Compositional Transformation of Message Sequence Charts into High–level Petri Boxes

(Extended Abstract)

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Abstract

The concern of this paper consists in utilizing the theoretical findings on the field of formal compositional semantics, in particular those of high level Petri nets, for the specification of communicating embedded systems. Transformation of these approaches, and their evaluation in practice occurs with the aid of one of the formal rotation of the UML namely the Message Sequence Charts, particularly the MSC’96. Communication requirements of embedded systems are graphically specified and then transformed into an executable class of high level Petri nets.

Keywords: Petri nets, compositional semantics, specification, MSC

1. Introduction

Message Sequence Charts (MSCs) have established themselves as a standard description notation for the specification of communicating embedded applications as known for example from the telecommunication area,. Their propagation found even entry into the UML which is becoming more and more popular in the industry. Z.120 [IT96] served here as a pattern for so-called Sequence Charts defined within the UML. The first effort to standardize the semantics of MSCs by means of a process algebra was undertaken in annex B of Z.120. As for all description notations it also applies to MSCs that a formally defined semantics is necessary in order to make conclusions about the system properties or to put it on the same formal basis as another system design notation like SDL in [FG98], gaining so the possibility to check them against each other, that is to verify whether the designed system meets its specification.

For two reasons we decided for so-called M–nets as our semantic domain. M–nets firstly have an algebraic structure and thus allows a compositional transformation. Secondly there is a possibility of a tool based analysis within the PEPTool [Gra97] and the export into another Petri net format.

We proceed as follows: In section 2 we repeat the most important facts about M–nets from [BFF’95]. Afterwards, in section 3 we describe the transformation process of MSCs into that high–level Petri nets. We begin with the High–Level Message Sequence Charts and go ahead
with the *Basic Message Sequence Charts* then. The transformation is based on the textuell syntax description in IT96] and is, due to a better readability, described in the same way as in annex B of Z.120 standard.

### 2. M–Nets

In this section we describe the syntactical and semantical domain of our transformation of MSCs into Petri nets. We use a special class of Petri nets so–called

![Diagram of M–Nets](image)

M–nets — a version of high–level Petri–Boxes [BDH92]. They were developed with the goal to give a fully compositional semantics for concurrent program–ming languages and system notations. More precise definitions are to be found in [BDH92, BFF’95, DK95]. First, we give, some auxiliary definitions and repeat the basic definitions concerning the M–nets.

Let $Q$ be a set, a multi–set over $Q$ is a function $\mu : Q \rightarrow \mathbb{N}_0$. The set of all finite multi–sets over $Q$ is described as $M_f(Q)$. Further we assume the existence of sets $\text{Val}$, $\text{Var}$, $\text{A}$ and $\text{B}$ of values, variables, action symbols and tie–symbols, respectively. Action symbols have arbitrary many parameters $\text{ar}(A) \in \mathbb{N}_0$. There is a bijective function defined over $A$ called conjugation $:\ A \rightarrow A$ satisfying $\forall A \in A : \ A \cong \ A$ and $\text{ar}(\ A) = \text{ar}(A)$. A construct $A(i_1,\ldots,i_{\text{ar}(A)})$ is an *action term* if $A$ is an action symbol and $\forall j : 1 \leq j \leq \text{ar}(A) : i_j \in \text{Val} \cup \text{Var}$. The set of all action terms is described as $AX$. A construct $b^{[n]}(a)$ is a *link symbol* if $b \in B$ and $a \in \text{Val} \cup \text{Var}$.

Definition 2.1 An M–net is a triple $(S,T,\iota)$, such that $S$, $T$ is the set of places and transitions respectively and $\iota$ is a function called inscription with domain $P \cup T \cup (P \times T) \cup (T \times P)$ such that:

![Diagram of M–Net Operations](image)
A marking of an M–net \((S,T,\lambda,\tau,\iota)\), \(M : S \rightarrow (\text{Val}_\lambda, \tau, \iota)\), assigns to each place \(s\) a multi–set of values from \(\tau(s)\). The transition firing rule corresponds to the one of colored Petri nets, i.e. transition \(t\) is enabled in \(M\) if there is an enabling binding \(\sigma\) for variables in the inscription of \(t\) such that there are enough tokens of the appropriate type to satisfy the required token amount and the guard \(\gamma(t)[\sigma]\) is true. The effect of occurrence of \(t\) consists in removing tokens from the input places and adding tokens to its output places according to \(\lambda(s)\) and \(\lambda(t)\) respectively.

