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ERRATA

Stack-based typed assembly language

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The following three figures (figures 10, 11 and 12) were not shown in the original published version of the article. These figures constitute the entire static semantics of the STAL type system.

$$\boxed{\Delta \vdash \tau \quad \Delta \vdash \sigma \quad \vdash \Psi \quad \Delta \vdash \Gamma}$$

$$\text{(type)}\ \frac{}{\Delta \vdash \tau}\ (\mathrm{fv}(\tau) \subseteq \Delta) \qquad \text{(stype)}\ \frac{}{\Delta \vdash \sigma}\ (\mathrm{fv}(\sigma) \subseteq \Delta)$$

$$\text{(htype)}\ \frac{\cdot \vdash \tau_1 \quad \cdots \quad \cdot \vdash \tau_n}{\vdash \{\ell_1{:}\tau_1, \ldots, \ell_n{:}\tau_n\}} \qquad \text{(rftype)}\ \frac{\Delta \vdash \sigma \quad \Delta \vdash \tau_1 \quad \cdots \quad \Delta \vdash \tau_n}{\Delta \vdash \{\mathtt{sp}{:}\sigma, r_1{:}\tau_1, \ldots, r_n{:}\tau_n\}}$$

$$\boxed{\Delta \vdash \sigma_1 = \sigma_2}$$

$$\text{(seq-refl)}\ \frac{\Delta \vdash \sigma}{\Delta \vdash \sigma = \sigma} \qquad \text{(seq-sym)}\ \frac{\Delta \vdash \sigma_2 = \sigma_1}{\Delta \vdash \sigma_1 = \sigma_2}$$

$$\text{(seq-trans)}\ \frac{\Delta \vdash \sigma_1 = \sigma_2 \quad \Delta \vdash \sigma_2 = \sigma_3}{\Delta \vdash \sigma_1 = \sigma_3}$$

$$\text{(seq-cons)}\ \frac{\Delta \vdash \tau \quad \Delta \vdash \sigma_1 = \sigma_2}{\Delta \vdash \tau{::}\sigma_1 = \tau{::}\sigma_2} \qquad \text{(seq-append)}\ \frac{\Delta \vdash \sigma_1 = \sigma_1' \quad \Delta \vdash \sigma_2 = \sigma_2'}{\Delta \vdash \sigma_1 \mathbin{@} \sigma_2 = \sigma_1' \mathbin{@} \sigma_2'}$$

$$\text{(stk}\beta\text{1)}\ \frac{\Delta \vdash \sigma}{\Delta \vdash \mathit{nil} \mathbin{@} \sigma = \sigma} \qquad \text{(stk}\beta\text{2)}\ \frac{\Delta \vdash \sigma}{\Delta \vdash \sigma \mathbin{@} \mathit{nil} = \sigma}$$

$$\text{(stk}\beta\text{3)}\ \frac{\Delta \vdash \tau \quad \Delta \vdash \sigma_1 \quad \Delta \vdash \sigma_2}{\Delta \vdash (\tau{::}\sigma_1) \mathbin{@} \sigma_2 = \tau{::}(\sigma_1 \mathbin{@} \sigma_2)}$$

$$\text{(stk}\beta\text{4)}\ \frac{\Delta \vdash \sigma_1 \quad \Delta \vdash \sigma_2 \quad \Delta \vdash \sigma_3}{\Delta \vdash (\sigma_1 \mathbin{@} \sigma_2) \mathbin{@} \sigma_3 = \sigma_1 \mathbin{@} (\sigma_2 \mathbin{@} \sigma_3)}$$

$$\boxed{\Delta \vdash \Gamma_1 \leq \Gamma_2}$$

$$\text{(rf-leq)}\ \frac{\Delta \vdash \tau_i \quad (\text{for } 1 \leq i \leq m) \quad \Delta \vdash \sigma = \sigma'}{\Delta \vdash \{\mathtt{sp}{:}\sigma, r_1{:}\tau_1, \ldots, r_m{:}\tau_m\} \leq \{\mathtt{sp}{:}\sigma', r_1{:}\tau_1, \ldots, r_n{:}\tau_n\}}\ (m \geq n)$$

