

1 構文

Type Variable	\ni	X, Y, Z
Term Variable	\ni	x, y, z
Type	\ni	$S, T, U ::= X \mid \mathbf{I} \mid T \oplus T \mid T \otimes T \mid T \multimap T \mid \mu X. T$
Term	\ni	$s, t, u ::= x \mid () \mid \text{inl } t \mid \text{inr } t \mid t \times t \mid t \mapsto t \mid \text{fold}_T t \mid \text{trace}_T t \mid t \parallel t \mid t \circ t \mid \emptyset \mid \text{id} \mid t^\dagger$
Expression	\ni	$e, f, g ::= t \mid e @ e$
Type Context	\ni	$\Theta ::= \mid \Theta, X$
Term Context	\ni	$\Gamma ::= \mid \Gamma, t : T$
Type Judgement	\ni	$\Theta \vdash T$
Term Judgement	\ni	$\Gamma \vdash t : T$
Expression Judgement	\ni	$\vdash e : T$
Reduction	\ni	$t \Rightarrow t$

図 1 Syntax

2 型の構成

$$\frac{}{\Theta, X \vdash X} \quad \frac{}{\Theta \vdash \mathbf{I}} \quad \frac{\Theta \vdash T_1 \quad \Theta \vdash T_2}{\Theta \vdash T_1 \oplus T_2 :} \quad \frac{\Theta \vdash T_1 \quad \Theta \vdash T_2}{\Theta \vdash T_1 \otimes T_2 :} \quad \frac{\Theta \vdash T_1 \quad \Theta \vdash T_2}{\Theta \vdash T_1 \multimap T_2} \quad \frac{\Theta, X \vdash T}{\Theta \vdash \mu X. T}$$

図 2 Formation rules

$$\begin{aligned} [\](X) &= X \\ [\sigma, X \rightarrow T](X) &= T \\ [\sigma, X' \rightarrow S](X) &= X \\ [\sigma](\mathbf{I}) &= \mathbf{I} \\ [\sigma](T_1 \oplus T_2) &= [\sigma](T_1) \oplus [\sigma](T_2) \\ [\sigma](T_1 \otimes T_2) &= [\sigma](T_1) \otimes [\sigma](T_2) \\ [\sigma](T_1 \multimap T_2) &= [\sigma](T_1) \multimap [\sigma](T_2) \\ [\sigma](\mu X. T) &= \mu X. [\sigma](T) \end{aligned}$$

図 3 Type Substitution

3 型検査

$$\begin{array}{c}
\text{Variable} \frac{}{x : T \vdash x : T} \quad \text{Exchange} \frac{\Gamma_2, \Gamma_1 \vdash t : T}{\Gamma_1, \Gamma_2 \vdash t : T} \\
\\
I_L \frac{\Gamma \vdash t : T}{\Gamma, () : I \vdash t : T} \quad \frac{}{\vdash () : I} I_R \\
\\
\oplus_{L_l} \frac{\Gamma, t_1 : T_1 \vdash t : T}{\Gamma, \text{inl } t_1 : T_1 \oplus T_2 \vdash t : T} \quad \frac{\Gamma \vdash t_1 : T_1}{\Gamma \vdash \text{inl } t_1 : T_1 \oplus T_2} \oplus_{R_l} \\
\\
\oplus_{L_r} \frac{\Gamma, t_2 : T_2 \vdash t : T}{\Gamma, \text{inr } t_2 : T_1 \oplus T_2 \vdash t : T} \quad \frac{\Gamma \vdash t_2 : T_2}{\Gamma \vdash \text{inr } t_2 : T_1 \oplus T_2} \oplus_{R_r} \\
\\
\otimes_L \frac{\Gamma, t_1 : T_1, t_2 : T_2 \vdash t : T}{\Gamma, t_1 \times t_2 : T_1 \otimes T_2 \vdash t : T} \quad \frac{\Gamma_1 \vdash t_1 : T_1 \quad \Gamma_2 \vdash t_2 : T_2}{\Gamma_1, \Gamma_2 \vdash t_1 \times t_2 : T_1 \otimes T_2} \otimes_R \\
\\
\multimap_L \frac{\Gamma_1 \vdash t_1 : T_1 \quad \Gamma_2, t_2 : T_2 \vdash t : T}{\Gamma_1, \Gamma_2, t_1 \mapsto t_2 : T_1 \multimap T_2 \vdash t : T} \quad \frac{\Gamma, t_1 : T_1 \vdash t_2 : T_2}{\Gamma \vdash t_1 \mapsto t_2 : T_1 \multimap T_2} \multimap_R \\
\\
\mu_L \frac{\Gamma, u : [X \rightarrow \mu X. U] U \vdash t : T}{\Gamma, \text{fold}_{\mu X. U} u : \mu X. U \vdash t : T} \quad \frac{\Gamma \vdash t : [X \rightarrow \mu X. T] T}{\Gamma \vdash \text{fold}_{\mu X. T} t : \mu X. T} \mu_R \\
\\
\text{Trace}_L \frac{\Gamma, u : S \oplus U_1 \multimap S \oplus U_2 \vdash t : T}{\Gamma, \text{trace}_S u : U_1 \multimap U_2 \vdash t : T} \quad \frac{\Gamma \vdash t : U \oplus T_1 \multimap U \oplus T_2}{\Gamma \vdash \text{trace}_U t : T_1 \multimap T_2} \text{Trace}_R \\
\\
\text{Par}_L \frac{\Gamma, t_1 : U \vdash t : T \quad \Gamma, t_2 : U \vdash t : T}{\Gamma, t_1 \parallel t_2 : U \vdash t : T} \quad \frac{\Gamma \vdash t_1 : T \quad \Gamma \vdash t_2 : T}{\Gamma \vdash t_1 \parallel t_2 : T} \text{Par}_R \\
\\
\text{Seq}_L \frac{\Gamma, t_1 : T_1 \multimap T_2, t_2 : T_2 \multimap T_3 \vdash t : T}{\Gamma, t_1 \circ t_2 : T_1 \multimap T_3 \vdash t : T} \quad \frac{\Gamma_1 \vdash t_1 : T_1 \multimap T_2 \quad \Gamma_2 \vdash t_2 : T_2 \multimap T_3}{\Gamma_1, \Gamma_2 \vdash t_1 \circ t_2 : T_1 \multimap T_3} \text{Seq}_R \\
\\
\dagger_L \frac{\Gamma, u : T_2 \multimap T_1 \vdash t : T}{\Gamma, u^\dagger : T_1 \multimap T_2 \vdash t : T} \quad \frac{\Gamma \vdash t : T_2 \multimap T_1}{\Gamma \vdash t^\dagger : T_1 \multimap T_2} \dagger_R \\
\\
\text{id}_L \frac{\Gamma \vdash t : T}{\Gamma, \text{id} : U \multimap U \vdash t : T} \quad \frac{}{\vdash \text{id} : T \multimap T} \text{id}_R \\
\\
\emptyset_L \frac{\Gamma \vdash t : T}{\Gamma, \emptyset : U \vdash t : T} \quad \frac{}{\Gamma \vdash \emptyset : T} \emptyset_R \\
\\
\text{App} \frac{\vdash f : T_1 \multimap T_2 \quad \vdash e : T_1}{\vdash f @ e : T_2}
\end{array}$$

