$termvar$, x	term variable
$variant$, V	variant
$typvar$, X	type variable
exc, Exc	exception
$effect$, E	effect
n	
m	

t	$::=$			term
	$\mid$	x		variable
	$\mid$	V		type constructors
	$\mid$	$\lambda(x : T) \to t$		abstraction
	$\mid$	$\lambda(X : K) \to t$		type abstraction
	$\mid$	$\lambda(E : \varphi) \to t$		effect abstraction
	$\mid$	$t\, t'$		application
	$\mid$	$t[T]$		type application
	$\mid$	$t[[\mathit{eff}]]$		effect application
	$\mid$	$\mathbf{let}\, x = t_1\, \mathbf{in}\, t_2$		let binding
	$\mid$	$\mathbf{let\, rec}\, x : T = \mathit{abs}\, \mathbf{in}\, t$		recursive let binding
	$\mid$	$\mathbf{match}\, t\, \mathbf{with}\, p_1 \to t_1 \mid .. \mid p_n \to t_n\, \mathbf{end}$		pattern matching
	$\mid$	$(t : [\mathit{eff}]\, T)$		annotation
	$\mid$	$\mathbf{fail}\, [T] \mathit{Exc}\, t_1 \, .. \, t_n$		fail
	$\mid$	$\mathbf{try}\, t\, \mathbf{with}\, pe_1 \to t_1 \mid .. \mid pe_n \to t_n\, \mathbf{end}$		try
	$\mid$	$t; t'$	S	sequence == let (_ : Unit) = t in t'
	$\mid$	(t)	S	
	$\mid$	$[x_1 \mapsto t_1, \, .. \, , x_n \mapsto t_n]t$	M	
	$\mid$	$[X \mapsto T]t$	M	
	$\mid$	$[E \mapsto \mathit{eff}]t$	M	
	$\mid$	$\mathbf{failure}\, \mathit{exnval}$	M	
	$\mid$	$\mathbf{TConstr}\ V\ v_1 \, .. \, v_n$	M	
v	$::=$			value
	$\mid$	$\mathbf{TConstr}\ V\ v_1 \, .. \, v_n$		type constructors
	$\mid$	$\lambda(x : T) \to t$		abstraction
abs	$::=$			lambda abstractions
	$\mid$	$\lambda(x : T) \to t$		abstraction
	$\mid$	$\lambda(X : K) \to \mathit{abs}$		type abstraction
	$\mid$	$\lambda(E : \varphi) \to \mathit{abs}$		effect abstraction
	$\mid$	$(\mathit{abs} : [\mathit{eff}]\, T)$		type annotation
p	$::=$			pattern
	$\mid$	$V\ p_1 \, .. \, p_n$		variant
	$\mid$	x		wildcard variable
pe	$::=$			try pattern
	$\mid$	$\mathit{Exc}\, x_1 \, .. \, x_n$		Exception pattern
exnval	$::=$			runtime value of exceptions
	$\mid$	$\mathit{Exc}\, v_1 \, .. \, v_n$		
effelm	$::=$			effects elements
	$\mid$	E		effect
	$\mid$	$\mathbf{IO}$		IO effect
	$\mid$	$\mathbf{Exn}\, [\mathit{exn}]$		exception

exn	::=			exceptions
	|	$\mathit{Exc}_1 \| \,..\, \| \mathit{Exc}_n$		
eff	::=			effect
	|	$\mathit{effelm}_1, \,..\,, \mathit{effelm}_n$		
	|	$\mathit{eff}_1 \cup \mathit{eff}_2 \cup \,..\, \cup \mathit{eff}_n$	M	
	|	$\mathit{eff}_1 \backslash [\mathit{exn}]$	M	
	|	(eff)	S	
K	::=			kinds
	|	$*$		star
	|	$K \rightarrow K'$		kind arrow
T	::=			type
	|	X		variable
	|	**Unit**		Unit type (contained in the module opened by default)
	|	$T \rightarrow T'$	S	pure function == T -[]-¿ T'
	|	$T - [\mathit{eff}] - > T'$		function
	|	$\lambda (X : K), T$		operator abstraction
	|	$\forall\, (X : K), T$		forall
	|	$\forall\, (E : \varphi), T$		effect forall
	|	$T\ T'$		operator application
	|	(T)	S	
	|	$[X \mapsto T] T'$	M	
	|	$[E \mapsto \mathit{eff}] T$	M	
Γ	::=			type environment
	|	**empty**		empty
	|	$\Gamma, x_1 : T_1, \,..\,, x_n : T_n$		vars
	|	$\Gamma, V : T$	S	type constructors (contained in the above values enviro
	|	$\Gamma, X : K$		tvars
	|	$\Gamma, T : \{ V_1 : T_1 \,..\, V_n : T_n \}$		variants
	|	$\Gamma, \mathit{Exc}\ \mathit{excTy}$		exceptions
	|	Γ, E		effects
	|	$\Gamma_1 \cup \,..\, \cup \Gamma_n$	M	
excTy	::=			
	|	$T_1 \,..\, T_n$		
$\mathit{terminals}$	::=			
	|	λ		
	|	$\backslash$		
	|	$\longrightarrow$		
	|	$\rightarrow$		
	|	$\vdash$		
	|	$\mapsto$		
	|	$\in$		

