`salt1`: Immutable References

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

Syntax

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

Typing

$$
\begin{array}{llr}
t & ::= \texttt{()} \mid \texttt{i32} \mid \texttt{\&}\, x & \text{(types, } \mathcal{T}\text{)} \\
m & ::= \mathsf{imm} \mid \mathsf{mut} & \text{(mutability)} \\
u & ::= \langle t \rangle^{m} & \text{(slot types, } \mathbb{S}_{\mathcal{T}}\text{)}
\end{array}
$$

$$
\begin{array}{lr}
\Gamma \in \mathcal{V} \mapsto \mathbb{S}_{\mathcal{T}} & \text{(contexts)}
\end{array}
$$

$$
\begin{array}{lr}
\Gamma \vdash w : u & \text{(place expressions)} \\
\Gamma \vdash \mathsf{writable}(x) & \text{(writability)} \\
\Gamma \vdash t \approx t & \text{(type compatibility)} \\
\Gamma \vdash e : t \dashv \Gamma & \text{(expressions)} \\
\Gamma \vdash s \dashv \Gamma & \text{(statments)} \\
\Gamma \vdash p : t \dashv \Gamma & \text{(programs)}
\end{array}
$$

$$\frac{(x \mapsto t^{m}) \in \Gamma}{\Gamma \vdash x : \langle t \rangle^{m}} \text{ (var)}$$

$$\frac{\Gamma \vdash w : \langle \texttt{\&}\, x \rangle^{m_1} \qquad \Gamma \vdash x : \langle t \rangle^{m_2}}{\Gamma \vdash \texttt{*}\, w : \langle t \rangle^{m_2}} \text{ (deref)}$$

$$\frac{}{\Gamma \vdash \texttt{()} : \texttt{()} \dashv \Gamma} \text{ (unit)}$$

$$\frac{n \in \mathbb{Z}}{\Gamma \vdash n : \texttt{i32} \dashv \Gamma} \text{ (int)}$$

$$\frac{\Gamma \vdash w : \langle t \rangle^{m}}{\Gamma \vdash w : t \dashv \Gamma} \text{ (place)}$$

$$\frac{\Gamma \vdash x : \langle t \rangle^{m}}{\Gamma \vdash \texttt{\&}\, x : \texttt{\&}\, x \dashv \Gamma} \text{ (ref-var)}$$

$$\frac{\Gamma \vdash w : \langle \texttt{\&}\ x \rangle^{m}}{\Gamma \vdash \texttt{\&}\,\texttt{*}\,w : \texttt{\&}\ x \dashv \Gamma}\ \text{(ref-drf)}$$

$$\frac{}{\Gamma \vdash \texttt{()} \approx \texttt{()}}\ (\approx\text{-unit})$$

$$\frac{}{\Gamma \vdash \texttt{i32} \approx \texttt{i32}}\ (\approx\text{-int})$$

$$\frac{\Gamma \vdash x_1 : \langle t_1 \rangle^{m} \qquad \Gamma \vdash x_2 : \langle t_2 \rangle^{m} \qquad \Gamma \vdash t_1 \approx t_2}{\Gamma \vdash \texttt{\&}\ x_1 \approx \texttt{\&}\ x_2}\ (\approx\text{-ref})$$

$$\frac{\nexists y.(y \mapsto \texttt{\&}\ x) \in \Gamma}{\Gamma \vdash \mathsf{writable}(x)}\ \text{(writable)}$$

