A NEW TOOL FOR MODULAR MODELLING: THE GENERALISED AND SYNCHRONISED STOCHASTIC PETRI NETS

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Abstract

The association between Stochastic Petri Nets and Markov chains constitute a powerful tool to perform a manufacturing system analysis. Unfortunately, the markovian's models obtained for complex manufacturing systems are so large (combinatory explosion) that their storage and analysis are very expensive and very long. To contain this explosion we are interested in modular modelling. This paper deals with a new tool call Generalised and Synchronised Stochastic Petri Nets (GS²PNs).

Keywords

Stochastic Petri Nets, Decomposition, Modular modelling, Model reduction, manufacturing systems.

1. INTRODUCTION

The models obtained for large and complex systems are often very heavy. Thus, they loose one of the most important advantage of Petri Nets which is the readability. Some tools like Coloured Petri Nets have been developed in Jensen (1981, 1982, 1983), and authorise to make a strong reduction of the number of places and transitions of the models. This sort of Petri Nets is very efficient to decrease the system's structural complexity but doesn't simplify their analysis. Another very important point for the markovian analysis that we want to realise is that we need to generate the marking graph of the Petri Net model which is often very large. The continuous Petri Nets developed by R.David and H.Alla in David (1987, 1988, 1989) bring an answer for combinatory explosion. In this sort of nets the number of tokens in a place can be a real and not only an integer. The interest of this tool is that we don't build a marking graph but an evolution graph which is smaller. The continuous Petri Nets offer an interesting answer to states combinatory explosion but, at the moment, they don't provide any way to

perform an analysis. Our aim is to develop a tool based on SPNs and that authorises modular modelisation.

2. THE GS²PNs - DEFINITIONS

The idea of decomposition as already been wildly explored. Many studies have yet been realised on that topic by Beounes (1984), Noyes (1987) or Jungnitz (1992).

The approach that we propose is different because it doesn't generate decomposable models but directly decomposed systems. Furthermore, our decomposition is not structural but functional.

Definition 2.1

Let $R = \{R_1, R_2, \dots, R_t\}$ a set of GSPNs.

R is a GS²PN if $\forall i \in \{1, 2, \dots, t\}$ then:

- $R_i = \langle P_i, T_i, \text{Pré}_i, \text{Post}_i, M0_i, \text{temp}_i, !S_i, ?S_i \rangle$ where:
- $P_i = \{P_{1i}, P_{2i}, \dots, P_{ni}\}$, finite set of places of R_i with $|P_i| = n_i$.
- $T_i = \{T_{1i}, T_{2i}, \dots, T_{mi}\}$, finite set of transitions of R_i with $|T_i| = m_i$.
- $\text{Pré}_i = P_i \times T_i \rightarrow \{0, 1\}$.
- $\text{post}_i = T_i \times P_i \rightarrow \{0, 1\}$.
- $M0_i = (M0(P_{1i}), M0(P_{2i}), \dots, M0(P_{ni}))$ the initial marking of R_i .
- $\text{temp}_i = \{\lambda_{1i}, \lambda_{2i}, \dots, \lambda_{mi}\}$ set of temporisations associated to the transitions of R_i .
- $!S_i$ = set of synchronisation signals sent by R_i .
- $?S_i$ = set of synchronisation signals awaited by R_i .

with:

$$(P_1 \cap P_2 \cap \dots \cap P_t) = \emptyset.$$

$$(T_1 \cap T_2 \cap \dots \cap T_t) = \emptyset.$$

$$(P_1 \cup P_2 \cup \dots \cup P_t) = P \text{ the set of places of } R.$$

$$T_1 \cup T_2 \cup \dots \cup T_t = T \text{ the set of transitions of } R.$$

□

The signals are sent by places when they contain one token (or more) and are received by transitions. Thus, we can find four sorts of transitions which are shared into the following four sets:

- $Tin = \{\text{immediate and not synchronised transitions}\}.$
- $Ttm = \{\text{timed and not synchronised transitions}\}.$
- $Tis = \{\text{immediate and synchronised transitions}\}.$
- $Tts = \{\text{timed and synchronised transitions}\}.$

We shall represent immediate transitions with an horizontal line and timed transition with an horizontal thick bar.

Definition 2.2

A synchronised transition is *authorised* if the synchronisation signal that it waits for is present.

Definition 2.3

A no synchronised transition is fireable if and only if it's validated.

