x	term variable		
α	type variable		
T	type constructor		
i, n	index variables		
t	::=		term
	|	x	variable
	|	$\lambda(x : \tau) \Rightarrow t$	abstraction
	|	$\lambda\{\alpha : \kappa\} \Rightarrow t$	type abstraction
	|	$t_1\ t_2$	application
	|	$t\ [\tau]$	type application
	|	$t : \theta$	type annotation
κ	::=		kind
	|	$*$	star
	|	!	effect
	|	$\kappa_1 \to \kappa_2$	kind arrow
τ	::=		type
	|	α	type variable
	|	T	type constructor
	|	$[\varphi]$	effects type
	|	$\tau_1 \dashv\!\![\varphi]\!\!\mapsto \tau_2$	$\equiv (\to)\ \tau_1\ [\varphi]\ \tau_2$
	|	$\lambda(\alpha : \kappa), \tau$	operator abstraction
	|	$\forall\,(\alpha : \kappa), \tau$	universal quantification
	|	$\tau_1\ \tau_2$	operator application
φ	::=		effects
	|	$\tau_1, \ldots, \tau_n$	effects
θ	::=		type annotations
	|	τ	type without effects annotation
	|	$[[\varphi]]\ \tau$	type with effects annotation
Γ	::=		typing environment
	|	$\emptyset$	empty
	|	$\Gamma, x : \tau$	variable
	|	$\Gamma, T : \kappa$	type constructor
	|	$\Gamma, \alpha : \kappa$	type variable
tv	::=		typed value
	|	$\lambda(x : \tau) \Rightarrow t$	abstraction
	|	$\lambda\{\alpha : \kappa\} \Rightarrow tv$	type abstraction
	|	$tv\ [\tau]$	type application
	|	$tv : \theta$	type annotation
v	::=		value
	|	$\lambda x \Rightarrow t$	abstraction

Initial environment: $\Gamma = \emptyset,$
$(\to) : * \to ! \to * \to *$

$\boxed{\Gamma \vdash t : [[\varphi]]\ \tau}$ Typing rules

$$\frac{x : \tau \in \Gamma}{\Gamma \vdash x : [[\,]]\ \tau} \quad \text{T\_Var}$$

$$\frac{\Gamma, x : \tau_1 \vdash t : [[\varphi]]\ \tau_2 \qquad \Gamma \vdash \tau_1 : *}{\Gamma \vdash (\lambda(x : \tau_1) \Rightarrow t) : [[\,]]\ \tau_1 \dashv\!\varphi\!\mapsto \tau_2} \quad \text{T\_Abs}$$

$$\frac{\alpha \notin \Gamma \qquad \Gamma, \alpha : \kappa \vdash t : [[\,]]\ \tau}{\Gamma \vdash (\lambda\{\alpha : \kappa\} \Rightarrow t) : [[\,]]\ \forall\,(\alpha : \kappa), \tau} \quad \text{T\_TyAbs}$$

$$\frac{\Gamma \vdash t_1 : [[\varphi_1]]\ \tau_2 \dashv\!\varphi_3\!\mapsto \tau_1 \qquad \tau_2' \prec \tau_2 \qquad \Gamma \vdash t_2 : [[\varphi_2]]\ \tau_2'}{\Gamma \vdash t_1\ t_2 : [[\varphi_1 \cup \varphi_2 \cup \varphi_3]]\ \tau_1} \quad \text{T\_App}$$

$$\frac{\Gamma \vdash t : [[\varphi]]\ \forall\,(\alpha : \kappa), \tau_2 \qquad \Gamma \vdash \tau_1 : \kappa \qquad [\alpha \mapsto \tau_1]\tau_2 \rhd \tau_2'}{\Gamma \vdash t\ [\tau_1] : [[\varphi]]\ \tau_2'} \quad \text{T\_TyApp}$$

$$\frac{\Gamma \vdash t : [[\varphi]]\ \tau_2 \qquad \tau_2 \prec \tau_1}{\Gamma \vdash (t : \tau_1) : [[\varphi]]\ \tau_1} \quad \text{T\_Annot1}$$

$$\frac{\Gamma \vdash t : [[\varphi_2]]\ \tau_2 \qquad \tau_2 \prec \tau_1 \qquad \varphi_2 \subseteq \varphi_1}{\Gamma \vdash (t : [[\varphi_1]]\ \tau_1) : [[\varphi_1]]\ \tau_1} \quad \text{T\_Annot2}$$

