Statechart and automatons in the supervisory robust control

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Abstract

The manufacturing control system must take into account the various changes intervening on it. The control system of a manufacturing cell must ensure a maximal productivity level, even if the presence of disturbance or perturbations. This production systems development is in particular characterised by the continuous searching of flexibility, and by the maximal reactivity. A particular attention is given to the influence of incidents over the productivity. We cannot stop the whole production because of a breakdown of a machine. For resolving this problem, we add a level to the supervisory named robust control level. The robustness is seen as the most high level productivity even if there are disturbances. Therefore the robust control module goal is to ensure the control system reaching production objectives even with disturbances. The first part of our contribution aims at providing a formalism to model change mechanisms between working modes. This formalism should help in nominal and degraded working mode validation. The second part of our contribution will consist in developing an approach based on the principle of supervisors commutation, for the robust control of discreet-events systems (DES). An example is presented to illustrate the proposed approach.

Keywords

DES, Statechart, Automatons, Hierarchical Control, Supervisory Control

1 INTRODUCTION

The idea of the structure is to couple, not only one, but several supervisors to the process. Indeed, our motivation is linked to the unpredictable and exceptional

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character of perturbations and, to the necessity to process critical perturbations not taken in account a priori. Generally, most current perturbations are integrated into the nominal functioning. If expected in advance, these perturbations lose in a certain manner their abnormal character. One of the main difficulties when using of such an approach (called integrated approach), resides in the fact that the designer needs to a priori envisage which symptoms are likely to appear and anticipate their processing. In our approach, Supervisors do not work simultaneously, contrarily to the modular supervision. They work towards to a global supervision of the process. A such approach is interesting in the sense where it simplifies complex problem resolution. Indeed, as the complexity of the different supervisors is lesser than the unique supervisor complexity of a centralised supervision. They can more easily synthesise, on the one hand, and on the other hand, in the case where a specification has to be added or modified, it is not necessary to modify the global strategy of control. Only the calculated supervisor for this specification will be added or modified. Each supervisor acts alone on the process in a certain context. It means that in this context, it has a global and total information. However, the global supervision results from the work of the whole supervisors, independent some of others. The structure that we propose is composed of nominal supervisors (noted Sn) and degraded supervisors (noted Sd). The different blocks are overlapped. Each sub-model is a supervisor that is going to control the system in a certain context. Sd, that represents the degraded supervisor is divided in several supervisors (Sd1, Sd2,…, Sdn). Thus the process is attacked by Sn, by Sd1, by Sd2,…,or by Sdn.
The replacement of a block by an other is made by commutation following the occurrence of an event characterised as relevant.

2 MIXED MODEL : STATECHART-AUTOMATONS

The automaton is a graphical language used to specify the control of discrete-event systems. When trying to use this tool beyond its preferential application field for example, to specify working modes, we meet problems triggered by the complexity of what it is necessary to describe and by the important size of descriptions. It becomes essential to structure specifications by exploitation the concept of hierarchy. In our proposed structure, our first constraint is the ability to commute from a supervisor to an other. That is to say to know how to switch from a set of states or activities to an other set of states or activities, during the commutation of the different blocks. We should be able to empty an automaton (to block it) and to activate an other automaton, that will control at one's turn the system. This is not allowed by automaton. We associate to automatons, a graphical language, the Statechart, Harel (1987), Sahraoui (1993), that offers an interesting representation of the notion of hierarchy. According to our objectives, Statechart is a more efficient tool. The Statechart allows us to deactivate some modules and launch some others, according to the workshop configuration. Thus we define a precise job framework for each of the two languages. Statechart defines the working modes and describes the logic of evolution between these modes. Automatons refine the expected behaviour when a mode is reached and mainly realise the efficient control. In other words the Statechart assures the passage from the nominal mode to a degraded mode (and inversely). When the nominal mode or a degraded mode is reached, automatons assure the supervised control, following the classic theory of Ramadge-Wonham, Ramadge (1987,1988,1989), Wonham (1994-1995). This proposition is illustrated in the figure 1.

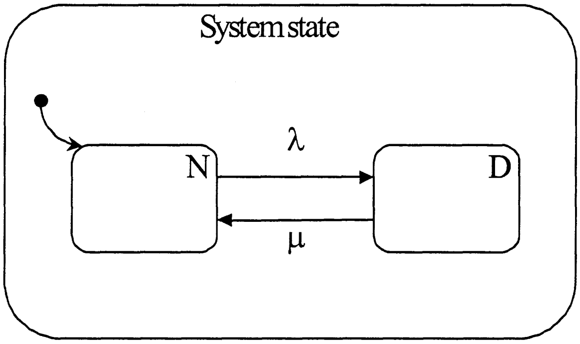

Figure 1 Partial specification Statechart showing only working modes

In our proposition, only one supervisor attacks the process at the same time. In figure 2, at an time t, only one supervisor is active at the same time in the model of the Statechart.

