Attività 10/05/21 - Guida alla Soluzione di Esercizio 5

- **Punti Critici** trattiamo questi per primi
  : Comandi etichettati;
  : Sequenza di Comandi;
  : Comando/Statement Goto;

- **Metodo** Seguire sempre:
  : Relazione Funzione Semantica - Regole Inferenza Costrutto ;
  : Regole Inferenza Semantica Statica Costrutto;
  (Controllo dei tipi e proprieta contestuali)
  : Regole di Inferenza Semantica Dinamica Costrutto;
  (Comportamento Computazione)

- I costrutti dei punti critici sono tutti comandi

cmdSem : $\texttt{cmd} \to \texttt{State} \to \texttt{Type} * \texttt{State}$
$(\forall \texttt{c}, \sigma) \quad \textbf{cmdSem}(\texttt{c}, \sigma) = (\texttt{t}, \sigma') \quad \textbf{iff} \quad \langle \texttt{c}, \sigma \rangle \to (\texttt{t}, \sigma') \in \textbf{Sem}_{\textbf{CMD}}$

stmSem : $\texttt{stm} \to \texttt{State} \to \texttt{Type} * \texttt{State}$
$(\forall \texttt{s}, \sigma) \quad \textbf{stmSem}(\texttt{s}, \sigma) = (\texttt{t}, \sigma') \quad \textbf{iff} \quad \langle \texttt{s}, \sigma \rangle \to (\texttt{t}, \sigma') \in \textbf{Sem}_{\textbf{STM}}$

Sistema Y: Regole per CMD, STM, PROG

$$[\text{Y19}]\ \frac{\begin{array}{c}\#\mathtt{Y}_\rho = 1 \\ \mathtt{Y}_\rho|_0(\mathtt{L}) = \bot \qquad [\mathtt{L}/[\mathtt{lab}]] \otimes \mathtt{Y}_\rho = \mathtt{Y}'_\rho \\ \langle \mathtt{s}, \mathtt{Y}'_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{void}], \mathtt{Y}''_\rho)\end{array}}{\langle \mathtt{L}\ [:]\ \mathtt{s}, \mathtt{Y}_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{void}], \mathtt{Y}'_\rho)}$$

$$[\text{Y22}]\ \frac{\begin{array}{c}\#\mathtt{Y}_\rho = 1 \\ \mathtt{Y}_\rho|_0(\mathtt{L}) = [\mathtt{lab}]\end{array}}{\langle [\mathtt{goto}]\ \mathtt{L}, \mathtt{Y}_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{void}], \mathtt{Y}_\rho)} \qquad [\text{Y23}]\ \frac{\begin{array}{c}\#\mathtt{Y}_\rho = 1 \\ \mathtt{Y}_\rho|_0(\mathtt{L}) = \bot \\ \mathtt{JumpAheadCheck}\end{array}}{\langle [\mathtt{goto}]\ \mathtt{L}, \mathtt{Y}_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{void}], \mathtt{Y}_\rho)}\ (***)$$

$$[\text{Y24}]\ \frac{\begin{array}{c}\#\mathtt{Y}_\rho = 1 \\ \langle \mathtt{c}_1, \mathtt{Y}_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{void}], \mathtt{Y}'_\rho) \\ \langle \mathtt{s}_2, \mathtt{Y}'_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{void}], \mathtt{Y}''_\rho)\end{array}}{\langle [\mathtt{seqC}]\ \mathtt{c}_1\ \mathtt{c}_2, \mathtt{Y}_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{void}], \mathtt{Y}''_\rho)}$$

Gestione Errori di Tipo:

$$[\text{E35}]\ \frac{\#\mathtt{Y}_\rho \neq 1}{\langle \mathtt{L}\ [:]\ \mathtt{s}, \mathtt{Y}_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}'_\rho)}$$

$$[\text{E36}]\ \frac{\mathtt{Y}_\rho|_0(\mathtt{L}) \neq \bot}{\langle \mathtt{L}\ [:]\ \mathtt{s}, \mathtt{Y}_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}'_\rho)} \qquad [\text{E37}]\ \frac{\begin{array}{c}\vdots \\ \langle \mathtt{s}, \mathtt{Y}'_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}'_\rho)\end{array}}{\langle \mathtt{L}\ [:]\ \mathtt{s}, \mathtt{Y}_\rho \rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}'_\rho)}$$

Notazione e Osservazioni: Costruttori Aggiuntivi

- JumpAheadCheck: Richiede Controllo a run-time (trattabile in Semantica dinamica);
- ***: In [Y22] e [Y23] dove affermiamo che goto può occore solo nel blocco più esterno di un programma?;
- [E36]: Non includere nella Semantica Statica (vedi slide successiva)

Sistema Y: La regola [E36]

La regola [E36] esprime correttamente l'unicità di una label in un blocco (in questo caso il blocco più esterno)

$$[\text{E36}]\ \frac{\mathtt{Y}_\rho|_0(\mathtt{L}) \neq \bot}{\langle \mathtt{L}\ [:]\ \mathtt{s}, \mathtt{Y}_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}'_\rho)}$$

Occorre tuttavia, fare alcune osservazioni circa il suo impiego nella successiva semantica dinamica (con controllo dinamico dei tipi, delle proprietà statiche e dei vincoli di sintassi contestuale).

