

**section** *StateflowAbstractSyntax* **parents** *basic\_toolkit*

$CNAME, SNAME, DNAME, ENAME, FNAME : \mathbb{P} NAME$	$\text{disjoint}(CNAME, SNAME, DNAME, ENAME, FNAME)$
$CID, SID, JID, TID, EID, DID, FID : \mathbb{P} \mathbb{N}$	$\text{disjoint}(CID, SID, JID, TID, EID, DID, FID)$

$EXPR ::= \text{name}\langle\langle DNAME \times \text{seq } EXPR \rangle\rangle \mid$   
 $\text{value}\langle\langle \mathbb{A} \rangle\rangle \mid$   
 $\text{array}\langle\langle \text{seq}_1 \mathbb{A} \rangle\rangle \mid$   
 $\text{matrix}\langle\langle \text{seq}_1 \text{seq}_1 \mathbb{A} \rangle\rangle \mid$   
 $\text{not}\langle\langle EXPR \rangle\rangle \mid$   
 $\text{and}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{or}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{bnot}\langle\langle EXPR \rangle\rangle \mid$   
 $\text{band}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{bor}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{bxor}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{neg}\langle\langle EXPR \rangle\rangle \mid$   
 $\text{sum}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{sub}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{mult}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{division}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{modulus}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{lshift}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{rshift}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{gt}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{lt}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{geq}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{leq}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{eq}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{neq}\langle\langle EXPR \times EXPR \rangle\rangle \mid$   
 $\text{in}\langle\langle SNAME \rangle\rangle \mid$   
 $\text{after}\langle\langle EXPR \times ENAME \rangle\rangle \mid$   
 $\text{before}\langle\langle EXPR \times ENAME \rangle\rangle \mid$   
 $\text{at}\langle\langle EXPR \times ENAME \rangle\rangle \mid$   
 $\text{every}\langle\langle EXPR \times ENAME \rangle\rangle \mid$   
 $\text{tempCount}\langle\langle ENAME \rangle\rangle$

$TEXPR == \text{ran after} \cup \text{ran before} \cup \text{ran at} \cup \text{ran every} \cup \text{ran tempCount}$

$ACTION ::= bcast\langle\langle ENAME \times (SID \cup CID) \rangle\rangle \mid$   
 $expr\langle\langle EXPR \rangle\rangle \mid$   
 $assign\langle\langle DNAME \times seq\ EXPR \times EXPR \rangle\rangle \mid$   
 $massign\langle\langle seq\ DNAME \times EXPR \rangle\rangle$

$ONACTION == ENAME \times seq\ ACTION$

$DECOMP ::= SEQ \mid PAR$

$STYPE == DECOMP$

$DACTION ::= action\langle\langle seq\ ACTION \rangle\rangle \mid on\langle\langle ONACTION \rangle\rangle$

#### State

$identifier : SID$   
 $name : SNAME$   
 $parent : CID \cup SID$   
 $decomp : DECOMP$   
 $type : STYPE$   
 $entry, exit : seq\ ACTION$   
 $during : seq\ DACTION$   
 $binding : seq(ENAME \cup DNAME)$   
 $history : \mathbb{B}$   
 $default, inner, outer : opt\ TID$   
 $left, right : opt\ SID$   
 $substates : seq\ SID$

#### Junction

$identifier : JID$   
 $parent : CID \cup SID$   
 $transition : opt\ TID$   
 $history : \mathbb{B}$

$TRIGGER ::= e\langle\langle ENAME \rangle\rangle \mid t\langle\langle TEXPR \rangle\rangle$

#### Transition

$identifier : TID$   
 $parent : CID \cup SID$   
 $source : opt( SID \cup JID)$   
 $destination : SID \cup JID$   
 $trigger : seq\ TRIGGER$   
 $condition : opt\ EXPR$   
 $conduct : seq\ ACTION$   
 $transact : seq\ ACTION$   
 $next : opt\ TID$