	$\|$	$\equiv$		
	$\|$	φ		
	$\|$	$\forall$		
	$\|$	$\cup$		
	$\|$	$\triangleright$		
	$\|$	$\leftarrow$		
	$\|$	$\&$		
formula	$::=$			
	$\|$	*judgement*		
	$\|$	$\mathit{formula}_1 \quad .. \quad \mathit{formula}_n$		
	$\|$	$\textbf{not}\,(\mathit{formula})$		
	$\|$	$T \equiv T'$		
	$\|$	$x : T \in \Gamma$		
	$\|$	$X : K \in \Gamma$		
	$\|$	$V : T \in \Gamma$		
	$\|$	$T : \{\mathit{Variant}\} \in \Gamma$		
	$\|$	$E \in \Gamma$		
	$\|$	$\mathit{Exc}\;\mathit{excTy} \in \Gamma$		
	$\|$	$\textbf{set}\,(\mathit{eff}) = \textbf{set}\,(\mathit{eff}')$		
	$\|$	$\textbf{set}\,(\mathit{exn}) = \textbf{set}\,(\mathit{exn}')$		
	$\|$	$V \in \mathit{Variant} \triangleright T_1 .. T_n$		
	$\|$	$\mathit{Variant}\,\textbf{is empty}$		
substs	$::=$			
	$\|$	$x_1 \leftarrow v_1, .., x_n \leftarrow v_n$		
	$\|$	$\mathit{substs}_1 \cup .. \cup \mathit{substs}_n$	M	
patterns	$::=$			
	$\|$	$p_1 .. p_n$		
VArgs	$::=$			
	$\|$	$T_1 .. T_n$		
Variant	$::=$			
	$\|$	$V_1\;\mathit{VArgs}_1 .. V_n\;\mathit{VArgs}_n$		
	$\|$	$\textbf{empty}$		
	$\|$	$\mathit{Variant}\backslash V$	M	
Jtype	$::=$			
	$\|$	$\Gamma \vdash t : [\mathit{eff}]\,T$		Typing
Jkind	$::=$			
	$\|$	$\Gamma \vdash T : K$		Kinding
JEff	$::=$			
	$\|$	$\Gamma \vdash \mathit{eff}$		Effects typing

JEffElm	::=		
	$\mid$	$\Gamma \vdash \mathit{effelm}$	Effects elements typing
JPatternsTyping	::=		
	$\mid$	$\mathit{Variant}\ \&\ \Gamma \vdash \mathit{patterns} : T \rhd \Gamma_1 \mathinner{..} \Gamma_n$	Patterns matching typing
JPatternTyping	::=		
	$\mid$	$\mathit{Variant}\ \&\ \Gamma \vdash p : T \rhd \Gamma'$	Pattern matching typing
JExnPatternTyping	::=		
	$\mid$	$\Gamma \vdash \mathit{pe} \rhd \mathit{Exc}\ \&\ \Gamma'$	Exception pattern matching
Jequiv	::=		
	$\mid$	$T \equiv T'$	Type equivalence
JEffEquiv	::=		
	$\mid$	$\mathit{eff} \equiv \mathit{eff}'$	Effects equivalence
JEffElmEquiv	::=		
	$\mid$	$\mathit{effelm} \equiv \mathit{effelm}'$	Effect element equivalence
Jop	::=		
	$\mid$	$t \longrightarrow t'$	Evaluation
JExnMatches	::=		
	$\mid$	$\mathit{exnval}\ \mathbf{matches}\ \mathit{pe} \rhd \{x_1 \leftarrow v_1, \mathinner{..}, x_n \leftarrow v_n\}$	Exception pattern matching
JMatches	::=		
	$\mid$	$v\ \mathbf{matches}\ p \rhd \{\mathit{substs}\}$	Pattern matching with subst
judgement	::=		
	$\mid$	*Jtype*	
	$\mid$	*Jkind*	
	$\mid$	*JEff*	
	$\mid$	*JEffElm*	
	$\mid$	*JPatternsTyping*	
	$\mid$	*JPatternTyping*	
	$\mid$	*JExnPatternTyping*	
	$\mid$	*Jequiv*	
	$\mid$	*JEffEquiv*	
	$\mid$	*JEffElmEquiv*	
	$\mid$	*Jop*	
	$\mid$	*JExnMatches*	
	$\mid$	*JMatches*	
user_syntax	::=		
	$\mid$	*termvar*	

