ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

CO-DIAGNOSABILITY APPROACH OF DISCRETE EVENT SYSTEMS WITHOUT GLOBAL MODEL BASED ON PETRI NETWORKS AND INTERNAL SUCCESSION EVENTS

Alaoui Ismaili Hajar*, Belmajdoub Fouad
Laboratoire des techniques industrielles (LTI), FST Fès, Université Sidi Mohamed Ben Abdellah.
30000 Fès, Maroc

DOI: 10.5281/zenodo.159314

ABSTRACT

Diagnosability ensures that the global model of a centralized system, will always be able to diagnose a predetermined set of faults previously listed unambiguously. However co-diagnosability guarantee that these faults are diagnosed in a decentralized manner using multiple local diagnosticians. The co-diagnosability property is stronger than diagnosability, because if a system is Co-diagnosable it is diagnosable; while a diagnosable system does not necessarily ensure the co-diagnosability of this system. The challenge of decentralized diagnosis approaches is to perform multiple local diagnostics and verify that they are equivalent to the global one without the need for a global model.

This paper proposes an approach to obtain a decentralized co-diagnosable diagnosis structure of the discrete event system, without the use of a global model, based on internal succession events of local diagnosticians and Petri networks.

KEYWORDS: Discrete event system; co-diagnosability; Petri networks; internal succession events.

INTRODUCTION

A defect can be defined as a deviation from normal behavior, this deviation is a dysfunction which does not prevent a process to perform its function, and it is expressed as a deviation of a property or a characteristic parameter of the process[1]. In this paper, we study Diagnosability of the faults of discrete event systems (DES), which is at the origin of many studies in recent years. The notion of diagnosability of DES was formally introduced in [2] and was widely studied later in [3-5] and [6].This type of system is defined by a finite set of transitions and a finite set of states. Different algorithms have also been developed to solve this problem by Diagnosability [5].

Other work has also been proposed. The first approach given in [7, 8] and [9], consists in making a local diagnosis using local diagnosability and then define a global diagnosability from local diagnosability. But the taking into account the temporal relationships between events, can allow to render some models diagnosable, This observation helped extend the initial work in the context of timed discrete event systems (DES-T), exploiting the timed Petri nets [4].

The work presented in this article is in the continuity of previous work related to Diagnosability of DES. It is also inspired by the study[10]. We study the co-diagnosability of DES by an approach based on local models, by the use of Petri network and internal succession events to obtain a decentralized co-diagnosable diagnosis without the use of a global model. In the second section we introduce some preliminary definitions and notations on Petri nets, related to Diagnosability and co-Diagnosability. In the third section, we will define the problematic and the existing approach. In the fourth section we will propose a modeling approach with Petri nets and the internal succession events. We will finish with a conclusion for considering the prospects of this work.

DIAGNOSABILITY OF DISCRETE EVENTS SYSTEMS BY PETRI NETS

Discrete event system

[11] A discrete event system is a dynamic system where the state space is discrete. Its trajectories of states are piecewise constant. This system operates in accordance with the occurrence of physical events (beginning treatment, end treatment, breakdown, repair), with generally irregular or unknown intervals.

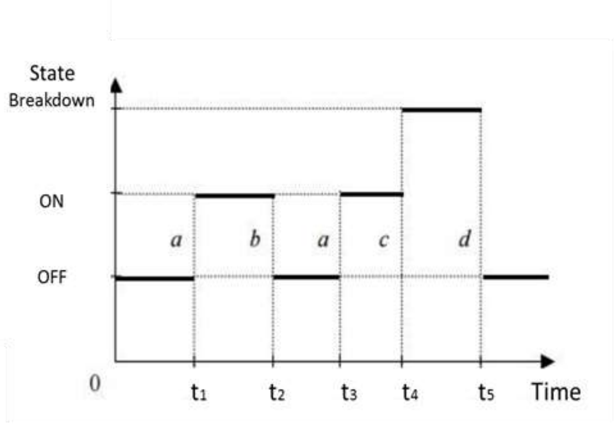


Figure1: the evolution of the state of a discrete event system

Petri nets

[12] Petri nets are used to model the dynamic behavior of discrete systems. They are composed of two types of objects: places and transitions. The places used to represent the state of the system; and the transitions represents all the events whose occurrence causes the change in the system state.

A Petri net is a 4-tuple [6 W+] where:

- P is a finite and not empty set of places.
- T is a finite set of transitions.
- W- (Respectively. W^+) is the incidence function front (respectively back.) of domain of P * T.

Diagnosability

[1] The concept of Diagnosability based on events can be formally defined as follows:
Definition: A language L closed prefix and living is diagnosable compared to a projection function PL and a set of partitions faults ΣΠ if and only if [1]:

$$\forall f \in \Pi FI, \forall i \in \{1,2,\ldots\ldots.,r\}, \exists ni \in N, \forall s \in \psi(\Pi FI), \forall t \in L/S : |t| \geq ni$$
$$\forall w \in PL\text{-}1\ (PL(St)) \rightarrow f \in w$$

This definition means that the language is diagnosable if and only if:
• There are at least a state of a diagnostician, for which the diagnostician decides with certainty the occurrence of fault belonging to a ΠFi partition.
• It should not be any cycles said "indeterminate", for which the diagnostician is unable to determine with certainty the occurrence of a fault belonging to a ΠFi partition.