- Non è adatta in caso di controllo dinamico e in presenza di statement goto.
- Gli statement goto richiedono la gestione delle sezioni di programma etichettate:.
  Ad esempio, sia s = l1:c1;s1;l2:c2;s2;l3:c3;s3; una sequenza del programma. Allora s contiene:
  per goto l1 la sezione c1;s1;l2:c2;s2;l3:c3;s3; e per goto l2 la sezione c2;s2;l3:c3;s3;
  che condividono una sequenza contenente l3.
  Ciò conduce ad una multipla occorrenza di l3 nelle sezioni.
- Come gestire [E36] quando attraversiamo la sezione di goto l2 dopo aver attraversato quella di goto l1?
- Le soluzioni per farlo sono sono inutilmente complicate nel caso di Small21.

La **Soluzione** che seguiremo è quella più semplice:

- La regola [E36] non è inclusa nella semantica dinamica - Vedi regola [C1'];
- Il controllo dell'Unicità delle labels è condotto:
  - staticamente dal Front-End ed assunto verificato sui programmi usati, oppure
  - staticamente da un controllo (pre-processor) condotto dal nostro esecutore attraversando i comandi dell'outermost block, prima di procedere con il calcolo della computazione.

Osservazioni

- Unicità della label: È possibile definire Linguaggi con multipla occorrenza di label di statement all'interno di uno stesso blocco.

Sistema Y: Regole per CMD, STM, PROG - 2

Gestione Errori di Tipo:

$$[\text{E43}]\ \frac{\mathtt{Y}_\rho|_0(\mathtt{L}) = \mathtt{t} \quad \mathtt{t} \neq [\mathtt{lab}]}{\langle [\mathtt{goto}]\ \mathtt{L}, \mathtt{Y}_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}_\rho)} \qquad [\text{E44}]\ \frac{\mathtt{Y}_\rho|_0(\mathtt{L}) = \bot \quad \texttt{JumpAheadCheckFail}}{\langle [\mathtt{goto}]\ \mathtt{L}, \mathtt{Y}_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}_\rho)} \qquad [\text{E45}]\ \frac{\#\mathtt{Y}_\rho \neq 1}{\langle [\mathtt{goto}]\ \mathtt{L}, \mathtt{Y}_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}_\rho)}$$

$$[\text{E56}]\ \frac{\#\mathtt{Y}_\rho \neq 1}{\langle [\mathtt{seqC}]\ \mathtt{c}_1\ \mathtt{c}_2, \mathtt{Y}_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}'_\rho)} \qquad [\text{E57}]\ \frac{\langle \mathtt{c}_1, \mathtt{Y}_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}'_\rho)}{\langle [\mathtt{seqC}]\ \mathtt{c}_1\ \mathtt{c}_2, \mathtt{Y}_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}'_\rho)}$$

$$[\text{E58}]\ \frac{\langle \mathtt{c}_1, \mathtt{Y}_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{void}], \mathtt{Y}'_\rho) \quad \langle \mathtt{s}_2, \mathtt{Y}'_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}''_\rho)}{\langle [\mathtt{seqC}]\ \mathtt{c}_1\ \mathtt{c}_2, \mathtt{Y}_\rho\rangle \rightarrow_{\mathtt{Y}} ([\mathtt{terr}], \mathtt{Y}''_\rho)}$$

Notazione e Osservazioni: Costruttori Aggiuntivi

- [E45]: Perchè anche questa regola?;

Comandi Small21 - Regole di Inferenza $\mathtt{SEM}_{\mathtt{CMD}}$, $\mathtt{SEM}_{\mathtt{STM}}$

Il Sistema definisce il comportamento dei comandi sulla Macchina Astratta AM21.
Controllo dei Tipi Dinamico: Il Sistema $\mathtt{Sem}_{\mathtt{CMD}}$ è Integrato con il Sistema Y (ultime 2 slide sopra, per i comandi).

$\mathtt{Cmd} ::= \mathtt{Lab}\ [:]\ \mathtt{Stm} \mid \mathtt{Stm} \mid [\mathtt{seqC}]\ \mathtt{Cmd}\ \mathtt{Cmd} \mid \ldots$

$$[\mathrm{C1}]\ \frac{\begin{array}{c}\#\Delta = 1 \qquad \Delta = {>}\mathtt{ar}_1] \\ \mathtt{ar}_1 = \{\mathtt{hd}, \mathtt{cs}, \mathtt{fr}, \mathtt{cnt}, \mathtt{v}\} \\ [\mathtt{seqC}]\ \mathtt{s}\ \mathtt{cnt} = \mathtt{c}' \\ \Delta|_0(\mathtt{L}) = \bot \qquad [\mathtt{L}/([\mathtt{lab}], \mathtt{c}')] \otimes \Delta = \Delta' \\ \langle \mathtt{s}, (\Delta', \mu)\rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})\end{array}}{\langle \mathtt{L}\ [:]\ \mathtt{s}, (\Delta, \mu)\rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})} \qquad [\mathrm{C1'}]\ \frac{\begin{array}{c}\#\Delta = 1 \\ \Delta|_0(\mathtt{L}) \neq \bot \\ \langle \mathtt{s}, (\Delta', \mu)\rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})\end{array}}{\langle \mathtt{L}\ [:]\ \mathtt{s}, (\Delta, \mu)\rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})} \quad (**15.05.21**)$$