Fig. 10. Static Semantics of STAL, Judgments for Types

$$\boxed{\vdash M \quad \vdash H : \Psi \quad \Psi \vdash S : \sigma \quad \Psi \vdash R : \Gamma}$$

$$\text{(mach)}\ \frac{\vdash H : \Psi \quad \Psi \vdash R : \Gamma \quad \Psi; \cdot; \Gamma \vdash I}{\vdash (H, R, I)}$$

$$\text{(heap)}\ \frac{\vdash \Psi \quad \Psi \vdash h_i : \Psi(\ell_i)\ \text{hval} \quad (\text{for } 1 \leq i \leq n)}{\vdash \{\ell_1 \mapsto h_1, \ldots, \ell_n \mapsto h_n\} : \Psi}$$

$$\text{(nil)}\ \frac{}{\Psi \vdash \mathit{nil} : \mathit{nil}} \qquad \text{(cons)}\ \frac{\Psi; \cdot; \cdot \vdash w : \tau \quad \Psi \vdash S : \sigma}{\Psi \vdash w{::}S : \tau{::}\sigma} \qquad \text{(stkeq)}\ \frac{\Psi \vdash S : \sigma_1 \quad \cdot \vdash \sigma_1 = \sigma_2}{\Psi \vdash S : \sigma_2}$$

$$\text{(regfile)}\ \frac{\Psi \vdash S : \sigma \quad \Psi; \cdot; \cdot \vdash w_i : \tau_i \quad (\text{for } 1 \leq i \leq n)}{\Psi \vdash \{\mathtt{sp} \mapsto S, r_1 \mapsto w_1, \ldots, r_m \mapsto w_m\} : \{\mathtt{sp}{:}\sigma, r_1{:}\tau_1, \ldots, r_n{:}\tau_n\}}\ (m \geq n)$$

$$\boxed{\Psi \vdash h : \tau\ \text{hval} \quad \Psi; \Delta; \Gamma \vdash v : \tau}$$

$$\text{(tuple)}\ \frac{\Psi; \cdot; \cdot \vdash w_i : \tau_i}{\Psi \vdash \langle w_1, \ldots, w_n \rangle : \langle \tau_1, \ldots, \tau_n \rangle\ \text{hval}} \qquad \text{(code)}\ \frac{\Delta \vdash \Gamma \quad \Psi; \Delta; \Gamma \vdash I}{\Psi \vdash \mathtt{code}[\Delta]\Gamma.I : \forall[\Delta].\Gamma\ \text{hval}}$$

$$\text{(label)}\ \frac{}{\Psi; \Delta; \Gamma \vdash \ell : \Psi(\ell)} \qquad \text{(int)}\ \frac{}{\Psi; \Delta; \Gamma \vdash i : \mathit{int}}$$

$$\text{(ns)}\ \frac{}{\Psi; \Delta; \Gamma \vdash \mathit{ns} : \top} \qquad \text{(ptr)}\ \frac{\Delta \vdash \sigma}{\Psi; \Delta; \Gamma \vdash \mathit{ptr}(i) : \mathit{ptr}(\sigma)}\ (|\sigma| = i)$$

$$\text{(reg)}\ \frac{}{\Psi; \Delta; \Gamma \vdash r : \Gamma(r)}$$

$$\text{(tapp)}\ \frac{\Delta \vdash \tau \quad \Psi; \Delta; \Gamma \vdash v : \forall[\alpha, \Delta'].\Gamma'}{\Psi; \Delta; \Gamma \vdash v[\tau] : \forall[\Delta'].\Gamma'[\tau/\alpha]} \qquad \text{(stapp)}\ \frac{\Delta \vdash \sigma \quad \Psi; \Delta; \Gamma \vdash v : \forall[\rho, \Delta'].\Gamma'}{\Psi; \Delta; \Gamma \vdash v[\sigma] : \forall[\Delta'].\Gamma'[\sigma/\rho]}$$

$$\text{(pack)}\ \frac{\Delta \vdash \tau \quad \Psi; \Delta; \Gamma \vdash v : \tau'[\tau/\alpha]}{\Psi; \Delta; \Gamma \vdash \mathit{pack}\ [\tau, v]\ \mathit{as}\ \exists\alpha.\tau' : \exists\alpha.\tau'}$$

