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Use of Petri Nets for Modeling an Agent-Based Interactive System: Basic Principles and Case Study

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1. Introduction

Several architecture models of interactive systems have been put forward by researchers over the past twenty years. Two main types of architecture can be distinguished: architectures with functional components: Langage (Foley & Vandam, 1982), Seeheim (Pfaff, 1985) and ARCH (Bass et al., 1991) and architectures with structural components: PAC (Coutaz, 1987), PAC-Amodeus (Nigay, et al., 1997), MVC (Goldberg, 1983), AMF (Tarpin-Bernard & David, 1999), H⁴ (Guittet, 1995),.... The approaches currently used in interactive system design adopt a modular structuring aimed towards a better apprehension of the reactivity, flexibility, maintainability and re-use. Agent-based approaches are promising in this way.

In the agent-based architecture proposed, we suggest using a division into three functional components: the *application agents* which handle the field concepts and cannot be directly accessed by the user; the *interactive agents* (or *interface agents*, or presentation agents) which, unlike the application agents, are in direct contact with the user (they can be seen by the user); the *dialogue control agents* which are also called mixed agents (Ezzedine & Trabelsi, 2005). Each agent therefore plays a role within its group; this role can be expressed in the form of the services it offers in the interactive system.

We use so-called agent Petri Nets (PN) to model a priori the services offered by each interface agent: a service is defined as being a quadruplet $S = \{E, C, R, P\}$, with E: the event which triggers the service, C: the conditions to be met in order to perform this service, R: the resources necessary for the service to be performed, P: the property of this service, which can be either an operation concerning the agent alone (with or without a change of state for the interactive agents), or a call for the service of another agent. The succession of various calls for services gives rise to the succession of page-screens in the human-computer interface.

This chapter begins with a state of the art about the use of Petri nets in Human-Machine Interaction. Then we explain the problem relating to agent-based architectures of interactive systems, and we propose a solution for the modeling of the interface agents of such architectures. Lastly, we illustrate our approach by a case study.

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2. Use of PN in the field of human-computer interaction

Petri nets allow the modeling and visualization of behaviors comprising parallelism, synchronization and resource sharing. Their power lies in their formal aspect; they allow the modeling of discrete systems evolving in parallel, which represents a great contribution for the modeling of various facets relating to human-machine interactions, particularly in complex systems. Various complementary approaches are found on this subject in the literature, based on the use of various types of PN in the field of human-machine interaction, a subject which has been developed ever since the end of the Eighties (Williem & Biljon, 1988). They are given here in a list which is not intended to be exhaustive, but rather to be representative.

Thus, PN were used: (1) before design phases (with an aim of human-computer interaction specification), for task modeling (also called prescribed or theoretical task); it corresponds to the task, envisaged by the designer(s), to be carried out by the user and/or the machine (*a priori* modeling); (2) for the modeling of the human activities (*a posteriori* modeling); this modeling follows the phase of evaluation of the interactive system in a real or simulated situation with users. By a confrontation of the *a priori* and *a posteriori* models, and by an analysis of the differences between these two complementary sets of PN, it is possible to detect design errors, lacks of information, and so on, and to put forward proposals, especially concerning the improvement of human-computer interaction (Abed, 1990; Abed et al. 1992; Abed, 2001). Figure 1 shows an example of modeling with PN of the human-machine interaction planned for part of an interactive application relating to a post of transport network supervision (Ezzedine et al., 2003). The places in the PN represent the actions carried out by the user whereas the transitions represent the reactions from the user interface; the graphic components present on it (bottom left part on figure 1) rise directly from the elements described on the PN (right part of figure 1).

Very important basic research was undertaken by P. Palanque, R. Bastide and their colleagues on the use of the PN for the checking and validation of interactive systems (Palanque & Bastide, 1990; Palanque et al., 1995; Navarre et al., 2003; Winkler et al., 2006...). For instance, they proposed rule-based mechanisms for the automatic evaluation of PN-based models of interactive systems (Palanque et al., 1999).

In the works on the ICO (Interactive Cooperative Objects) (Palanque, 1992; Palanque 1997) and the TOOD method (Task Object Oriented Design) (Mahfoudhi et al., 1995; Tabary & Abed, 2002), Object Petri nets are used to model human tasks in a HCI context and to specify and then design object oriented interactive systems.