図 4 Typing rules

$$\begin{array}{c}
\vdash t : T \triangleright \\
\text{Variable } \frac{\Gamma(x) = T}{\Gamma \vdash x : T \triangleright \Gamma \setminus x} \\
I_L \frac{\Gamma \vdash t : T \triangleright \Gamma'}{\Gamma, () : I \vdash t : T \triangleright \Gamma'} \quad \frac{}{\Gamma \vdash () : I \triangleright \Gamma} I_R \\
\oplus_{Ll} \frac{\Gamma, t_1 : T_1 \vdash t : T \triangleright \Gamma'}{\Gamma, \text{inl } t_1 : T_1 \oplus T_2 \vdash t : T \triangleright \Gamma'} \quad \frac{\Gamma \vdash t_1 : T_1 \triangleright \Gamma'}{\Gamma \vdash \text{inl } t_1 : T_1 \oplus T_2 \triangleright \Gamma'} \oplus_{Rl} \\
\oplus_{Lr} \frac{\Gamma, t_2 : T_2 \vdash t : T \triangleright \Gamma'}{\Gamma, \text{inr } t_2 : T_1 \oplus T_2 \vdash t : T \triangleright \Gamma'} \quad \frac{\Gamma \vdash t_2 : T_2 \triangleright \Gamma'}{\Gamma \vdash \text{inr } t_2 : T_1 \oplus T_2 \triangleright \Gamma'} \oplus_{Rr} \\
\otimes_L \frac{\Gamma, t_1 : T_1, t_2 : T_2 \vdash t : T \triangleright \Gamma'}{\Gamma, t_1 \times t_2 : T_1 \otimes T_2 \vdash t : T \triangleright \Gamma'} \quad \frac{\Gamma \vdash t_1 : T_1 \triangleright \Gamma' \quad \Gamma' \vdash t_2 : T_2 \triangleright \Gamma''}{\Gamma \vdash t_1 \times t_2 : T_1 \otimes T_2 \triangleright \Gamma''} \otimes_R \\
\multimap_L \frac{\Gamma \vdash t_1 : T_1 \triangleright \Gamma' \quad \Gamma', t_2 : T_2 \vdash t : T \triangleright \Gamma''}{\Gamma, t_1 \mapsto t_2 : T_1 \multimap T_2 \vdash t : T \triangleright \Gamma''} \quad \frac{\Gamma, t_1 : T_1 \vdash t_2 : T_2 \triangleright \Gamma'}{\Gamma \vdash t_1 \mapsto t_2 : T_1 \multimap T_2 \triangleright \Gamma'} \multimap_R \\
\mu_L \frac{\Gamma, u : [X \rightarrow \mu X.U]U \vdash t : T \triangleright \Gamma'}{\Gamma, \text{fold}_{\mu X.U} u : \mu X.U \vdash t : T \triangleright \Gamma'} \quad \frac{\Gamma \vdash t : [X \rightarrow \mu X.T]T \triangleright \Gamma'}{\Gamma \vdash \text{fold}_{\mu X.T} t : \mu X.T \triangleright \Gamma'} \mu_R \\
\text{Trace}_L \frac{\Gamma, u : S \oplus U_1 \multimap S \oplus U_2 \vdash t : T \triangleright \Gamma'}{\Gamma, \text{trace}_S u : U_1 \multimap U_2 \vdash t : T \triangleright \Gamma'} \quad \frac{\Gamma \vdash t : U \oplus T_1 \multimap U \oplus T_2 \triangleright \Gamma'}{\Gamma \vdash \text{trace}_U t : T_1 \multimap T_2 \triangleright \Gamma'} \text{Trace}_R \\
\text{Par}_L \frac{\Gamma, t_1 : U \vdash t : T \triangleright \Gamma' \quad \Gamma, t_2 : U \vdash t : T \triangleright \Gamma'}{\Gamma, t_1 \parallel t_2 : U \vdash t : T \triangleright \Gamma'} \quad \frac{\Gamma \vdash t_1 : T \triangleright \Gamma' \quad \Gamma \vdash t_2 : T \triangleright \Gamma'}{\Gamma \vdash t_1 \parallel t_2 : T \triangleright \Gamma'} \text{Par}_R \\
\text{Seq}_L \frac{\Gamma, t_1 : T_1 \multimap T_2, t_2 : T_2 \multimap T_3 \vdash t : T \triangleright \Gamma'}{\Gamma, t_1 \circ t_2 : T_1 \multimap T_3 \vdash t : T \triangleright \Gamma'} \quad \frac{\Gamma \vdash t_1 : T_1 \multimap T_2 \triangleright \Gamma' \quad \Gamma' \vdash t_2 : T_2 \multimap T_3 \triangleright \Gamma''}{\Gamma \vdash t_1 \circ t_2 : T_1 \multimap T_3 \triangleright \Gamma''} \text{Seq}_R \\
\dagger_L \frac{\Gamma, u : T_2 \multimap T_1 \vdash t : T \triangleright \Gamma'}{\Gamma, u^\dagger : T_1 \multimap T_2 \vdash t : T \triangleright \Gamma'} \quad \frac{\Gamma \vdash t : T_2 \multimap T_1 \triangleright \Gamma'}{\Gamma \vdash t^\dagger : T_1 \multimap T_2 \triangleright \Gamma'} \dagger_R \\
\text{id}_L \frac{\Gamma \vdash t : T \triangleright \Gamma'}{\Gamma, \text{id} : U \multimap U \vdash t : T \triangleright \Gamma'} \quad \frac{}{\Gamma \vdash \text{id} : T \multimap T \triangleright \Gamma} \text{id}_R \\
\emptyset_L \frac{\Gamma \vdash t : T \triangleright \Gamma'}{\Gamma, \emptyset : U \vdash t : T \triangleright \Gamma'} \quad \frac{}{\Gamma \vdash \emptyset : T \triangleright \Gamma} \emptyset_R \\
\text{App} \frac{\vdash f : T_1 \multimap T_2 \triangleright \quad \vdash e : T_1 \triangleright}{\vdash f @ e : T_2 \triangleright}
\end{array}$$

