

metavariable, x , y

term, t, u	$::=$ $ $ v $ $ x $ $ \bar{x} $ $ tu $ $ $t \circ u$ $ $ $\text{case } t \text{ of } \{\star \mapsto u\}$ $ $ $\text{case } t \text{ of } \{\text{Ur } x \mapsto u\}$ $ $ $\text{case } t \text{ of } \{\text{Inl } x_1 \mapsto u_1, \text{Inr } x_2 \mapsto u_2\}$ $ $ $\text{case } t \text{ of } \{\langle x_1, x_2 \rangle \mapsto u\}$ $ $ $\text{case } t \text{ of } \{\text{@R } x \mapsto u\}$ $ $ $\text{alloc } \mathcal{C} \ x. t$ $ $ $t \text{ with hole_subs}$ $ $ $t \triangleleft^p \star$ $ $ $t \triangleleft^p \lambda x:A. u$ $ $ $t \triangleleft^p u$ $ $ $t \triangleleft^p \text{Ur } y. u$ $ $ $t \triangleleft^p \text{Inl } y. u$ $ $ $t \triangleleft^p \text{Inr } y. u$ $ $ $t \triangleleft^p \langle y_1, y_2 \rangle. u$ $ $ $t \triangleleft^p \text{@R } y. u$ $ $ (t) $ $ $t[\text{subs}]$	term value variable application effect sequencing pattern-matching on unit pattern-matching on exponentiated value pattern-matching on sum pattern-matching on product pattern-matching on recursive data get data from a dest-filling statement hole composition fill destination with unit fill destination with function fill destination with value fill destination with exponential fill destination with sum variant 1 fill destination with sum variant 2 fill destination with product fill destination with recursive data S M
<i>hole</i> , h	$::=$ $ $ $\mathcal{C}[x]$	hole in the lexical store
val, v	$::=$ $ $ \bullet $ $ d	value (unreducible term) empty effect data structure
data, d	$::=$ $ $ x^{\downarrow} $ $ h $ $ \star $ $ $\lambda x:A. t$ $ $ $\text{Ur } d$ $ $ $\text{Inl } d$ $ $ $\text{Inr } d$ $ $ $\langle d_1, d_2 \rangle$ $ $ $\text{@R } d$ $ $ (d)	stored destination hole unit lambda abstraction exponential sum variant 1 sum variant 2 product recursive data S
<i>multiplicity</i> , p	$::=$ $ $ 1 $ $ ω	multiplicity for holes/destinations not under a Ur for holes/destinations under a Ur
sub	$::=$ $ $ var_sub $ $ hole_sub	substitution

subs	$::=$ $\begin{array}{ l} \text{var_subs} \\ \text{hole_subs} \end{array}$	substitutions
var_sub	$::=$ $\begin{array}{ l} x := v \end{array}$	variable substitution
var_subs	$::=$ $\begin{array}{ l} \text{var_sub} \\ \text{var_sub}, \text{var_subs} \end{array}$	variable substitutions
hole_sub	$::=$ $\begin{array}{ l} h := t \end{array}$	hole substitution
hole_subs	$::=$ $\begin{array}{ l} \text{hole_sub} \\ \text{hole_sub}, \text{hole_subs} \end{array}$	hole substitutions
dest_conns, \mathcal{C}	$::=$ $\begin{array}{ l} \emptyset \\ \{\text{dest_conn}\} \end{array}$	dest substitutions by holes
dest_conn	$::=$ $\begin{array}{ l} x \mapsto h \\ x \mapsto h, \text{dest_conn} \\ \bar{x} \mapsto \bar{h} \end{array}$	M
type, A	$::=$ $\begin{array}{ l} \perp \\ \boxed{H}D \\ \parallel D \end{array}$	bottom (effect) type
data_type, D	$::=$ $\begin{array}{ l} 1 \\ R \\ D_1 \otimes D_2 \\ D_1 \oplus D_2 \\ A_1 \multimap A_2 \\ [D]^p \\ [\bar{D}]^{\bar{p}} \\ !D \\ (D) \\ \underline{D}[X := D] \end{array}$	unit type recursive type bound to a name product type sum type linear function type destination type destination type exponential S M unroll a recursive data type
type_with_var, \underline{A}	$::=$ $\begin{array}{ l} \perp \\ \boxed{H}D \\ \parallel D \end{array}$	