Ezzedine and Kolski (2005) present a method for the modeling of cognitive activity also using object Petri nets: the method includes the recognition of the various classes of situation (normal and abnormal) which human operators are likely to meet whilst performing their tasks; each of these classes is described according to the characteristics of the state of the system (Kaddouri et al., 1995).

From a description of normal and abnormal situations possible in process control applications, Moussa et al. (2002, 2006) use interpreted Petri Nets for human-machine dialogue specification.

Kontogianis (2003) chooses to use colored Petri nets for ergonomic task analysis and modeling with emphasis on adaptation to system changes. Gomes et al. (2001) propose an interesting approach based on reactive Petri nets (inherited from colored Petri nets) for human-machine interface modeling.

Fig. 1. Human-computer interaction modeling using PN

Bernonville et al. (2006) propose a method to facilitate the re-engineering of existing interactive software by proposing a common framework for Software Engineers and Human Factor specialists: their method explicitly combines Petri Nets and ergonomic criteria. To our knowledge, none of these works is interested in modeling the agents which make up agent-based interactive systems, by establishing a direct link with the software architecture.

3. Problem of modeling related to agent-based architectures of interactive systems

The architecture of a computer system is a set of structures, each including: components, outside visible properties of these components and relations which the components maintain (Bass et al., 1991). We are only interested in interactive systems: in this context, the architecture models aim to provide a framework for the design and the realization of the complete system, emphasizing clearly the part with which the user interacts. Existing architectures break up the interactive system into modules and define specific roles for each module, contributing to the correct execution of the complete system. Two main types of architecture can be distinguished: architectures with functional components (Langage, Seeheim and Arch) and architectures with structural components (PAC, PAC-Amodeus, MVC...). It should also be noted that certain classifications emphasize three categories (centralized models, distributed or agent-based model, hybrid models).

The classic models of interactive systems distinguish three essential functions (*presentation, control and application*). Some models, such as the Seeheim (Pfaff, 1985) and ARCH models, consider these three functions as being three distinct functional units. Other approaches using structural components, and in particular those said to be distributed or agent

approaches, suggest grouping the three functions together into one unit, the agent. The agents are then organised in a hierarchical manner according to principles of composition or communication: for example PAC (Coutaz, 1997) or its variants, or the MVC model (Model-View-Controller) of Smalltalk and its recent evolutions (Goldberg, 1984), AMF and its variants (Ouadou, 1994), H⁴ (Guittet, 1995)...

These architecture models preach the same principle based on a separation between the system (application) and the human-computer interface (HCI). Thus, an architecture must separate the application and the HCI, define a distribution of the services of the interface and define a protocol of information exchange. One of the interests in separating the interface and the application is to make it easier to modify the interface without changing the application (Coutaz, 1997).

The architecture adopted can be considered as being intermediate as it borrows elements for its principles from both types of model given above at the same time whilst being functional and structural (Ezzedine et al., 2001). In (Ezzedine et al., 2003) and (Ezzedine et al., 2005), we proposed an architecture ensuring separation in three functional components, which we called respectively: *interface with the application* (connected to the application), *dialogue controller* and *presentation* (this component is directly linked to the user), figure 2.

Fig. 2. Agent-based Architecture of interactive system

These three components group together agents:

- the *application agents* which handle the field concepts and cannot be directly accessed by the user. One of their roles is to ensure the correct functioning of the application and the real time dispatch of the information necessary for the other agents to perform their task;
- the *control* (or *dialogue controller*) *agents* which are also called mixed agents; these provide services for both the application and the user. They are intended to guarantee coherency in the exchanges emanating from the application towards the user, and vice versa;
- the *interactive agents* (or *interface agents*, or *presentation agents*); unlike the application agents, these are in direct contact with the user (they can be seen by the user). These agents co-ordinate between themselves in order to intercept the user commands or requests, and to form a presentation which allows the user to gain an overall understanding of the current state of the application. In this way, a window may be considered as being an interactive agent in its own right; its specification describes its presentation and the services it has to perform.

In the following part, we explain how the agents which make up such agent-based interactive systems are modeled. We focus on the interface agents.