图 5 Syntax-Directed Typing rules

4 型推論

$$\begin{aligned}
& \text{unify} := \text{Set of Constraint} \rightarrow \text{Substitution} \\
& \text{unify}(\{\}) = [] \\
& \text{unify}(\{X = T\} \cup C) = \text{unify}([X \rightarrow T]C) \circ [X \rightarrow T] \\
& \text{unify}(\{T = X\} \cup C) = \text{unify}([X \rightarrow T]C) \circ [X \rightarrow T] \\
& \text{unify}(\{S_1 \oplus S_2 = T_1 \oplus T_2\} \cup C) = \text{unify}(C \cup \{S_1 = T_1, S_2 = T_2\}) \\
& \text{unify}(\{S_1 \otimes S_2 = T_1 \otimes T_2\} \cup C) = \text{unify}(C \cup \{S_1 = T_1, S_2 = T_2\}) \\
& \text{unify}(\{S_1 \multimap S_2 = T_1 \multimap T_2\} \cup C) = \text{unify}(C \cup \{S_1 = T_1, S_2 = T_2\}) \\
& \text{unify}(\{\mu X.S = \mu Y.T\} \cup C) = \text{unify}(C \cup \{X = Y, S = T\})
\end{aligned}$$

図6 単一化

$$\begin{aligned}
& \vdash t : X \triangleright \mid C \\
& \text{Variable} \frac{\Gamma(x) = V_2}{\Gamma \vdash x : V_1 \triangleright \Gamma \setminus (x : T) \mid \{V_1 = V_2\}} \\
& I_L \frac{\Gamma \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, () : V \vdash t : T \triangleright \Gamma' \mid C \cup \{V = I\}} \quad \frac{}{\Gamma \vdash () : V \triangleright \Gamma \mid \{V = I\}} I_R \\
& \oplus_{L_l} \frac{\Gamma, t_1 : X_1 \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, \text{inl } t_1 : V \vdash t : T \triangleright \Gamma' \mid C \cup \{V = X_1 \oplus X_2\}} \quad \frac{\Gamma \vdash t_1 : X_1 \triangleright \Gamma' \mid C}{\Gamma \vdash \text{inl } t_1 : V \triangleright \Gamma' \mid C \cup \{V = X_1 \oplus X_2\}} \oplus_{R_l} \\
& \oplus_{L_r} \frac{\Gamma, t_2 : X_2 \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, \text{inr } t_2 : V \vdash t : T \triangleright \Gamma' \mid C \cup \{V = X_1 \oplus X_2\}} \quad \frac{\Gamma \vdash t_2 : X_2 \triangleright \Gamma' \mid C}{\Gamma \vdash \text{inr } t_2 : V \triangleright \Gamma' \mid C \cup \{V = X_1 \oplus X_2\}} \oplus_{R_r} \\
& \otimes_L \frac{\Gamma, t_1 : X_1, t_2 : X_2 \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, t_1 \times t_2 : V \vdash t : T \triangleright \Gamma' \mid C \cup \{V = X_1 \otimes X_2\}} \quad \frac{\Gamma \vdash t_1 : X_1 \triangleright \Gamma' \mid C_1 \quad \Gamma' \vdash t_2 : X_2 \triangleright \Gamma'' \mid C_2}{\Gamma \vdash t_1 \times t_2 : V \triangleright \Gamma'' \mid C_1 \cup C_2 \cup \{V = X_1 \otimes X_2\}} \otimes_R \\
& \multimap_L \frac{\Gamma \vdash t_1 : X_1 \triangleright \Gamma' \mid C_1 \quad \Gamma', t_2 : X_2 \vdash t : T \triangleright \Gamma'' \mid C_2}{\Gamma, t_1 \mapsto t_2 : V \vdash t : T \triangleright \Gamma'' \mid C_1 \cup C_2 \cup \{V = X_1 \multimap X_2\}} \quad \frac{\Gamma, t_1 : X_1 \vdash t_2 : X_2 \triangleright \Gamma' \mid C}{\Gamma \vdash t_1 \mapsto t_2 : V \triangleright \Gamma' \mid C \cup \{V = X_1 \multimap X_2\}} \multimap_R \\
& \mu_L \frac{\Gamma, u : [Y \rightarrow \mu Y.U]U \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, \text{fold}_{\mu Y.U} u : V \vdash t : T \triangleright \Gamma' \mid C \cup \{V = \mu Y.U\}} \quad \frac{\Gamma \vdash t : [X \rightarrow \mu X.T]T \triangleright \Gamma' \mid C}{\Gamma \vdash \text{fold}_{\mu X.T} t : V \triangleright \Gamma' \mid C \cup \{V = \mu X.T\}} \mu_R \\
& \text{Trace}_L \frac{\Gamma, u : U \oplus X_1 \multimap U \oplus X_2 \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, \text{trace}_U u : V \vdash t : T \triangleright \Gamma' \mid C \cup \{V = X_1 \multimap X_2\}} \quad \frac{\Gamma \vdash t : T \oplus X_1 \multimap T \oplus X_2 \triangleright \Gamma' \mid C}{\Gamma \vdash \text{trace}_T t : V \triangleright \Gamma' \mid C \cup \{V = X_1 \multimap X_2\}} \text{Trace}_R \\
& \text{Par}_L \frac{\Gamma, t_1 : X \vdash t : T \triangleright \Gamma' \mid C_1 \quad \Gamma, t_2 : X \vdash t : T \triangleright \Gamma' \mid C_2}{\Gamma, t_1 \parallel t_2 : V \vdash t : T \triangleright \Gamma' \mid C_1 \cup C_2 \cup \{V = X\}} \quad \frac{\Gamma \vdash t_1 : X \triangleright \Gamma' \mid C_1 \quad \Gamma \vdash t_2 : X \triangleright \Gamma' \mid C_2}{\Gamma \vdash t_1 \parallel t_2 : V \triangleright \Gamma' \mid C_1 \cup C_2 \cup \{V = X\}} \text{Par}_R \\
& \text{Seq}_L \frac{\Gamma, t_1 : X_1 \multimap X_2, t_2 : X_2 \multimap X_3 \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, t_1 ; t_2 : V \vdash t : T \triangleright \Gamma' \mid C \cup \{V = X_1 \multimap X_3\}} \quad \frac{\Gamma \vdash t_1 : X_1 \multimap X_2 \triangleright \Gamma' \mid C_1 \quad \Gamma' \vdash t_2 : X_2' \multimap X_3 \triangleright \Gamma'' \mid C_2}{\Gamma \vdash t_1 ; t_2 : V \triangleright \Gamma'' \mid C_1 \cup C_2 \cup \{V = X_1 \multimap X_3\}} \text{Seq}_R \\
& \dagger_L \frac{\Gamma, u : X_2 \multimap X_1 \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, u^\dagger : \vdash t : T \triangleright \Gamma' \mid C \cup \{V = X_1 \multimap X_2\}} \quad \frac{\Gamma \vdash t : X_2 \multimap X_1 \triangleright \Gamma' \mid C}{\Gamma \vdash t^\dagger : V \triangleright \Gamma' \mid C \cup \{V = X_1 \multimap X_2\}} \dagger_R \\
& \text{id}_L \frac{\Gamma \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, \text{id} : V \vdash t : T \triangleright \Gamma' \mid C \cup \{V = X \multimap X\}} \quad \frac{}{\Gamma \vdash \text{id} : V \triangleright \Gamma \mid \{V = X \multimap X\}} \text{id}_R \\
& \emptyset_L \frac{\Gamma \vdash t : T \triangleright \Gamma' \mid C}{\Gamma, \emptyset : V \vdash t : T \triangleright \Gamma' \mid C \cup \{V = X\}} \quad \frac{}{\Gamma \vdash \emptyset : V \triangleright \Gamma \mid \{V = X\}} \emptyset_R \\
& \text{App} \frac{\vdash f : X_1 \multimap X_2 \triangleright \mid C_1 \quad \vdash e : X_1 \triangleright \mid C_2}{\vdash f @ e : V \triangleright \mid C_1 \cup C_2 \cup \{V = X_2\}}
\end{aligned}$$

図7 Type Inference rules

5 表示の意味論

$$\begin{aligned}
\llbracket \Theta \vdash T \rrbracket &: \mathcal{V}^{|\Theta|} \rightarrow \mathcal{V} \\
\llbracket \Theta \vdash X_i \rrbracket &:= \Pi_i \\
\llbracket \Theta \vdash \mathbf{I} \rrbracket &:= K_I \\
\llbracket \Theta \vdash T_1 \oplus T_2 \rrbracket &:= \oplus \circ \langle \llbracket \Theta \vdash T_1 \rrbracket, \llbracket \Theta \vdash T_2 \rrbracket \rangle \\
\llbracket \Theta \vdash T_1 \otimes T_2 \rrbracket &:= \otimes \circ \langle \llbracket \Theta \vdash T_1 \rrbracket, \llbracket \Theta \vdash T_2 \rrbracket \rangle \\
\llbracket \Theta \vdash T_1 \multimap T_2 \rrbracket &:= \otimes \circ \langle \llbracket \Theta \vdash T_1 \rrbracket^*, \llbracket \Theta \vdash T_2 \rrbracket \rangle \\
\llbracket \Theta \vdash \mu X. T \rrbracket &:= \llbracket \Theta, X \vdash T \rrbracket^\# \\
\llbracket \Theta \vdash T[X \rightarrow U] \rrbracket &:= \llbracket \Theta \vdash T \rrbracket \circ \langle Id, \llbracket \Theta \vdash U \rrbracket \rangle \\
\llbracket T \rrbracket &:= \llbracket \vdash T \rrbracket(*) \in \text{Obj}(\mathcal{V})
\end{aligned}$$