$$\boxed{\Psi; \Delta; \Gamma \vdash I}$$

$$\text{(seq)}\ \frac{\Psi; \Delta; \Gamma \vdash \iota \Rightarrow \Delta'; \Gamma' \quad \Psi; \Delta'; \Gamma' \vdash I}{\Psi; \Delta; \Gamma \vdash \iota; I} \qquad \text{(jmp)}\ \frac{\Delta \vdash \Gamma_1 \leq \Gamma_2 \quad \Psi; \Delta; \Gamma_1 \vdash v : \forall[\,].\Gamma_2}{\Psi; \Delta; \Gamma_1 \vdash \mathtt{jmp}\ v}$$

$$\text{(halt)}\ \frac{\Psi; \Delta; \Gamma \vdash \mathtt{r1} : \tau}{\Psi; \Delta; \Gamma \vdash \mathtt{halt}[\tau]}$$

Fig. 11. STAL Static Semantics, Term Constructs except Instructions

$$(\text{aop})\ \frac{\Psi;\Delta;\Gamma \vdash r_s : \mathit{int} \quad \Psi;\Delta;\Gamma \vdash v : \mathit{int}}{\Psi;\Delta;\Gamma \vdash \mathit{aop}\ \ r_d, r_s, v \Rightarrow \Delta;\Gamma\{r_d{:}\mathit{int}\}}$$

$$(\text{bop})\ \frac{\Psi;\Delta;\Gamma_1 \vdash r : \mathit{int} \quad \Psi;\Delta;\Gamma_1 \vdash v : \forall[\,].\Gamma_2 \quad \Delta \vdash \Gamma_1 \leq \Gamma_2}{\Psi;\Delta;\Gamma_1 \vdash \mathit{bop}\ \ r, v \Rightarrow \Delta;\Gamma_1}$$

$$(\text{ld})\ \frac{\Psi;\Delta;\Gamma \vdash r_s : \langle \tau_0, \ldots, \tau_{n-1} \rangle}{\Psi;\Delta;\Gamma \vdash \texttt{ld}\ \ r_d, r_s(i) \Rightarrow \Delta;\Gamma\{r_d{:}\tau_i\}}\ (0 \leq i < n)$$

$$(\text{malloc})\ \frac{\Psi;\Delta;\Gamma \vdash v_i : \tau_i}{\Psi;\Delta;\Gamma \vdash \texttt{malloc}\ \ r_d, \langle v_1, \ldots, v_n \rangle \Rightarrow \Delta;\Gamma\{r_d{:}\langle \tau_1, \ldots, \tau_n \rangle\}}\ (1 \leq i \leq n)$$

$$(\text{mov})\ \frac{\Psi;\Delta;\Gamma \vdash v : \tau}{\Psi;\Delta;\Gamma \vdash \texttt{mov}\ \ r_d, v \Rightarrow \Delta;\Gamma\{r_d{:}\tau\}}$$

$$(\text{unpack})\ \frac{\Psi;\Delta;\Gamma \vdash v : \exists \alpha.\tau}{\Psi;\Delta;\Gamma \vdash \texttt{unpack}\ \ [\alpha, r_d], v \Rightarrow \alpha, \Delta;\Gamma\{r_d{:}\tau\}}\ (\alpha \notin \Delta)$$

$$(\text{get-sp})\ \frac{}{\Psi;\Delta;\Gamma \vdash \texttt{mov}\ \ r_d, \texttt{sp} \Rightarrow \Delta;\Gamma\{r_d{:}\mathit{ptr}(\sigma)\}}\ (\Gamma(\texttt{sp}) = \sigma)$$

$$(\text{set-sp})\ \frac{\Psi;\Delta;\Gamma \vdash r_s : \mathit{ptr}(\sigma_2) \quad \Delta \vdash \sigma_1 = \sigma_3 \mathbin{@} \sigma_2}{\Psi;\Delta;\Gamma \vdash \texttt{mov}\ \ \texttt{sp}, r_s \Rightarrow \Delta;\Gamma\{\texttt{sp}{:}\sigma_2\}}\ (\Gamma(\texttt{sp}) = \sigma_1)$$