3. Principles of modeling by PN of interactive systems with agent-based architecture

Initially, we will point out the basic principles of the parametrized Petri nets which inspired our modeling approach. Then we will explain how the services of the various interface agents of interface can be modeled.

3.1 Parametrized Petri nets

Parametrized Petri nets are classified amongst the high level PN. They allow the modelling of dynamic systems (Gracanin et al., 1994) according to the following principle: it is possible to link, in one parameter of these PN, a coherent set of objects or of values taken by the objects. This makes it possible to handle sets of objects, thus reducing the complexity of the representation.

A parameterized Petri net is a n-tuple: (C, D, Pp, T, I, O) where:

- C: the set of the values of the parameters; a parameter is a class of objects or values taken by the objects.
- D: the set of all the vectors built starting from the values. In such a network, in fact the vectors are produced or consumed (tokens).
- Pp: the set of the places of the network, called parameterization descriptor.
- T: the set of all the transitions from vectors representing all the actions which can be carried out by the system.
- I: the set of consumed tokens (input)
- O: the set of produced tokens (output)

3.2 Modeling of interface agents according to a set of services

The concept of an agent's service such as it was introduced by (Maoudji et al., 2001) considers the service as an action which involves the agent itself or other agents. For a service to be started, the agent needs:

- the appearance of the trigger event
- the checking of the condition in connection with the service,
- the checking of some resources which may be necessary for the establishment of the service.

Formally the service is defined by a quadruplet (Moldt et Wienberg, 1997), Figure 2, $Service = \{E, C, R, P\}$ where:

- E: the event which triggers the service, for example a user action or a display of an alarm or anomaly message coming from an application.
- C: a condition to check in order to carry out the service, such as the exceeding of a threshold as regards the value of one of the application's variables, or the presence of any risk for the application
- R: the resources necessary for the service to be performed.
- P: the property of the service which can be internal (the resulting action affects the agent itself) or external (the resulting action relates to other agents); the latter will be interpreted as an event.

Fig. 2. Modeling of an agent’s service (Maoudji et al., 2001)

3.3 Concept of PN used to model the agents of the interactive system (Agent PN)

Taking the concept of service of an agent introduced by (Maoudji et al., 2001) as a starting point, we propose the modeling of the behaviour of an agent by the modeling of the set of its services, Figure 3. The services of each agent can be represented by external actions on

Fig. 3. Modeling of agent’s services with agent PN (Ezzedine et al., 2001)

other agents; they are then interpreted as trigger events for other agents such as e'_1 , e'_2 and up to e'_n , or by actions on the agents themselves such as looping on the place which is at the entry of their condition C. The service of an agent can be achieved by the execution of an internal or external action only if the condition C is true: i.e. if the place upstream of the condition C is marked (and thus has at least one token), and if event e_i is triggered and the resource necessary to achieve the action is available.

We distinguish three types of place in the PN agent which are:

1. An *agent* place: which always contains the current view of the agent (result of a service).
2. An *event* place: which contains an event which triggers the service.
3. An *intermediate* place: which contains the events bound for another agent.

If we model an interface with n agents and m services for each agent, we will obtain a less readable PN agent, because of this and in order to mitigate the problem of the complexity of the PN, we increase the model by the capacity to abstract the set of services of an agent in one single form, Figure 4.

Fig. 4. Abstraction of the services of an agent.

Formally, an agent (set of n services) is defined by a quadruplet as follows:

Agent= $\{E, C, R, P\}$ where:

- $E = \{e_1, e_2, \dots, e_i, \dots, e_n\}$, set of events which trigger agent services (n events for n services). An event is characterized by two fields: its identifier and the moment of the appearance. For example, an alarm may be triggered when the threshold of a variable to be supervised in an industrial process is exceeded (temperature too high in a chemical process, late bus in a transport system...).
- $C = \{c_1, c_2, \dots, c_i, \dots, c_n\}$, set of conditions necessary for the establishment of the services. Each service must check a condition so that it can trigger itself off. For example: an event may appear following the triggering of an alarm. A condition can be made of several elementary conditions. It at least includes the elementary condition: presence of

the service trigger event.