\(M\)–nets represent a combination of colored and labeled high–level nets. The net elements i.e. places, transitions and arcs are labeled in addition to types, terms and transition guards with auxiliary information which determines the status of each place (entry, exit or internal) and assigns to each transition a communication resp. refinement interface. These additional inscriptions \(\lambda(s)\) and \(\lambda(t)\) were introduced in order to define some compositional operators over \(M\)–nets [BFF+95]. These are either operators which determine the control flow or the communication with the environment. To the former set belongs the sequential, parallel, alternative and interactive composition (\(;\), \(\parallel\), \([]\) resp. \([**]\)). The later group contains operations for synchronous and asynchronous communication, sy bzw. tie. The latter one was introduced first in [KP99].

As already mentioned above, transitions are labeled with multi–sets of actions. They represent the capability to a synchronous communication With the environment.
Its mechanism is illustrated by means of the figure 1. Nets $N_1$ and $N_2$ each contains one transition with $X(.,.)$ resp. i.e. both transitions can synchronise, in respect of $X$. The result is in the middle of the figure. Transition synchronization gives rise to a new transition labeled with $\alpha_1 + \alpha_2 - \{X(.,.)\}$, i.e. a sum of the both multi-sets minus the synchronization pair. Afterwards, the resulting net is restricted with respect to the action $X$ by the $rs$-operator (restriction). This restriction consists in deleting all transitions labeled with $X$ from the net.

For the explanation of the tie-operator we use a figure 2 from [KP99]. In the left hand part of this figure the tie-operator takes an M-net $N$ and a link symbol $b$ and produces an M-net $tie b$ in the right hand part which is like $N$ but has an additional internal place $s_b$ of the same type as $b$, and additional arcs to and from $s_b$. These arcs connect $s_b$ to every transition $t$ with $b^-$ resp. $b^+$ in such a way that $(t, s_b)$ and $(s_b, t)$ arise. The inscription of the new arcs corresponds to the argument of the link symbol $b$. In other words, the tie-operator realizes a kind of intermediate storage for information which occurs somewhere in the net.

Another important operator which we will make use of is a transition refinement $\tilde{\alpha}:N[X \leftarrow N]$. It is allowed only for hierarchical transitions, i.e. transitions labeled with a variable.

Beyond this, input and output places surrounding the transition to be refined, $\tilde{\alpha}$, must be of the same type. A precise definition of the refinement operator for high-level Petri-nets is in [DK95].

### 3. Transformation of MSCs into M-nets

In this section we describe our approach for transformation of MSCs into M-nets. For the illustration of our approach we use some small examples of an $HMSC Ex$, $MSC Driving$ and $MSC Ref$ in figure 3, 8 resp. 10.

The semantic function $S$ translates every MSC into an M-net. In the style of [IT96] the
general appearance of $S$ is

$$S_{<X>[i]} : \mathcal{L}(<X>) \rightarrow M\text{-}net$$

with $<X>$ a non–terminal from the grammar of MSC’96 [IT96] and $i$ the actual argument representing (part of) an MSC. For example, let $a_1, a_2 \in L(<\text{msc ref expr}>)$ i.e. two sequences of the language derived from the non–terminal symbol $<\text{msc ref expr}>$ then $a_1$ and $a_2$ $\text{alt} a_2$ are valid argument, the latter one representing a sequence constructed from $a_1$, the terminal symbol $\text{alt}$ and $a_2$.

We start with the HMSCs and proceed then in a top–down manner with the BMSCs, instances, events and coregions until the references and inlines. Further, we assume that a maximum number $max_i$ of possibly concurrent instances$^1$ of one and the same BMSC is given, $max_i \in N$ and that places without any type inscription carry implicitly as their type theset{dot}.

