Types.hs

$T ::=$ Int | Char | Bool | Unit Types

| Skip | $T;T$ | $!T$ | $?T$

| $+\{l_i : T_i\}$ | $\&\{l_i : T_i\}$

| $T \to^m T$ | $T \times T$ -- un pairs as well?

| ~~$[l_i : T_i]$~~ use & instead

| $\mu \alpha^{::K} . T$ | α default S^u

rename at parse time

default S^u

$C ::= \Delta \Rightarrow T$ | $\alpha :: K \Rightarrow C$ Type Schemes

TypeScheme = Functional Type
| Scheme ~~TypeVar Kind~~ TypeScheme
TypeVarBind

Kinds.hs

$v ::= S \mid T$ prekinds

$m ::= u \mid l$ multiplicities

$K ::= v^m$ use a record (newtype) Kinds

$\Delta ::= \varepsilon \mid \Delta, \alpha :: K$ kinding environment

Map α K

Expressions.hs

constructors are term vars

$e ::= c \mid x$ ~~| C~~ expression

| $e\,e$ | **let** $x, x = e$ **in** e | **if** e **then** e **else** e

| ~~match~~ case e ~~with~~ of $\{C_k\ x_1 \cdots x_{n_k} \to e\}_{k=1}^m$

| **new** T | select x e choice

| $e[T]$ -- type application

When Δ is ε write T rather than $\varepsilon \Rightarrow T$ for a type scheme.

$\Gamma ::= \underbrace{\varepsilon \mid \Gamma, x :: C}_{\text{Map } x\ C}$ typing environment

$\Gamma_0 \triangleq \varepsilon,$

fork :: $\mathrm{Unit} \to^{u} \mathrm{Unit}$

pair e e — X pair :: $\forall \alpha :: T^{l}, \beta :: T^{l} \Rightarrow \alpha \to^{u} \beta \to^{l} \alpha \times \beta$

receive e — X receive :: $\forall \alpha :: T^{l}, \beta :: S^{l} \Rightarrow ?\alpha;\beta \to^{u} \alpha \times \beta$

send e e — X send :: $\alpha :: S^{l}, \beta :: T^{l} \Rightarrow \alpha \to^{u} !\beta;\alpha \to^{l} \alpha$

Type checking expressions

$$\boxed{\Delta;\Gamma \vdash e : T ; \Gamma}$$

$$\frac{\mathrm{typeof}(c) = \tau}{\Delta;\Gamma \vdash c : \tau ; \Gamma}$$

$$\frac{C :: \_^{\,\ell}}{\Delta;\Gamma, x : C \vdash x : C ; \Gamma} \qquad \frac{C :: \_^{\,u}}{\Delta;\Gamma, x : C \vdash x : C ; \Gamma, x : C}$$

$$\frac{\Delta;\Gamma_1 \vdash e_1 : \overset{\to T_2}{T_1} ; \Gamma_2 \quad \Delta;\Gamma_2 \vdash e_2 : T_3 ; \Gamma_3 \quad \Delta \vdash T_1 \sim T_3}{\Delta;\Gamma_1 \vdash e_1\, e_2 : T_2 ; \Gamma_3}$$

$$\frac{\Delta;\Gamma_1 \vdash e_1 : \overset{\times T_2}{T_1} ; \Gamma_2 \qquad \Delta;\Gamma, x : T_1, y : T_2 \vdash e_2 : T_3 ; \Gamma_2}{\Delta;\Gamma_1 \vdash \underline{\mathrm{let}}\ x, y = e_1\ \underline{\mathrm{in}}\ e_2 : T_3 ; \Gamma_2}$$

$$\frac{\Delta;\Gamma_1 \vdash e_1 : \mathrm{bool} ; \Gamma_2 \quad \Delta;\Gamma_2 \vdash e_2 : T_1 ; \Gamma_3 \quad \Delta;\Gamma_3 \vdash e_3 : T_2 ; \Gamma_4 \quad \Delta \vdash T_1 \sim T_2 \quad \overset{\Delta\vdash}{\Gamma_3 \sqcap \Gamma_4} \to \Gamma_5}{\Delta;\Gamma_1 \vdash \underline{\mathrm{if}}\ e_1\ \underline{\mathrm{then}}\ e_2\ \underline{\mathrm{else}}\ e_3 : T_1 ; \Gamma_5}$$

$$\frac{\Delta \vdash T :: S^{\kappa}}{\Delta;\Gamma \vdash \underline{\mathrm{new}}\ T :: T \times \overline{T} ; \Gamma}$$

$$\frac{\Delta;\Gamma_1 \vdash e : \overbrace{\&\{x_i : T_i\}}^{\text{canonical}} ; \Gamma_2 \quad \Delta;\Gamma_2 \vdash e_i : T_i' ; \Gamma_i \quad \Delta \vdash \sim T_i' \quad \overset{\Delta\vdash}{\sqcap \Gamma_i'} \to \Gamma_3}{\Delta;\Gamma_1 \vdash \underline{\mathrm{case}}\ e\ \underline{\mathrm{of}}\ x_i \to e_i : T_1' ; \Gamma_3}$$

$$\frac{\Delta;\Gamma_1 \vdash e : \overbrace{+\{x_i : T_i\}_{i \in I}}^{\text{canonical}} ; \Gamma_2 \quad k \in I}{\Delta;\Gamma_1 \vdash \underline{\mathrm{select}}\ x_k\ e : T_k ; \Gamma_2}$$