- $R = \{r_1, r_2, \dots, r_i, \dots, r_p\}$, set of resources which may be necessary for the establishment of the services (if the services have visible actions). A resource can be made of several elementary resources. For example, it may be necessary to have a display screen, a printer or another peripheral device (possibly a sound device) in order to inform the user of the type of alarm message. The information contained in the fields of each resource relates particularly to its size, color(s) and all kinds of information contributing to the characteristics of the human-computer interface.
- P: Properties of the services. Each service results from the execution:
 1. either of a non visible action ac_N (an action which affects the agent itself): for example the service which deals with the displaying of a value of a process variable where the display service alone is involved in updating the value of the variable in question; we then speak about an internal property of the service.
 2. or of a visible action ac_V (an action which relates to another agent); for example actions of the human operator which consist in writing a message with a goal to send it to another person, or the change of a value of a process parameter; we then speak about an external property of the service.

A service can have two properties at the same time: in other words, following the appearance of an event, an agent can act on itself (such as the service which is in charge of the reactualization of a value of a variable) and on another agent at the same time (for instance in the case of exceeding a tolerated threshold of the value of the variable); in this case it will be necessary to generate and display an alarm message, which is the subject of another service.

An external action can relate to several agents (for instance, sending the same message to several agents); it will be regarded as a vector which includes the number of the action and the list of the identifiers of the agents concerned. If several screens of the human-machine interface are concerned with the same message, the agents of message acquisition, treatment and display each perform a different service.

3.4 Mathematical model

A mathematical formulation of the PN agent can be put forward, using (Moldt et Wienberg, 1997) as a starting point:

- An agent a_j is a set S_j of n services, $S_j = \{s_1, s_2, \dots, s_i, \dots, s_n\}$.
- For each service is associated an event e_i belonging to the set E of the events, $E = \{e_1, e_2, \dots, e_i, \dots, e_n\}$.
- To each service, a condition c_i is associated, belonging to the set C of the conditions, $C = \{c_1, c_2, \dots, c_i, \dots, c_n\}$; a condition can be composed of several elementary conditions.
- If the service comprises a visible action, a resource r_i belonging to the set R of the resources is necessary, $R = \{r_1, r_2, \dots, r_i, \dots, r_p\}$.
- the set of the actions of the agent is composed of two subsets; AC_V is the set of visible actions and AC_N corresponds to the set of non visible actions.
 $AC_V = \{ac_{V1}, ac_{V2}, \dots, ac_{Vp}\}$, $AC_N = \{ac_{N1}, ac_{N2}, \dots, ac_{Nq}\}$ with $p \leq n$ and $q \leq n$.

We have:

$\text{Card}(E) = n$, $\text{Card}(C) = n$, $\text{Card}(R) = p$, $\text{Card}(AC_V) = p$, $\text{Card}(AC_N) = q$.

A service results from a minimum of one action (which can be visible in the form of a

display, input coming from a keyboard, a click on the mouse, speech acquisition, ..., or non visible, for instance when there are interactions between internal agents, such as the control agents) and a maximum of two actions (visible and non visible).

The number of all the services of the agent is defined by:

$$\text{Nb_Services} = \text{Card}(E) = n.$$

The number of all the actions of the agent is defined by:

$$\text{Nb_Actions} = \text{Card}(AC_V) + \text{Card}(AC_N) = p + q.$$

It is included in the margin: $n \leq \text{Nb_Actions} \leq 2 \times n$.

We define the result of the service with a couple of actions (AC_{V_k}, AC_{N_t}) , where the indices k and t take the zero value if the service does not contain a visible action or a non visible action. The number of the couples of actions is defined by:

$$\text{Nb_Couples} = \text{Nb_Actions} - \text{Card}(E)$$

We will order for example the couples of actions so that the couples which contain visible and non visible actions are the first, then the couples which contain only visible actions are in second place, while those which contain only non visible actions are in last place.

