CSC 530

Assignment #5: Parametric Polymorphism

Overview

This assignment extends the type system implementation to support universal and existential quantification.

Starting Point

Extend your solution to Assignment #4. Extend your type representation to include representations for universal and existential types. Extend your expression representation to include terms for type abstraction, type application, packing, and unpacking.

Tests

Include in your submission a set of tests verifying that your implementation works as expected, both for terms that are well-typed and terms that are not.

Include a set of tests translated from the examples in the Ungraded Problem Set #5.

Typing Function

Extend your typing function to support the polymorphism rules given on the last page. Think carefully about your implementation of substitution within the rules for T-TAPP and T-PACK. If there are free variables in β , can they be captured by the substitution?

Grading

Grading will be divided as follows, and will be based on both functionality and quality of implementation.

Part	Percentage
Universal Quantification	45
Existential Quantification	45
Tests	10

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The terms for the expression language are to be inferred from the rules below coupled with the discussion in lecture (and in the textbook). Your implementation, of course, will work on the internal AST representation of such expressions, so you should be able to map the terms used in the typing rules to the variants declared in the Rust code.

nv is for numeric values.

$\Gamma \vdash \text{true} : \text{Bool}$	(T-TRUE)
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$$\Gamma \vdash \text{false} : \text{Bool}$$
 (T-FALSE)

$$\Gamma \vdash nv$$
: Int (T-INTCONST)

$$\frac{t_1: Int}{\Gamma \vdash \text{iszero } t_1: \text{Bool}}$$
(T-IsZERO)

$$\frac{\Gamma \vdash t_1 : \operatorname{Int} \quad \Gamma \vdash t_2 : \operatorname{Int}}{\Gamma \vdash t_1 + t_2 : \operatorname{Int}}$$
(T-ADD)

$$\frac{\Gamma \vdash t_1 : \text{Int} \quad \Gamma \vdash t_2 : \text{Int}}{\Gamma \vdash t_1 - t_2 : \text{Int}}$$
(T-SUB)

$$\frac{\mathbf{x}:\tau\in\Gamma}{\Gamma\vdash\mathbf{x}:\tau} \tag{T-VAR}$$

$$\frac{\Gamma, \mathbf{x} : \alpha \vdash t_1 : \beta}{\Gamma \vdash \lambda \mathbf{x} : \alpha \cdot t_1 : \alpha \to \beta}$$
(T-Abs)

$$\frac{\text{for each } i \quad \Gamma \vdash t_i : \tau_i}{\Gamma \vdash \{l_i = t_i \stackrel{i \in 1..n}{}\} : \{l_i : \tau_i \stackrel{i \in 1..n}{}\}}$$
(T-RcD)

$$\frac{\Gamma \vdash t_1 : \{l_i : \tau_i \stackrel{i \in 1..n}{}\}}{\Gamma \vdash t_1.j : \tau_j}$$
(T-PROJ)

$$\frac{\Gamma \vdash t_j : \tau_j}{\Gamma \vdash \langle l_j = t_j \rangle \text{ as } \langle l_i : \tau_i^{i \in 1..n} \rangle : \langle l_i : \tau_i^{i \in 1..n} \rangle}$$
(T-VARIANT)

$$\frac{\Gamma \vdash t_0 : \langle l_i : \tau_i \stackrel{i \in 1..n}{\leftarrow} \text{ for each } i \quad \Gamma, x_i : \tau_i \vdash t_i : \tau}{\Gamma \vdash \text{ case } t_0 \text{ of } \langle l_i = x_i \rangle \Rightarrow t_i \stackrel{i \in 1..n}{\leftarrow} : \tau}$$
(T-CASE)

$$\Gamma \vdash \text{unit} : \text{Unit}$$
 (T-UNIT)

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$$S <: S$$
 (S-Refl)

$$\frac{S <: U \quad U <: T}{S <: T}$$
 (S-Trans)

$$\frac{\Gamma \vdash t: S \quad S <: T}{\Gamma \vdash t: T}$$
(S-SUB)

$$\frac{\mathbf{P}_2 <: \mathbf{P}_1 \quad \mathbf{R}_1 <: \mathbf{R}_2}{\mathbf{P}_1 \to \mathbf{R}_1 <: \mathbf{P}_2 \to \mathbf{R}_2}$$
(S-Arrow)

$$\frac{\{l_i \ ^{i\in 1..n}\} \subseteq \{k_j \ ^{j\in 1..m}\} \quad k_j = l_i \text{ implies } \alpha_j <: \beta_i}{\{k_j : \alpha_j \ ^{j\in 1..m}\} <: \{l_i : \beta_i \ ^{i\in 1..n}\}}$$
(S-RCD)

$$\frac{\Gamma \vdash t_1 : \text{Bool} \quad \Gamma \vdash t_2 : \tau_1 \quad \Gamma \vdash t_3 : \tau_2 \quad \tau_2 <: \tau_1}{\Gamma \vdash \text{if } t_1 \text{ then } t_2 \text{ else } t_3 : \tau_1}$$
(T-IF1)

$$\frac{\Gamma \vdash t_1 : \text{Bool} \quad \Gamma \vdash t_2 : \tau_1 \quad \Gamma \vdash t_3 : \tau_2 \quad \tau_1 <: \tau_2}{\Gamma \vdash \text{if } t_1 \text{ then } t_2 \text{ else } t_3 : \tau_2}$$
(T-IF2)

$$\frac{\Gamma \vdash t_1 : \alpha \to \beta \quad \Gamma \vdash t_2 : \alpha' \quad \alpha' <: \alpha}{\Gamma \vdash t_1 \; t_2 : \beta}$$
(T-APP)

Polymorphism Rules

$$\frac{\Gamma, \mathbf{X} \vdash t_1 : \tau}{\Gamma \vdash \lambda \mathbf{X}. \ t_1 : \forall X. \tau}$$
(T-TABS)
$$\frac{\Gamma \vdash t_1 : \forall \mathbf{X}. \tau}{\Gamma \vdash t_1 : \forall \mathbf{X}. \tau}$$

$$\overline{\Gamma \vdash t_1 \ [\beta] : [\mathbf{X} \mapsto \beta] \tau} \tag{T-TAPP}$$

$$\frac{\Gamma \vdash t_1 : [\mathbf{X} \mapsto \mathbf{U}]\tau_1}{\Gamma \vdash \{*\mathbf{U}, t_1\} \text{ as } \{\exists \mathbf{X}, \tau_1\} : \{\exists \mathbf{X}, \tau_1\}}$$
(T-PACK)

$$\frac{\Gamma \vdash t_1 : \{\exists \mathbf{X}, \tau_1\} \quad \Gamma, \mathbf{X}, \mathbf{x} : \tau_1 \vdash t_2 : \tau_2}{\Gamma \vdash \det \{\mathbf{X}, \mathbf{x}\} = t_1 \text{ in } t_2 : \tau_2} \quad (\text{T-UNPACK})$$