*EVENTSTRIGGER* ::= *RISINGEDGE* | *FALLINGEDGE* |  
*EITHEREDGE* | *FUNCTIONCALL*

*EVENTSCOPE* ::= *LOCALEVENT* | *INPUTEVENT* | *OUTPUTEVENT*

*Event*

*identifier* : *EID*  
*name* : *ENAME*  
*parent* : *CID*  $\cup$  *SID*  
*scope* : *EVENTSCOPE*  
*trigger* : *EVENTSTRIGGER*

*DATASCOPE* ::= *LOCALDATA* | *INPUTDATA* | *OUTPUTDATA* |  
*CONSTANTDATA* | *PARAMETERDATA* |  
*DATASTOREMEMORYDATA*

*SCALAR* ::= *BOOLEAN* | *DOUBLE* | *SINGLE* | *INT32* | *INT16* | *INT8* |  
*UINT32* | *UINT16* | *UINT8*

*DATATYPE* ::= *scalar* $\langle\langle$ *SCALAR* $\rangle\rangle$  | *vector* $\langle\langle$ *SCALAR*  $\times$  seq *N* $\rangle\rangle$

*Data*

*identifier* : *DID*  
*name* : *DNAME*  
*parent* : *CID*  $\cup$  *SID*  
*scope* : *DATASCOPE*  
*type* : *DATATYPE*  
*initial* : *EXPR*

*SimulinkFunction*

*identifier* : *FID*  
*name* : *FNAME*  
*inputs, outputs* : seq *DNAME*  
*parent* : *CID*  $\cup$  *SID*  
*block* : *NAME*

*GraphicalFunction*

*identifier* : *FID*  
*name* : *FNAME*  
*inputs, outputs* : seq *DNAME*  
*parent* : *CID*  $\cup$  *SID*  
*chart* : *CID*

## Chart

*identifier* : *CID*  
*name* : *CNAME*  
*default* : opt *TID*  
*substates* : seq *SID*  
*decomp* : *DECOMP*  
*states* : *SID*  $\mapsto$  *State*  
*junctions* : *JID*  $\mapsto$  *Junction*  
*transitions* : *TID*  $\mapsto$  *Transition*  
*events* : *EID*  $\mapsto$  *Event*  
*data* : *DID*  $\mapsto$  *Data*  
*sfunctions* : *FID*  $\mapsto$  *SimulinkFunction*  
*gfunctions* : *FID*  $\mapsto$  *GraphicalFunction*

*snames* : *Chart*  $\rightarrow$   $\mathbb{P}$  *SNAME*  
*dnames* : *Chart*  $\rightarrow$   $\mathbb{P}$  *DNAME*  
*enames* : *Chart*  $\rightarrow$   $\mathbb{P}$  *ENAME*  
*sfnames* : *Chart*  $\rightarrow$   $\mathbb{P}$  *FNAME*  
*gfnames* : *Chart*  $\rightarrow$   $\mathbb{P}$  *FNAME*

$\forall c : \text{Chart} \bullet \text{snames}(c) = \{s : \text{ran } c.\text{states} \bullet s.\text{name}\}$   
 $\forall c : \text{Chart} \bullet \text{dnames}(c) = \{\text{data} : \text{ran } c.\text{data} \bullet \text{data}.\text{name}\}$   
 $\forall c : \text{Chart} \bullet \text{enames}(c) = \{e : \text{ran } c.\text{events} \bullet e.\text{name}\}$   
 $\forall c : \text{Chart} \bullet \text{sfnames}(c) = \{f : \text{ran } c.\text{sfunctions} \bullet f.\text{name}\}$   
 $\forall c : \text{Chart} \bullet \text{gfnames}(c) = \{f : \text{ran } c.\text{gfunctions} \bullet f.\text{name}\}$

*unary* :  $\mathbb{P}(\text{EXPR} \rightarrow \text{EXPR})$   
*binary* :  $\mathbb{P}(\text{EXPR} \times \text{EXPR} \rightarrow \text{EXPR})$   
*tempbinary* :  $\mathbb{P}(\text{EXPR} \times \text{ENAME} \rightarrow \text{EXPR})$

*unary* = {*not*, *bnot*, *neg*}  
*binary* = {*and*, *or*, *band*, *bor*, *bxor*, *sum*, *sub*, *mult*, *division*, *modulus*, *lshift*, *rshift*, *gt*, *lt*,  
*geq*, *leq*, *eq*, *neq*}  
*tempbinary* = {*after*, *before*, *at*, *every*}