Then the services are defined by the following parameterized function (the parameter j being the identifier of the agent):

$$\begin{aligned} S_j: E_j \times C_j \times R_j &\longrightarrow AC_V \times AC_N. \\ (e_{i,j}; c_{i,j}; r_{k,j}) &\longrightarrow (ac_{V_{k,j}}; ac_{N_{t,j}}). \quad \begin{aligned} &j = 1, \dots, \text{number of agents} \\ &i = 1, \dots, n. \\ &0 \leq k \leq p \text{ such as if } i \leq p \text{ then } k=i. \\ &\text{else } k=0. \\ &0 \leq t \leq q \text{ such as if } i \leq \text{Nb_Couples} \text{ then } t=i \\ &\text{else} \\ &\text{if } i > p \text{ then } t = i - p + \text{Nb_Couples}. \\ &\text{else } t=0. \end{aligned} \end{aligned}$$

j : identifier of the agent

i : number of the event

AC_V : to express that it is a Visible action.

AC_N : to express that it is a Not Visible action.

k, t : number of the action (if the service does not result by a visible action, then $k=0$; if the service does not result by a non visible action, then $t=0$).

Then the specification of an agent a_j consists in the definition of the sets E_i , C_i , R_k and the mathematical specification of a task of an agent consists of the definition of a sequence of triplets (e_i, c_i, r_k) associated with their couples of actions $(ac_{V_{k,j}}, ac_{N_{t,j}})$, by chronological order of appearance of the events.

4. Case study

The case study relates to an application of supervision of a complex process. It is supposed that a human operator (or group of human operators) is located in a control room: he or she must supervise it by the intermediary of an interactive system. The human operator intervenes in various normal situations as well as in abnormal ones. In the abnormal situations, it must intervene following the arrival of disturbances, or even anticipate them (Stanton, 1994; Moray, 1997). It is supposed that the application relates to the supervision of an urban transport network (such as tramways, buses...).

The architecture suggested for the interactive system consists of three modules: *Application*,

Control and Presentation (figure 5). Each module is composed of agents interacting between themselves and/or with the agents of other modules. Let us recall that an agent (set of n services) is defined by a quadruplet as follows:

Agent = {E, C, R, P}.

It is the presentation module (composed of interactive agents) which we will model according to the following scenario of disturbance:

1. An event e_1 comes from a *dialogue controller* agent, following a disturbance in the application.
2. There is Ac_8 action of agent a_1 (a request for service of the agent a_1 to the agent a_2), following an analysis of the condition c_1 for the execution of the action a_1 ; this Ac_8 action in its turn becomes the event release e_5 for the agent a_2 (for example for the display of a message).
3. Agent a_2 carries out the Ac_3 action which consists in presenting the message to the user if the resource "Window" is available.
4. The event e_3 occurs; it represents the reaction of the user, following the display of the message. It consists of an input of a text with the keyboard or an acknowledgement of the message with the keyboard or the mouse.
5. The agent a_3 carries out the Ac_5 action following an event trigger e_3 which can be a return of an acknowledgement message or the validation of an action provided that c_3 is checked and that the display resource is available.

Fig. 5. Global view of the agent-based architecture, with arrival of a disturbance (Rehim, 2005).

While reformulating more formally, using (Moldt & Wienberg, 1997) as a source of inspiration, the presentation module can be defined by the following elements (figure 6):

$A = \{a_1, a_2, a_3\}$: set of the presentation agents (in the example of figure 6, all three of them are

visible to the user).

$E = \{e_{1,1}; e_{1,2}; e_{1,3}; e_{2,3}; e_{2,1}; e_{2,2}; e_{3,1}; e_{3,2}\}$: set of events coming (1) from the agents of the interface with the application module (via the *dialogue controller* agents which send $e_{1,1}$ and $e_{1,2}$ events to the presentation module), such as alerts, dysfunctional events, incidents, and so on (2) from user actions such as: commands or confirmations ($e_{1,3}; e_{2,3}$), (3) from non visible actions which become events for other agents ($e_{2,1}; e_{2,2}; e_{3,1}; e_{3,2}$).

$AC = \{ac_{v1,1}; ac_{v2,1}; ac_{v1,2}; ac_{v2,2}; ac_{N1,1}; ac_{N1,2}; ac_{N1,3}; ac_{N2,3}; ac_{N3,3}\}$: set of agent actions; these actions can be visible ($ac_{v1,1}; ac_{v2,1}; ac_{v1,2}; ac_{v2,2}; ac_{v1,3}$), such as the display of information on a screen, or non visible ($ac_{N1,1}; ac_{N1,2}; ac_{N1,3}; ac_{N2,3}; ac_{N3,3}$), such as a request for service to other agents.