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$^1$ Not to confuse with process instances a BMSC consist of.
In dealing with MSCs one MSC–document is a combination of High–level Message Sequence Charts (HMSCs) and Basic Message Sequence Charts (BMSCs). The HMSCs determine the control flow within the scenario and represent a means of abstraction. Therefore the meaning of an MSC–document results from the parallel composition of all referenced BMSCs and the M–net of the actual HMSC. All BMSCs are translated only once. Different references of one and the same BMSC are translated as a sequence of a reference call and termination similar to a procedure call in an imperative programming language [FG97]. Thereby it is possible to keep the M–net size small.

**Definition 3.1** Let \( m \in \mathcal{L}(\text{<msc doc>}), i \in \mathcal{L}(\text{<bmse>}) \) and \( j \in \mathcal{L}(\text{<hmsc>}) \)

such that

\[
S_{\text{<msc doc>}}[m] = [\text{sync} : (\| i \in \text{AllBmsc}(m) \| S_{\text{<bmse>}}[i] \| \| S_{\text{<hmsc>}}[\text{ExtrHmsc}(j)])]
\]

where \( \text{sync} = \{M_c, M_r | c, r \in \text{AllRefName}(m)\} \) is the set of all MSC reference calls and terminations of all referenced BMSCs in \( m \) referenced BSMS and where analogous \( \text{AllBmsc()} \) is the set of all BMSC and \( \text{ExtrHmsc()} \) the set of all HMSC definitions.

Expression \([a : E]\) is a shortened spelling for \((E \text{ synergy} a \text{ rs a})\).

### 3.2 High–level MSC

High–level MSCs describe how a set of BMSCs is combined within a single dia–gram and therefore they describe the control flow between several BMSCs. An HMSC is a directed graph \( G = (N, V) \) whose nodes are either a start symbol, an end symbol, an MSC reference, a connector, a condition or a parallel frame,

\[
i.e. \ N = N_S \cup N_T \text{ with } N_S = N_{\text{startsymbol}} \cup N_{\text{endsymbol}} \cup N_{\text{connector}} \cup N_{\text{condition}} \text{ and } N_T = N_{\text{reference}} \cup N_{\text{frame}}.
\]

**Definition 3.2** Let \( R_a \in \mathcal{L}(\text{<node>}) \) then the semantics of an HMSCs \( H \) is defined as a refinement \( S_{\text{<hmsc>}}[H] = N[X_a \leftarrow S_{\text{<node>}}[R_a]] \) \( \forall a \in N_T \) where \( N = (S, T, v) \) with,
\[ S = N_S \times \{\ast\} \cup \{(x, y) \mid x, y \in N_T \land (x, y) \in V\} \]

\[ T = N_T \times \{\ast\} \cup \{(x, y) \mid x, y \in N_S \land (x, y) \in V\} \]

\[ W((x, \ast), (y, \ast)) = V(x, y), \text{ if } (x, y) \in N_S \times N_T \cup N_T \times N_S \]

\[ W((x, \ast), (x, y)) = V(x, y), \text{ if } (x, y) \in N_S \times N_S \cup N_T \times N_T \]

\[ W((x, y), (y, \ast)) = V(x, y), \text{ if } (x, y) \in N_S \times N_S \cup N_T \times N_T \]

\[
\iota((a, b)) = \begin{cases} 
\emptyset, \{\text{dot}\}, & \text{if } a \in N_{\text{startsymbol}} \land b = \ast \\
\{x\}, \{\text{dot}\}, & \text{if } a \in N_{\text{endsymbol}} \land b = \ast \\
\{\emptyset\}, \{\text{dot}\}, & \text{wenn } a \in N_S \setminus N_{\text{startsymbol}} \cup N_{\text{endsymbol}} \text{ or } \\
a \neq \ast \neq b \land (a, b) \in N_S \times N_T \cup N_T \times N_T \\
\{X\}, \emptyset, \emptyset, & \text{wenn } a \in N_T \land X_e \in \text{Var} 
\end{cases}
\]
where $S_{\text{node}}$ is the \textit{semantic function for the translation of an} HMSC node.