$$(\text{salloc})\ \frac{}{\Psi;\Delta;\Gamma \vdash \texttt{salloc}\ \ n \Rightarrow \Delta;\Gamma\{\texttt{sp}{:}\underbrace{\top{::}\cdots{::}\top}_{n}{::}\sigma\}}\ (\Gamma(\texttt{sp}) = \sigma)$$

$$(\text{sfree})\ \frac{\Delta \vdash \sigma_1 = \tau_0{::}\cdots{::}\tau_{n-1}{::}\sigma_2}{\Psi;\Delta;\Gamma \vdash \texttt{sfree}\ \ n \Rightarrow \Delta;\Gamma\{\texttt{sp}{:}\sigma_2\}}\ (\Gamma(\texttt{sp}) = \sigma_1)$$

$$(\text{sld1})\ \frac{\Delta \vdash \sigma_1 = \tau_0{::}\cdots{::}\tau_i{::}\sigma_2}{\Psi;\Delta;\Gamma \vdash \texttt{sld}\ \ r_d, \texttt{sp}(i) \Rightarrow \Delta;\Gamma\{r_d{:}\tau_i\}}\ (\Gamma(\texttt{sp}) = \sigma_1 \wedge 0 \leq i)$$

$$(\text{sld2})\ \frac{\begin{array}{c}\Psi;\Delta;\Gamma \vdash r_s : \mathit{ptr}(\sigma_3) \qquad \Delta \vdash \sigma_1 = \sigma_2 \mathbin{@} \sigma_3 \\ \Delta \vdash \sigma_3 = \tau_0{::}\cdots{::}\tau_i{::}\sigma_4\end{array}}{\Psi;\Delta;\Gamma \vdash \texttt{sld}\ \ r_d, r_s(i) \Rightarrow \Delta;\Gamma\{r_d{:}\tau_i\}}\ (\Gamma(\texttt{sp}) = \sigma_1 \wedge 0 \leq i)$$

$$(\text{sst1})\ \frac{\Delta \vdash \sigma_1 = \tau_0{::}\cdots{::}\tau_i{::}\sigma_2 \quad \Psi;\Delta;\Gamma \vdash r_s : \tau}{\Psi;\Delta;\Gamma \vdash \texttt{sst}\ \ \texttt{sp}(i), r_s \Rightarrow \Delta;\Gamma\{\texttt{sp}{:}\tau_0{::}\cdots{::}\tau_{i-1}{::}\tau{::}\sigma_2\}}\ (\Gamma(\texttt{sp}) = \sigma_1 \wedge 0 \leq i)$$

$$(\text{sst2})\ \frac{\begin{array}{c}\Psi;\Delta;\Gamma \vdash r_d : \mathit{ptr}(\sigma_3) \qquad \Psi;\Delta;\Gamma \vdash r_s : \tau \\ \Delta \vdash \sigma_1 = \sigma_2 \mathbin{@} \sigma_3 \qquad \Delta \vdash \sigma_3 = \tau_0{::}\cdots{::}\tau_i{::}\sigma_4 \\ \Delta \vdash \sigma_5 = \tau_0{::}\cdots{::}\tau_{i-1}{::}\tau{::}\sigma_4\end{array}}{\Psi;\Delta;\Gamma \vdash \texttt{sst}\ \ r_d(i), r_s \Rightarrow \Delta;\Gamma\{\texttt{sp}{:}\sigma_2 \mathbin{@} \sigma_5, r_d{:}\mathit{ptr}(\sigma_5)\}}\ (\Gamma(\texttt{sp}) = \sigma_1 \wedge 0 \leq i)$$

$$(\text{st})\ \frac{\Psi;\Delta;\Gamma \vdash r_d : \langle \tau_0, \ldots, \tau_{n-1} \rangle \quad \Psi;\Delta;\Gamma \vdash r_s : \tau_i}{\Psi;\Delta;\Gamma \vdash \texttt{st}\ \ r_d(i), r_s \Rightarrow \Delta;\Gamma}\ (0 \leq i < n)$$

Fig. 12. STAL Static Semantics, Instructions