$R = \{r_{1,1}; r_{2,1}; r_{1,2}; r_{2,2}; r_{1,3}\}$: set of resources (such as keyboard, mouse, windows...) necessary for the visible actions of the agents, in order to carry out their actions ($r_{1,1}$ is related to $ac_{v1,1}$, $r_{2,1}$ is related to $ac_{v2,1}$, and so on).

$C = \{c_{v1,1}; c_{v2,1}; c_{v1,2}; c_{v2,2}; c_{N1,1}; c_{N1,2}; c_{N1,3}; c_{N2,3}; c_{N3,3}\}$: set of conditions related to the execution of the visible or non visible actions ($c_{v1,1}$ is related to $ac_{v1,1}$, $c_{v2,1}$ is related to $ac_{v2,1}$, and so on).

Fig. 6. Reformulated example related to the disturbance (*presentation module*)

For a better representation of the example visible in figure 6, one associates an agent identifier i,j with all the information present in the example; i is the event, action or necessary resource number; j is the agent number (from 1 to N). The possible couples constituted with visible ($ac_{vi,j}$) and non visible ($ac_{Ni,j}$) actions are obtained following the appearance of an $e_{i,j}$ event, under the conditions that $c_{i,j}$ is true and the $r_{i,j}$ resource is available. The modeling of services of each of the three agents forming the presentation module can be expressed as follows, with $r_{0,j}$: resource not necessary for the execution of the non visible action ($ac_{N0,j}$) by an agent j , and with $ac_{v0,j}$ and $ac_{N0,j}$: visible and non visible actions which are not performed by the agent j .

Agent1:

$E1 = \{e_{1,1}; e_{2,1}; e_{3,1}\}$

$Ac_{v1} = \{ac_{v1,1}; ac_{v2,1}\}$, $Ac_{N1} = \{ac_{N1,1}\}$,

$R = \{r_{1,1}; r_{2,1}\}$,

$C = \{c_{v1,1}; c_{v2,1}; c_{N1,1}\}$.

$\text{Card}(E_1) = 3, \text{Card}(Ac_{v1}) = 2, \text{Card}(Ac_{N1}) = 1.$
 $\text{Nb_Actions} = \text{Card}(Ac_{v1}) + \text{Card}(Ac_{N1}) = 2+1=3.$
 $\text{Nb_Couples} = \text{Nb_Actions} - \text{Nb_Services} = 3 - 3 = 0.$
 $S1: E_1 \times C_1 \times R_1 \longrightarrow Ac_{v1} \times Ac_{N1}$
 $(e_{1,1}; c_{v1,1}; r_{1,1}) \longrightarrow (ac_{v1,1}; ac_{N1,1})$
 $(e_{2,1}; c_{v2,1}; r_{2,1}) \longrightarrow (ac_{v2,1}; ac_{N1,1})$
 $(e_{3,1}; c_{N1,1}; r_{0,1}) \longrightarrow (ac_{v0,1}; ac_{N1,1})$

Agent2:

$E_2 = \{e_{1,2}; e_{2,2}; e_{3,2}\},$
 $Ac_{v2} = \{ac_{v1,2}; ac_{v2,2}\}, Ac_{N2} = \{ac_{N1,2}\},$
 $R_2 = \{r_{1,2}; r_{2,2}\},$
 $C_2 = \{c_{v1,2}; c_{v2,2}; c_{N1,2}\}.$

$\text{Card}(E_2) = 3, \text{Card}(Ac_{v2}) = 2, \text{Card}(Ac_{N2}) = 1.$
 $\text{Nb_Actions} = \text{Card}(Ac_{v2}) + \text{Card}(Ac_{N2}) = 2+1=3.$
 $\text{Nb_Couples} = \text{Nb_Actions} - \text{Nb_Services} = 3 - 3 = 0.$
 $S2: E_2 \times C_2 \times R_2 \longrightarrow Ac_{v2} \times Ac_{N2}$
 $(e_{1,2}; c_{v1,2}; r_{1,2}) \longrightarrow (ac_{v1,2}; ac_{N1,2})$
 $(e_{2,2}; c_{v2,2}; r_{2,2}) \longrightarrow (ac_{v2,2}; ac_{N1,2})$
 $(e_{3,2}; c_{N1,2}; r_{0,2}) \longrightarrow (ac_{v0,2}; ac_{N1,2})$