$$[\mathrm{C2}]\ \frac{\begin{array}{c}\#\Delta = 1 \qquad \Delta = {>}\mathtt{ar}_1] \\ \mathtt{ar}_1 = \{\mathtt{hd}, \mathtt{cs}, \mathtt{fr}, \mathtt{cnt}, \mathtt{v}\} \\ [\mathtt{seqC}]\ \mathtt{c}_2\ \mathtt{cnt} = \mathtt{cnt}' \\ \{\mathtt{hd}, \mathtt{cs}, \mathtt{fr}, \mathtt{cnt}', \mathtt{v}\} = \mathtt{ar}_1' \\ {>}\mathtt{ar}_1'] = \Delta' \\ \langle \mathtt{c}_1, (\Delta', \mu)\rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})\end{array}}{\langle [\mathtt{seqC}]\ \mathtt{c}_1\ \mathtt{c}_2, (\Delta, \mu)\rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})}$$

Notazione e Osservazioni: Costruttori Aggiuntivi

- `Denotazione`: Estese con $(\mathtt{t}, \mathcal{C})$ per le label con `t = Lab` e $\mathcal{C}$ una continuazione (rappresentata cpme sotto)
- `Continuazione` $\mathcal{C}$: Rappresentata con AST di Small21e c in testa alla continuazione $\mathcal{C}$;
- $[\mathtt{seqC}]\ \mathtt{c}\ \mathcal{C}$: Aggiunge c in testa alla continuazione $\mathcal{C}$;
- `(*corretto13/05/21*)`: Perchè una volta incontrata e legata nel frame, una label deve essere ignorata?;
- Il predicato $\Delta = {>}\mathtt{ar}_1]$ implica $\Delta = {>}\mathtt{ar}_1]$: Perchè ?;

Comandi Small121 - Regole di Inferenza $\mathtt{SEM}_{\mathtt{CMD}}$, $\mathtt{SEM}_{\mathtt{STM}}$ - 2

Il Sistema definisce il comportamento dei comandi sulla Macchina Astratta AM21.
Controllo dei Tipi Dinamico: Il Sistema $\mathtt{Sem}_{\mathtt{CMD}}$ è Integrato con il Sistema Y.

$\mathtt{Stm} ::= [\mathtt{goto}]\ \mathtt{Lab} \mid \ldots$

$$[\mathrm{S3}]\ \frac{\begin{array}{c}\Delta|_0(\mathtt{L}) = ([\mathtt{lab}], \mathtt{c}) \\ \Delta = {>}\mathtt{ar}_1] \\ \mathtt{ar}_1 = \{\mathtt{hd}, \mathtt{cs}, \mathtt{fr}, \mathtt{cnt}, \mathtt{v}\} \\ \{\mathtt{hd}, \mathtt{cs}, \mathtt{fr}, \mathtt{emptyC}, \mathtt{v}\} = \mathtt{ar}_1' \\ ({>}\mathtt{ar}_1'], \mu) = \sigma' \\ \langle \mathtt{c}, \sigma' \rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})\end{array}}{\langle [\mathtt{goto}]\ \mathtt{L}, (\Delta, \mu)\rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})}$$

$$[\mathrm{S3'}]\ \frac{\begin{array}{c}\Delta|_0(\mathtt{L}) = \bot \qquad \Delta = {>}\mathtt{ar}_1] \\ \mathtt{ar}_1 = \{\mathtt{hd}, \mathtt{cs}, \mathtt{fr}, \mathtt{cnt}, \mathtt{v}\} \\ \mathtt{JAC\ L\ cnt} = [\mathtt{seqC}]\ \mathtt{c\ cs} \\ {>}\mathtt{ar}_1'] = \Delta' \qquad \mathtt{c} = \mathtt{L}\ [:]\ \mathtt{s} \\ \{\mathtt{hd}, \mathtt{cs}, \mathtt{fr}, \mathtt{cs}, \mathtt{v}\} = \mathtt{ar}_1' \\ [\mathtt{seqC}]\ \mathtt{s\ cs} = \mathtt{c}' \\ [\mathtt{L}/([\mathtt{lab}], \mathtt{c}')] \otimes \Delta' = \Delta'' \\ \langle \mathtt{s}, (\Delta'', \mu)\rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})\end{array}}{\langle [\mathtt{goto}]\ \mathtt{L}, (\Delta, \mu)\rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})}\ (***)$$

Notazione ed Osservazioni: Costruttori Aggiuntivi

- $[\mathtt{seqC}]\ \mathtt{c}\ \mathcal{C}$: Aggiunge c in testa alla continuazione $\mathcal{C}$;
- $\mathtt{JAC\ L}\ \mathcal{C} = \mathcal{C}'$: Vera quando $\mathcal{C}'$ è la sotto-sequenza terminale con primo comando etichettato con L. Falsa altr.
- emptyC: Indica "nessuna continuazione"
- (***): Usa l'invariante di inserire il binding di una label e successivamente ignorarne la presenza ogni prima volta che si seleziona un comando etichettato e se ne considera la trasformazione definita.

Nucleo di Small21 per Macchina a Stato Minsky-Wang
Costrutti Minori: Semantica Statica e Dinamica -1

Il Sistema definisce il comportamento dei comandi sulla Macchina Astratta AM21.

Stm ::= [ifT] Exp Stm | ...