$$
\begin{array}{ll}
| & \mathit{variant}\\
| & \mathit{typvar}\\
| & \mathit{exc}\\
| & \mathit{effect}\\
| & \mathit{n}\\
| & \mathit{m}\\
| & \mathit{t}\\
| & \mathit{v}\\
| & \mathit{abs}\\
| & \mathit{p}\\
| & \mathit{pe}\\
| & \mathit{exnval}\\
| & \mathit{effelm}\\
| & \mathit{exn}\\
| & \mathit{eff}\\
| & K\\
| & T\\
| & \Gamma\\
| & \mathit{excTy}\\
| & \mathit{terminals}\\
| & \mathit{formula}\\
| & \mathit{substs}\\
| & \mathit{patterns}\\
| & \mathit{VArgs}\\
| & \mathit{Variant}
\end{array}
$$

$\boxed{\Gamma \vdash t : [\mathit{eff}]\, T}$ Typing

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

$$\frac{V \ : T \ \in \ \Gamma}{\Gamma \vdash \ V : [\,]\, T} \quad \text{T\_VARIANT}$$

$$\frac{\begin{array}{l}\Gamma, x_1 : T_1 \vdash t : [\mathit{eff}]\, T\\ \Gamma \vdash \ T_1 : *\end{array}}{\Gamma \vdash \lambda(x_1 : T_1) \to t : [\,]\, T_1 - [\mathit{eff}]- > T} \quad \text{T\_ABS}$$

$$\frac{\begin{array}{l}\Gamma \vdash t : [\mathit{eff}_1]\, T_1 - [\mathit{eff}_2]- > T_2\\ \Gamma \vdash t' : [\mathit{eff}_3]\, T_1\end{array}}{\Gamma \vdash t\, t' : [\mathit{eff}_1 \ \cup \ \mathit{eff}_2 \ \cup \ \mathit{eff}_3]\, T_2} \quad \text{T\_APP}$$

$$\frac{\Gamma, X : K \vdash t : [\mathit{eff}]\, T}{\Gamma \vdash \lambda(X : K) \to t : [\mathit{eff}]\forall\, (X : K), T} \quad \text{T\_TABS}$$

$$\frac{\Gamma, E \vdash t : [\mathit{eff}]\, T}{\Gamma \vdash \lambda(E : \varphi) \to t : [\mathit{eff}]\forall\, (E : \varphi), T} \quad \text{T\_EABS}$$

$$\frac{\begin{array}{l}\Gamma \vdash t : [\mathit{eff}]\forall\, (X : K), T_2\\ \Gamma \vdash \ T_1 : K\end{array}}{\Gamma \vdash t[T_1] : [\mathit{eff}][X \mapsto \ T_1]\, T_2} \quad \text{T\_TAPP}$$

$$\frac{\begin{array}{l}\Gamma \vdash t : [\mathit{eff}]\forall\, (E : \varphi), T\\ \Gamma \vdash \mathit{eff}'\end{array}}{\Gamma \vdash t[[\mathit{eff}']] : [\mathit{eff}][E \mapsto \ \mathit{eff}']\, T} \quad \text{T\_EAPP}$$

$$\frac{\begin{array}{l}\Gamma \vdash t : [\mathit{eff}]X \\ X \equiv X' \\ \Gamma \vdash X' : *\end{array}}{\Gamma \vdash t : [\mathit{eff}]X'} \quad \textsc{T\_Eq}$$

$$\frac{\Gamma, x : T_1 \vdash t_2 : [\mathit{eff}_2]\, T_2}{\Gamma \vdash \textbf{let}\, x = (t_1 : [\mathit{eff}_1]\, T_1)\, \textbf{in}\, t_2 : [\mathit{eff}_1 \,\cup\, \mathit{eff}_2]\, T_2} \quad \textsc{T\_Let}$$