図 8 Type Interpretation

$$\begin{aligned}
\llbracket \Gamma \rrbracket &\in \text{Obj}(\mathcal{V}) \\
\llbracket \rrbracket &:= I \\
\llbracket \Gamma, () : \mathbf{I} \rrbracket &:= \llbracket \Gamma \rrbracket \\
\llbracket \Gamma, \text{inl } t_1 : T_1 \oplus T_2 \rrbracket &:= \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \oplus \llbracket T_2 \rrbracket) \\
\llbracket \Gamma, \text{inr } t_2 : T_1 \oplus T_2 \rrbracket &:= \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \oplus \llbracket T_2 \rrbracket) \\
\llbracket \Gamma, t_1 \times t_2 : T_1 \otimes T_2 \rrbracket &:= \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \otimes \llbracket T_2 \rrbracket) \\
\llbracket \Gamma, t_1 \mapsto t_2 : T_1 \multimap T_2 \rrbracket &:= \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket) \\
\llbracket \Gamma, \text{fold}_{\mu X. T} u : \mu X. T \rrbracket &:= \llbracket \Gamma \rrbracket \otimes \llbracket \mu X. T \rrbracket \\
\llbracket \Gamma, \text{trace}_T t : T_1 \multimap T_2 \rrbracket &:= \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket) \\
\llbracket \Gamma, t_1 \parallel t_2 : T \rrbracket &:= \llbracket \Gamma \rrbracket \otimes \llbracket T \rrbracket \\
\llbracket \Gamma, t_1 \circ t_2 : T_1 \multimap T_3 \rrbracket &:= \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \multimap \llbracket T_3 \rrbracket) \\
\llbracket \Gamma, t^\dagger : T_1 \multimap T_2 \rrbracket &:= \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket) \\
\llbracket \Gamma, \text{id} : T \multimap T \rrbracket &:= \llbracket \Gamma \rrbracket \\
\llbracket \Gamma, \emptyset : T \rrbracket &:= \llbracket \Gamma \rrbracket \\
\llbracket f @ e : T \rrbracket &:= \llbracket \Gamma \rrbracket \otimes \llbracket T \rrbracket
\end{aligned}$$

