TP sur l'Ingénierie des protcoles

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Durée: 6h

TP : Réseau de Petri
TD – Séance n°

Exercice 1 – L'utilisation des réseaux de Petri pour le contrôle commande

Les réseaux de Petri sont particulièrement bien adaptés pour représenter le contrôle des automatisme, où les actions sont effectuées dans un ordre déterminé par des conditions extérieures. La méthode générale est la suivante :

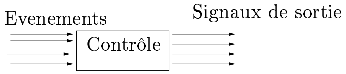


FIG. 1 – Contôle d'un système

On considère un système dont l'état est modifié par des événements externes. A partir de ces événements, le contrôle détermine la valeur des signaux de sortie. Les réseaux utilisés sont des réseaux normés. A chaque place est associée une combinaison booléenne de signaux de sortie. Si la place est marquée, cette combinaison de signaux est émise. A chaque transition est associée une combinaison booléenne de signaux d'entrée. Si cette combinaison de signaux est réalisée, on dit que la transition peut être franchie quand elle est validée et franchissable. Une combinaison de signaux d'entrée peut être vide, ce qui signifie que la transition peut être franchie dès qu'elle est franchissable.

Soit le système constitué d'une pièce qui doit être imprimée sur deux cotés. Deux pochoirs avancent et reculent, mû chacun par deux moteurs actionnés par des signaux Ad, Ag, Rd et Rg. Le signal mg (resp. pg) indique que le pochoir de gauche a atteint la position de repos (resp. a imprimé) (voir la figure 2).

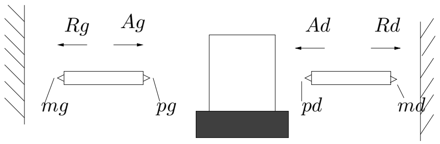


FIG. 2 – Système d'impression par pochoirs

L'opération commence quand un signal p, qui indique que la ppièce est prête, et un signal d de début sont présents.

Le réseau de Petri modélisant ce système est donné par la figuer 3.

1. Donner le réseau de Petri modélisant ce système.

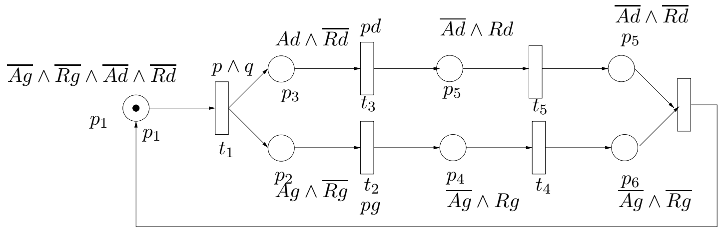


FIG. 3 – Réseau de Petri associé

2. Faites évoluer le réseau de Petri et donner la signification des évolutions.
3. Est-ce que le réseau est cohérent c'est à dire que chaque place ne peut recevoir qu'une seule marque.
4. Est-ce qu'il y a exclusion mutuelle pour tous couples de places étiquetées par des combinaisons booléennes incompatibles de signaux de sorties.
5. Donner le graphe des marquages accessibles.
6. Donner la matrice d'incidence du réseau.
7. Déterminer les P-semi flots associés au réseau.
8. Est-ce que le réseau admet des blocages ?
9. Est-ce que le réseau est un graphe d'événements. Donner les deux circuits élémentaires.

Exercice 2 – Etude d'un réseau de Petri particulier

Considérons le réseau marqué N_0^n de la figure 4 sfrag22

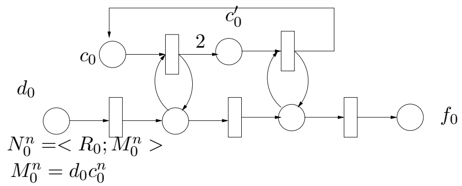
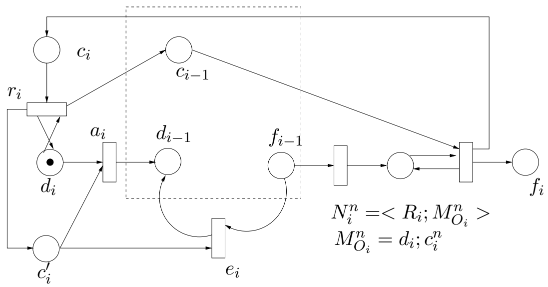


FIG. 4 – Exemple

Le marquage M_0^n est exprimé sous la forme d'un mot : une marque dans d_0, n marques dans c_0).