$$\frac{\begin{array}{l}\Gamma, x : T_1 \vdash \mathit{abs} : [\,]\, T_1 \\ \Gamma, x : T_1 \vdash t_2 : [\mathit{eff}]\, T_2\end{array}}{\Gamma \vdash \textbf{let rec}\, x : T_1 = \mathit{abs}\, \textbf{in}\, t_2 : [\mathit{eff}]\, T_2} \quad \textsc{T\_LetRec}$$

$$\frac{\begin{array}{l}\Gamma \,\cup\, \Gamma_1 \vdash t_1 : [\mathit{eff}_1] T_2 \quad .. \quad \Gamma \,\cup\, \Gamma_n \vdash t_n : [\mathit{eff}_n] T_2 \\ T_1 : \{\mathit{Variant}\} \,\in\, \Gamma \\ \mathit{Variant} \;\&\; \Gamma \vdash p_1 \,..\, p_n : T_1 \rhd \Gamma_1 \,..\, \Gamma_n \\ \Gamma \vdash t : [\mathit{eff}]\, T_1\end{array}}{\Gamma \vdash \textbf{match}\, t\, \textbf{with}\, p_1 \to t_1 | \,..\, | p_n \to t_n\, \textbf{end} : [\mathit{eff} \,\cup\, \mathit{eff}_1 \,\cup\, .. \,\cup\, \mathit{eff}_n]\, T_2} \quad \textsc{T\_Match}$$

$$\frac{\begin{array}{l}\Gamma \vdash t : [\mathit{eff}]\, T \\ \Gamma \vdash T : * \\ \Gamma \vdash \mathit{eff}\end{array}}{\Gamma \vdash (t : [\mathit{eff}]\, T) : [\mathit{eff}]\, T} \quad \textsc{T\_Annot}$$

$$\frac{\begin{array}{l}\Gamma \vdash t_1 : [\mathit{eff}_1]\, T_1 \quad .. \quad \Gamma \vdash t_n : [\mathit{eff}_n]\, T_n \\ \Gamma \vdash T : * \\ \mathit{Exc}\ T_1 \,..\, T_n \,\in\, \Gamma\end{array}}{\Gamma \vdash \textbf{fail}\, [T] \mathit{Exc}\, t_1 \,..\, t_n : [\textbf{Exn}\, [\mathit{Exc}] \,\cup\, \mathit{eff}_1 \,\cup\, .. \,\cup\, \mathit{eff}_n]\, T} \quad \textsc{T\_Fail}$$

$$\frac{\begin{array}{l}\Gamma_1 \vdash t_1 : [\mathit{eff}_1]\, T \quad .. \quad \Gamma_n \vdash t_n : [\mathit{eff}_n]\, T \\ \Gamma \vdash \mathit{pe}_1 \rhd \mathit{Exc}_1 \;\&\; \Gamma_1 \quad .. \quad \Gamma \vdash \mathit{pe}_n \rhd \mathit{Exc}_n \;\&\; \Gamma_n \\ \Gamma \vdash t : [\mathit{eff}]\, T\end{array}}{\Gamma \vdash \textbf{try}\, t\, \textbf{with}\, \mathit{pe}_1 \to t_1 | \,..\, | \mathit{pe}_n \to t_n\, \textbf{end} : [(\mathit{eff} \backslash [\mathit{Exc}_1 | \,..\, | \mathit{Exc}_n]) \,\cup\, \mathit{eff}_1 \,\cup\, .. \,\cup\, \mathit{eff}_n]\, T} \quad \textsc{T\_Try}$$

$\boxed{\Gamma \vdash T : K}$ Kinding

$$\frac{X : K \,\in\, \Gamma}{\Gamma \vdash X : K} \quad \textsc{K\_TVar}$$

$$\frac{\Gamma, X : K_1 \vdash T : K_2}{\Gamma \vdash \lambda(X : K_1), T : K_1 \to K_2} \quad \textsc{K\_Abs}$$

$$\frac{\begin{array}{l}\Gamma \vdash T_1 : K_{11} \to K_{12} \\ \Gamma \vdash T_2 : K_{11}\end{array}}{\Gamma \vdash T_1\ T_2 : K_{12}} \quad \textsc{K\_App}$$

$$\frac{\begin{array}{l}\Gamma \vdash T_1 : * \\ \Gamma \vdash \mathit{eff} \\ \Gamma \vdash T_2 : *\end{array}}{\Gamma \vdash T_1 - [\mathit{eff}] - > T_2 : *} \quad \textsc{K\_Arrow}$$

$$\frac{\Gamma, X : K_1 \vdash T_2 : *}{\Gamma \vdash \forall\, (X : K_1), T_2 : *} \quad \textsc{K\_All}$$

$$\frac{\Gamma, E \vdash T : *}{\Gamma \vdash \forall\, (E : \varphi), T : *} \quad \textsc{K\_EAll}$$