<code>data_type_with_var</code> , \underline{D}	$::=$ $ \begin{array}{l} \text{X} \\ 1 \\ R \\ \underline{D}_1 \otimes \underline{D}_2 \\ \underline{D}_1 \oplus \underline{D}_2 \\ \underline{A}_1 \multimap \underline{A}_2 \\ [\underline{D}]^p \\ !\underline{D} \\ (\underline{D}) \end{array} $	S	
<code>rec_type_bound</code> , R	$::=$		name for recursive type
<code>rec_type_def</code>	$::=$ $ \mu \text{X} . \underline{D}$		recursive type definition
<code>type_affect</code> , ta	$::=$ $ \begin{array}{l} \text{x} : \text{A} \\ \text{h}^p : \underline{D} \\ \bar{\text{h}}^{\bar{p}} : \bar{\underline{D}} \end{array} $	M	type affectation variable hole
<code>type_affects</code>	$::=$ $ \begin{array}{l} \text{ta} \\ \text{ta}, \text{type_affects} \end{array} $		type affectations
<code>typing_context</code> , Γ , $\Gamma _{\sqcup}$, \mathcal{U} , H , $\text{H} _{\omega}$	$::=$ $ \begin{array}{l} \emptyset \\ \{\text{type_affects}\} \\ \Gamma_1 \sqcup \Gamma_2 \end{array} $		typing context
<code>terminals</code>	$::=$ $ \begin{array}{l} () \\ \mapsto \\ \multimap \\ := \\ \vdash \\ \sqcup \\ \emptyset \\ \neq \\ \in \\ \notin \\ \backslash n \\ \langle \\ \rangle \\ \text{Inl} \\ \text{Inr} \\ \text{Ur} \\ \text{Dest} \\ \triangleleft \end{array} $		

	\triangleright $ $ \Downarrow $\underline{\text{fix}}$ \perp \bullet \subset \mathcal{N} \Rightarrow $@$ \wedge $;$	
formula	$::=$ $ $ judgement	
Ctx	$::=$ $ $ $x \in \mathcal{N}(\Gamma)$ $ $ $x \notin \mathcal{N}(\Gamma)$ $ $ $\text{type_affect} \in \Gamma$ $ $ $\mathcal{N}(\Gamma_1) \cap \mathcal{N}(\Gamma_2) = \emptyset$ $ $ $p_1 = p_2 \Rightarrow \Gamma_1 = \Gamma_2$ $ $ $p_1 = p_2 \Rightarrow (\Gamma_1 = \Gamma_2 \wedge \Gamma_3 = \Gamma_4)$	Γ_1 and Γ_2 are disjoint typing contexts with n
Store	$::=$ $ $ fresh h $ $ $\text{store_affect} \in S$ $ $ $x \notin \mathcal{N}(S)$	
Eq	$::=$ $ $ $A_1 = A_2$ $ $ $A_1 \neq A_2$ $ $ $t = u$ $ $ $\Gamma = D$	
Ty	$::=$ $ $ $R \stackrel{\text{fix}}{=} \text{rec_type_def}$ $ $ $\mathcal{U} ; \Gamma \vdash t : A$	
judgement	$::=$ $ $ Ctx $ $ Store $ $ Eq $ $ Ty	
user_syntax	$::=$ $ $ metavariable $ $ term $ $ <i>hole</i>	