Sistema Y:

$$[\text{Y21}]\ \frac{\langle \texttt{e}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{[bool]}, \texttt{Y}_\rho) \quad \langle \texttt{s}_1, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{[void]}, \texttt{Y}_\rho)}{\langle \texttt{[ifT]}\ \texttt{e}\ \texttt{s}_1, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{[void]}, \texttt{Y}_\rho)}$$

Gestione Errori di Tipo:

$$[\text{E41}]\ \frac{\langle \texttt{e}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{t}, \texttt{Y}_\rho) \quad \texttt{t} \neq \texttt{[bool]}}{\langle \texttt{[ifT]}\ \texttt{e}\ \texttt{s}_1, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{[terr]}, \texttt{Y}_\rho)} \qquad [\text{E42}]\ \frac{\langle \texttt{s}_1, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{[terr]}, \texttt{Y}_\rho)}{\langle \texttt{[ifT]}\ \texttt{e}\ \texttt{s}_1, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{[terr]}, \texttt{Y}_\rho)}$$

Regole di Inferenza $\texttt{SEM}_{\texttt{CMD}}$

$$[\text{S2}]\ \frac{\langle \texttt{e}, \sigma\rangle \rightarrow \lfloor \texttt{[bool]}, \texttt{true}, \sigma_{\texttt{e}}\rfloor \quad \langle \texttt{c}, \sigma_{\texttt{e}}\rangle \rightarrow (\texttt{[void]}, \sigma_1)}{\langle \texttt{[ifT]}\ \texttt{e}\ \texttt{c}, \sigma\rangle \rightarrow (\texttt{[void]}, \sigma_1)} \qquad [\text{S2'}]\ \frac{\langle \texttt{e}, \sigma\rangle \rightarrow \lfloor \texttt{[bool]}, \texttt{false}, \sigma_{\texttt{e}}\rfloor}{\langle \texttt{[ifT]}\ \texttt{e}\ \texttt{c}, \sigma\rangle \rightarrow (\texttt{[void]}, \sigma_{\texttt{e}})}$$

Osservazioni

- Definizione Completa dello Statement con guardia: Costrutto condizionale if;

Nucleo di Small21 per Macchina a Stato Minsky-Wang
Costrutti Minori: Semantica Statica e Dinamica -1

$\texttt{Stm} ::= \texttt{Exp}\ [=]\ \texttt{Exp} \mid \texttt{ES} \mid \ldots$

Sistema Y:

$$[\text{Y15}]\ \frac{\langle \texttt{e}_\texttt{l}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{DY}} (\texttt{t}_\texttt{l}, \texttt{Y}_\rho) \quad \langle \texttt{e}_\texttt{r}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{t}_\texttt{r}, \texttt{Y}_\rho) \quad \texttt{t}_\texttt{l} = [\texttt{Mut}]\ \texttt{t} \quad \texttt{t} = \texttt{t}_\texttt{r} \quad \texttt{t} \in \texttt{Simple}}{\langle \texttt{e}_\texttt{l}\ [=]\ \texttt{e}_\texttt{r}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{t}, \texttt{Y}_\rho)} \qquad [\text{Y??}]\ \frac{}{\langle \texttt{ES}, \texttt{Y}_\rho\rangle \rightarrow ([\texttt{void}], \texttt{Y}_\rho)}$$

Gestione Errori di Tipo:

$$[\text{E17}]\ \frac{\langle \texttt{e}_\texttt{l}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{DY}} ([\texttt{mut}]\ \texttt{t}, \texttt{Y}_\rho) \quad \texttt{t} \notin \texttt{Simple}}{\langle \texttt{e}_\texttt{l}\ [=]\ \texttt{e}_\texttt{r}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} ([\texttt{terr}], \texttt{Y}_\rho)} \quad [\text{E18}]\ \frac{\langle \texttt{e}_\texttt{r}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{t}, \texttt{Y}_\rho) \quad \texttt{t} \notin \texttt{Simple}}{\langle \texttt{e}_\texttt{l}\ [=]\ \texttt{e}_\texttt{r}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} ([\texttt{terr}], \texttt{Y}_\rho)} \quad [\text{E19}]\ \frac{\langle \texttt{e}_\texttt{l}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{DY}} (\texttt{t}_\texttt{l}, \texttt{Y}_\rho) \quad \langle \texttt{e}_\texttt{r}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{t}_\texttt{r}, \texttt{Y}_\rho) \quad \texttt{t}_\texttt{l} = [\texttt{Mut}]\ \texttt{t} \quad \texttt{t} \neq \texttt{t}_\texttt{r}}{\langle \texttt{e}_\texttt{l}\ [=]\ \texttt{e}_\texttt{r}, \texttt{Y}_\rho\rangle \rightarrow_{\texttt{Y}} (\texttt{t}, \texttt{Y}_\rho)}$$