図 9 Context Interpretation

$$\begin{aligned}
& \llbracket \Gamma \vdash t : T \rrbracket : \llbracket \Gamma \rrbracket \rightarrow \llbracket T \rrbracket \\
& \llbracket x : T \vdash x : T \rrbracket := \llbracket T \rrbracket \xrightarrow{id_{\llbracket T \rrbracket}} \llbracket T \rrbracket \\
& \llbracket \Gamma_1, \Gamma_2 \vdash t : T \rrbracket := \llbracket \Gamma_1 \rrbracket \otimes \llbracket \Gamma_2 \rrbracket \xrightarrow{\sigma_{\llbracket \Gamma_1 \rrbracket, \llbracket \Gamma_2 \rrbracket}} \llbracket \Gamma_2 \rrbracket \otimes \llbracket \Gamma_1 \rrbracket \xrightarrow{\llbracket \Gamma_2, \Gamma_1 \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket \Gamma, () : I \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \otimes I \xrightarrow{\rho_{\llbracket \Gamma \rrbracket}} \llbracket \Gamma \rrbracket \xrightarrow{\llbracket \Gamma \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket () \vdash () : I \rrbracket := \llbracket I \rrbracket \xrightarrow{id_I} \llbracket I \rrbracket \\
& \llbracket \Gamma, \text{inl } t_1 : T_1 \oplus T_2 \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \oplus \llbracket T_2 \rrbracket) \xrightarrow{id_{\llbracket \Gamma \rrbracket} \otimes \pi_1} \llbracket \Gamma \rrbracket \otimes \llbracket T_1 \rrbracket \xrightarrow{\llbracket \Gamma, t_1 : T_1 \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket \Gamma \vdash \text{inl } t_1 : T_1 \oplus T_2 \rrbracket := \llbracket \Gamma \rrbracket \xrightarrow{\llbracket \Gamma \vdash t_1 : T_1 \rrbracket} \llbracket T_1 \rrbracket \xrightarrow{t_1} \llbracket T_1 \rrbracket \oplus \llbracket T_2 \rrbracket \\
& \llbracket \Gamma, \text{inr } t_2 : T_1 \oplus T_2 \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \oplus \llbracket T_2 \rrbracket) \xrightarrow{id_{\llbracket \Gamma \rrbracket} \otimes \pi_2} \llbracket \Gamma \rrbracket \otimes \llbracket T_2 \rrbracket \xrightarrow{\llbracket \Gamma, t_2 : T_2 \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket \Gamma \vdash \text{inr } t_2 : T_1 \oplus T_2 \rrbracket := \llbracket \Gamma \rrbracket \xrightarrow{\llbracket \Gamma \vdash t_2 : T_2 \rrbracket} \llbracket T_2 \rrbracket \xrightarrow{t_2} \llbracket T_1 \rrbracket \oplus \llbracket T_2 \rrbracket \\
& \llbracket \Gamma, t_1 \times t_2 : T_1 \otimes T_2 \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \otimes \llbracket T_2 \rrbracket) \xrightarrow{\llbracket \Gamma, t_1 : T_1, t_2 : T_2 \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket \Gamma_1, \Gamma_2 \vdash t_1 \times t_2 : T_1 \otimes T_2 \rrbracket := \llbracket \Gamma_1 \rrbracket \otimes \llbracket \Gamma_2 \rrbracket \xrightarrow{\llbracket \Gamma_1 \vdash t_1 : T_1 \rrbracket \otimes \llbracket \Gamma_2 \vdash t_2 : T_2 \rrbracket} \llbracket T_1 \rrbracket \otimes \llbracket T_2 \rrbracket \\
& \llbracket \Gamma_1, \Gamma_2, t_1 \mapsto t_2 : T_1 \multimap T_2 \vdash t : T \rrbracket := \left(\llbracket \Gamma_1 \rrbracket \otimes \llbracket \Gamma_2 \rrbracket \otimes (\llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket) \cong \llbracket \Gamma_1 \rrbracket \otimes (\llbracket \Gamma_2 \rrbracket \otimes \llbracket T_2 \rrbracket) \otimes \llbracket T_1 \rrbracket^* \rightarrow \llbracket T \rrbracket \right) \\
& \quad \cong \left(\llbracket \Gamma_1 \rrbracket \otimes (\llbracket \Gamma_2 \rrbracket \otimes \llbracket T_2 \rrbracket) \xrightarrow{\llbracket \Gamma_1 \vdash t_1 : T_1 \rrbracket \otimes \llbracket \Gamma_2, t_2 : T_2 \vdash t : T \rrbracket} \llbracket T_1 \rrbracket \otimes \llbracket T \rrbracket \right) \\
& \llbracket \Gamma \vdash t_1 \mapsto t_2 : T_1 \multimap T_2 \rrbracket := \llbracket \Gamma \rrbracket \rightarrow \llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket \cong \left(\llbracket \Gamma \rrbracket \otimes \llbracket T_1 \rrbracket \xrightarrow{\llbracket \Gamma, t_1 : T_1 \vdash t_2 : T_2 \rrbracket} \llbracket T_2 \rrbracket \right) \\
& \llbracket \Gamma, \text{fold}_{\mu X.U} u : \mu X.U \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \otimes \llbracket \mu X.U \rrbracket \xrightarrow{id_{\llbracket \Gamma \rrbracket} \otimes \text{unfold}_{\mu X.U}} \llbracket \Gamma \rrbracket \otimes \llbracket [X \rightarrow \mu X.U](U) \rrbracket \\
& \quad \xrightarrow{\llbracket \Gamma, u : [X \rightarrow \mu X.U](U) \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket \Gamma \vdash \text{fold}_{\mu X.T} t : \mu X.T \rrbracket := \llbracket \Gamma \rrbracket \xrightarrow{\llbracket \Gamma \vdash t : [X \rightarrow \mu X.T](T) \rrbracket} \llbracket [X \rightarrow \mu X.T](T) \rrbracket \xrightarrow{\text{fold}_{\mu X.T}} \llbracket \mu X.T \rrbracket \\