$\boxed{\Gamma \vdash \tau : \kappa}$ Kinding rules

$$\frac{\alpha : \kappa \in \Gamma}{\Gamma \vdash \alpha : \kappa} \quad \text{K\_Var}$$

$$\frac{T : \kappa \in \Gamma}{\Gamma \vdash T : \kappa} \quad \text{K\_TypeConstr}$$

$$\frac{\Gamma \vdash \tau_1 : ! \quad .. \quad \Gamma \vdash \tau_n : !}{\Gamma \vdash [\tau_1, .., \tau_n] : !} \quad \text{K\_Eff}$$

$$\frac{\alpha \notin \Gamma \qquad \Gamma, \alpha : \kappa_1 \vdash \tau : \kappa_2}{\Gamma \vdash (\lambda(\alpha : \kappa_1), \tau) : \kappa_1 \to \kappa_2} \quad \text{K\_Abs}$$

$$\frac{\Gamma \vdash \tau_1 : \kappa_2 \to \kappa_1 \qquad \Gamma \vdash \tau_2 : \kappa_2}{\Gamma \vdash \tau_1\ \tau_2 : \kappa_1} \quad \text{K\_App}$$

$$\frac{\alpha \notin \Gamma \qquad \Gamma, \alpha : \kappa \vdash \tau : *}{\Gamma \vdash (\forall\,(\alpha : \kappa), \tau) : *} \quad \text{K\_Forall}$$

$\boxed{\tau_1 \prec \tau_2}$ Subtyping relation

$$\frac{}{\tau \prec \tau} \quad \text{TSub\_Refl}$$

$$\frac{\tau_1 \prec \tau_2 \qquad \tau_2 \prec \tau_3}{\tau_1 \prec \tau_3} \quad \text{TSub\_Trans}$$

$$\frac{}{\alpha \prec \alpha} \quad \text{TSub\_Var}$$

$$\frac{}{T \prec T} \quad \textsc{TSub\_TypeConstr}$$

$$\frac{\varphi_1 \subseteq \varphi_2}{[\varphi_1] \prec [\varphi_2]} \quad \textsc{TSub\_Eff}$$

$$\frac{\tau_1 \prec \tau_2}{(\forall\,(\alpha : \kappa), \tau_1) \prec (\forall\,(\alpha : \kappa), \tau_2)} \quad \textsc{TSub\_Forall}$$

$$\frac{\tau_1 \prec \tau_2}{(\lambda(\alpha : \kappa), \tau_1) \prec (\lambda(\alpha : \kappa), \tau_2)} \quad \textsc{TSub\_Abs}$$

$$\frac{\tau_1 \prec \tau_1' \qquad \tau_2' \prec \tau_2}{\tau_1\,\tau_2 \prec \tau_1'\,\tau_2'} \quad \textsc{TSub\_App}$$

$$\frac{[\alpha \mapsto \tau_2]\tau_1 \rhd \tau_1'}{(\lambda(\alpha : \kappa), \tau_1)\,\tau_2 \prec \tau_1'} \quad \textsc{TSub\_AppAbs}$$

$\boxed{\varphi_1 \subseteq \varphi_2}$ Effects subset relation

$$\frac{}{\emptyset \subseteq \varphi} \quad \textsc{ESub\_Empty}$$

$$\frac{\exists\,(\tau_i \in \varphi_2), \tau \prec \tau_i \qquad \varphi_1 \subseteq \varphi_2}{\tau, \varphi_1 \subseteq \varphi_2} \quad \textsc{ESub\_Eff}$$

