`salt1`: Immutable References

`CS392-M1`: *Rust, In Practice and in Theory*

Syntax

$$
\begin{aligned}
&x && \text{(variables, } \mathcal{V}\text{)} \\
&n && \text{(integers, } \mathbb{Z}\text{)} \\
&w ::= x \mid \texttt{*}\, w && \text{(place expression, } \mathcal{W}\text{)} \\
&e ::= \texttt{()} \mid n \mid w \mid \texttt{\&}\, w \mid x \texttt{ = } e && \text{(expressions, } \mathcal{E}\text{)} \\
&s ::= \texttt{let } x \texttt{ = } e \mid \texttt{let mut } x \texttt{ = } e \mid e && \text{(statements, } \mathcal{S}\text{)} \\
&p ::= e \mid s \texttt{ ; } p && \text{(programs, } \mathcal{P}\text{)}
\end{aligned}
$$

Typing

$$t ::= \texttt{()} \mid \texttt{i32} \mid \texttt{\&}\, x \qquad \text{(types, } \mathcal{T}\text{)}$$

$$m ::= \mathsf{imm} \mid \mathsf{mut} \qquad \text{(mutability)}$$

$$u ::= \langle t \rangle^m \qquad \text{(slot types, } \mathbb{S}_{\mathcal{T}}\text{)}$$

$$\Gamma \in \mathcal{V} \mapsto \mathbb{S}_{\mathcal{T}} \qquad \text{(contexts)}$$

$$\Gamma \vdash \mathsf{writable}(x) \qquad \text{(writability)}$$

$$\Gamma \vdash w : u \qquad \text{(place expressions)}$$

$$\Gamma \vdash t \approx t \qquad \text{(type compatibility)}$$

$$\Gamma \vdash e : t \dashv \Gamma \qquad \text{(expressions)}$$

$$\Gamma \vdash s \dashv \Gamma \qquad \text{(statments)}$$

$$\Gamma \vdash p : t \dashv \Gamma \qquad \text{(programs)}$$

$$\frac{(x \mapsto \langle t \rangle^m) \in \Gamma}{\Gamma \vdash x : \langle t \rangle^m}\ \textsc{var} \qquad \frac{\Gamma \vdash w : \langle \texttt{\&}\, x \rangle^{m_1} \qquad \Gamma \vdash x : \langle t \rangle^{m_2}}{\Gamma \vdash \texttt{*}\, w : \langle t \rangle^{m_2}}\ \textsc{deref} \qquad \frac{}{\Gamma \vdash \texttt{()} : \texttt{()}}\ \textsc{unit}$$

$$\frac{n \in \mathbb{Z}}{\Gamma \vdash n : \texttt{i32} \dashv \Gamma}\ \textsc{int} \qquad \frac{\Gamma \vdash w : \langle t \rangle^m}{\Gamma \vdash w : t \dashv \Gamma}\ \textsc{place} \qquad \frac{\Gamma \vdash x : \langle t \rangle^m}{\Gamma \vdash \texttt{\&}\, x : \texttt{\&}\, x \dashv \Gamma}\ \textsc{refVar}$$

$$\frac{\Gamma \vdash w : \langle \texttt{\&}\, x \rangle^m}{\Gamma \vdash \texttt{\&}\, \texttt{*}\, w : \texttt{\&}\, x \dashv \Gamma}\ \textsc{refDeref} \qquad \frac{}{\Gamma \vdash \texttt{()} \approx \texttt{()}}\ \approx\text{-}\textsc{unit} \qquad \frac{}{\Gamma \vdash \texttt{i32} \approx \texttt{i32}}\ \approx\text{-}\textsc{int}$$

$$\frac{\Gamma \vdash x_1 : \langle t_1 \rangle^{m_1} \qquad \Gamma \vdash x_2 : \langle t_2 \rangle^{m_2} \qquad \Gamma \vdash t_1 \approx t_2}{\Gamma \vdash \texttt{\&}\, x_1 \approx \texttt{\&}\, x_2}\ \approx\text{-}\textsc{ref} \qquad \frac{\nexists y.(y \mapsto \langle \texttt{\&}\, x \rangle^m) \in \Gamma}{\Gamma \vdash \mathsf{writable}(x)}\ \textsc{writable}$$