$\boxed{\Gamma \vdash \mathit{eff}}$ Effects typing

$$\frac{\Gamma \vdash \mathit{effelm}_1 \quad .. \quad \Gamma \vdash \mathit{effelm}_n}{\Gamma \vdash \mathit{effelm}_1, \,..\,, \mathit{effelm}_n} \quad \textsc{Eff\_Eff}$$

$\boxed{\Gamma \vdash \mathit{effelm}}$ Effects elements typing

$$\frac{E \,\in\, \Gamma}{\Gamma \vdash E} \quad \textsc{EffElm\_Eff}$$

$$\frac{}{\Gamma \vdash \mathbf{IO}} \quad \textsc{EffElm\_IO}$$

$$\frac{\mathit{Exc}_1\ \mathit{excTy}_1 \,\in\, \Gamma \quad .. \quad \mathit{Exc}_n\ \mathit{excTy}_n \,\in\, \Gamma}{\Gamma \vdash \mathbf{Exn}\,[\mathit{Exc}_1|\,..\,|\mathit{Exc}_n]} \quad \textsc{EffElm\_Exn}$$

$\boxed{\mathit{Variant}\ \&\ \Gamma \vdash \mathit{patterns} : T \rhd \Gamma_1 \,..\, \Gamma_n}$ Patterns matching typing

$$\frac{\mathit{Variant}\ \&\ \Gamma \vdash p_1 : T \rhd \Gamma_1 \quad .. \quad \mathit{Variant}\ \&\ \Gamma \vdash p_n : T \rhd \Gamma_n}{\mathit{Variant}\ \&\ \Gamma \vdash p_1 \,..\, p_n : T \rhd \Gamma_1 \,..\, \Gamma_n} \quad \textsc{PsTy\_Patterns}$$

$\boxed{\mathit{Variant}\ \&\ \Gamma \vdash p : T \rhd \Gamma'}$ Pattern matching typing

$$\frac{\begin{array}{l} V \,\in\, \mathit{Variant} \rhd T_1 \,..\, T_n \\ T_1 : \{\mathit{Variant}_1\} \,\in\, \Gamma \quad .. \quad T_n : \{\mathit{Variant}_n\} \,\in\, \Gamma \\ \mathit{Variant}_1\ \&\ \Gamma \vdash p_1 : T_1 \rhd \Gamma_1 \quad .. \quad \mathit{Variant}_n\ \&\ \Gamma \vdash p_n : T_n \rhd \Gamma_n \end{array}}{\mathit{Variant}\ \&\ \Gamma \vdash V\ p_1 \,..\, p_n : T \rhd \Gamma_1 \,\cup\, .. \,\cup\, \Gamma_n} \quad \textsc{PTy\_Variant}$$

$$\frac{}{\mathit{Variant}\ \&\ \Gamma \vdash x : T \rhd \mathbf{empty}, x : T} \quad \textsc{PTy\_Wildcard}$$

$\boxed{\Gamma \vdash \mathit{pe} \rhd \mathit{Exc}\ \&\ \Gamma'}$ Exception pattern matching typing

$$\frac{\mathit{Exc}\ T_1 \,..\, T_n \,\in\, \Gamma}{\Gamma \vdash \mathit{Exc}\, x_1 \,..\, x_n \rhd \mathit{Exc}\ \&\ \Gamma, x_1 : T_1, \,..\,, x_n : T_n} \quad \textsc{PETy\_Exc}$$