$\boxed{t \longrightarrow tv}$ Operational semantics

$$\frac{t_2 \longrightarrow tv_2 \qquad t_1\,tv_2 \longrightarrow tv_3}{t_1\,t_2 \longrightarrow tv_3} \quad \textsc{E\_App1}$$

$$\frac{t \longrightarrow tv_1 \qquad tv_1\,tv_2 \longrightarrow tv_3}{t\,tv_2 \longrightarrow tv_3} \quad \textsc{E\_App2}$$

$$\frac{[x \mapsto tv_1]t \rhd t' \qquad t' \longrightarrow tv_2}{(\lambda(x : \tau) \Rightarrow t)\,tv_1 \longrightarrow tv_2} \quad \textsc{E\_AppAbs}$$

$$\frac{t \longrightarrow tv}{(\lambda\{\alpha : \kappa\} \Rightarrow t) \longrightarrow (\lambda\{\alpha : \kappa\} \Rightarrow tv)} \quad \textsc{E\_TAbs}$$

$$\frac{t \longrightarrow tv}{t\ [\tau] \longrightarrow tv\ [\tau]} \quad \textsc{E\_TApp}$$

$$\frac{[\alpha \mapsto \tau]t \rhd t' \qquad t' \longrightarrow tv}{(\lambda\{\alpha : \kappa\} \Rightarrow t)\ [\tau] \longrightarrow tv} \quad \textsc{E\_TAppAbs}$$

$$\frac{t \longrightarrow tv}{(t : \tau) \longrightarrow (tv : \tau)} \quad \textsc{E\_Annot}$$

$\boxed{tv \longrightarrow v}$ type erasure

$$\frac{}{(\lambda(x : \tau) \Rightarrow t) \longrightarrow (\lambda x \Rightarrow t)} \quad \textsc{Erase\_Abs}$$

$$\frac{tv \longrightarrow v}{(\lambda\{\alpha : \kappa\} \Rightarrow tv) \longrightarrow v} \quad \textsc{Erase\_TAbs}$$

$$\frac{tv \longrightarrow v}{(tv\ [\tau]) \longrightarrow v} \quad \textsc{Erase\_TApp}$$

$$\frac{tv \longrightarrow v}{(tv : \tau) \longrightarrow v} \quad \textsc{Erase\_Annot}$$

$\boxed{[\alpha \mapsto \tau_1]\tau_2 \rhd \tau_3}$ Type substitution

$$\frac{}{[\alpha \mapsto \tau]\alpha \rhd \tau} \quad \textsc{SubstT\_Var1}$$

$$\frac{\alpha_1 \neq \alpha_2}{[\alpha_1 \mapsto \tau]\alpha_2 \rhd \alpha_2} \quad \textsc{SubstT\_Var2}$$

$$\frac{}{[\alpha \mapsto \tau]T \rhd T} \quad \textsc{SubstT\_Type}$$

$$\frac{[\alpha \mapsto \tau]\varphi_1 \rhd \varphi_2}{[\alpha \mapsto \tau][\varphi_1] \rhd [\varphi_2]} \quad \textsc{SubstT\_Eff}$$

$$\frac{\alpha_1 \neq \alpha_2 \qquad [\alpha_1 \mapsto \tau_1]\tau_2 \rhd \tau_2'}{[\alpha_1 \mapsto \tau_1](\lambda(\alpha_2 : \kappa), \tau_2) \rhd (\lambda(\alpha_2 : \kappa), \tau_2')} \quad \textsc{SubstT\_Abs}$$

$$\frac{\alpha_1 \neq \alpha_2 \qquad [\alpha_1 \mapsto \tau_1]\tau_2 \rhd \tau_2'}{[\alpha_1 \mapsto \tau_1](\forall\,(\alpha_2 : \kappa), \tau_2) \rhd (\forall\,(\alpha_2 : \kappa), \tau_2')} \quad \textsc{SubstT\_Forall}$$

$$\frac{[\alpha \mapsto \tau_1]\tau_2 \rhd \tau_2' \qquad [\alpha \mapsto \tau_1]\tau_3 \rhd \tau_3'}{[\alpha \mapsto \tau_1](\tau_2\,\tau_3) \rhd \tau_2'\,\tau_3'} \quad \textsc{SubstT\_App}$$