Definition 2.4

A synchronised transition is fireable if it's both validated and authorised.

As mentioned above, the places send the signals which will be received by the transitions.

Definition 2.5

We shall call « *sending place* », any place which occupation by at least one token induces the emission of a signal.

Example 2.1

The place P_i of net of the picture 2.1 is a sending place.

Definition 2.6

We shall call « *receptive transition* » or « *synchronised transition* », any transition which firing is linked to the presence of a synchronisation signal.

Example 2.2

The transition T_j of the net of the picture 2.1 is receptive.

Graphically, the emission (reception) of a signal by a place (transition) will be represented with a broken arrow leaving (arriving) the place (on the transition)

Picture 2.1 Emission of X_i by P_i , reception of X_i by T_j

Thus, let consider a GS^2PN R constituted by two $GSPNs$ R_1 and R_2 . Some transitions of R_2 are synchronised with signals sent by places of R_1 and vice versa. We can remark that the sending places of R_1 (R_2) are the ones which marking influence the evolution of R_2 (R_1).

3. EVOLUTION RULES AND ALGORITHM

The problems linked to the modelisation with GS^2PNs are principally encountered when trying to interpret the conflicts. For classical $GSPNs$, the only problematic case is the one for which many immediate transitions are simultaneously validated. The GS^2PNs are quite similar. If in the conflict are implied only transitions $\in Tin$, then they are required to belong to the same net (we'll say « *internal conflict* ») and, the conflict can be solved by the classical way which consists in using priorities or switching distributions (see Marsan (1984) or Marsan (1987)). If in the conflict appear some immediate and synchronised transitions, two ways are possible:

- If the conflict concerns transitions of the same net, there is an internal conflict (see above).
- If the conflict concerns transitions from many different nets we'll speak then of « *extended conflict* ».

The extended conflicts are more difficult to solve. The picture 3.1 shows an example of an extended conflict.

Picture 3.1 Extended conflict

This system represents two GSPNs (R1 and R2) synchronised by a send receive. R2 waits for a message from R1 (X1) to go on with its evolution. R1 after the emission of X1 waits for the answer from R2 (X4).

Let suppose that a token is deposited in P3. Transition T2 is then validated but not authorised because signal X1 is not present. Therefore, if a token is deposited in P1, signal X1 is sent and T2 is then authorised. We fire T2 and we reach the marking P1P4. There is here an extended conflict between T1 and T3. In fact, if we fire T3 first then the emission of signal X4 will be stopped and transition T1 will be unauthorised. On the other hand, if we fire T1 first then transition T3 is still firable. To solve this sort of conflict we will use the VFP interpretation which has been proposed in Jacot (1992). This interpretation consists in making the balance-sheet between the tokens produced and consumed by the firing of the transitions in conflict. If this balance-sheet is positive or null then we can fire all the transitions simultaneously. Thus if two transitions are in conflict and if one of them is a reading transition, then the VFP interpretation authorises to fire them simultaneously (see picture 3.2).

Picture 3.2 Conflict which needs the VFP interpretation

In the picture 3.2, transitions T1 and T2 are in conflict. T2 takes a token in P1 and puts it back at once (balance-sheet = 0). T1 consumes one token (balance-sheet = -1). The global balance-sheet is: $0-1=-1$ and there is just one token in P1. This way, we can fire T1 and T2 simultaneously.

Now, let observe the effect of this interpretation on the GS²PNs. The conflict of picture 3.1 may be seen as following.

Picture 3.3 conflict of picture 3.1 with classical PN's

In fact, the synchronisation signal X4 corresponds to a reading of the contents of place P4 by transition T1. The VFP interpretation authorises us to fire T1 and T3 simultaneously.

Definition 3.1

In the case of an external conflict, and according to the VFP interpretation, we fire simultaneously all the transitions.

□

Picture 3.4 shows another case of conflict that can be solve with the VFP interpretation.

Picture 3.4 A conflict a: with GS²PNs, b: with PN's

X1 represents the reading of the contents of P1 by T2 and X2 is the reading of the contents of P2 by T1. T1 consumes one token (balance-sheet = -1) and T2 consumes one token too (balance-sheet = -1). The global balance-sheet is: -1 - 1 = -2 and we dispose of exactly two tokens. Thus, we can fire simultaneously T1 and T2.