$\alpha :: \kappa \Rightarrow C$

$$\frac{\Delta;\Gamma_1 \vdash e : \overset{::\kappa}{\forall \alpha}.C ; \Gamma_2 \quad \Delta \vdash T :: \kappa}{\Delta;\Gamma_1 \vdash e[T] : C[T/\alpha] ; \Gamma_2}$$

B

Environment meet (infimum)

$$\boxed{\Delta \vdash \Gamma \sqcap \Gamma \rightsquigarrow T}$$

$$\frac{\Delta \vdash \Gamma_1 \restriction \bar{x} \sim \Gamma_2 \restriction \bar{x} \qquad \Gamma_1 \setminus \Gamma_1 \restriction \bar{x} :: \_^{u} \qquad \Gamma_2 \setminus \Gamma_2 \restriction \bar{x} :: \_^{u} \qquad \underline{\text{where}}\ \bar{x} = \mathrm{dom}\,\Gamma_1 \cap \mathrm{dom}\,\Gamma_2}{\Delta \vdash \Gamma_1 \sqcap \Gamma_2 \rightsquigarrow \Gamma_3}$$

$$\frac{\Delta \vdash T_1 = U_1 \quad \cdots \quad \Delta \vdash T_n = U_n}{\Delta \vdash (x_1 : T_1 \ldots x_n : T_n) \sim (x_1 : U_1 \ldots x_n : U_n)}$$

Data declaration

$$DD ::= \varepsilon \mid DD \text{ data } \alpha :: \kappa = x\, T_1 \dots T_n \qquad n \geq 0$$

default γ^{u}

$$\boxed{\Delta \vdash DD : \Delta}$$

$$\frac{}{\Delta \vdash \varepsilon : \varepsilon}$$

$$\frac{\Delta_1 \vdash DD : \Delta_2 \qquad \kappa \geq \gamma^{u}}{\Delta_1 \vdash DD\ \alpha :: \kappa = (x\, \vec{T}) : \Delta_2, \alpha :: \kappa}$$

$$\boxed{\Delta \vdash DD}$$

$$\frac{}{\Delta \vdash \varepsilon}$$

$$\frac{\Delta \vdash DD \qquad \Delta \vdash T_{ij} :: \kappa_{ij}}{\Delta \vdash DD\ \alpha :: \kappa = (x_i\, T_{i_1} \dots T_{i_n})_{i=1}^{m}}$$

Function Type declaration

$$FTD ::= \varepsilon \mid FTD\ \ x :: C$$

$$\boxed{\Delta \vdash FTD}$$

$$\frac{}{\Delta \vdash \varepsilon}$$

$$\frac{\Delta \vdash FTD \qquad \Delta \vdash C :: \kappa}{\Delta \vdash FTD\ \ x :: C}$$

Function declaration

$$FD ::= \varepsilon \mid FD\ x\ x_1 \dots x_n = e \qquad (n \geq 0)$$

$$\begin{cases} \Gamma_3 :: \_^{u} \\ \Delta \vdash T_{n+1}\ NU \end{cases}$$

$$\boxed{\Delta ; \Gamma \vdash FD}$$

$$\frac{}{\Delta ; \Gamma \vdash \varepsilon}$$

$$\frac{\Delta ; \Gamma_1 \vdash FD \quad \Delta ; \Gamma_1 \vdash x : \overline{\alpha :: \kappa} \Rightarrow T_1 \to \dots \to T_{n+1} ; \Gamma_2 \quad \overline{\alpha :: \kappa}\, \Delta ; \Gamma_2, x_1 : T_1 \dots x_n : T_n \vdash e : U ; \Gamma_3}{\Delta ; \Gamma_1 \vdash FD\ \ x\ x_1 \dots x_n = e \ : (U, \Gamma_3)}$$

Program

$$P ::= DD\ \ FTD\ \ FD$$

$$\frac{\overset{①}{\Delta_1 \vdash DD : \Delta_2} \quad \overset{②}{\Delta_2 \vdash DD} \quad \overset{③}{\Delta_2 \vdash FTD \leadsto} \quad \overset{④}{\Delta_2 ; \Gamma_1 \vdash FD}}{\Delta_1 ; \Gamma_1 \vdash DD\ \ FTD\ \ FD}$$

A