Ce réseau est borné, c_0' peut recevoir au plus $2n$ marques, il y a blocage quand f_0 a une marque, c_0 peut recevoir au plus $2n$ marques également. Considérons alors la suite de réseaux marqués définie par la figure 5.

1. Donner le P-semiflot associé aux réseau de Petri donné par la figure 4 et 5. Vous donnerez les solutions données par Tina et celle que vous calculerez.



Construction de N_i^n à partir de R_{i-1}

Fig. 5 – Exemple suite

2. Donner les séquences maximales tel que le nombre de jeton dans les sommets b_i sont unitaires.
3. Donner l'arborescence de couverture et le graphe de couverture.
4. En faisant varier le nombre de jetons dans les places b_i donner les limites de l'outil Tina.

Exercice 3 – Spécification d'une construction d'une maison

For scheduling purposes it is usual to describe a work process as a set of partially related tasks. As a very simple (and naive) example, the construction of a house may be described in the following way, where an arc from one task to another indicates that the first task be fully completed before the second can be started (see figure 6).

1. Modify the diagram above so that it becomes a PT-net, where each task is represented by a transition (whiles places represent the states which exist between the ending of some tasks and the beginning of the succeeding ones) Make a simulation of the constructed PT-net.
2. Modify the diagram above so that it becomes a PT-net, where each task is represented by a place (while transitions represent the ending of some tasks and the beginning of the following ones). Make a simultation of the constructed PT-net.
3. Discuss the two PT-nets constructed above. Which one is the more suitable - in the sense that you do not have to introduce places or transitions without a straighforward interpretation in the original system ?

Exercice 4 – Producers and Consumers

The PT-net given by Figure (7) describe a **Producer** who **Sends** some kind of messages via a **Buffer** to a **Consumer** who **Receives** and **Consumes** them.

1. Modify the PT-net so that there are p different **Producers** and c different **Consummers** ($p, c \geq 1$). It is not necessary to be able to distinguish between the individual producers and consumers. Make a simulation of the constructed PT-net.
2. Modify the PT-net in question 1, so that the **Buffer** may contain at most b different messages at the same time ($b \geq 1$). Make a simulation of the constructed PT-net.

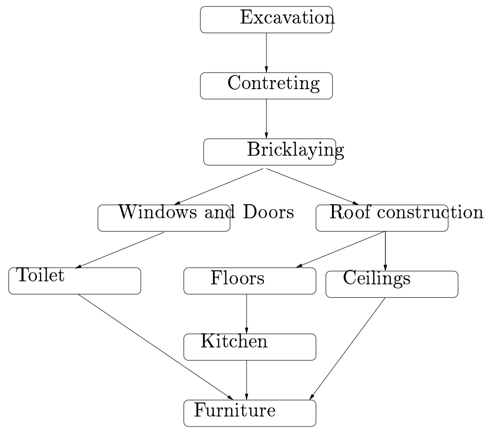


Fig. 6 – Acyclic graph

3. Modify the PT-net created in question 2, so that the messages are **Received** in the same order as they were **Sent**. Make a simulation of the constructed PT-net.

Exercice 5 – Producers and Consumers bis

Conider the same producer/consumer system as in previous exercice. Assume that there is

- A set of Producers $PROD = \{P_1, P_2, \ldots, P_{np}\}$ with $np, \geq 1$
- A set of Consumer $CONS = \{C_1, C_2, \ldots, C_{nc}\}$ with $nc, \geq 1$
- A set of Data $DATA = \{D_1, D_2, \ldots, D_{ncd}\}$ with $nd, \geq 1$
- $val\ np = 3; val\ nc = 2, val\ nd = 4$
- $color\ PROD = index\ P$ with $1 \ldots np$ declare ms ;
- $color\ CONS = index\ C$ with $1 \ldots nc$ declare ms ;
- $color\ DATA = index\ D$ with $1 \ldots nd$;
- $var\ p : PROD; var\ c : CONS; var\ d : DATA$

The system may be described by the CP-net (see figure 8 (in which we have 3 producters, 2 consumers and 4 different kinds of data). Notice that the variable, d (on the outpout arc of Send), does not appear in thz guard or input acr expression of Send. This mean that binding of d does not influence the enabling of Send, and thus each producer can send all kinds of messages (from DATA).