*WF\_EXPR* : *Chart*  $\leftrightarrow$  *EXPR*

$\forall c : \text{Chart}; n : \text{DNAME}; s : \text{seq } \text{EXPR} \bullet$   
 $(c, \text{name}(n, s)) \in \text{WF\_EXPR} \Leftrightarrow n \in \text{dnames}(c) \wedge (\forall e : \text{ran } s \bullet (c, e) \in \text{WF\_EXPR})$   
 $\forall c : \text{Chart}; n : \text{NAME}; s : \text{seq } \text{EXPR} \bullet (c, \text{fun}(n, s)) \in \text{WF\_EXPR} \Leftrightarrow$   
 $n \in \text{sfnames}(c) \cup \text{gfnames}(c) \wedge (\forall e : \text{ran } s \bullet (c, e) \in \text{WF\_EXPR})$   
 $\forall c : \text{Chart}; a : \mathbb{A} \bullet (c, \text{value}(a)) \in \text{WF\_EXPR}$   
 $\forall c : \text{Chart}; s : \text{seq}_1 \mathbb{A} \mid \# s > 1 \bullet (c, \text{array}(s)) \in \text{WF\_EXPR}$   
 $\forall c : \text{Chart}; s : \text{seq}_1 \text{seq}_1 \mathbb{A} \mid \# s > 1 \bullet$   
 $(c, \text{matrix}(s)) \in \text{WF\_EXPR} \Leftrightarrow \exists n : \mathbb{N} \bullet \forall \text{row} : \text{ran } s \bullet \# \text{row} = n$   
 $\forall c : \text{Chart}; e : \text{EXPR}; \text{op} : \text{unary} \bullet (c, \text{op}(e)) \in \text{WF\_EXPR} \Leftrightarrow (c, e) \in \text{WF\_EXPR}$   
 $\forall c : \text{Chart}; e_1, e_2 : \text{EXPR}; \text{op} : \text{binary} \bullet$   
 $(c, \text{op}(e_1, e_2)) \in \text{WF\_EXPR} \Leftrightarrow (c, e_1) \in \text{WF\_EXPR} \wedge (c, e_2) \in \text{WF\_EXPR}$   
 $\forall c : \text{Chart}; s : \text{SNAME} \bullet (c, \text{in}(s)) \in \text{WF\_EXPR} \Leftrightarrow s \in \text{snames}(c)$   
 $\forall c : \text{Chart}; e : \text{EXPR}; n : \text{ENAME}; \text{op} : \text{tempbinary} \bullet$   
 $(c, \text{op}(e, n)) \in \text{WF\_EXPR} \Leftrightarrow (c, e) \in \text{WF\_EXPR} \wedge n \in \text{enames}(c)$   
 $\forall c : \text{Chart}; n : \text{ENAME} \bullet (c, \text{tempCount}(n)) \in \text{WF\_EXPR} \Leftrightarrow n \in \text{enames}(c)$

$WF\_ACTION : Chart \leftrightarrow ACTION$

$\forall c : Chart; e : Event; d : (SID \cup CID) \bullet (c, bcast(e.name, d)) \in WF\_ACTION \Leftrightarrow$   
 $(e.scope \neq INPUTEVENT \wedge e \in \text{ran } c.events \wedge$   
 $(d \in (\text{dom } c.states) \vee d = c.identifier))$   
 $\forall c : Chart; e : EXPR \bullet (c, expr(e)) \in WF\_ACTION \Leftrightarrow (c, e) \in WF\_EXPR$   
 $\forall c : Chart; n : DNAME; s : \text{seq } EXPR; e : EXPR \bullet$   
 $(c, assign(n, s, e)) \in WF\_ACTION \Leftrightarrow$   
 $n \in \text{dnames}(c) \wedge (\forall e : \text{ran } s \bullet (c, e) \in WF\_EXPR) \wedge (c, e) \in WF\_EXPR$