$\boxed{T \equiv T'}$ Type equivalence

$$\frac{}{T \equiv T} \quad \textsc{Q\_Refl}$$

$$\frac{T \equiv T'}{T' \equiv T} \quad \textsc{Q\_Symm}$$

$$\frac{\begin{array}{c} T_1 \equiv T_2 \\ T_2 \equiv T_3 \end{array}}{T_1 \equiv T_3} \quad \textsc{Q\_Trans}$$

$$\frac{\begin{array}{c} T_{11} \equiv T_{21} \\ \mathit{eff}_1 \equiv \mathit{eff}_2 \\ T_{12} \equiv T_{22} \end{array}}{T_{11} - [\mathit{eff}_1]- > T_{12} \equiv T_{21} - [\mathit{eff}_2]- > T_{22}} \quad \textsc{Q\_Arrow}$$

$$\frac{T_1 \equiv T_2}{\forall\,(X : K), T_1 \equiv \forall\,(X : K), T_2} \quad \textsc{Q\_All}$$

$$\frac{T_1 \equiv T_2}{\forall\,(E : \varphi), T_1 \equiv \forall\,(E : \varphi), T_2} \quad \textsc{Q\_EAll}$$

$$\frac{T_1 \equiv T_2}{\lambda(X : K), T_1 \equiv \lambda(X : K), T_2} \quad \textsc{Q\_Abs}$$

$$\frac{\begin{array}{c} T_{11} \equiv T_{21} \\ T_{12} \equiv T_{22} \end{array}}{T_{11}\ T_{12} \equiv T_{21}\ T_{22}} \quad \textsc{Q\_App}$$

$$\frac{}{(\lambda(X : K), T_{11})\ T_{12} \equiv [X \mapsto T_{12}]\, T_{11}} \quad \textsc{Q\_AppAbs}$$

$\boxed{\mathit{eff} \equiv \mathit{eff}'}$ Effects equivalence

$$\frac{}{\mathit{eff} \equiv \mathit{eff}} \quad \textsc{EffEq\_Refl}$$

$$\frac{\mathbf{set}\,(\mathit{effelm}_1, .., \mathit{effelm}_n) = \mathbf{set}\,(\mathit{effelm}'_1, .., \mathit{effelm}'_n)}{\mathit{effelm}_1, .., \mathit{effelm}_n \equiv \mathit{effelm}'_1, .., \mathit{effelm}'_n} \quad \textsc{EffEq\_Eq}$$

$\boxed{\mathit{effelm} \equiv \mathit{effelm}'}$ Effect element equivalence

$$\frac{}{\mathit{effelm} \equiv \mathit{effelm}} \quad \textsc{EffElmEq\_Refl}$$

$$\frac{\mathit{effelm} \equiv \mathit{effelm}'}{\mathit{effelm}' \equiv \mathit{effelm}} \quad \textsc{EffElmEq\_Symm}$$

$$\frac{\begin{array}{c} \mathit{effelm}_1 \equiv \mathit{effelm}_2 \\ \mathit{effelm}_2 \equiv \mathit{effelm}_3 \end{array}}{\mathit{effelm}_1 \equiv \mathit{effelm}_3} \quad \textsc{EffElmEq\_Trans}$$

$$\frac{\mathbf{set}\,(\mathit{Exc}_1 |\, .. \,| \mathit{Exc}_n) = \mathbf{set}\,(\mathit{Exc}'_1 |\, .. \,| \mathit{Exc}'_n)}{\mathbf{Exn}\,[\mathit{Exc}_1 |\, .. \,| \mathit{Exc}_n] \equiv \mathbf{Exn}\,[\mathit{Exc}'_1 |\, .. \,| \mathit{Exc}'_n]} \quad \textsc{EffElmEq\_ExnEq}$$

$\boxed{t \longrightarrow t'}$ Evaluation

$$\frac{}{V \longrightarrow \mathbf{TConstr}\ V} \quad \textsc{E\_Variant}$$

$$\frac{}{(\mathbf{failure}\ \mathit{exnval})\ t \longrightarrow \mathbf{failure}\ \mathit{exnval}} \quad \textsc{E\_App1Failure}$$

$$\frac{}{v\ (\mathbf{failure}\ \mathit{exnval}) \longrightarrow \mathbf{failure}\ \mathit{exnval}} \quad \textsc{E\_App2Failure}$$

$$\frac{t_1 \longrightarrow t'_1}{t_1\ t \longrightarrow t'_1\ t} \quad \textsc{E\_App1}$$

$$\frac{t_1 \longrightarrow t'_1}{v\ t_1 \longrightarrow v\ t'_1} \quad \textsc{E\_App2}$$

$$\frac{}{(\mathbf{TConstr}\ V\ v_1 .. v_n)\ v_m \longrightarrow \mathbf{TConstr}\ V\ v_1 .. v_n\ v_m} \quad \textsc{E\_AppVariant}$$