Picture 3.5 shows an other case of conflict that the VFP interpretation can't solve.

Picture 3.5 Other sort of conflict

This case is the resource share. Two processes require the same resource and create a conflict between. The global balance sheet of this configuration is negative and we can't fire T1 and T2 simultaneously. Fortunately, T1 and T2 belong to the same net and the conflict is an internal conflict that we can solve by using switching distributions.

Now, let see the GS²PNs evolution rules.

A GS²PN possesses two sorts of markings which are « *tangible markings* » and « *wanishing markings* ». According to the sort of marking is the system in, we shall have two sorts of emitted signals. If the system is in a vanishing marking the emitted signal will be a *pulse* (Dirac $\delta(t)$). If the system is in a tangible state, the emitted signal is a *rectangular signal* (Heaviside $H(t)$) that endures till there are no more tokens in the concerned places.

Definition 3.2

The reception of a « pulse signal » by a transition authorises the passage of only one token. $\square$

The evolution of a GS²PN is subject to the three following rules.

- R1:** If a marking M validate only timed transitions we use the same evolutions rules than for classical SPNs.
- R2:** If a marking M validate only immediate transitions, we fire them simultaneously after solving the external and internal conflicts.
- R3:** If a marking M validate both timed and immediate transitions, we consider only the immediate ones and then apply the rule R2.

Remark 3.1

A signal received by a transition can be a logical combination of signals emitted by others nets.

The picture 3.6 shows three examples of signals logical combinations

Picture 3.6 Logical combinations of synchronisations signals

For the picture 3.6a, T1 will be fired if the signals X1 and X3 are simultaneously present and T2 will be fired if X1 or X3 is present. Notice that if X1 and X3 are simultaneously present, there will be an internal conflict that we solve by using a switching distribution. For example, a switching distribution should be:

$$Pr \{fire\ T1\} = 1/3 \quad Pr \{fire\ T2\} = 2/3$$

The picture 3.7 give some equivalencies between GS²PNs and classical PN.

Picture 3.7 Equivalencies between GS²PNs and classical PN

The following algorithm is the interpretation algorithm for the GS²PNs.

ALGORITHM I

- step1:** Build list L1 of transitions $\in \{T_{in} \cup T_{tn}\}$ and which are validated for M.
- step2:** Build the list L2 of transitions $\in \{T_{is} \cup t_s\}$ and which are validated for M.
- step3:** Build list L3 of transitions $\in \{T_{is} \cup T_{ts}\}$ and which are authorised for M.
- step4:** Build L4 = L2 $\cap$ L3 the list of transitions $\in \{T_{is} \cup T_{ts}\}$ and which are both validated and authorised for M.
- step5:** Build L5 = L1 $\cup$ L4 the list of all the transitions which are fireable for M.
- step6:** If L5 contains both immediate and timed transitions then consider only the immediate ones. Apply rule R3 and obtain:

$$L6 = L5 - \{T_i / T_i \in \{\{T_{tn} \cup T_{ts}\} \cap L5\}\}$$
- step7:** Solve the conflicts between transitions in the list L6. We obtain L7 the list of fireable transitions.
- step8:** Firing of all the transitions with the rules mentioned above.
- step9:** Return to **step1**.

4. FUNDAMENTAL EQUATION

The classical PN have got their fundamental equation that realise the iring. But, what about GS²PNs We shall work on the following GS²PN.

Picture 4.1 Example of GS2PN

Let R a GS²PN composed by two GSPNs $R1$ and $R2$. The incidence matrix W and the initial marking $M0$ are given:

$$W = \begin{bmatrix} -1 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & 0 & -1 & 1 \\ 0 & 0 & 1 & -1 \end{bmatrix} \quad M0 = \begin{bmatrix} 1 \\ 0 \\ 1 \\ 0 \end{bmatrix}$$

Let apply the algorithm I:

- step1:** $L1 = \{T1\}$
- step2:** $L2 = \{T3\}$
- step3:** $L3 = \{T3\}$
- step4:** $L4 = L2 \cap L3 = \{T3\}$
- step5:** $L5 = L1 \cup L4 = \{T1, T3\}$
- step6:** $L6 = L5 - \{T1\} = \{T3\}$
- step7:** No conflicts. $L7 = L6 = \{T3\}$
- step8:** The new marking is calculated by firing $T3$ and is $P1P4$.