- | val
- | data
- | *multiplicity*
- | sub
- | subs
- | var_sub
- | var_subs
- | hole_sub
- | hole_subs
- | dest_conns
- | dest_conn
- | type
- | data_type
- | type_with_var
- | data_type_with_var
- | rec_type_bound
- | rec_type_def
- | type_affect
- | type_affects
- | typing_context
- | terminals

$x \in \mathcal{N}(\Gamma)$

$x \notin \mathcal{N}(\Gamma)$

$\text{type_affect} \in \Gamma$

$\mathcal{N}(\Gamma_1) \cap \mathcal{N}(\Gamma_2) = \emptyset$ Γ_1 and Γ_2 are disjoint typing contexts with no clashing variable names or labels

$p_1 = p_2 \implies \Gamma_1 = \Gamma_2$

$p_1 = p_2 \implies (\Gamma_1 = \Gamma_2 \wedge \Gamma_3 = \Gamma_4)$

fresh h

$\text{store_affect} \in S$

$x \notin \mathcal{N}(S)$

$A_1 = A_2$

$A_1 \neq A_2$

$t = u$

$\Gamma = D$

$R \stackrel{\text{fix}}{=} \text{rec_type_def}$

$\mathcal{U}; \Gamma \vdash t : A$

$\overline{\mathcal{U}; \emptyset \vdash \bullet : \perp}$ TyTERM_NOEFF

$\overline{\mathcal{U}; \emptyset \vdash h : \{h^p; D\} D}$ TyTERM_H

$\overline{\mathcal{U}; \{x : \llbracket D \rrbracket^p\} \vdash x : \llbracket D \rrbracket^p}$ TyTERM_DEST *Used to restrict syntax space for values*

$\overline{\mathcal{U}; \emptyset \vdash \star : \llbracket 1 \rrbracket}$ TyTERM_U

$\frac{\emptyset; \Gamma|_{\llbracket \rrbracket} \sqcup \{x : A_1\} \vdash t : A_2}{\mathcal{U}; \Gamma|_{\llbracket \rrbracket} \vdash \lambda x : A_1. t : \llbracket A_1 \multimap A_2 \rrbracket}$ TyTERM_FN