Corollary 1 **:** The structure is an automaton, because in the theory of automatons, only one state is active at the same time.

3 INTEREST OF THE MODEL

Hierarchical control is used when system management becomes too complex and / or in presence of strongly dependent modules, Long (1993). Our approach is based on a global system subdivided in a set of sub-systems. This method leads to successive resolutions of acceptable dimension problems. The efficiency of an hierarchical approach depends on the conception of levels and mechanisms of information return. Our architecture allows a decomposition of the problem in two levels by giving autonomy to each module. This hierarchy does not express only a hierarchy for decision but also a hierarchy for abstraction because the vision of the process is not the same at the different levels. This architecture is suitable to our approach, that will consist in giving to the system strong flexibility and reactivity to disturbances. By taking in account criteria of choice for the model tool, the mixed model Statechart - Automatons seems the most adapted. The Statechart allows to fulfil the gap concerning the impossibility of automatons to express the hierarchy (in term of aggregation). More, for the purpose to obtain a more complete and power graphical tool, Statechart allows in particular to approach more efficiently the description of working modes. The proposition to couple to the automatons the Statechart language, which belong to the same family, offers a graphical mechanism associated to the concept of hierarchy.

4 AN EXAMPLE OF APPLICATION

To illustrate our proposition of supervisory robust control, we consider the example of a production system. Workshop is composed by three machine (M1, M2, M3) and an intermediate buffer (capacity 1). The machine M1 draws brute workpieces in an infinite source and deposits manufactured workpieces in the intermediate buffer. Machines M2 and M3 are identical. They draw workpieces in the intermediate buffer and deposit them, after manufacturing in an infinite well (figure 2).

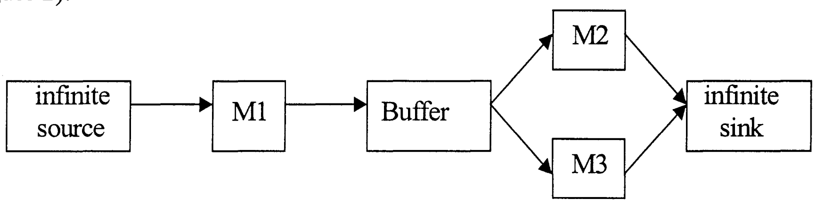

Figure 2 Production System

We consider that the machine M1 never breaks down. But if M2 breaks down and M3 is in good working state, or when M3 breaks down and M2 is in good working state, we want to anticipate a degraded working. We wish to add a constraint of repair priority. If M2 and M3 simultaneously fall in failure, we first repair the machine 2 then the machine 3.

4.1 Description of the problem

The general model proposed is based on the commutation of N distinct models at the occurrence of relevant events. Management of disturbances is mainly supported by the definition of a nominal working and the placement under control of this nominal working . Then the robust control can be then decomposed in two distinct stages:
- out of disturbance: it concerns to find a supervisor that controls the system;
- during the disturbance: it concerns to commute to others specifications.

We are going to develop in this part, in reference to previous works on the supervisory control, an application to the Supervisory Robust Control of production System. Our argument will be developed around a mixed model: Statechart - Automatons. We define a field of action proper to each of them. The Statechart will serve to put in place working modes (nominal mode, degraded modes) and to describe the logic of evolution between these modes; it realises the commutation. Automatons will serve to describe the precise behaviour of the control when they will reach a particular mode following the occurrence of events signalling a disturbance. They will be used, in a first time, to refine leaf states of the Statechart defining modes and, in a second time to realise the effective control.

4.2 Analysis

Our concept is based mainly on the partition of the global alphabet. Let us have Σn, the set of events of the nominal working and Σd the set of events of the degraded working, with $\Sigma n \cap \Sigma d = \varnothing$ ($\Sigma d = \{ \lambda, \mu\}$) It is true that this classification comes naturally, by simple knowledge of the physical process. We have to validate two different levels. The first level will be interested only in relevant events corresponding to a detection of degradation of the nominal working. Thus only breakdown and repair events will be represented. The second level is a refinement of the first level at each state. The validation of the second level corresponds to the each refined state validation of the first level. As alphabets and dynamics are non-contiguous, the sum of separated proofs is equivalent to the global proof. The first level of the model, qualified "high level", is therefore a Statechart. The “low level” is an active state of the Statechart, and therefore modelled by an automaton. In the application that we have chosen, the Statechart serves to define modes and the logic of working.

4.3 Modelling global supervisor

Modelling process

Machines 2 and 3 possesses two states (working, breakdown) (figure 3).