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

$$\frac{\Gamma_1 \vdash e : t \dashv \Gamma_2 \qquad x \notin \mathsf{dom}(\Gamma_2)}{\Gamma_1 \vdash \texttt{let}\ x \ \texttt{=}\ e \dashv \Gamma_2[x \mapsto t^{\mathsf{imm}}]}\ \text{(let)}$$

$$\frac{\Gamma_1 \vdash e : t \dashv \Gamma_2 \qquad x \notin \mathsf{dom}(\Gamma_2)}{\Gamma_1 \vdash \texttt{let mut}\ x \ \texttt{=}\ e \dashv \Gamma_2[x \mapsto t^{\mathsf{mut}}]}\ \text{(let-mut)}$$

$$\frac{\Gamma_1 \vdash e : t \dashv \Gamma_2}{\Gamma_1 \vdash e \dashv \Gamma_2}\ \text{(expr-stmt)}$$

$$\frac{\Gamma_1 \vdash s \dashv \Gamma_2 \qquad \Gamma_2 \vdash p : t \dashv \Gamma_3}{\Gamma_1 \vdash s\ \texttt{;}\ p : t \dashv \Gamma_3}\ \text{(prog)}$$

Evaluation

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

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

$$\begin{aligned}
w &\rightsquigarrow \ell && \text{(place locations)} \\
\langle\, S \,,\, e \,\rangle &\Downarrow \langle\, S \,,\, v \,\rangle && \text{(expressions)} \\
\langle\, S \,,\, s \,\rangle &\Downarrow S && \text{(statements)} \\
\langle\, S \,,\, p \,\rangle &\Downarrow \langle\, S \,,\, v \,\rangle && \text{(programs)}
\end{aligned}$$

$$\frac{}{x \rightsquigarrow \ell_x}\ \text{(loc-var)}$$

$$\frac{w \rightsquigarrow \ell_x \qquad (\ell_x \mapsto \ell_y) \in S}{\texttt{*}\, w \rightsquigarrow \ell_y}\ \text{(loc-drf)}$$

$$\frac{}{\langle\, S \,,\, \texttt{()} \,\rangle \Downarrow \langle\, S \,,\, \texttt{()} \,\rangle}\ \text{(unit)}$$

$$\frac{n \in \mathbb{Z}}{\langle\, S \,,\, n \,\rangle \Downarrow \langle\, S \,,\, n \,\rangle}\ \text{(int)}$$

$$\frac{w \rightsquigarrow \ell_x \qquad (\ell_x \mapsto v) \in S}{\langle\, S \,,\, w \,\rangle \Downarrow \langle\, S \,,\, v \,\rangle}\ \text{(place)}$$

$$\frac{w \rightsquigarrow \ell_x}{\langle\, S \,,\, \texttt{\&}\, w \,\rangle \Downarrow \langle\, S \,,\, \ell_x \,\rangle}\ \text{(ref)}$$

$$\frac{\langle\, S_1 \,,\, e \,\rangle \Downarrow \langle\, S_2 \,,\, v \,\rangle}{\langle\, S_1 \,,\, x \texttt{ = } e \,\rangle \Downarrow \langle\, S_2[x \mapsto v] \,,\, \texttt{()} \,\rangle}\ \text{(assign)}$$

$$\frac{\langle\, S_1\,,\, e\,\rangle \Downarrow \langle\, S_2\,,\, v\,\rangle}{\langle\, S_1\,,\, \texttt{let}\ x \,\texttt{=}\, e\,\rangle \Downarrow S_2[x \mapsto v]}\ \text{(let)}$$

$$\frac{\langle\, S_1\,,\, e\,\rangle \Downarrow \langle\, S_2\,,\, v\,\rangle}{\langle\, S_1\,,\, \texttt{let mut}\ x \,\texttt{=}\, e\,\rangle \Downarrow S_2[x \mapsto v]}\ \text{(let-mut)}$$

$$\frac{\langle\, S_1\,,\, e\,\rangle \Downarrow \langle\, S_2\,,\, v\,\rangle}{\langle\, S_1\,,\, e\,\rangle \Downarrow S_2}\ \text{(expr-stmt)}$$

$$\frac{\langle\, S_1\,,\, s\,\rangle \Downarrow S_2 \qquad \langle\, S_2\,,\, p\,\rangle \Downarrow \langle\, S_3\,,\, v\,\rangle}{\langle\, S_1\,,\, s\ \texttt{;}\ p\,\rangle \Downarrow \langle\, S_3\,,\, v\,\rangle}\ \text{(prog)}$$