This means that a start, an end, a connector, a condition symbol and edges between any two symbols from $N_T$ become places. All MSC reference, a parallel frame and any two edges between symbols from $N_S$ become transitions. The resulting M–net is then refined with the meaning of the MSC references.
Figure 5: $S_{\text{hMSC}}[\text{Ex}] = \ldots S_{\text{node}}[\text{loop} \ldots ] \ldots$

An example of all HMSC and corresponding M–net are depicted in figure 3. It describes the order of individual BMSCs, namely at first an MSC reference $B1$ occurs and then a connector node comes where the flow branches out either to the reference $B2$ or to another reference consisting of a complex expression.

$((B4 \text{ seq } B5) \text{ par } (\text{loop } B6 \text{ seq } B7))$

Definition 3.3 Let $\text{name} \in \mathcal{L}(<\text{msc name}>)$, $\text{par} \in \mathcal{L}(<\text{par expr list}>)$, $\text{exp}$
$\in \lambda L(<\text{msc ref expr}>)$ and $H$ be an HMSC, then $S_{\text{node}}$ is defined as

$$S_{\text{node}}[\text{par}] = \parallel_{\in \text{AllParHmsc(par)}} S_{\text{node}}[\text{par}]$$

$$S_{\text{node}}[\text{exp}] = S_{\text{msc ref expr}}[\text{exp}]$$

$$S_{\text{node}}[\text{name}] = \begin{cases} N_{\text{ref}}, & \text{if name is an BMSC} \\ S_{\text{hmsc}}[H], & \text{if name is an HMSC } H \end{cases}$$

where $\text{AllParHmsc(par)}$ is the set of all HMSCs within a parallel frame $\text{par}$.

This definition says that a parallel frame is translated by means of the parallel operator $\parallel$. A reference expression combines a number of MSCs to one and is consequently translated according to the following definition (see figures 4 and 5). Finally, an BMSC–reference is translated as a procedure call. The net $N_{\text{ref}}$ is in figure 6.

**Definition 3.4** Let $a_1, a_2, \text{exp} \in L(<\text{msc ref expr}>)$, $p_1, p_2 \in L(<\text{msc ref par expr}>)$, $s_1, s_2 \in L(<\text{msc ref seq expr}>)$, $l p \in L(<\text{loop boundary}>)$ and $\text{name} \in$
The individual stages of an HMSC translation can be seen in figures 3 to 5. Figure 4 shows the M–net after translating the `par` expression; figure 5 is the M–net after resolving the `loop` expression.

### 3.3 Basic Message Sequence Charts

As mentioned above, an BMSC–reference is translated like a procedure call. On the other hand, an BMSC resembles again the body of a procedure.

**Definition 3.5** Let \( p \in \mathcal{L}(\texttt{<bsmc>}) \) then \( S_{\texttt{bsmc}}[p] \) is defined as

\[
S_{\texttt{bsmc}}[p] = N_{\texttt{bsmc}}[B \leftarrow S_{\texttt{bsmc body}}[p]]
\]
Definition 3.6 Let \( p \in \mathcal{L}(\text{<msc body>}) \), \( i \in \mathcal{L}(\text{<inst def>}) \), \( j \in \mathcal{L}(\text{<msc ref expr>}) \)

and \( k \in \mathcal{L}(\text{<inline expr>}) \) then \( S_{\text{<msc body>}} \) is defined as

where \( S_{\text{<msc body>}} \) is the semantic function for an MSC body.

The M–net \( \mathcal{N}_{\text{MSCDed}} \) is defined in the middle part of figure 6. A new instance of the referenced BMSC is created or destroyed through the action names \( M_c \) and \( M_r \) once the respective reference is entered. In order to achieve reusability of instance identifiers a stack similar mechanism consisting of places \( p_2 \) and \( p_1 \) is modeled. Once an MSC reference is entered by synchronizing with \( M_c \) the next free position is taken from the pool \( p_2 \) of free stack positions and the number of currently existing instances in \( p_1 \) is incremented. If an BMSC has finished, identifier is put back onto \( p_2 \) by synchronizing with \( M_r \) and \( p_1 \) is decremented.