$$\frac{}{(\lambda(x : T) \to t_{12})\ v_2 \longrightarrow [x \mapsto v_2]t_{12}} \quad \textsc{E\_AppAbs}$$

$$\frac{}{(\mathbf{failure}\ \mathit{exnval})[T] \longrightarrow \mathbf{failure}\ \mathit{exnval}} \quad \textsc{E\_TAppFailure}$$

$$\frac{t \longrightarrow t'}{t[T] \longrightarrow t'[T]} \quad \textsc{E\_TApp}$$

$$\frac{}{(\lambda(X : K) \to t)[T] \longrightarrow [X \mapsto T]t} \quad \textsc{E\_TAppTAbs}$$

$$\frac{}{(\mathbf{failure}\ \mathit{exnval})[[\mathit{eff}]] \longrightarrow \mathbf{failure}\ \mathit{exnval}} \quad \textsc{E\_EAppFailure}$$

$$\frac{t \longrightarrow t'}{t[[\mathit{eff}]] \longrightarrow t'[[\mathit{eff}]]} \quad \textsc{E\_EApp}$$

$$\frac{}{(\lambda(E : \varphi) \to t)[[\mathit{eff}]] \longrightarrow [E \mapsto \mathit{eff}]t} \quad \textsc{E\_EAppEAbs}$$

$$\frac{}{\mathbf{let}\, x = \mathbf{failure}\, \mathit{exnval}\, \mathbf{in}\, t_2 \longrightarrow \mathbf{failure}\, \mathit{exnval}} \quad \textsc{E\_LetFailure}$$

$$\frac{t_1 \longrightarrow t_1'}{\mathbf{let}\, x = t_1\, \mathbf{in}\, t_2 \longrightarrow \mathbf{let}\, x = t_1'\, \mathbf{in}\, t_2} \quad \textsc{E\_Let1}$$

$$\frac{}{\mathbf{let}\, x = v\, \mathbf{in}\, t \longrightarrow [x \mapsto v]t} \quad \textsc{E\_Let2}$$

$$\frac{}{\mathbf{let\,rec}\, x : T = \mathit{abs}\, \mathbf{in}\, t \longrightarrow [x \mapsto (\mathbf{let\,rec}\, x : T = \mathit{abs}\, \mathbf{in}\, \mathit{abs})]t} \quad \textsc{E\_LetRec}$$

$$\frac{}{\mathbf{match}\, \mathbf{failure}\, \mathit{exnval}\, \mathbf{with}\, p_1 \to t_1 |\, ..\, | p_n \to t_n\, \mathbf{end} \longrightarrow \mathbf{failure}\, \mathit{exnval}} \quad \textsc{E\_MatchFailure}$$

$$\frac{t \longrightarrow t'}{\mathbf{match}\, t\, \mathbf{with}\, p_1 \to t_1 |\, ..\, | p_n \to t_n\, \mathbf{end} \longrightarrow \mathbf{match}\, t'\, \mathbf{with}\, p_1 \to t_1 |\, ..\, | p_n \to t_n\, \mathbf{end}} \quad \textsc{E\_Match}$$

$$\frac{v\, \mathbf{matches}\, p_1 \rhd \{x_1 \leftarrow v_1, .., x_n \leftarrow v_n\}}{\mathbf{match}\, v\, \mathbf{with}\, p_1 \to t_1 |\, ..\, | p_n \to t_n\, \mathbf{end} \longrightarrow [x_1 \mapsto v_1, .., x_n \mapsto v_n]t_1} \quad \textsc{E\_MatchFound}$$

$$\frac{\mathbf{not}\, (v\, \mathbf{matches}\, p_1 \rhd \{x_1 \leftarrow v_1, .., x_n \leftarrow v_n\})}{\mathbf{match}\, v\, \mathbf{with}\, p_1 \to t_1 | p_2 \to t_2 |\, ..\, | p_n \to t_n\, \mathbf{end} \longrightarrow \mathbf{match}\, v\, \mathbf{with}\, p_2 \to t_2 |\, ..\, | p_n \to t_n\, \mathbf{end}} \quad \textsc{E\_MatchStep}$$

$$\frac{t \longrightarrow t'}{(t : [\mathit{eff}]\, T) \longrightarrow t'} \quad \textsc{E\_Annot}$$

$$\frac{t \longrightarrow t'}{\mathbf{fail}\, [T] \mathit{Exc}\, v_1 \,..\, v_n\, t\, t_1 \,..\, t_n \longrightarrow \mathbf{fail}\, [T] \mathit{Exc}\, v_1 \,..\, v_n\, t'\, t_1 \,..\, t_n} \quad \textsc{E\_FailureArgs}$$