$$\frac{\Gamma_1 \vdash x : \langle t_1 \rangle^{\mathsf{mut}} \qquad \Gamma_1 \vdash e : t_2 \dashv \Gamma_2 \qquad \Gamma_2 \vdash t_1 \approx t_2 \qquad \Gamma_2 \vdash \mathsf{writable}(x)}{\Gamma_1 \vdash x \,\texttt{=}\, e : \texttt{()} \dashv \Gamma_2[x \mapsto \langle t_2 \rangle^{\mathsf{mut}}]}\ \textsc{assign}$$

$$\frac{\Gamma_1 \vdash e : t \dashv \Gamma_2 \qquad x \notin \mathrm{dom}(\Gamma_2)}{\Gamma_1 \vdash \texttt{let}\ x \,\texttt{=}\, e \dashv \Gamma_2[x \mapsto \langle t \rangle^{\mathsf{imm}}]}\ \textsc{let} \qquad \frac{\Gamma_1 \vdash e : t \dashv \Gamma_2 \qquad x \notin \mathrm{dom}(\Gamma_2)}{\Gamma_1 \vdash \texttt{let mut}\ x \,\texttt{=}\, e \dashv \Gamma_2[x \mapsto \langle t \rangle^{\mathsf{mut}}]}\ \textsc{letMut}$$

$$\frac{\Gamma_1 \vdash e : t \dashv \Gamma_2}{\Gamma_1 \vdash e \dashv \Gamma_2}\ \textsc{exprStmt} \qquad \frac{\Gamma_1 \vdash s \dashv \Gamma_2 \qquad \Gamma_2 \vdash p : t \dashv \Gamma_3}{\Gamma_1 \vdash s\ \texttt{;}\ p : t \dashv \Gamma_3}\ \textsc{prog}$$

Evaluation

$$\ell ::= \ell_x \qquad \text{(locations, } \mathcal{L}\text{)}$$
$$v ::= \texttt{()} \mid n \mid \ell \qquad \text{(values, } \mathbb{V}\text{)}$$

$$S \in \mathcal{L} \mapsto \mathbb{V} \qquad \text{(store)}$$

$$S \vdash w \rightsquigarrow \ell \qquad \text{(place locations)}$$
$$S \vdash e \Downarrow v \dashv S \qquad \text{(expressions)}$$
$$S \vdash s \dashv S \qquad \text{(statements)}$$
$$S \vdash p \Downarrow v \dashv S \qquad \text{(programs)}$$

$$\frac{}{S \vdash x \rightsquigarrow \ell_x}\ \textsc{LocVar} \qquad \frac{S \vdash w \rightsquigarrow \ell_x \qquad (\ell_x \mapsto \ell_y) \in S}{S \vdash \texttt{*}\, w \rightsquigarrow \ell_y}\ \textsc{LocDeref} \qquad \frac{}{S \vdash \texttt{()} \Downarrow \texttt{()} \dashv S}\ \textsc{Unit}$$

$$\frac{n \in \mathbb{Z}}{S \vdash n \Downarrow n \dashv S}\ \textsc{Int} \qquad \frac{S \vdash w \rightsquigarrow \ell_x \qquad (\ell_x \mapsto v) \in S}{S \vdash w \Downarrow v \dashv S}\ \textsc{Place} \qquad \frac{S \vdash w \rightsquigarrow \ell_x}{S \vdash \texttt{\&}\, w \Downarrow \ell_x \dashv S}\ \textsc{Ref}$$

$$\frac{\ell_x \in \mathrm{dom}(S) \qquad S_1 \vdash e \Downarrow v \dashv S_2}{S_1 \vdash x \texttt{ = } e \Downarrow \texttt{()} \dashv S_2[\ell_x \mapsto v]}\ \textsc{Assign} \qquad \frac{S_1 \vdash e \Downarrow v \dashv S_2}{S_1 \vdash \texttt{let}\ x \texttt{ = } e \dashv S_2[\ell_x \mapsto v]}\ \textsc{Let}$$

$$\frac{S_1 \vdash e \Downarrow v \dashv S_2}{S_1 \vdash \texttt{let mut}\ x \texttt{ = } e \dashv S_2[\ell_x \mapsto v]}\ \textsc{LetMut} \qquad \frac{S_1 \vdash e \Downarrow v \dashv S_2}{S_1 \vdash e \dashv S_2}\ \textsc{ExprStmt}$$

$$\frac{S_1 \vdash s \dashv S_2 \qquad S_2 \vdash p \Downarrow v \dashv S_3}{S_1 \vdash s\ \texttt{;}\ p \Downarrow v \dashv S_3}\ \textsc{Prog}$$