The semantics of a body of a Basic Message Sequence Chart is obtained by placing all process instances in parallel together with all MSC references and inlines. Process instances communicate with each other by exchanging asynchronous messages.

\[
S_{\text{<msc body>}} [p] = \\
\sref \cup \inline : (\| i \in \text{AllInst}(p) S_{\text{<inst def>}} [i]) \text{ and } \text{AllMsg}(p) \\
\| (\| j \in \text{AllRef}(p) S_{\text{<msc reference>}} [j]) \\
\| (\| k \in \text{AllInl}(p) S_{\text{<inline expr>}} [k])
\]

where \( \text{AllInst}(p) \) is the set of all instance definitions in \( p \), \( \text{AllRef}(p) \) is the set of all MSC references in \( p \) and \( \text{AllInl}(p) \) is the set of all inlines in \( p \); analogously

\( S_{\text{<inst def>}} \), \( S_{\text{<msc reference>}} \) and \( S_{\text{<inline expr>}} \) are the semantic functions for one instance, reference and inline definition. \( \text{AllMsg}(p) \) is the set of all
\[ S_{\text{inst def}}[e] = S_{\text{event}}[e] \]
\[ S_{\text{inst def}}[e, r] = S_{\text{event}}[e]; S_{\text{inst def}}[r] \]

Figure 7: From the left: \( N_{m^+} \), \( N_{m^-} \) and \( N_{\text{action}} \)

message and timer names in \( p \). Further, it applies to the sets \( \text{Ref} \) and \( \text{Inl} \) that

\[ \text{Ref} = \{ i_{\text{call}} \mid i \in \text{AllInstNames}(p) \land r \in \text{AllRefNames}(p) \} \quad \text{and} \quad \text{Inl} = \{ i_{\text{call}} \mid i \in \text{AllInstNames}(p) \land r \in \text{AllInlNames}(p) \} \]

The precise meaning of functions \( S_{\text{msc reference}} \) and \( S_{\text{inline expr}} \) is explained by means of an example in section 3.7.

3.4 Instance

The semantics of an instance is a sequence of a number of events which occur from the top to the bottom along the instance. The order in which they appear in the textual representation is the order in which they are to be executed. We assume that each message event has a unique name.

Definition 3.7 Let \( e \in L(\text{event}) \) and \( r \in L(\text{inst def}) \) then \( S_{\text{inst def}} \) is defined as

\[ S_{\text{inst def}}[e] = S_{\text{event}}[e] \]
\[ S_{\text{inst def}}[e, r] = S_{\text{event}}[e]; S_{\text{inst def}}[r] \]

where \( S_{\text{event}} \) is the semantic function for instance events.

Definition 3.8 Let \( bl \in L(\text{event name list}) \), \( en \in L(\text{event name}) \), \( m \in L(\text{msg name}) \) and \( i \in L(\text{instance name}) \)

\[ S_{\text{event}}[en \text{ out m to i bl}] = N_{m^+} \]
\[ S_{\text{event}}[en \text{ in m from i bl}] = N_{m^-} \]
\[ S_{\text{event}}[\text{action} at] = N_{\text{action}} \]
3.5 Communication, Action and Timer

Asynchronous communication is modeled by the application of the tie–operation in definition 3.6. Each send event of message $m$ is translated as an M–net $N_{m+}$ in figure 7; each receive event as an M–net $N_{m-}$.

Definition 3.8 Let $bl \in L(<\text{event name list}>)$, $en \in L(<\text{event name}>)$, $m \in L(<\text{msg name}>)$, $i \in L(<\text{event name}>)$

$$S_{<\text{event>}}[en \text{ out m to i b}]] = N_{m+}$$
$$S_{<\text{event>}}[en \text{ in m from i b}]] = N_{m-}$$
$$S_{<\text{event>}}[\text{action a}]] = N_{action}$$

where both the sets $S$ and $R$ are defined as $S = \{L_{m}^*(\text{BeforeList}(bl) \cap iId)\}$ and $R = \{L_{name}(iId) \mid name \in \text{IsBefore (m)}\}$. Functions BeforeList(bl), IsBefore(m) $\subset L(<\text{event name}>)$ define the set of event names whose meaning is explained in definition 3.9.