The incidence matrix is diagonal by blocks. Each block represents one of the two nets constituting R . $M0$ is also constituted by two blocks which each one represents the initial marking of one of the two nets constituting R . We notice that the i th block of the incidence matrix and the i th block of the marking corresponds both to the same net R_i . Let apply the classical PN's fundamental equation to W and $M0$ with a firing sequence $S^T = [0 \ 0 \ 1 \ 0]$ (firing of $T3$). We notice that the firing sequence S^T is also constituted by blocks.

$$M1 = M0 + W.S = \begin{bmatrix} 1 \\ 0 \\ 1 \\ 0 \end{bmatrix} + \begin{bmatrix} -1 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & 0 & -1 & 1 \\ 0 & 0 & 1 & -1 \end{bmatrix} \cdot \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 1 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

We find, without any surprise, exactly the previous result. The classical PN's fundamental equation can always be used and we can generalise this result to a GS²PN constituted by t GSPNs.

This result is interesting but, isn't it possible to take advantage of the modular nature of the

GS²PNs to find an adapted and more rapid fundamental equation?

Let realise the same calculus but on R1 and R2 separately. Let evaluate M11 and M12 the markings reached by R1 and R2 after the firing of T3. The incidence matrix and the initial markings of R1 and R2 are given:

$$\begin{aligned} W1 &= \begin{bmatrix} -1 & 1 \\ 1 & -1 \end{bmatrix} & W2 &= \begin{bmatrix} -1 & 1 \\ 1 & -1 \end{bmatrix} \\ M01 &= \begin{bmatrix} 1 \\ 0 \end{bmatrix} & M02 &= \begin{bmatrix} 1 \\ 0 \end{bmatrix} \end{aligned}$$

The new marking can be evaluate separately because R1 and R2 are two classical PN. As T3 belongs to R2, the two firing sequences S1 and S2 that we must apply to R1 and R2 are respectively $S_1^T = [0,0]$ and $S_2^T = [1,0]$. Thus, we obtain:

$$\begin{aligned} M11 &= M01 + W1 \cdot S1 = \begin{bmatrix} 1 \\ 0 \end{bmatrix} + \begin{bmatrix} -1 & 1 \\ 1 & -1 \end{bmatrix} \cdot \begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} = M01 \\ M11 &= M01 + W1 \cdot S1 = \begin{bmatrix} 1 \\ 0 \end{bmatrix} + \begin{bmatrix} -1 & 1 \\ 1 & -1 \end{bmatrix} \cdot \begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} = M01 \end{aligned}$$

This new marking is the one that we expected. The calculation of the successive markings reached by the GS²PN R can be realised by using the classical fundamental equation on each net separately. This result is more interesting than the previous one. In fact, it is more efficient and simple to apply the classical fundamental equation on r ($r \leq t$) little nets $(n_i \times m_i)$ than on a big one $(\sum_{i=1}^t n_i \times \sum_{i=1}^t m_i)$. Furthermore, and practically, the fundamental equation is applied less than r times. In fact, the markings of the nets for which no transitions are fired are not modified. We shall not consider them.

Definition 4.1

If a GS²PN is constituted by t nets then we shall say that its order is t and we shall talk about t -GS²PN.

□

Property 4.1

Let R be a t -GS²PN.

$$\left\{ \begin{array}{l} n_i, \text{ the number of places of } R_i \\ m_i, \text{ the number of transitions of } R_i \end{array} \right\} i \in (1, 2, \dots, t)$$

The **step8** of the algorithm1 can be performed as following:

- Build the firing sequence S_i for each net R_i as:

$$\left\{ \begin{array}{ll} S_{ij} = 1 & \text{if } T_j \in L7 \\ S_{ij} = 0 & \text{else} \end{array} \right\} \text{with } T_j \in R_i$$

- Apply the fundamental equation to each net R_i separately, if at least one element of the firing sequence S_i is positive.

$$M'_i = M_i + W_i \cdot S_i$$

□

5. INVARIANTS

To perform the structural validation we must prove that each place of the GS^2PN is *bounded* and that each transition of the GS^2PN is *alive*. This structural validation is usually realised by the research of the *p-semi-flots* and *t-semi-flots*.

A p-semi-flot is a vector F ($n_i \times 1$) as: $F^T \cdot W = 0$.

A t-semi-flot is a vector S ($m_i \times 1$) as: $W \cdot S = 0$.

