salt1: Immutable References

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

Syntax

$$x \qquad\qquad\qquad\qquad \text{(variables, } \mathcal{V})$$

$$n \qquad\qquad\qquad\qquad \text{(integers, } \mathbb{Z})$$

$$w ::= x \mid {*}\, w \qquad\qquad\qquad\qquad \text{(place expression, } \mathcal{W})$$

$$e ::= () \mid n \mid w \mid \&\, w \mid x = e \qquad\qquad\qquad\qquad \text{(expressions, } \mathcal{E})$$

$$s ::= \texttt{let } x = e \mid \texttt{let mut } x = e \mid e \qquad\qquad\qquad\qquad \text{(statements, } \mathcal{S})$$

$$p ::= e \mid s \,;\, p \qquad\qquad\qquad\qquad \text{(programs, } \mathcal{P})$$

Typing

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\frac{\Gamma \vdash x_1 : \langle t_1 \rangle^{m_1} \qquad \Gamma \vdash x_2 : \langle t_2 \rangle^{m_2} \qquad \Gamma \vdash t_1 \approx t_2}{\Gamma \vdash \texttt{\&}\ x_1 \approx \texttt{\&}\ x_2} \ \text{($\approx$-ref)}$$

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

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

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

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

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

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

Evaluation

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

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

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

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

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

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

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

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

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

$$\frac{\ell_x \in \mathsf{dom}(S) \qquad \langle\, S_1\, ,\, e\, \rangle \Downarrow \langle\, S_2\, ,\, v\, \rangle}{\langle\, S_1\, ,\, x = e\, \rangle \Downarrow \langle\, S_2[\ell_x \mapsto v]\, ,\, ()\, \rangle} \text{ (assign)}$$

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

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

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

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