Regole di Inferenza $\texttt{SEM}_{\texttt{CMD}}$

$$[\text{S1}]\ \frac{\begin{array}{c}\langle \texttt{e}_\texttt{r}, \sigma\rangle \rightarrow \lfloor \texttt{t}_\texttt{r}, \texttt{v}_\texttt{r}, \sigma_\texttt{r}\rfloor \\ \langle \texttt{e}_\texttt{l}, \sigma_\texttt{r}\rangle \rightarrow_{\texttt{DEN}} \lfloor \texttt{t}_\texttt{l}, \texttt{loc}_\texttt{t}, \sigma_\texttt{l}\rfloor \\ \texttt{t}_\texttt{l} = [\texttt{mut}]\ \texttt{t} \quad \texttt{t} = \texttt{t}_\texttt{r} \\ \texttt{t} \in \texttt{Simple} \quad \sigma_\texttt{l} = (\Delta_\texttt{l}, \mu_\texttt{l}) \\ \mu_\texttt{l}[\texttt{loc}_\texttt{t} \leftarrow \texttt{v}_\texttt{r}] = \mu_\texttt{F}\end{array}}{\langle \texttt{e}_\texttt{l}\ [=]\ \texttt{e}_\texttt{r}, \sigma\rangle \rightarrow ([\texttt{void}], (\Delta_\texttt{l}, \mu_\texttt{F}))} \qquad [\text{S8}]\ \frac{}{\langle \texttt{ES}, \sigma\rangle \rightarrow ([\texttt{void}], \sigma)}$$

Notazione e Osservazioni

- $\rightarrow_{\texttt{DY}}$ è l'inferenza di Tipo del Valore Denotabile di espressioni con doppio significato.
- $\rightarrow_{\texttt{DEN}}$ è l'inferenza semantica dinamica di espressioni con doppio significato.
- $=$ valuta gli argomenti da destra a sinistra come in C/C++
- $\texttt{Simple} = \{[\texttt{int}], [\texttt{bool}]\}$

Nucleo di Small21 per MaS: Espressioni con Stato

$$\texttt{Exp} ::= \texttt{[num]}\ \texttt{Num} \mid \texttt{[true]} \mid \texttt{[false]} \mid \texttt{[emptyE]} \mid \texttt{DExp} \mid \texttt{Exp}\ \texttt{[+]}\ \texttt{Exp} \mid \texttt{Exp}\ \texttt{[-]}\ \texttt{Exp} \mid \texttt{Exp}\ \texttt{[==]}\ \texttt{Exp} \mid \ldots$$

$$\texttt{DExp} ::= \texttt{[val]}\ \texttt{Ide} \mid \ldots$$

$$[\text{Y8}]\ \frac{}{\langle \texttt{[num]}\ \texttt{N}, \texttt{Y}_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[int]}, \texttt{Y}_\rho)} \qquad [\text{Y9}]\ \frac{}{\langle \texttt{[true]}, \texttt{Y}_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[bool]}, \texttt{Y}_\rho)} \qquad [\text{Y10}]\ \frac{}{\langle \texttt{[false]}\ , \texttt{Y}_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[bool]}, \texttt{Y}_\rho)}$$

$$[\text{Y11}]\ \frac{}{\langle \texttt{[emptyE]}\ , \texttt{Y}_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[bool]}, \texttt{Y}_\rho)}$$

$$[\text{Y12}]\ \frac{\texttt{Y}_\rho(\texttt{I}) = \texttt{[mut]}\ \texttt{t} \qquad \texttt{t} \in \texttt{Simple}}{\langle \texttt{[val]}\ \texttt{I}, \texttt{Y}_\rho \rangle \rightarrow_{\texttt{DY}} (\texttt{[mut]}\ \texttt{t}, \texttt{Y}_\rho)} \qquad [\text{Y13}]\ \frac{\texttt{Y}_\rho(\texttt{I}) = \texttt{[mut]}\ \texttt{t} \qquad \texttt{t} \in \texttt{Simple}}{\langle \texttt{[val]}\ \texttt{I}, \texttt{Y}_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{t}, \texttt{Y}_\rho)} \qquad [\text{Y14}]\ \frac{\texttt{Y}_\rho(\texttt{I}) = \texttt{t} \qquad \texttt{t} \in \texttt{Simple}}{\langle \texttt{[val]}\ \texttt{I}, \texttt{Y}_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{t}, \texttt{Y}_\rho)}$$

$$[\text{Y17}]\ \frac{\begin{array}{c}\langle \texttt{e}_1, \texttt{Y}_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{t}_1, \texttt{Y}_\rho) \qquad \langle \texttt{e}_2, \texttt{Y}_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{t}_2, \texttt{Y}_\rho) \\ \texttt{Y}_\rho(\texttt{op}) = \texttt{[abs]}\ \texttt{t}\texttt{[::]}\texttt{t}'_1\texttt{[::]}\texttt{t}'_2 \qquad \texttt{op} \in \mathcal{O}_2 \\ \texttt{t}'_1 = \texttt{t}_1 \qquad \texttt{t}'_2 = \texttt{t}_2\end{array}}{\langle \texttt{e}_1\ \texttt{[op]}\ \texttt{e}_2, \texttt{Y}_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{t}, \texttt{Y}_\rho)}$$

Notazione

- $\texttt{Exp}\ \texttt{[-]}\ \texttt{Exp}$ Costrutto da aggiungere a Small21 per ottenere un nucleo per i programmi MaS.
- $\rightarrow_{\texttt{DY}}$ è l'inferenza di Tipo del Valore Denotabile di espressioni con doppio significato.
- $\mathcal{O}_2 = \{+, ==, >, <, \texttt{or}\}; \quad \mathcal{O}_1 = \{\}.$
- $\texttt{Simple} = \{\texttt{[int]}, \texttt{[bool]}\}$