$$\begin{array}{c}
\frac{\emptyset ; \emptyset \vdash d : \boxed{H|_{\omega}} D}{\mathcal{U} ; \emptyset \vdash \text{Ur } d : \boxed{H|_{\omega}} !D} \text{TYTERM_E} \\
\\
\frac{\emptyset ; \Gamma|_{\sqcup} \vdash d : \boxed{H} D_1}{\mathcal{U} ; \Gamma|_{\sqcup} \vdash \text{Inl } d : \boxed{H} D_1 \oplus D_2} \text{TYTERM_INL} \\
\\
\frac{\emptyset ; \Gamma|_{\sqcup} \vdash d : \boxed{H} D_2}{\mathcal{U} ; \Gamma|_{\sqcup} \vdash \text{Inr } d : \boxed{H} D_1 \oplus D_2} \text{TYTERM_INR} \\
\\
\frac{\begin{array}{c} \emptyset ; \Gamma|_{\sqcup 1} \vdash d_1 : \boxed{H_1} D_1 \\ \emptyset ; \Gamma|_{\sqcup 2} \vdash d_2 : \boxed{H_2} D_2 \end{array}}{\mathcal{U} ; \Gamma|_{\sqcup 1} \sqcup \Gamma|_{\sqcup 2} \vdash \langle d_1, d_2 \rangle : \boxed{H_1 \sqcup H_2} D_1 \otimes D_2} \text{TYTERM_P} \\
\\
\frac{\begin{array}{c} R \stackrel{\text{fix}}{=} \mu X. \underline{D} \\ \emptyset ; \emptyset \vdash d : \boxed{H} \underline{D}[X := R] \end{array}}{\mathcal{U} ; \emptyset \vdash @R d : \boxed{H} R} \text{TYTERM_R} \\
\\
\frac{x \notin \mathcal{N}(\mathcal{U})}{\mathcal{U} ; \{x : A\} \vdash x : A} \text{TYTERM_ID} \\
\\
\frac{}{\mathcal{U} \sqcup \{x : A\} ; \emptyset \vdash x : A} \text{TYTERM_ID'} \\
\\
\frac{\begin{array}{c} \mathcal{U} ; \Gamma_1 \vdash t : \llbracket A_1 \multimap A_2 \rrbracket \\ \mathcal{U} ; \Gamma_2 \vdash u : A_1 \end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t u : A_2} \text{TYTERM_APP} \\
\\
\frac{\begin{array}{c} \mathcal{U} ; \Gamma_1 \vdash t : \perp \\ \mathcal{U} ; \Gamma_2 \vdash u : A_2 \end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t \mathbin{\text{\textcircled{\tiny ;}}} u : A_2} \text{TYTERM_EFFSEQ} \\
\\
\frac{\begin{array}{c} \mathcal{U} ; \Gamma_1 \vdash t : \llbracket 1 \rrbracket \\ \mathcal{U} ; \Gamma_2 \vdash u : A \end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash \text{case } t \text{ of } \{\star \mapsto u\} : A} \text{TYTERM_PATU} \\
\\
\frac{\begin{array}{c} \mathcal{U} ; \Gamma_1 \vdash t : \llbracket !D \rrbracket \\ \mathcal{U} \sqcup \{x : \llbracket D \rrbracket\} ; \Gamma_2 \vdash u : A \end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash \text{case } t \text{ of } \{\text{Ur } x \mapsto u\} : A} \text{TYTERM_PATE} \\
\\
\frac{\begin{array}{c} \mathcal{U} ; \Gamma_1 \vdash t : \llbracket D_1 \oplus D_2 \rrbracket \\ \mathcal{U} ; \Gamma_2 \sqcup \{x_1 : \llbracket D_1 \rrbracket\} \vdash u_1 : A \\ \mathcal{U} ; \Gamma_2 \sqcup \{x_2 : \llbracket D_2 \rrbracket\} \vdash u_2 : A \end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash \text{case } t \text{ of } \{\text{Inl } x_1 \mapsto u_1, \text{Inr } x_2 \mapsto u_2\} : A} \text{TYTERM_PATs} \\
\\
\frac{\begin{array}{c} \mathcal{U} ; \Gamma_1 \vdash t : \llbracket D_1 \otimes D_2 \rrbracket \\ \mathcal{U} ; \Gamma_2 \sqcup \{x_1 : \llbracket D_1 \rrbracket, x_2 : \llbracket D_2 \rrbracket\} \vdash u : A \end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash \text{case } t \text{ of } \{\langle x_1, x_2 \rangle \mapsto u\} : A} \text{TYTERM_PATP} \\
\\
\frac{\begin{array}{c} R \stackrel{\text{fix}}{=} \mu X. \underline{D} \\ \mathcal{U} ; \Gamma_1 \vdash t : \llbracket R \rrbracket \\ \mathcal{U} ; \Gamma_2 \sqcup \{x : \llbracket \underline{D}[X := R] \rrbracket\} \vdash u : A \end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash \text{case } t \text{ of } \{ @R x \mapsto u \} : A} \text{TYTERM_PATR} \\
\\
\frac{\begin{array}{c} \mathcal{U} ; \Gamma \sqcup \{x : \llbracket [D]^I \rrbracket\} \vdash t \mathbin{\text{\textcircled{\tiny ;}}} \bar{x} : \llbracket [\bar{D}]^{\bar{P}} \rrbracket \end{array}}{\mathcal{U} ; \Gamma \vdash \text{alloc } \{\bar{x} \mapsto \bar{h}\} x. t : \boxed{\{\bar{h}^{\bar{P}} : \bar{D}\} D} \text{TYTERM_ALLOC}
\end{array}$$