$$\frac{}{\mathbf{fail}\, [T] \mathit{Exc}\, v_1 \,..\, v_n \longrightarrow \mathbf{failure}\, \mathit{Exc}\, v_1 \,..\, v_n} \quad \textsc{E\_Failure}$$

$$\frac{t \longrightarrow t'}{\mathbf{try}\, t\, \mathbf{with}\, \mathit{pe}_1 \to t_1 |\, ..\, | \mathit{pe}_n \to t_n\, \mathbf{end} \longrightarrow \mathbf{try}\, t'\, \mathbf{with}\, \mathit{pe}_1 \to t_1 |\, ..\, | \mathit{pe}_n \to t_n\, \mathbf{end}} \quad \textsc{E\_Try}$$

$$\frac{}{\mathbf{try}\, v\, \mathbf{with}\, \mathit{pe}_1 \to t_1 |\, ..\, | \mathit{pe}_n \to t_n\, \mathbf{end} \longrightarrow v} \quad \textsc{E\_TryNoFailure}$$

$$\frac{\mathbf{not}\, (\mathit{exnval}\, \mathbf{matches}\, \mathit{pe}_1 \rhd \{x_1 \leftarrow v_1, .., x_n \leftarrow v_n\})}{\mathbf{try}\, \mathbf{failure}\, \mathit{exnval}\, \mathbf{with}\, \mathit{pe}_1 \to t_1\, \mathbf{end} \longrightarrow \mathbf{failure}\, \mathit{exnval}} \quad \textsc{E\_TryNotFound}$$

$$\frac{\mathit{exnval}\, \mathbf{matches}\, \mathit{pe}_1 \rhd \{x_1 \leftarrow v_1, .., x_n \leftarrow v_n\}}{\mathbf{try}\, \mathbf{failure}\, \mathit{exnval}\, \mathbf{with}\, \mathit{pe}_1 \to t_1 |\, ..\, | \mathit{pe}_n \to t_n\, \mathbf{end} \longrightarrow [x_1 \mapsto v_1, .., x_n \mapsto v_n]t_1} \quad \textsc{E\_TryFound}$$

$$\frac{\mathbf{not}\, (\mathit{exnval}\, \mathbf{matches}\, \mathit{pe}_1 \rhd \{x_1 \leftarrow v_1, .., x_n \leftarrow v_n\})}{\mathbf{try}\, \mathbf{failure}\, \mathit{exnval}\, \mathbf{with}\, \mathit{pe}_1 \to t_1 | \mathit{pe}_2 \to t_2 |\, ..\, | \mathit{pe}_n \to t_n\, \mathbf{end} \longrightarrow \mathbf{try}\, \mathbf{failure}\, \mathit{exnval}\, \mathbf{with}\, \mathit{pe}_2 \to t_2 |\, ..\, | \mathit{pe}_n \to t_n\, \mathbf{enc}}$$

$\boxed{\mathit{exnval}\, \mathbf{matches}\, \mathit{pe} \rhd \{x_1 \leftarrow v_1, .., x_n \leftarrow v_n\}}$ Exception pattern matching with substitution creation

$$\frac{}{\mathit{Exc}\, v_1 \,..\, v_n\, \mathbf{matches}\, \mathit{Exc}\, x_1 \,..\, x_n \rhd \{x_1 \leftarrow v_1, .., x_n \leftarrow v_n\}} \quad \textsc{ExnMatches\_Matches}$$

$\boxed{v\, \mathbf{matches}\, p \rhd \{\mathit{substs}\}}$ Pattern matching with substitution creation

$$\frac{}{v\, \mathbf{matches}\, x \rhd \{x \leftarrow v\}} \quad \textsc{Matches\_Any}$$

$$\frac{v_1\, \mathbf{matches}\, p_1 \rhd \{\mathit{substs}_1\} \quad .. \quad v_n\, \mathbf{matches}\, p_n \rhd \{\mathit{substs}_n\}}{\mathbf{TConstr}\, V\, v_1 \,..\, v_n\, \mathbf{matches}\, V\, p_1 \,..\, p_n \rhd \{\mathit{substs}_1 \cup .. \cup \mathit{substs}_n\}} \quad \textsc{Matches\_Matches}$$

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Definition rules:         76 good    0 bad
Definition rule clauses: 155 good    0 bad
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