We can extract, from the p-semi-flots the list of the bounded places and, from the t-semi-flots the list of the alive transitions. If all the places are bounded we shall say that the net is bounded and if all the transitions are alive we shall say that the net is alive.

for example and for the net of the picture 4.1, if $F^T = [f_1 \ f_2 \ f_3 \ f_4]$ and $S^T = [s_1 \ s_2 \ s_3 \ s_4]$ then we obtain:

$$F_1^T = \begin{bmatrix} 1 & 1 & 0 & 0 \end{bmatrix} \text{ and } F_2^T = \begin{bmatrix} 0 & 0 & 1 & 1 \end{bmatrix}$$

$$S_1^T = \begin{bmatrix} 1 & 1 & 0 & 0 \end{bmatrix} \text{ and } S_2^T = \begin{bmatrix} 0 & 0 & 1 & 1 \end{bmatrix}$$

We can then extract from F_1 and F_2 the two following minimal marking invariants:

$$\left\{ \begin{array}{l} M(P_1) + M(P_2) = M_0(P_1) + M_0(P_2) = 1 \\ M(P_3) + M(P_4) = M_0(P_3) + M_0(P_4) = 1 \end{array} \right\}$$

We can also extract from S_1 and S_2 the two following minimal firing invariants:

$$\left\{ T_1 T_2 \text{ and } T_3 T_4 \right\}$$

In the same way that for the fundamental equation, couldn't we use the modular nature of the GS^2PN s to deduce its invariants from the invariants of its sub-nets?

5.1. MARKING INVARIANTS

This calculus is evident for the marking invariants. In fact, as there are no possible transfer of tokens from one sub-net to an other, it is sufficient to prove that each sub-net is bounded.

Let F_j be a p-semi-flot of the sub-net R_j ($j \in (1, 2, \dots, n)$). It is by definition a column vector ($n_j \times 1$). Let extend this vector to the GS^2PN R by adding αp_j zeros above and βp_j zeros below as:

$$\left\{ \begin{array}{l} \alpha p_j = \sum_{i=1}^{j-1} n_i \quad \text{if } j > 1, \text{ else } 0 \\ \beta p_j = \sum_{i=j+1}^n n_i \quad \text{if } j < n, \text{ else } 0 \end{array} \right\}$$

We then obtain the vector $F^T_j = [0 \ \dots \ 0 \ F_j \ 0 \ \dots \ 0]$ which is a p-semi-flot of the net R . The marking invariants of each sub-net R_j are also marking invariants of the GS^2PN R and this

without any modification.

Example 5.1

For the GS^2PN of the picture 4.1 the p -semi-flots of $R1$ and $R2$ are:

$$F1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix} \quad F2 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

We extend these two p -semi-flots as explain above and we obtain:

$$\alpha p_1 = 0 \quad \text{and} \quad \beta p_1 = \sum_{i=2}^2 n_i = n_2 = 2$$

We must add no zero above and two zeros below and obtain $F1^T = [1 \ 1 \ 0 \ 0]$ which is a p -semi-flot of R .

$$\alpha p_2 = \sum_{i=1}^1 n_i = n_1 = 2 \quad \text{and} \quad \beta p_2 = 0$$

We must add 2 zeros above and no zero below and obtain $F2^T = [0 \ 0 \ 1 \ 1]$ which is a p -semi-flot of R .

5.2. FIRING INVARIANTS

The search of firing invariants can be perform by applying a similar method than for marking invariants. This method consists in searching the t -semi-flots for each sub-net separately. To each t -semi-flot corresponds a firing invariant of the sub-net. The firing invariants of the GS^2PN are, without any modification, those of its constituting sub-nets.

On an other hand, the GS^2PN 's t -semi-flots are deduced from the sub-nets' t -semi-flots by : Let S_j be a t -semi-flot of the sub-net R_j ($j \in (1, 2, \dots, n)$). It is by definition a column vector ($m_j \times 1$). Let extend this vector to the GS^2PN R by addicting αt_j zeros above and βt_j zeros below as:

$$\left\{ \begin{array}{l} \alpha t_j = \sum_{i=1}^{j-1} m_i \quad \text{if } j > 1, \quad \text{else } 0 \\ \beta t_j = \sum_{i=j+1}^m m_i \quad \text{if } j < m, \quad \text{else } 0 \end{array} \right\}$$

We then obtain the vector $S^T_j = [0 \ \dots \ 0 \ S_j \ 0 \ \dots \ 0]$ which is a t -semi-flot of the net R .