& \llbracket \Gamma, \text{trace}_U u : T_1 \multimap T_2 \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket) \xrightarrow{id_{\llbracket \Gamma \rrbracket} \otimes \text{Tr}_{\llbracket T_1 \rrbracket, \llbracket T_2 \rrbracket}^{\llbracket U \rrbracket}} (\llbracket \Gamma, t : (U \oplus T_1) \multimap (U \oplus T_2) \vdash t : T \rrbracket) \rightarrow \llbracket T \rrbracket \\
& \llbracket \Gamma \vdash \text{trace}_U t : T_1 \multimap T_2 \rrbracket := \llbracket \Gamma \rrbracket \xrightarrow{\text{Tr}_{\llbracket T_1 \rrbracket, \llbracket T_2 \rrbracket}^{\llbracket U \rrbracket}(\llbracket \Gamma \vdash t : U \oplus T_1 \multimap U \oplus T_2 \rrbracket)} \llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket \\
& \llbracket \Gamma, t_1 \parallel t_2 : U \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \otimes \llbracket U \rrbracket \xrightarrow{id_{\llbracket \Gamma \rrbracket} \otimes (\llbracket \Gamma, t_1 : U \vdash t : T \rrbracket + \llbracket \Gamma, t_2 : U \vdash t : T \rrbracket)} \llbracket T \rrbracket \\
& \llbracket \Gamma \vdash t_1 \parallel t_2 : T \rrbracket := \llbracket \Gamma \rrbracket \xrightarrow{\llbracket \Gamma \vdash t_1 : T \rrbracket + \llbracket \Gamma \vdash t_2 : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket \Gamma, t_1 \circ t_2 : T_1 \multimap T_3 \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \multimap \llbracket T_3 \rrbracket) \\
& \quad \xrightarrow{id_{\llbracket \Gamma \rrbracket} \otimes \text{decomp}_{\llbracket T_1 \rrbracket, \llbracket T_2 \rrbracket, \llbracket T_3 \rrbracket}} \llbracket \Gamma \rrbracket \otimes ((\llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket) \otimes (\llbracket T_2 \rrbracket \multimap \llbracket T_3 \rrbracket)) \\
& \quad \xrightarrow{\llbracket \Gamma, t_1 : T_1 \multimap T_2, t_2 : T_2 \multimap T_3 \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket \Gamma_1, \Gamma_2 \vdash t_1 \circ t_2 : T_1 \multimap T_3 \rrbracket := \llbracket \Gamma_1 \rrbracket \otimes \llbracket \Gamma_2 \rrbracket \xrightarrow{\llbracket \Gamma_1 \vdash t_1 : T_1 \multimap T_2 \rrbracket \otimes \llbracket \Gamma_2 \vdash t_2 : T_2 \multimap T_3 \rrbracket} (\llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket) \otimes (\llbracket T_2 \rrbracket \multimap \llbracket T_3 \rrbracket) \\
& \quad \xrightarrow{\text{comp}_{\llbracket T_1 \rrbracket, \llbracket T_2 \rrbracket, \llbracket T_3 \rrbracket}} \llbracket T_1 \rrbracket \multimap \llbracket T_3 \rrbracket \\
& \llbracket \Gamma, u^\dagger : T_1 \multimap T_2 \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \otimes (\llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket) \xrightarrow{id_{\llbracket \Gamma \rrbracket} \otimes \text{dagger}_{\llbracket T_1 \rrbracket, \llbracket T_2 \rrbracket}} \llbracket \Gamma \rrbracket \otimes (\llbracket T_2 \rrbracket \multimap \llbracket T_1 \rrbracket) \xrightarrow{\llbracket \Gamma, u : T_2 \multimap T_1 \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket \Gamma \vdash t^\dagger : T_1 \multimap T_2 \rrbracket := \llbracket \Gamma \rrbracket \xrightarrow{\llbracket \Gamma \vdash t : T_2 \multimap T_1 \rrbracket} \llbracket T_2 \rrbracket \multimap \llbracket T_1 \rrbracket \xrightarrow{\text{dagger}_{\llbracket T_1 \rrbracket, \llbracket T_2 \rrbracket}} \llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket \\
& \llbracket \Gamma, \text{id} : U \multimap U \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \xrightarrow{\llbracket \Gamma \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket () \vdash \text{id} : T \multimap T \rrbracket := \llbracket I \rrbracket \rightarrow \llbracket T \rrbracket \multimap \llbracket T \rrbracket \cong \left(\llbracket T \rrbracket \xrightarrow{id_{\llbracket T \rrbracket}} \llbracket T \rrbracket \right) \\
& \llbracket \Gamma, \emptyset : U \vdash t : T \rrbracket := \llbracket \Gamma \rrbracket \xrightarrow{\llbracket \Gamma \vdash t : T \rrbracket} \llbracket T \rrbracket \\
& \llbracket \Gamma \vdash \emptyset : T \rrbracket := \llbracket \Gamma \rrbracket \xrightarrow{0_{\llbracket \Gamma \rrbracket, \llbracket T \rrbracket}} \llbracket T \rrbracket \\
& \llbracket () \vdash t @ t_1 : T_2 \rrbracket := \llbracket I \rrbracket \xrightarrow{\llbracket () \vdash t : T_1 \multimap T_2 \rrbracket \otimes \llbracket () \vdash t_1 : T_1 \rrbracket} (\llbracket T_1 \rrbracket \multimap \llbracket T_2 \rrbracket) \otimes \llbracket T_1 \rrbracket \xrightarrow{\text{eval}_{\llbracket T_1 \rrbracket, \llbracket T_2 \rrbracket}} \llbracket T_2 \rrbracket
\end{aligned}$$