$WF\_ONACTION : Chart \leftrightarrow ONACTION$

$\forall c : Chart; n : ENAME; as : \text{seq } ACTION \bullet$   
 $(c, (n, as)) \in WF\_ONACTION \Leftrightarrow$   
 $(n \in \text{enames}(c) \wedge (\exists_1 e : \text{ran } c.events \mid e.name = n \bullet e.scope \neq OUTPUTEVENT)) \wedge$   
 $(\forall a : \text{ran } as \bullet (c, a) \in WF\_ACTION)$

$WF\_DACTION : Chart \leftrightarrow DACTION$

$\forall c : Chart; as : \text{seq } ACTION \bullet$   
 $(c, action(as)) \in WF\_DACTION \Leftrightarrow \forall a : \text{ran } as \bullet (c, a) \in WF\_ACTION$   
 $\forall c : Chart; a : ONACTION \bullet$   
 $(c, on(a)) \in WF\_DACTION \Leftrightarrow (c, a) \in WF\_ONACTION$

$WF\_BINDING : Chart \leftrightarrow \text{seq}(ENAME \cup DNAME)$

$\forall c : Chart; s : \text{seq}(ENAME \cup DNAME) \bullet$   
 $(c, s) \in WF\_BINDING \Leftrightarrow \forall n : \text{ran } s \bullet n \in \text{enames}(c) \cup \text{dnames}(c)$

$WF\_STATE : Chart \leftrightarrow State$

$\forall c : Chart; s : State \bullet (c, s) \in WF\_STATE \Leftrightarrow$   
 $s \in \text{ran } c.states \wedge$   
 $s.parent \in \text{dom } c.states \cup \{c.identifier\} \wedge$   
 $s.parent \in \text{dom } c.states \Rightarrow (s.type = PAR \Leftrightarrow (c.states \ s.parent).decomp = PAR) \wedge$   
 $s.parent \notin \text{dom } c.states \Rightarrow (s.type = PAR \Leftrightarrow c.decomp = PAR) \wedge$   
 $s.parent \in \text{dom } c.states \Rightarrow (s.type = SEQ \Leftrightarrow (c.states \ s.parent).decomp = SEQ) \wedge$   
 $s.parent \notin \text{dom } c.states \Rightarrow (s.type = SEQ \Leftrightarrow c.decomp = SEQ) \wedge$   
 $\forall a : \text{ran } s.entry \bullet (c, a) \in WF\_ACTION \wedge$   
 $\forall a : \text{ran } s.exit \bullet (c, a) \in WF\_ACTION \wedge$   
 $\forall a : \text{ran } s.during \bullet (c, a) \in WF\_DACTION \wedge$   
 $(c, s.binding) \in WF\_BINDING \wedge$   
 $s.history = \mathbf{True} \Rightarrow s.decomp = SEQ \wedge$   
 $\text{ran } s.default \subseteq \text{dom } c.transitions \wedge$   
 $\text{ran } s.inner \subseteq \text{dom } c.transitions \wedge$   
 $\text{ran } s.outer \subseteq \text{dom } c.transitions \wedge$   
 $\text{ran } s.left \subseteq \text{dom } c.states \wedge$   
 $\text{ran } s.right \subseteq \text{dom } c.states \wedge$   
 $\text{ran } s.substates \subseteq \text{dom } c.states$

$WF\_JUNCTION : Chart \leftrightarrow Junction$

$$\begin{aligned} \forall c : Chart; j : Junction \bullet (c, j) \in WF\_JUNCTION \Leftrightarrow \\ j \in \text{ran } c.junctions \wedge \\ j.parent \in \text{dom } c.states \cup \{c.identifier\} \wedge \\ \text{ran } j.transition \subseteq \text{dom } c.transitions \wedge \\ j.parent = c.identifier \Rightarrow j.history = \mathbf{False} \wedge \\ j.parent \in \text{dom } c.states \Rightarrow (c.states j.parent).decomp = PAR \Rightarrow j.history = \mathbf{False} \end{aligned}$$