The semantics of a timer $T$ i.e. the setting of a timer $set_{T}$, a subsequent reset $reset_{T}$ or timeout $timeout_{T}$ are treated in the same way. We assume that for each timer setting in an BMSC or inline there is a corresponding timeout or reset event. All timers have unique names.

3.6 Coregion and General Ordering

The purpose of a coregion is to specify unordered events on a process instance that, is within a coregion all send or receive events may occur in any order even parallel. Only send and receive events are allowed inside a coregion. According to this explanation the semantics of a coregion is the parallel composition of all the events defined within the coregion.

Definition 3.9 Let $cr \in L(f(<\text{coregion}>)$)

$$S_{<\text{event>}}[cr] = ([e \in \text{CoEvents}(cr) \ S_{<\text{event>}}[e]] \text{ tie Ordering}(cr))$$

where $\text{CoEvents}(cr)$ is the set of all message events inside $cr$ and $\text{Ordering}(cr)$ is the set of all message event names which have a before–clause assigned to it.

In definition 3.8 there are the sets $S$ and $R$ defined. Their meaning and that of definition 3.9 are explained in figure 8 and 9. In the upper part of figure 9 there is the M–net corresponding to the coregion on the AS_System process instance befor the tie–operation is applied. The receive event wheel has a before–list $bl = \{\text{brake}, \text{angle}\}$ attached to it, i.e. this message event has to occur before any of the events in $bl$. The same effect is achieved in the M–net through the link
symbol $S = \{Lwheel^{\ell}(x \Theta iid)\}$ with $x = |\text{BeforeList}(bl)|$, i.e. $Lwheel$ puts as many instance identifier tokens onto the place $S_{wheel}$ as the cardinality of the BeforeList set. $\Theta$ is used to relate an element of a multi-set $A$ to the number of its occurrences in a multi-set over $A$. On the other side all message events which appear in any BeforeList are assigned a link symbol $L_{name}^{\ell}(iid)$.

In the MSC of figure 8 this corresponds to the arrows inside the coregion. This is what is called general ordering since causal ordering among otherwise causal unrelated events of a coregion can be enforced. It applies to the process instance AS_System that Wheel occurs before Brake and Angle, but Brake and Angle are unrelated among each other (analogously for Accel and Strength).

![Figure 8: MSC Driving with a coregion](image-url)
Figure 9: From top: coregion before and after the application of the tie–operation
Figure 10: From the left: MSC Ref, $N_{mul}$ and M–net skeleton for MSC Ref

3.7 Inline and BMSC–reference

for reasons of a more comfortable modeling MSC’96 is enriched with so–called *inlines* by which means composition of small and clear event structures may be defined. They serve as a substitute for otherwise small sized BMSC–references. In figure 10 there is an BMSC example with one BMSC–reference expression and inline operator expression. They both are translated in the same way that is all BMSC–reference and an inline operator expression become processes running concurrent side by side with the BMSC body. They have the form of $N_{mul}$ in figure 10.

Definition 3.10 Let $i \in L (<musc ref expr>)$, $n \in L (<inline expr name>)$ and iname $\in L (<name>)$
where $N_{\text{ref}}$ structurally equals to $N_{\text{ref}}$ in figure 6 except for the action symbols $Mc(iid)$ and $Mr(iid)$ which are replaced by $iname_n^{\text{call}}$ and $iname_n^{\text{ret}}$ respectively.

The individual process instances synchronize mutually, similar to a procedure call, all entry into the MSC reference or inline expression so that they simultaneously enter the body. The same comes about while termination.

Definition 3.11 Let $p \in L(<\text{msc ref expr}>)$ the $S_{<\text{msc ref expr}>}$ is defined as

$$S_{<\text{msc ref expr}>}[p] = N_{mul}[B \leftarrow S_{<\text{msc ref expr}>}[p]]$$

where $S_{<\text{msc ref expr}>}$ is defined in section 3.2.