Knowing the firing invariants of a GS^2PN is not enough to prove its vivacity. At the moment, it doesn't exist a mathematical method which prove the vivacity for GS^2PN s. So, we propose two necessary conditions which, if they are not verified, prove that a GS^2PN is not alive.

Necessary condition n°1

To be alive, a GS^2PN needs necessary that all its constituting sub-nets are alive. The proof of the vivacity of each sub-net can be perform separately by searching its t -semi-flots.

The fact that each sub-net is alive is necessary but not sufficient to prove the vivacity of the GS^2PN . In fact, it is easy to find some structures that induce problems. The picture 5.1 is one example of this sort of structure that we have named « *cross synchronisation* ».

Picture 5.1 Cross synchronisation

The notion of cross synchronisation needs some restrictions. In fact, the fact that the GS²PNs of the picture 5.2a and picture 5.2b contain cross synchronisations is not sufficient to affirm that they are dead.

Picture 5.2 Examples of GS²PNs containing cross synchronisations and not necessary dead

Then we introduce, by the following definition, the notion of « *strong cross synchronisation* ».

Definition 5.1

A cross synchronisation is called *strong* if the two following conditions are verified :

1. The places which send of cross synchronisation signals are only filled by the transitions that they lock.
2. The cross synchronisation signals are wether simple or builded with the logical AND of other signals.

□

We can deduce from this a necessary condition that a GS²PN must possess to be alive:

Necessary condition n°2

To be alive, a GS²PN must not contain any strong cross synchronisation.

If a GS²PN doesn't contain any strong cross synchronisations we can use the same method than for

Example 6.2

For the GS²PN of the picture 4.1 the *t-semi-flots* of R1 and R2 are:

$$S1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix} \quad S2 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

We extend these two *t-semi-flots* as explain above and we obtain:

$$\alpha_1 = 0 \quad \text{and} \quad \beta_1 = \sum_{i=2}^2 m_i = m_2 = 2$$

We must add no zero above and two zeros below and obtain $S1^T = [1 \ 1 \ 0 \ 0]$ which is a t -semi-flot of R .

$$\alpha_2 = \sum_{i=1}^1 m_i = m_1 = 2 \quad \text{and} \quad \beta_2 = 0$$

We must add 2 zeros above and no zero below and obtain $S2^T = [0 \ 0 \ 1 \ 1]$ which is a t -semi-flot of R .

The two necessary conditions are verified and it is not possible to affirm (absolutely) that the GS^2PN of the picture 4.1 is alive. However, the simplicity of this net authorises us to affirm (empirically) that it is alive.

6. BLACK BOX REPRESENTATION

A GS^2PN may be seen as constituted by a set of black boxes. Each of those black box contain a $GSPN$ which evolution depends on signals sent by the other black boxes, and sending also synchronisation signals to the other black boxes. The manufacturing systems are well adapted to this sort of representation. In fact, a manufacturing system can be consider as constituted by a set of machines separated by stocks. We have defined generic models for machines and stocks and a manufacturing system can be easily represented with a sort of « construction game ». Generic models for machines and stocks are given by picture 6.1a and picture 6.1b.

Picture 6.1 a: generic machine, b: generic stock

The picture 6.2a and the picture 6.2b represent the generic models for machines and stocks as black boxes that can be used to describe any manufacturing system

Picture 6.2 generic black boxes for, a: machines, b:stocks

This kind of representation authorises to add other generic models for other function like maintenance or routing scenari.

7. CONCLUSION

In this paper is presented a new tool called GS²PN. This tool is very flexible and authorises a modular description of a system. We can describe each functionality separately and add finally the synchronisations signals.

The evolution rules are simple and more rapid because we work only on little nets and, on an other hand, because only a few sub-nets are concerned for each firing.

The principal reproach with this tool is that we sometimes must add some sets « sending place and immediate transition » to create the emission of a signal. But, to minimise this problem, we must say that the markings thus generate are vanishing markings and don't appear in the marking graph.

We have developed an algorithm which authorises to generate automatically the markovian process of a system describe with GS²PNs. The markovian model obtained is also modular and we have developed an iterative algorithm which extracts the RAM's parameters from this representation.

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