$WF\_TRIGGER : Chart \leftrightarrow TRIGGER$

$$\begin{aligned} \forall c : Chart; n : ENAME \bullet (c, e(n)) \in WF\_TRIGGER \Leftrightarrow \\ \exists event : \text{ran } c.events \bullet event.name = n \wedge event.scope \neq OUTPUTEVENT \\ \forall c : Chart; texp : TEXPR \bullet (c, t(texp)) \in WF\_TRIGGER \Leftrightarrow \\ (c, texp) \in WF\_EXPR \end{aligned}$$

$WF\_TRANSITION : Chart \leftrightarrow Transition$

$$\begin{aligned} \forall c : Chart; t : Transition \bullet (c, t) \in WF\_TRANSITION \Leftrightarrow \\ t \in \text{ran } c.transitions \wedge \\ \text{ran } t.source \subseteq (\text{dom } c.states \cup \text{dom } c.junctions) \wedge \\ t.destination \in (\text{dom } c.states \cup \text{dom } c.junctions) \wedge \\ t.parent \in \text{dom } c.states \cup \{c.identifier\} \wedge \\ \# t.condition > 0 \Rightarrow (c, t.condition 1) \in WF\_EXPR \wedge \\ \forall a : \text{ran } t.conduct \bullet (c, a) \in WF\_ACTION \wedge \\ \forall a : \text{ran } t.transact \bullet (c, a) \in WF\_ACTION \end{aligned}$$

$WF\_DATA : Chart \leftrightarrow Data$

$$\begin{aligned} \forall c : Chart; data : Data \bullet (c, data) \in WF\_DATA \Leftrightarrow \\ data \in \text{ran } c.data \wedge \\ data.parent \in \text{dom } c.states \cup \{c.identifier\} \end{aligned}$$

$WF\_EVENT : Chart \leftrightarrow Event$

$$\begin{aligned} \forall c : Chart; e : Event \bullet (c, e) \in WF\_EVENT \Leftrightarrow \\ e \in \text{ran } c.events \wedge \\ e.parent \in \text{dom } c.states \cup \{c.identifier\} \end{aligned}$$

$WF\_SFUNCTION : Chart \leftrightarrow SimulinkFunction$

$$\begin{aligned} \forall c : Chart; f : SimulinkFunction \bullet (c, f) \in WF\_SFUNCTION \Leftrightarrow \\ f \in \text{ran } c.sfunctions \wedge \\ \text{ran } f.inputs \subseteq sfnames(c) \wedge \\ \text{ran } f.outputs \subseteq sfnames(c) \wedge \\ f.parent \in \text{dom } c.states \cup \{c.identifier\} \end{aligned}$$

$WF\_GFUNCTION : Chart \leftrightarrow GraphicalFunction$

$$\begin{aligned} \forall c : Chart; f : GraphicalFunction \bullet (c, f) \in WF\_GFUNCTION \Leftrightarrow \\ f \in \text{ran } c.gfunctions \wedge \\ \text{ran } f.inputs \subseteq gfnames(c) \wedge \\ \text{ran } f.outputs \subseteq gfnames(c) \wedge \\ f.parent \in \text{dom } c.states \cup \{c.identifier\} \wedge \\ f.chart \in \text{dom } c.transitions \end{aligned}$$

$WF\_CHART : \mathbb{P} Chart$

$\forall c : Chart \bullet c \in WF\_CHART \Leftrightarrow$   
     $\text{ran } c.\text{substates} \subseteq \text{dom } c.\text{states} \wedge$   
     $\forall s : \text{ran } c.\text{states} \bullet (c, s) \in WF\_STATE \wedge$   
     $\forall j : \text{ran } c.\text{junctions} \bullet (c, j) \in WF\_JUNCTION \wedge$   
     $\forall t : \text{ran } c.\text{transitions} \bullet (c, t) \in WF\_TRANSITION \wedge$   
     $\forall data : \text{ran } c.\text{data} \bullet (c, data) \in WF\_DATA \wedge$   
     $\forall e : \text{ran } c.\text{events} \bullet (c, e) \in WF\_EVENT \wedge$   
     $\forall f : \text{ran } c.\text{gfunctions} \bullet (c, f) \in WF\_GFUNCTION \wedge$   
     $\forall f : \text{ran } c.\text{sfunctions} \bullet (c, f) \in WF\_SFUNCTION$