$$\begin{array}{c}
\frac{\begin{array}{l}
\mathcal{U} ; \Gamma_1 \vdash t : \boxed{H_1 \sqcup \{h^p : D'\}} D \\
\mathcal{U} ; \Gamma_2 \vdash u : \boxed{H_2} D' \\
p = \omega \implies \Gamma_2 = \emptyset
\end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t \text{ with } h := u : \boxed{H_1 \sqcup H_2} D} \text{TyTERM_HCOMP} \\
\\
\frac{\mathcal{U} ; \Gamma \vdash t : \llbracket 1 \rrbracket^p}{\mathcal{U} ; \Gamma \vdash t \triangleleft^p \star : \perp} \text{TyTERM_FILLU} \\
\\
\frac{\begin{array}{l}
\mathcal{U} ; \Gamma_1 \vdash t : \llbracket A_1 \multimap A_2 \rrbracket^p \\
\mathcal{U} ; \Gamma_2 \sqcup \{x : A_1\} \vdash u : A_2 \\
p = \omega \implies \Gamma_2 = \emptyset
\end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t \triangleleft^p \lambda x : A_1 . u : \perp} \text{TyTERM_FILLFN} \\
\\
\frac{\begin{array}{l}
\mathcal{U} ; \Gamma_1 \vdash t : \llbracket D \rrbracket^p \\
\mathcal{U} ; \Gamma_2 \vdash u : D \\
p = \omega \implies \Gamma_2 = \emptyset
\end{array}}{\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t \triangleleft^p u : \perp} \text{TyTERM_FILLL } \textit{How to propagate holes ?} \\
\\
\frac{\begin{array}{l}
\mathcal{U} ; \Gamma_1 \vdash t : \llbracket !D \rrbracket^p \\
\mathcal{U} ; \Gamma_2 \sqcup \{x : \llbracket D \rrbracket^\omega\} \vdash u : A \\
\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t \triangleleft^p \text{Ur } x . u : A
\end{array}}{\text{TyTERM_FILLE}} \\
\\
\frac{\begin{array}{l}
\mathcal{U} ; \Gamma_1 \vdash t : \llbracket D_1 \oplus D_2 \rrbracket^p \\
\mathcal{U} ; \Gamma_2 \sqcup \{x : \llbracket D_1 \rrbracket^p\} \vdash u : A \\
\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t \triangleleft^p \text{Inl } x . u : A
\end{array}}{\text{TyTERM_FILLINL}} \\
\\
\frac{\begin{array}{l}
\mathcal{U} ; \Gamma_1 \vdash t : \llbracket D_1 \oplus D_2 \rrbracket^p \\
\mathcal{U} ; \Gamma_2 \sqcup \{x : \llbracket D_2 \rrbracket^p\} \vdash u : A \\
\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t \triangleleft^p \text{Inr } x . u : A
\end{array}}{\text{TyTERM_FILLINR}} \\
\\
\frac{\begin{array}{l}
\mathcal{U} ; \Gamma_1 \vdash t : \llbracket D_1 \otimes D_2 \rrbracket^p \\
\mathcal{U} ; \Gamma_2 \sqcup \{x_1 : \llbracket D_1 \rrbracket^p, x_2 : \llbracket D_2 \rrbracket^p\} \vdash u : A \\
\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t \triangleleft^p \langle x_1, x_2 \rangle . u : A
\end{array}}{\text{TyTERM_FILLP}} \\
\\
\frac{\begin{array}{l}
R \stackrel{\text{fix}}{=} \mu X . \underline{D} \\
\mathcal{U} ; \Gamma_1 \vdash t : \llbracket R \rrbracket^p \\
\mathcal{U} ; \Gamma_2 \sqcup \{x : \llbracket \underline{D}[X := R] \rrbracket^p\} \vdash u : A \\
\mathcal{U} ; \Gamma_1 \sqcup \Gamma_2 \vdash t \triangleleft^p @R x . u : A
\end{array}}{\text{TyTERM_FILLR}}
\end{array}$$

Definition rules: 29 good 0 bad

Definition rule clauses: 76 good 0 bad