Sistema Y: Regole per EXP - Errori di tipo

$$\texttt{Exp} ::= \texttt{[num] Num} \mid \texttt{[true]} \mid \texttt{[false]} \mid \texttt{[emptyE]} \mid \texttt{DExp} \mid \texttt{Exp [+] Exp} \mid \texttt{Exp [==] Exp} \mid \ldots$$
$$\texttt{DExp} ::= \texttt{[val] Ide} \mid \ldots$$

$$\text{[E16]}\ \frac{\mathtt{Y}_\rho(\mathtt{I}) = \texttt{[mut]}\,\mathtt{t} \qquad \mathtt{t} \notin \texttt{Simple}}{\langle \texttt{[val]}\,\mathtt{I}, \mathtt{Y}_\rho\rangle \to_{\mathtt{DY}} (\texttt{[terr]}, \mathtt{Y}_\rho)} \qquad \text{[E17]}\ \frac{\mathtt{Y}_\rho(\mathtt{I}) = \mathtt{t} \qquad \mathtt{t} \neq \texttt{[mut]}\,\mathtt{t}'}{\langle \texttt{[val]}\,\mathtt{I}, \mathtt{Y}_\rho\rangle \to_{\mathtt{DY}} (\texttt{[terr]}, \mathtt{Y}_\rho)} \qquad \text{[E18]}\ \frac{\mathtt{Y}_\rho(\mathtt{I}) \neq \texttt{[mut]}\,\mathtt{t}}{\langle \texttt{[val]}\,\mathtt{I}, \mathtt{Y}_\rho\rangle \to_{\mathtt{Y}} (\texttt{[terr]}, \mathtt{Y}_\rho)}$$

$$\text{[E19]}\ \frac{\mathtt{Y}_\rho(\mathtt{I}) = \bot}{\langle \texttt{[val]}\,\mathtt{I}, \mathtt{Y}_\rho\rangle \to_{\mathtt{Y}} (\texttt{[terr]}, \mathtt{Y}_\rho)}$$

$$\text{[E25]}\ \frac{\langle \mathtt{e}_1, \mathtt{Y}_\rho\rangle \to_{\mathtt{Y}} (\mathtt{t}_1, \mathtt{Y}_\rho) \quad \mathtt{Y}_\rho(\mathtt{op}) = \texttt{[abs]}\ \mathtt{t}\ \mathtt{t}_1'[\mathtt{x}]\mathtt{t}_2' \quad \mathtt{t}_1' \neq \mathtt{t}_1}{\langle \mathtt{e}_1\ \texttt{[op]}\ \mathtt{e}_2, \mathtt{Y}_\rho\rangle \to_{\mathtt{Y}} (\texttt{[terr]}, \mathtt{Y}_\rho)} \qquad \text{[E26]}\ \frac{\langle \mathtt{e}_2, \mathtt{Y}_\rho\rangle \to_{\mathtt{Y}} (\mathtt{t}_2, \mathtt{Y}_\rho) \quad \mathtt{Y}_\rho(\mathtt{op}) = \texttt{[abs]}\ \mathtt{t}\ \mathtt{t}_1'[\mathtt{x}]\mathtt{t}_2' \quad \mathtt{t}_2' \neq \mathtt{t}_2}{\langle \mathtt{e}_1\ \texttt{[op]}\ \mathtt{e}_2, \mathtt{Y}_\rho\rangle \to_{\mathtt{Y}} (\texttt{[terr]}, \mathtt{Y}_\rho)} \qquad \text{[E27]}\ \frac{\langle \mathtt{e}, \mathtt{Y}_\rho\rangle \to_{\mathtt{Y}} (\mathtt{t}_\mathtt{e}, \mathtt{Y}_\rho) \quad \mathtt{Y}_\rho(\mathtt{op}) = \texttt{[abs]}\ \mathtt{t}\ \mathtt{t}' \quad \mathtt{t}' \neq \mathtt{t}_\mathtt{e}}{\langle \texttt{[op]}\ \mathtt{e}, \mathtt{Y}_\rho\rangle \to_{\mathtt{Y}} (\texttt{[terr]}, \mathtt{Y}_\rho)}$$

Notazione

$\to_{\mathtt{DY}}$ è l'inferenza di Tipo del Valore Denotabile di espressioni con doppio significato.
$\mathcal{O}_2 = \{+, -, *, \mathtt{div}, ==, >, <, \mathtt{or}, \mathtt{and}\}$; $\mathcal{O}_1 = \{-_1, \mathtt{not}\}$.
$\texttt{Simple} = \{\texttt{[int]}, \texttt{[bool]}\}$

Espressioni con Stato: Le Transizioni SEM_{EXP} e SEM_{DEN}

Il Sistema di regole Sem_{EXP} (risp. Sem_{DEN}) definisce il comportamento delle r-espressioni (risp. l-espressioni) durante la computazione dei Programmi Small21 sulla Macchina Astratta AM21.
Controllo dei Tipi Dinamico: I Sistemi Sem_{EXP} e Sem_{DEN} sono Integrati con il Sistema Y (ultime 2 slides precedenti, per le espressioni).

$$\texttt{Exp} ::= \texttt{[val] Ide} \mid \texttt{[num] N} \mid \texttt{[true]} \mid \texttt{[false]} \mid \texttt{[emptyE]} \mid \ldots$$

X1: $$\frac{}{\langle \texttt{[num] N}, \sigma\rangle \rightarrow \lfloor \texttt{[int], N}, \sigma \rfloor}$$