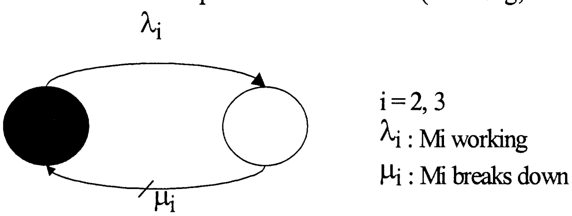

Figure 3 Automatons modelling the working of the two machines.

Initially Mi machines ($i \in \{1, 2\}$) are supposed in working.
The automaton model of the process G is given by the asynchronous product of the two automatons of the figure 3. Then we obtain the model of the figure 4, representing the set of the physically possible working of the production system.

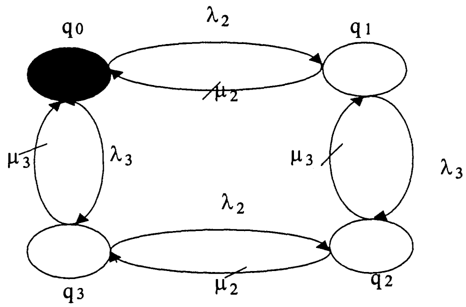

Figure 4 Automaton model of the process G.

Modelling specifications

The specification of the considered production system is linked to the priority of repair. The automaton model of the figure 5 describes the constraint imposed by the specifications. Note S, this model of specification.

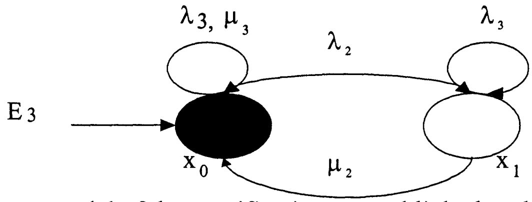

Figure 5 Automaton model of the specification control linked to the priority of repair of the machine M2 (S).

Proof and Synthesis

The research of the working in closed loop shows that the specification of supervision S, is controllable. It is therefore a supervisor. The automaton SUP, represented in the figure 6 is a supervisor for G allowing to guarantee the priority of repair of machines. SUP has the desired behaviour, taking in account priorities and commutations of models control.

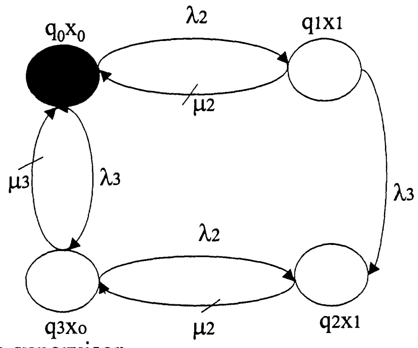

Figure 6 Model of the supervisor

4.4 Comments

We have validated the first level, by using the classic theory of RW [1] [2] [3]. The second level remains to be validate by refining each state of SUP. The Statechart model corresponding to the automaton SUP is given in the figure 7. We replace each circle (state of the automaton) by an end rounded square (state of the Statechart).

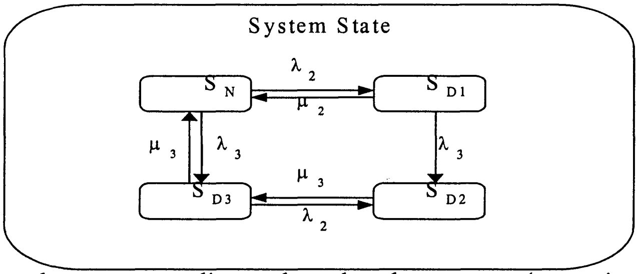

Figure 7 Statechart corresponding to the reduced automaton (supervisory robust control).

The structure that we propose is composed of nominal supervisors (noted Sn) and degraded supervisors (noted Sd). The process is controlled by Sn, by Sd1, by Sd2,..., or by Sdn. At time t, only one of the four supervisors is coupled to the process. Then the robust control module is an automaton, because only one of the states is active at the same time. The stage that corresponds to refine each state of the supervisor is equally a classic procedure, Ramadge (1987, 1988, 1989), Wonham (1994-1995): modelling physical system, determination of the specification, possibly the calculation of a specification, more restrictive but controllable, determination of the supervisor.

5 CONCLUSION

The proposed structure is based on the commutation between supervisors. It allows to reduce considerably the complexity. Thanks to Statechart, the logic of evolution between the different supervisors is very legible, which considerably structure the model of the system. This contribution has following originalities :

- It allows the pursuit of the service , avoiding to penalise productivity in particular situations ;
- It aims to approach the problematical aspect of synthesis and validation by exploiting the formal framework of the theory of RW;
- It attaches to formalise inter-mode switching;
- It uses a mixed model: Statechart-Automatons

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7 BIOGRAPHY

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