6 操作的意味論

$$\sigma_1 \cup_{\perp}^+ \sigma_2 := \begin{cases} \perp & \text{if } \sigma_1 = \perp \vee \sigma_2 = \perp \\ \sigma_1 \cup \sigma_2 & \text{otherwise} \end{cases}$$

$$\sigma_1 \cup_{\perp}^{\times} \sigma_2 := \begin{cases} \perp & \text{if } \sigma_1 = \perp \wedge \sigma_2 = \perp \\ \sigma_1 & \text{if } \sigma_2 = \perp \\ \sigma_2 & \text{if } \sigma_1 = \perp \\ \sigma_1 \cup \sigma_2 & \text{otherwise} \end{cases}$$

図 11 Operations on Environment σ

$$\begin{aligned} x \triangleright t &:= [x \rightarrow t] \\ () \triangleright () &:= [] \\ \text{inl } t \triangleright \text{inl } u &:= t \triangleright u \\ \text{inl } t \triangleright \text{inr } u &:= \perp \\ \text{inr } t \triangleright \text{inr } u &:= t \triangleright u \\ \text{inr } t \triangleright \text{inl } u &:= \perp \\ t_1 \times t_2 \triangleright u_1 \times u_2 &:= (t_1 \triangleright u_1) \cup_{\perp}^{\times} (t_2 \triangleright u_2) \\ t_1 \mapsto t_2 \triangleright u_1 \mapsto u_2 &:= (t_1 \triangleright u_1) \cup_{\perp}^{\times} (t_2 \triangleright u_2) \\ \text{fold}_T t \triangleright \text{fold}_T u &:= t \triangleright u \\ \text{trace}_T t \triangleright \text{trace}_T u &:= t \triangleright u \\ t \triangleright u_1 \parallel u_2 &:= (t \triangleright u_1) \cup_{\perp}^+ (t \triangleright u_2) \\ t_1 \parallel t_2 \triangleright u &:= (t_1 \triangleright u) \cup_{\perp}^+ (t_2 \triangleright u) \\ t_1 \circ t_2 \triangleright u_1 \circ u_2 &:= (t_1 \triangleright u_1) \cup_{\perp}^{\times} (t_2 \triangleright u_2) \\ t \circ x \triangleright u &:= x \triangleright t^{\dagger} \circ u \\ x \circ t \triangleright u &:= x \triangleright u \circ t^{\dagger} \\ t^{\dagger} \triangleright u &:= t \triangleright u^{\dagger} \\ \text{id} \triangleright \text{id} &:= [] \\ \emptyset \triangleright u &:= \perp \\ t \triangleright \emptyset &:= \perp \end{aligned}$$

図 12 Constructing Environment

$$\begin{aligned} [](x) &:= \emptyset \\ [\sigma, x \rightarrow t](x) &:= t \\ [\sigma, x' \rightarrow t](x) &:= \emptyset \\ [\sigma]() &:= () \\ [\sigma](\text{inl } t) &:= \text{inl } [\sigma](t) \\ [\sigma](\text{inr } t) &:= \text{inr } [\sigma](t) \\ [\sigma_1, \sigma_2](t_1 \times t_2) &:= [\sigma](t_1) \times [\sigma](t_2) \\ [\sigma_1, \sigma_2](t_1 \mapsto t_2) &:= [\sigma](t_1) \mapsto [\sigma](t_2) \\ [\sigma](\text{fold}_T t) &:= \text{fold}_T [\sigma](t) \\ [\sigma](\text{trace}_T t) &:= \text{trace}_T [\sigma](t) \\ [\sigma_1, \sigma_2](t_1 \parallel t_2) &:= [\sigma](t_1) \parallel [\sigma](t_2) \\ [\sigma](t_1 \circ t_2) &:= [\sigma](t_1) \circ [\sigma](t_2) \\ [\sigma](t^{\dagger}) &:= [\sigma](t)^{\dagger} \\ [\sigma](\text{id}) &:= \text{id} \\ [](\emptyset) &:= \emptyset \\ [\perp](t) &:= \emptyset \end{aligned}$$