Agent3:

$E_3 = \{e_{1,3}; e_{2,3}\},$
 $Ac_{v3} = \{ac_{v1,3}\}, Ac_{N3} = \{ac_{N1,3}; ac_{N2,3}; ac_{N3,3}\},$
 $R_3 = \{r_{1,3}\},$
 $C_3 = \{c_{v1,3}; c_{N1,3}; c_{N2,3}; c_{N3,3}\}.$

$\text{Card}(E_3) = 2, \text{Card}(Ac_{v3}) = 1, \text{Card}(Ac_{N3}) = 3.$
 $\text{Nb_Actions} = \text{Card}(Ac_{v3}) + \text{Card}(Ac_{N3}) = 1+3=4.$
 $\text{Nb_Couples} = \text{Nb_Actions} - \text{Nb_Services} = 4 - 4 = 0.$
 $S3: E_3 \times C_3 \times R_3 \longrightarrow Ac_{v3} \times Ac_{N3}$
 $(e_{1,3}; c_{v1,3}; r_{1,3}) \longrightarrow (ac_{v1,3}; ac_{N1,3})$
 $(e_{2,3}; c_{N2,3}; r_{0,3}) \longrightarrow (ac_{v0,3}; ac_{N2,3})$
 $(e_{3,3}; c_{N3,3}; r_{0,3}) \longrightarrow (ac_{v0,3}; ac_{N3,3})$

From the mathematical modeling above, which made it possible to formulate the interactions of the agents in figure 6, each agent is modeled with the determination of its inputs and outputs in terms of condition, action, event and resource necessary to achieve the service. In figure 7, we present a model of interaction between the agents of the *presentation* module of the human-machine interface.

Figure 8 shows an example of release of the service $s_{7,1}$ "Change_Delay_Threshold_Vehicle" of the agent called *Traffic_State* belonging to the presentation module of the human-machine interface. Following the appearance of the event $e_{7,1}$ "Delay_Threshold_Vehicle" the interface agent *Vehicle* checks the corresponding condition $c_{7,1}$ "Appearance of the event and delay > 5". If the condition is verified, the service is started; the visible action $ac_{v7,1}$ is activated. The activation of this action exploits the resource $r_{7,1}$ "Dialog_Box" and reveals an alarm message bound for the human operator.

Fig. 7. Modeling of the example related to the disturbance (Rehim, 2005)

We notice, with the example presented above (figure 8), that there is no non visible action ($ac_{N0,1}$) of agent 1 in transition T1, i.e. that there is no interaction with other internal agents; but on the other hand, thanks to the visible action $ac_{v7,1}$, agent 1 acts on an external agent which is the window n°2 belonging to the presentation module of the interactive system.

Fig. 8. Example of release of a service of the *Traffic_State* agent (Trabelsi, 2006)

4. Conclusion

Through their formal aspect and their capacity to model the dynamics of systems, Petri Nets have been bringing complementary and significant contributions in the human-computer interaction domain since the end of the Eighties. In this chapter, we have explained their utility for the modeling of agents which make up interactive systems with an architecture containing agents. A scenario made it possible to illustrate the approach proposed.

The PN used represent a promising tool for the modeling of such interactive systems. Their originality and their power reside in (1) their capacity to visualize the behavior of each agent (external or internal actions), as well as (2) their capacity of abstraction which makes it possible to keep the same information without any visual complexity, and (3) their formal aspect also enables them to be potentially efficient at the time of the evaluation and validation phase (which is not dealt with in this article).

There are several perspectives with this work. We are currently studying and developing an assistance tool for the evaluation of interactive systems. This tool makes it possible to connect to each interface agent, evaluation agents intended to analyze their behavior at the time of situations of use. The PN must make it possible to

reconstitute the human activities performed (Trabelsi, 2006; Tran et al., 2007). A second perspective relates to generalization with the agents of the two other modules: (1) interface with the application, (2) dialogue controller. Another perspective relates to the evaluation of the approach suggested in various application domains (for instance design and evaluation web sites).

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