1. Modify the CP-net so that each message is **Sent** to a single specified consumer (who is the only one who may **Receive** it). This can be done by changing the colour set for the **Buffer** from $DATA$ to $CONS \times DATA$ (where $CONS \times DATA$ denotes the cartesian product of $CONS$ and $DATA$, i.e. all pair (c, d) such that $c \in CONS$ and $d \in DATA$). Make a simulation of the constructed CP-net.
2. Modify the CP-net created in question 1, so that the message are **Received** in the same order as they were *Sent*. This can be done by changing the colour set the **Buffer** to $(CONS \times$

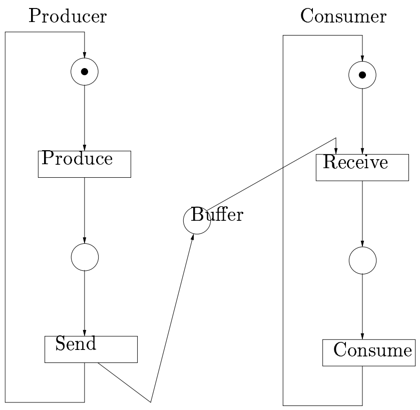


FIG. 7 – Producer and Consumer

$DATA)^*$ containing all finite lists with elements from $CONS \times DATA$. Make a simulation of the constructed CP-net.

Exercice 6 – Semaphore

A semaphore is a device which allows two or more processes to synchronize their actions, e.g. to access shared memory in a safe way. A semaphore has two operations, V and P (also called signal and wait). Each of these operations updates the semaphore value, which is of type integer. THe V operation increases the semaphore by one, while the P operation decreases it by one. However, it is guaranteed that the semaphore value never becomes negative. This implies that it may be necessary to postpone the execution of a P operation until more V operations have occurred.

1. Contruct a PT-net modelling a semaphore system. The net should have two transitions (modelling the V and P operations) and a single place (modelling the semaphore value). Make a simulation of the constructed PT-net. Can the V and V transitions be concurrent to each other ? Can each of them be concurrent to itself ?
2. Construct a CP-net modelling a semaphore system. Again, the net should have two transitions (modelling the V and P oprations) and a single place (modelling the semaphore value). The place should have a colour set in which is of type integer. Make a simulation of the constructed CP-net. Can the V and P trnasitions be concurrent to each other ? Can each of them be concurrent to itself ?

Exercice 7 – L'utilisation des réseaux de Petri pour le contrôle des trains

A small model railway has a circular track with two trains A and B, which move in the same direction. THe track is - for safety reasons- divided into seven different sectors $S = \{s_1, \ldots, s_7\}$. At the start of each sector a signal post indicates whether a train may proceed or not. By means of a set sensors situated at the signal posts it can be automatically determined whether a given sector is empty or not.

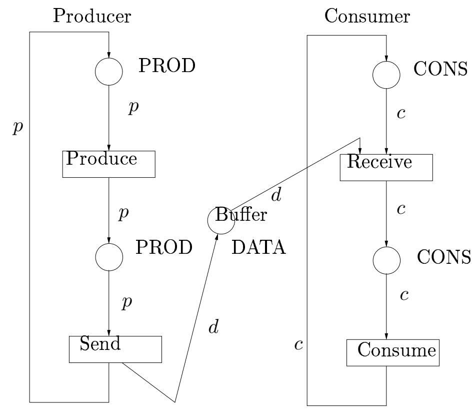


FIG. 8 – Producers and consumers

To allow a train to enter a sector s_i it is course necessary to require that sector to be empty. However, it is also necessary to require the next sector s_{i+1} to be empty (because a stopped train could be situated at the very beginning of s_{i+1}- so near to the signal post that it would be impossible for the incomming train to stop before colliding with the train ahead).