X2: $$\frac{}{\langle \texttt{[true]}, \sigma\rangle \rightarrow \lfloor \texttt{[bool], [true]}, \sigma \rfloor}$$

X2': $$\frac{}{\langle \texttt{[false]}, \sigma\rangle \rightarrow \lfloor \texttt{[bool], [true]}, \sigma \rfloor}$$

X3: $$\frac{}{\langle \texttt{[emptyE]} , \sigma\rangle \rightarrow \lfloor \texttt{[unit], [emptyE]}, \sigma \rfloor}$$

X4: $$\frac{\begin{array}{c}\sigma = (\Delta, \mu) \\ \Delta(\texttt{I}) = (\texttt{t}, \texttt{loc}_{\texttt{t}'}) \\ \texttt{t} = \texttt{[mut] t}' \\ \texttt{t}' \in \texttt{Simple}\end{array}}{\langle \texttt{[val] I}, \sigma\rangle \rightarrow_{\texttt{Den}} \lfloor \texttt{t}, \texttt{loc}_{\texttt{t}'}, \sigma \rfloor}$$

X5: $$\frac{\begin{array}{c}\sigma = (\Delta, \mu) \\ \Delta(\texttt{I}) = (\texttt{[mut] t}, \texttt{loc}_{\texttt{t}}) \\ \texttt{t} \in \texttt{Simple} \\ \mu(\texttt{loc}_{\texttt{t}}) = \texttt{v}_{\texttt{t}}\end{array}}{\langle \texttt{[val] I}, \sigma\rangle \rightarrow \lfloor \texttt{t}, \texttt{v}_{\texttt{t}}, \sigma \rfloor}$$

X6: $$\frac{\begin{array}{c}\sigma = (\Delta, \mu) \\ \Delta(\texttt{I}) = (\texttt{t}, \texttt{v}_{\texttt{t}}) \\ \texttt{t} \in \texttt{Simple}\end{array}}{\langle \texttt{[val] I}, \sigma\rangle \rightarrow \lfloor \texttt{t}, \texttt{v}_{\texttt{t}}, \sigma \rfloor}$$

Notazione e Osservazioni
- $\rightarrow$ ha termine destro una tripla indicante tipo, valore (esprimibile/denotabile), stato, racchiusa da $\lfloor\ \rfloor$.
- $\rightarrow_{\text{DEN}}$ è la relazione per di Tipo-ValoreDenotato di espressioni con doppio significato.
- $\texttt{N} \in [0..\texttt{N}_{\texttt{k}} - 1]$ è il controllo a run-time sui bounds inferiore e superiore per i componenti di array statico.

Espressioni con Stato: Le Regole di Inferenza SEM_{EXP} - 2

$\texttt{Exp} ::= \texttt{Exp}\ [\texttt{op}]\ \texttt{Exp} \mid \ldots$

$$[\text{X9})\ \frac{\begin{array}{c}\langle \texttt{e}_1, \sigma\rangle \rightarrow \lfloor \texttt{t}_1, \texttt{v}_1, \sigma_1\rfloor \\ \langle \texttt{e}_2, \sigma_1\rangle \rightarrow \lfloor \texttt{t}_2, \texttt{v}_2, \sigma_2\rfloor \\ \Delta(\texttt{op}) = [\texttt{abs}]\ \texttt{t}[::]\texttt{t}_1'[::]\texttt{t}_2' \\ \texttt{t}_1' = \texttt{t}_1 \qquad \texttt{t}_2' = \texttt{t}_2 \\ \texttt{op} \in \mathcal{O}_2 \qquad \overline{\texttt{op}}(\texttt{v}_1, \texttt{v}_2) = \texttt{v}\end{array}}{\langle \texttt{e}_1\ [\texttt{op}]\ \texttt{e}_2, \sigma\rangle \rightarrow \lfloor \texttt{t}, \texttt{v}, \sigma 2\rfloor}$$

Osservazioni (Dispatcher)
La regola [X9] è adatta all'uso del modello dispatcher per la gestione delle operazioni.
Dispatcher è un meccanismo hw-sw per la selezione dell'operazione (procedura, funzione, ect..) data una sigature, i.e. nome e tipo, dell'operazione richiesta.

Notazione
- $\Delta(\texttt{op})$ fornisce il tipo di operatori primitivi (forniti dallo RTS di AM21)
- $\mathcal{O}_2 = \{+, -, *, \texttt{div}, ==, >, <, \texttt{or}, \texttt{and}\}$; $\mathcal{O}_1 = \{-_1, \texttt{not}\}$.
- $\overline{\texttt{op}}$ è l'operazione dello RTS con cui implementiamo l'operatore op: Usiamo le corrispondenti op di Ocaml (se definite), implementazioni ad hoc, altrimenti.
- $\texttt{Simple} = \{[\texttt{int}], [\texttt{bool}]\}$

Small21: Programma e outermost inline block

Il Sistema definisce il comportamento dei comandi sulla Macchina Astratta AM21.