The M–net $N_{mul}$ synchronizes with the corresponding process instances via the reference or inline names. For this purpose $N_{mul}$ is assigned the action set

$$C = \{i_1^{\text{call}}_{(B_1 \text{alt} B_2)}, i_2^{\text{call}}_{(B_1 \text{alt} B_2)}\}$$

and

$$R = \{i_1^{\text{ret}}_{(B_1 \text{alt} B_2)}, i_2^{\text{ret}}_{(B_1 \text{alt} B_2)}\}$$

The transition in the middle of the sequence labeled with $B$ is refined with the contents of MSC reference or inline expression. This can be similar to an HMSC node, a simple BMSC reference or a reference expression containing $\text{alt}$, $\text{par}$ or $\text{seq}$ combined sub–expressions.
Definition 3.12 Let \( n, m \in \mathbb{N} \), \( ba \in \mathcal{L}( \text{alt } \text{msc body} ) \), further \( bp \in \mathcal{L}( \text{par } \text{msc body} ) \), \( b \in \mathcal{L}( \text{msc body} ) \)

\[
S_{\text{inline expr}}[\text{loop } n, m \text{ begin } b \text{ loop end } ] = \\
\frac{N_{\text{loop}}^{n,m}[B \leftarrow S_{\text{msc body}}[b]]}{S_{\text{inline expr}}[\text{alt begin } ba \text{ alt end } ] = \|_{i \in \text{Alt}(ba)} S_{\text{msc body}}[i]}\\
S_{\text{inline expr}}[\text{par begin } bp \text{ par end } ] = \|_{i \in \text{Par}(bp)} S_{\text{msc body}}[i]
\]

where \( \text{AllAlt}(ba) \) is the set of all alternative event definitions and \( \text{AllPar}(bp) \) is the set of all parallel event definitions.

This definition has a similar structure as definition 3.4.

4 Comparison to other Work

There has already been a few works attempting to give a formal semantics to MSCs e.g. [LL93, MR94, Klu97, IT96]. The main determination feature of all these works is less the semantic domain but much more the MSC model elements considered. The older works are concerned with the translation of BMSCs only, the recent one [Klu97] with HMSCs. Both [MR94, Klu97] and annex B of the MSC’96 standard [IT96] translate into a process algebra.

In our work we use a high–level colored Petri net class— M–nets [BFF’95]. We fully utilize both features of M–nets: On the one hand it is their algebraic structure and on the other hand the color of tokens. The former allows us a relatively simple translation of both BMSCs and HMSCs, latter allows us to keep the net size small. In contrast to other works we have defined translation for MSC reference, inline operation expressions, coregion and general ordering. We have achieved similar results for the translation of HMSCs comparing to [Klu97] especially both for simple MSC references, MSC reference expressions and parallel frames by one–step application of the refinement operation.

5 Conclusion

We have showed in this article how to translate MSCs into an executable formal notation based on M–nets. BMSCs are translated by the composition of small and easy to understand M–nets to larger M–nets by the application of some few operations. Due to the possibility of drawing any arbitrary structured HMSC a compositional approach is not feasible here. Instead of this, we assign directly to any HMSC a structure similar M–net whose nodes are refined with subnets in the next step. In order to keep the net size small each referenced BMSC is translated only once. Different instances of one and the same BMSC are distinguished from each other by different integer identifiers. Necessity of a colored high–level Petri net class results out of this.
An extension of our approach with temporal restrictions according to [Hau] is straightforward. Timing restrictions can be assigned to messages, a whole scenario or pairs of events on a process instance. Restrictions have the form of all interval \([sft, lft]\). Such intervals specify the lower and upper bounds on the delay of message delivery, execution duration of whole MSCs or the delay between two consecutive events. Timing information can be used to deduce additional causal information or to rule out possible system traces. Since communication is asynchronous timing restrictions are related always to two events, i.e. two transitions in the M–net. However, most Petri net classes assign timing information only to one net element class that is to transitions, arcs or tokens. Two possibilities result from it: Either the restrictions can be added to the respective net as a set of linear inequalities or the restrictions are split up onto two net elements. In the former case one gets a new Petri net class, i.e. a new theoretical framework is necessary in order to be able to combine it with other net classes. In the latter case there is a risk of inconsistent MSC specification [AHP96] arises. However, this can be analyzed and therefore avoided.

References


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