $\lambda x. (\text{fst} \ x) (\text{snd} \ x) (\text{snd} \ x)$
4. $\lambda x. \lambda y. \lambda z. (x \ z) (y \ z)$

Task 2 (L14.2, 15 points) Write out a proof term for each of the following propositions. As you know from this lecture, this is the same as writing a program of the translated type in our program language without the use of fixed points.

1. $(A \land (A \supset \bot)) \supset B$
2. $(A \lor (A \supset \bot)) \supset (((A \supset \bot) \supset \bot) \supset A)$

2 Parametric Polymorphism

Task 3 (L15.1, 10 points) Find closed types $\tau$ and $\sigma$ such that

$\tau \vdash \lambda x. x : \sigma$
Task 4 (L15.3, 20 points) For each of the following potential isomorphisms, fill in the missing entry and write down properly typed candidate functions \textit{Forth} and \textit{Back} to witness an isomorphism. You do not need to prove the isomorphism property. On the left side of each candidate isomorphism, we have a type with only universal quantification and function types. On the right side we have a type using any of the type constructors from this course (functions, eager products, lazy products, unit, sum, recursive types, lazy products) but not universally quantified types. We have filled in the first line for you, and you can find the \textit{Forth} and \textit{Back} functions in Section L15.4 (no need to repeat them).

\[
\forall \alpha. \alpha \to \alpha \to \alpha \quad \Rightarrow \quad 1 + 1
\]
(1) \quad \forall \alpha. \alpha \to \alpha

(2) \quad \forall \alpha. \alpha

(3) \quad \Rightarrow \quad \rho \alpha. (e : 1) + (b0 : \alpha) + (b1 : \alpha)

(4) \quad \Rightarrow \quad \text{nat} \times \text{nat}

The type \textit{nat} = \rho \alpha. (\text{zero} : 1) + (\text{succ} : \alpha). You may use the functions from Section L15.4 in your solution to Part 4.