$\texttt{Prog} ::= \texttt{[prog] Ide Block}$
$\texttt{Block} ::= \texttt{[block] Dcl Cmd}$

Sistema Y:

$$[\text{Y44}]\ \frac{\begin{array}{c}\texttt{Bc} = \texttt{[block]dscs} \\ \langle \texttt{ds}, \texttt{Y}^0_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[void]}, \texttt{Y}^1_\rho) \\ \langle \texttt{cs}, \texttt{Y}^1_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[void]}, \texttt{Y}^{\texttt{F}}_\rho)\end{array}}{\langle \texttt{[prog] I Bc}, \texttt{Y}^0_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[void]}, \texttt{Y}^{\texttt{F}}_\rho)}$$

Gestione Errori di Tipo:

$$[\text{E96}]\ \frac{\langle \texttt{ds}, \texttt{Y}^0_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[terr]}, \texttt{Y}^1_\rho)}{\langle \texttt{[prog] I Bc}, \texttt{Y}^0_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[terr]}, \texttt{Y}^1_\rho)} \qquad [\text{E97}]\ \frac{\begin{array}{c}\langle \texttt{ds}, \texttt{Y}^0_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[void]}, \texttt{Y}^1_\rho) \\ \langle \texttt{cs}, \texttt{Y}^1_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[terr]}, \texttt{Y}^{\texttt{F}}_\rho)\end{array}}{\langle \texttt{[prog] I Bc}, \texttt{Y}^0_\rho \rangle \rightarrow_{\texttt{Y}} (\texttt{[terr]}, \texttt{Y}^{\texttt{F}}_\rho)}$$

Regole di Inferenza $\texttt{SEM}_{\texttt{CMD}}$
Introduciamo Un iteratore di stati per la computazione e lo utilizziamo nella regola [P1] per i programmi:

$$[\text{R1}]\ \frac{\begin{array}{c}\sigma \rightarrow_{\texttt{R}} (\texttt{[void]}, \sigma_{\texttt{F}}) \\ \sigma_{\texttt{F}} = (\Delta_{\texttt{F}}, \mu_{\texttt{F}}) \qquad \#\Delta_{\texttt{F}} = 1 \\ \Delta_{\texttt{F}} =>! \{\texttt{id}, \texttt{lc}, \texttt{fr}, [], \texttt{v}\}]\end{array}}{\sigma \rightarrow_{\texttt{R}*} \sigma_{\texttt{F}}} \qquad [\text{R1}]\ \frac{\begin{array}{c}\Delta => \texttt{ar}_{\texttt{top}} \ldots] \qquad \#\Delta_{\texttt{F}} = 1 \\ \texttt{ar}_{\texttt{top}} = \{\texttt{id}, \texttt{lc}, \texttt{fr}, \texttt{c} + \texttt{cnt}, \texttt{v}\} \\ \langle \texttt{c}, (\Delta, \mu) \rangle \rightarrow ([\texttt{void}], \sigma_{\texttt{next}})\end{array}}{(\Delta, \mu) \rightarrow_{\texttt{R}} ([\texttt{void}], \sigma_{\texttt{next}})}$$

Osservazioni

- $\texttt{Y}^0_\rho$: Contesto contenente i binding di tipo per tutti gli identificatori di primitive del Linguaggio;
- $\texttt{c} + \texttt{cnt}$: sta per $\texttt{SeqC c cnt}$, quando la continuazione, cnt, sia una sequenza di comandi;

Small21: Programma e outermost inline block - 2

Il Sistema definisce il comportamento dei comandi sulla Macchina Astratta AM21.

Prog ::= [prog] Ide Block
Block ::= [block] Dcl Cmd

Regole di Inferenza $\mathtt{SEM}_{\mathtt{CMD}}$

$$\text{[P1]}\ \frac{\begin{array}{c}\{\mathtt{I}, 0, \rho^0, [], []\} = \mathtt{ar}_0 \\ > \mathtt{ar}_0] = \Delta_0 \qquad [] = \mu_0 \\ (\Delta_0, \mu_0) = \sigma_0 \qquad \mathtt{Bc} = [\mathtt{block}]\ \mathtt{ds}\ \mathtt{cs} \\ \langle \mathtt{ds}, \sigma_0 \rangle \rightarrow ([\mathtt{void}], (\Delta_1, \mu_1)) \\ \mathtt{ar}_1 = \{\mathtt{id}, \mathtt{lc}, \mathtt{fr}, \mathtt{cnt}, \mathtt{v}\} \\ \{\mathtt{id}, \mathtt{lc}, \mathtt{fr}, \mathtt{cs}, \mathtt{v}\} = \mathtt{ar}_2 \\ > \mathtt{ar}_0] = \Delta_2 \qquad (\Delta_2, \mu_1) = \sigma_2 \\ \sigma_2 \rightarrow_{\mathtt{R}} \sigma_{\mathtt{F}}\end{array}}{\langle [\mathtt{prog}]\ \mathtt{I}\ \mathtt{Bc}, \quad \rangle \rightarrow ([\mathtt{void}], \sigma_{\mathtt{F}})}$$

Osservazioni

- ρ^0: Contesto contenente i binding di tipo per tutti gli identificatori di primitive del Linguaggio;

Small21: inline block

Il Sistema definisce il comportamento dei comandi sulla Macchina Astratta AM21.

`BlockS` ::= [`blockS`] `Dcl` `Cmd`

Sistema Y:

[Y32]

Gestione Errori di Tipo:

[E51] [E52]

Regole di Inferenza $\texttt{SEM}_{\texttt{CMD}}$

[S13]

Osservazioni

- $\texttt{ar} + \Delta$: indica l'estensione dello stack Δ con il record `ar` posto come top del nuovo stack;
- [S13] : Dovremo optare per questa definizione, data la presenza del "return" tra gli statements;