

# CIS 500 Software Foundations

## Homework Assignment 9

### Subtyping

**Due:** Wednesday, December 1 2004, by noon

**Submission instructions:** Same as last time.

- 1 Exercise** Suppose we extend the calculus with the product type constructor  $T_1 \times T_2$  described in Section 11.6. It is natural to add a subtyping rule:

$$\frac{S_1 <: T_1 \quad S_2 <: T_2}{S_1 \times S_2 <: T_1 \times T_2}$$

corresponding to S-RcdDepth for records. Would it be a good idea to add a permutation subtyping rule for products

$$T_1 \times T_2 <: T_2 \times T_1 \quad (\text{S-PAIRPERM})$$

as well?

- 2 Exercise** Suppose we added the subtyping rule  $\text{Top} <: \text{Top} \rightarrow \text{Top}$ . Do any of the lemmas (15.3.2 - 15.3.7) break?

- 3 Exercise** Prove the inversion lemma for variants (in Fig. 15-5): If  $\Gamma \vdash \langle l_1 = t_1 \rangle <: \langle l_1 : T_1 \rangle$  then  $\Gamma \vdash t_1 : T_1$ .

- 4 Exercise** 15.5.3 in TAPL

- 5 Exercise** 16.1.2 in TAPL (Even though the answer at the back of the book says “straightforward induction” for part 1, please show the details of the proof of part (1)).

- 6 Exercise** For each of the following questions, answer YES or NO. Additionally, if the answer NO, give a term that demonstrates how type safety breaks if we allow the two types in the subtype relation.

- Is  $\{x : \text{Top}\}$  a subtype of  $\{x : \text{Top} \rightarrow \text{Top}\}$  ?
- Is  $\{x : \text{Ref Top}\}$  a subtype of  $\{x : \text{Top}\}$  ?
- Is  $\text{Ref Top}$  a subtype of  $\text{Ref (Ref Top)}$ ?

- 7 Exercise** 16.2.5 in TAPL

### 8 Debriefing

1. How many hours (per person) did you spend on this assignment?
2. Would you rate it as easy, moderate, or difficult?
3. Did everyone in your study group participate?
4. How deeply do you feel you understand the material it covers (0%–100%)?

If you have any other comments, we would like to hear them; please send them to [cis500@cis.upenn.edu](mailto:cis500@cis.upenn.edu).