$\boxed{[x \mapsto tv]t_1 \rhd t_2}$ substitution

$$\frac{}{[x \mapsto tv]x \rhd tv} \quad \textsc{Subst\_Var1}$$

$$\frac{x_1 \neq x_2}{[x_1 \mapsto tv]x_2 \rhd x_2} \quad \textsc{Subst\_Var2}$$

$$\frac{}{[x \mapsto tv](\lambda(x : \tau) \Rightarrow t) \rhd (\lambda(x : \tau) \Rightarrow t)} \quad \textsc{Subst\_Abs1}$$

$$\frac{x_1 \neq x_2 \qquad [x_1 \mapsto tv]t_1 \rhd t_2}{[x_1 \mapsto tv](\lambda(x_2 : \tau) \Rightarrow t_1) \rhd (\lambda(x_2 : \tau) \Rightarrow t_2)} \quad \textsc{Subst\_Abs2}$$

$$\frac{[x \mapsto tv]t_1 \rhd t_2}{[x \mapsto tv](\lambda\{\alpha : \kappa\} \Rightarrow t_1) \rhd (\lambda\{\alpha : \kappa\} \Rightarrow t_2)} \quad \textsc{Subst\_TAbs}$$

$$\frac{[x \mapsto tv]t_1 \rhd t_1' \qquad [x \mapsto tv]t_2 \rhd t_2'}{[x \mapsto tv](t_1\ t_2) \rhd t_1'\ t_2'} \quad \textsc{Subst\_App}$$

$$\frac{[x \mapsto tv]t_1 \rhd t_2}{[x \mapsto tv](t_1\ [\tau]) \rhd (t_2\ [\tau])} \quad \textsc{Subst\_TApp}$$

$$\frac{[x \mapsto tv]t_1 \rhd t_2}{[x \mapsto tv](t_1 : \tau) \rhd (t_2 : \tau)} \quad \textsc{Subst\_Annot}$$

$\boxed{[\alpha \mapsto \tau]t_1 \rhd t_2}$ substitution of type variable in term

$$\frac{}{[\alpha \mapsto \tau]x \rhd x} \quad \textsc{TtSubst\_Var}$$

$$\frac{[\alpha \mapsto \tau_1]\tau_2 \rhd \tau_2' \qquad [\alpha \mapsto \tau_1]t_1 \rhd t_2}{[\alpha \mapsto \tau_1](\lambda(x : \tau_2) \Rightarrow t_1) \rhd (\lambda(x : \tau_2') \Rightarrow t_2)} \quad \textsc{TtSubst\_Abs}$$

$$\frac{\alpha_1 \neq \alpha_2 \qquad [\alpha_1 \mapsto \tau]t_1 \rhd t_2}{[\alpha_1 \mapsto \tau](\lambda\{\alpha_2 : \kappa\} \Rightarrow t_1) \rhd (\lambda\{\alpha_2 : \kappa\} \Rightarrow t_2)} \quad \textsc{TtSubst\_TAbs}$$

$$\frac{[\alpha \mapsto \tau]t_1 \rhd t_1' \qquad [\alpha \mapsto \tau]t_2 \rhd t_2'}{[\alpha \mapsto \tau](t_1\ t_2) \rhd t_1'\ t_2'} \quad \textsc{TtSubst\_App}$$

$$\frac{[\alpha \mapsto \tau_1]t_1 \rhd t_2 \qquad [\alpha \mapsto \tau_1]\tau_2 \rhd \tau_2'}{[\alpha \mapsto \tau_1](t_1\ [\tau_2]) \rhd (t_2\ [\tau_2'])} \quad \textsc{TtSubst\_TApp}$$

$$\frac{[\alpha \mapsto \tau_1]t_1 \rhd t_2 \qquad [\alpha \mapsto \tau_1]\tau_2 \rhd \tau_2'}{[\alpha \mapsto \tau_1](t_1 : \tau_2) \rhd (t_2 : \tau_2')} \quad \textsc{TtSubst\_Annot}$$

$\boxed{[\alpha \mapsto \tau]\varphi_1 \rhd \varphi_2}$ substitution of type variable in effects

$$\frac{}{[\alpha \mapsto \tau]\emptyset \rhd \emptyset} \quad \textsc{ESubst\_Empty}$$

$$\frac{[\alpha \mapsto \tau_1]\tau_2 \rhd \tau_2' \qquad [\alpha \mapsto \tau_1]\varphi \rhd \varphi'}{[\alpha \mapsto \tau_1]\tau_2, \varphi \rhd \tau_2', \varphi'} \quad \textsc{ESubst\_Eff}$$

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Definition rules:         58 good    0 bad
Definition rule clauses: 105 good    0 bad
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