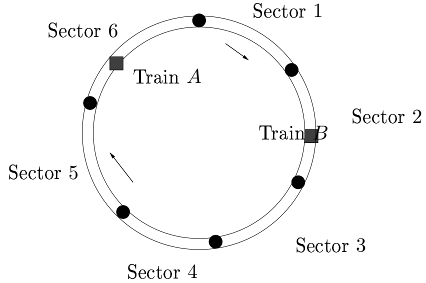


FIG. 9 – A small model railway

1. Describe the train system by a PT-net. Each sector s_i may be represented by three places O_{ia}, O_{ib} and E_i (where O_{ix} is shorthand for "sector s_i occupied by train x" and E_i is shorthand for "sector s_i empty"). Make a simulation of the constructed PT-net.
2. Describe the same system by a CP-net where each sector is described by two places O_i and E_i. Then, O_i has the set $\{a, b\}$ as possible token colours, while E_i has $E = \{e\}$ as token colour. Make a simulation of the constructed CP-net. Compare the CP-net with the PT-net from 1.

3. Describe the same system by a CP-net which only has two places O and E, and a single transition Move to next sector. Make a simulation of the constructed CP-net.

Exercice 8 – L'utilisation des réseaux de Petri pour le contrôle d'un système téléphonique

The functionning of the public telephone system- as it is conceived by a user and not by a telephone technician- may be described by a CP-net with less 15 places and 15 transitions. Each phone may be in a number of different states each of which may be represented by a single place having the set of all phone numbers U as the set of possible token colours :

- **Inactive** the reciver is replaced, and the phone is not involved in any **Connection**
- **Engaged** the opposite of **Inactive**
- **Continuous** the receiver has been lifted and a continuous tone indicates that a number may now be dialled,
- **No Tone** for a short period, while it is investigated whether the dialled phone is **Inactive** or **Engaged**
- **Short** tone with short intervals, indicating that the dialled phone is **Engaged**,
- **Long** tone with long intervals, indicating that the dialled phone is **Inactive**,
- **Ringing** the phone is ringing,
- **Connected** the phone is connected to another phone, and a conversation may take place.

In addition it is necessary to have three places representing the state of the telephone exchange. Each of these places has $U \times U$ as possible token colours. This means that each token is a pair (x, y), where $x \in U$ is the dialling phone and $y \in U$ is the dialled phone :

- **Request** from phone x the number y has been dialled (but nothing else has happened yet),
- **Call** the phone y turned out be **Inactive**- now x has a tone with **Long** intervals, while y is **Ringing**,
- **Connection** the two phones x and y are **Connected**.

The part of the CP-net which describees dialling of a number may look as shown by figure 10.

1. Extend the CP-net so that it becomes a complete description of the public telephone service. Ignore times outs, local switchboards, conferences calls, etc.
2. Make a simulation of the constructed CP-net. What happens when a phone dials its own number ? Can the dialled phone break the connection, or is it only the dialling phone ? Is this correcet model of the telephone system in jours country ? If not, how should be it be modified ?
3. Modify the CP-net so that there are unused phone numbers. An unused number can be activated at any time, while a used only can be deactivated when the corresponding phone is **Inactive**.
4. Modify the CP-net so that it also describes time-outs.

Exercice 9 – Réseau de Petri temporel

Considérons le réseau donné par la figure 11.

1. Donner le graphe de classes.
2. Donner le graphe des composantes fortement connexes du graphe des classes.

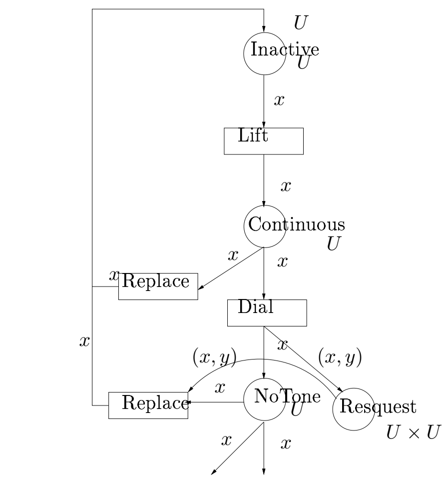


FIG. 10 – PN-net

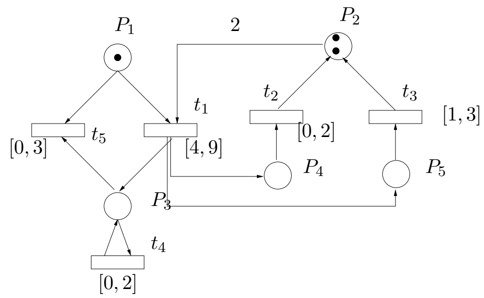


FIG. 11 – Un réseau temporel