図 13 Consumption of Environment

$$\begin{array}{ll}
\emptyset \parallel t \Rightarrow t & \emptyset^\dagger \Rightarrow \emptyset \\
(t_1 \parallel t_2) \parallel t_3 \Rightarrow t_1 \parallel (t_2 \parallel t_3) & \text{id}^\dagger \Rightarrow \text{id} \\
t_1 \parallel t_2 \Rightarrow t_2 \parallel t_1 & ()^\dagger \Rightarrow () \\
t \parallel t \Rightarrow t & (t_1 \parallel t_2)^\dagger \Rightarrow t_1^\dagger \parallel t_2^\dagger \\
\text{id} \circ t \Rightarrow t & (t_1 \circ t_2)^\dagger \Rightarrow t_1^\dagger \circ t_2^\dagger \\
t \circ \text{id} \Rightarrow t & (\text{inl } t)^\dagger \Rightarrow \text{inl } t^\dagger \\
(t_1 \circ t_2) \circ t_3 \Rightarrow t_1 \circ (t_2 \circ t_3) & (\text{inr } t)^\dagger \Rightarrow \text{inr } t^\dagger \\
\emptyset \circ t \Rightarrow \emptyset & (t_1 \times t_2)^\dagger \Rightarrow t_1^\dagger \times t_2^\dagger \\
t \circ \emptyset \Rightarrow \emptyset & (t_1 \mapsto t_2)^\dagger \Rightarrow t_1^\dagger \mapsto t_2^\dagger \\
(t_1 \parallel t_2) \circ t_3 \Rightarrow (t_1 \circ t_3) \parallel (t_2 \circ t_3) & (\text{fold}_T t)^\dagger \Rightarrow \text{fold}_T t^\dagger \\
t_1 \circ (t_2 \parallel t_3) \Rightarrow (t_1 \circ t_2) \parallel (t_1 \circ t_3) & (\text{trace}_T t)^\dagger \Rightarrow \text{trace}_T t^\dagger \\
& (t^\dagger)^\dagger \Rightarrow t \\
\text{inl } \emptyset \Rightarrow \emptyset & \text{inl } (t_1 \parallel t_2) \Rightarrow \text{inl } t_1 \parallel \text{inl } t_2 \\
\text{inr } \emptyset \Rightarrow \emptyset & \text{inr } (t_1 \parallel t_2) \Rightarrow \text{inr } t_1 \parallel \text{inr } t_2 \\
\emptyset \times t \Rightarrow \emptyset & (t_1 \parallel t_2) \times t_3 \Rightarrow (t_1 \times t_3) \parallel (t_2 \times t_3) \\
t \times \emptyset \Rightarrow \emptyset & t_1 \times (t_2 \parallel t_3) \Rightarrow (t_1 \times t_2) \parallel (t_1 \times t_3) \\
\emptyset \mapsto t \Rightarrow \emptyset & (t_1 \parallel t_2) \mapsto t_3 \Rightarrow (t_1 \mapsto t_3) \parallel (t_2 \mapsto t_3) \\
t \mapsto \emptyset \Rightarrow \emptyset & t_1 \mapsto (t_2 \parallel t_3) \Rightarrow (t_1 \mapsto t_2) \parallel (t_1 \mapsto t_3) \\
\text{fold}_T \emptyset \Rightarrow \emptyset & \text{fold}_T (t_1 \parallel t_2) \Rightarrow \text{fold}_T t_1 \parallel \text{fold}_T t_2 \\
\text{trace}_T \emptyset \Rightarrow \emptyset & \\
\\
t_1 \Rightarrow t'_1 \Rightarrow t_2 \Rightarrow t'_2 \Rightarrow t_1 \parallel t_2 \Rightarrow t'_1 \parallel t'_2 & \\
t_1 \Rightarrow t'_1 \Rightarrow t_2 \Rightarrow t'_2 \Rightarrow t_1 \circ t_2 \Rightarrow t'_1 \circ t'_2 & \\
t \Rightarrow t' \Rightarrow \text{inl } t \Rightarrow \text{inl } t' & \\
t \Rightarrow t' \Rightarrow \text{inr } t \Rightarrow \text{inr } t' & \\
t_1 \Rightarrow t'_1 \Rightarrow t_2 \Rightarrow t'_2 \Rightarrow t_1 \times t_2 \Rightarrow t'_1 \times t'_2 & \\
t_1 \Rightarrow t'_1 \Rightarrow t_2 \Rightarrow t'_2 \Rightarrow t_1 \mapsto t_2 \Rightarrow t'_1 \mapsto t'_2 & \\
t \Rightarrow t' \Rightarrow \text{fold}_T t \Rightarrow \text{fold}_T t' & \\
t \Rightarrow t' \Rightarrow \text{trace}_T t \Rightarrow \text{trace}_T t' & \\
t_1 \Rightarrow t'_1 \Rightarrow t_2 \Rightarrow t'_2 \Rightarrow t_1 @ t_2 \Rightarrow t'_1 @ t'_2 & \\
\\
(t_1 \mapsto t_2) @ t \Rightarrow (t_1 \triangleright t) t_2 & \\
\emptyset @ t \Rightarrow \emptyset & (t_1 \parallel t_2) @ t \Rightarrow (t_1 @ t) \parallel (t_2 @ t) \\
t @ \emptyset \Rightarrow \emptyset & t @ (t_1 \parallel t_2) \Rightarrow (t @ t_1) \parallel (t @ t_2) \\
\text{id} @ t \Rightarrow t & t_1 \circ t_2 @ t \Rightarrow t_2 @ (t_1 @ t) \\
\\
t @ (\text{inr } u) \Rightarrow \text{inr } u' \Rightarrow (\text{trace}_T t) @ u \Rightarrow u' & \\
t @ (\text{inl } u) \Rightarrow \text{inl } u' \Rightarrow (\text{trace}_T t) @ (\text{inl } u') \Rightarrow u'' \Rightarrow (\text{trace}_T t) @ u \Rightarrow u'' & \\
t @ (\text{inl } u) \Rightarrow \text{inl } u' \Rightarrow (\text{trace}_T t) @ (\text{inl } u') \Rightarrow u'' \Rightarrow (\text{trace}_T t) @ u \Rightarrow u'' & \\
t @ (\text{inl } u) \Rightarrow \text{inr } u' \Rightarrow (\text{trace}_T t) @ (\text{inl } u) \Rightarrow u' &
\end{array}$$

⊠ 14 Reduction