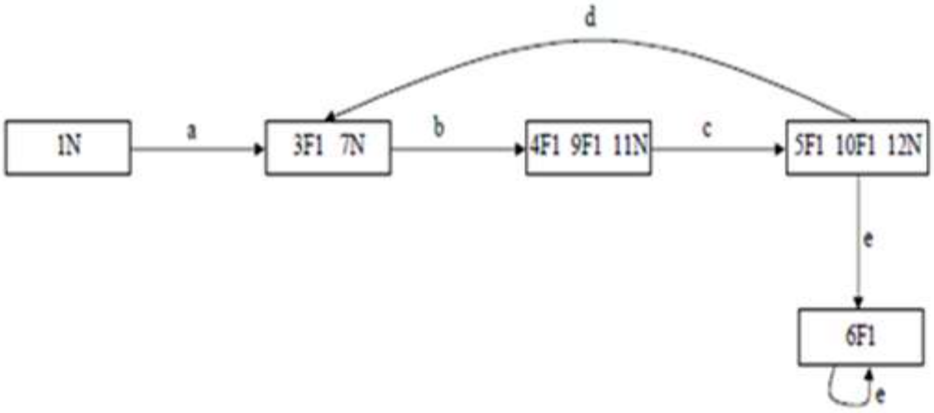


Figure 2: Example of a system with an F1-indeterminate cycle as a diagnostician

This example: Figure (2) present a diagnostician who satisfies the condition 1 since there is a state {6F1} for which the diagnostician decides with certainty a fault occurrence belonging to ΠF1. But it does not verify the condition 2 since there is a cycle (bcd) for which the diagnostician can stay until infinity uncertain of the occurrence of a type of defect F1 ({3F1, 7N}, {4F1, 9f1, 11N} {5F1, 10f1, 12N}). The presence of this indeterminate cycle makes the system not diagnosable.

Co-Diagnosability

The concept of *Co-Diagnosability* must ensure that any failure must be diagnosed in a bounded time by at least one local diagnostician using his own observations.

Definition: A language L closed prefix and living says F-co-diagnosable compared to projection functions PLJ (j ε {1, ..., m}) if and only if:[9]

$$\forall f \in \Pi FI, \forall i \in \{1,2,\ldots\ldots,r\}, \exists ni \in N, \forall s \in \psi(\Pi FI), \forall st \in L, |t| \geq ni$$

$$\exists j \in \{1,2\ldots,m\}, \forall w \in PLj\text{-}1\ (PLj(St)) \cap L \rightarrow f \in w$$

We talk about the *Co-Diagnosability* of decentralized systems, when there are several local diagnosticians, this is to ensure that any failure must be diagnosed in a bounded time by at least one local diagnostician.

Definitions

- A 'Fi certain' state: is a state of diagnostician that contains only the Fi label to indicate with certainty the occurrence of a default.
- A 'Ni certain' state: is a state of diagnostician that contains only the Ni label indicating the absence of any fault of the type Fi.
- A 'Fi uncertain' state: is a state that contains both labels Fi and Ni.
- A 'Fi indeterminate cycle': is a cycle formed by the states ' Fi uncertain'.

EXISTING APPROACH

Comparative Study: the approach of decision making

Most real systems are complex. They are constituted by interconnected and distributed components in terms of information and geographic location. Therefore, Calculating of the diagnosis in a central point increases the complexity of reasoning and causes errors, loss of information, and communication delays during transmission to the central point. A decentralized diagnostic approach is more appropriate and efficient for the diagnosis of real systems.

The table below (1) presents a comparative study of the different structures of decision making diagnosis of DES:

Table 1: Comparative study of the different structures of decision making

Structure of decision making	Model of Process /diagnostician	Communication Protocol	Advantages	Disadvantages
centralized	Global model / global	none	-Don't need a communication protocol - One model with one diagnostician	- Combinatorial explosion - Low robustness - Low maintainability - Tolerant to failures - Slowly progressive
Decentralized Without coordinator	Global model / local	none	-Diminution of combinatorial explosion	- Risk of Decisional conflicts - Conditional architecture
Decentralized With coordinator	Global model / local	coordinator	- Diminution of the explosion And managing conflict by the coordinator	- Need for a coordinator
distributed	Local model / local	between modules	- Managing conflicts directly	- Communication Protocol

From the table (1), we show that:
- Centralized decision-making structures should be avoided because of the combinatorial explosion in the number of states.
- Distributed decision-making structures used to reduce the combinatorial explosion but sometimes imposes heavy and complex communication protocols for resolving cases of indecision.
- Decentralized decision-making structures can both, reduce the risk to the combinatorial explosion and resolve indecision with a simple coordinator decisions.

So, a decentralized diagnosis approach is more appropriate and efficient for the diagnosis of real systems.

Existing approach of decentralized diagnosis

The notion of "Diagnosability" allows to verify if a set of predefined faults, can be diagnosed in a bounded time from a model of the system and a set of observable events. The concept of co-diagnosability should verify that any fault diagnosable by a centralized diagnostician is also diagnosable by at least one local diagnostician using his own observations. The concept of co-diagnosability allows to verify the global diagnosability property of a decentralized system, based on all the local diagnosticians, in a decentralized manner.

The major disadvantage of this method is the need for a global system model to build local diagnosticians and eliminate the indecision states. Obtaining this model can be a very difficult task, if not impossible in the case of systems with a very large number of components.

Our study is situated in the context of the diagnosis based on events: all events of Σ are divided into two disjoint sets, $\Sigma = \Sigma o \cup \Sigma u$, where Σo is a finite set of observable events and Σu is a finite set of unobservable events. Faults are unobservable events ($\Sigma f \varepsilon \Sigma u$). Σf is the set of system faults. Consequently, all of the transitions is also divided into two disjoint subsets of transitions: observable To and unobservable Tu ($T = To \cup Tu$).

- **Example**: Given a global system composed of two local subsystems as shown in Figure (3):
  - Subsystem A, which has two observable events: $\Sigma 1o = \{a, a'\}$. Figure (4.a)
  - Subsystem B, which has two observable events: $\Sigma 2o = \{b, b'\}$. Figure (4.b)

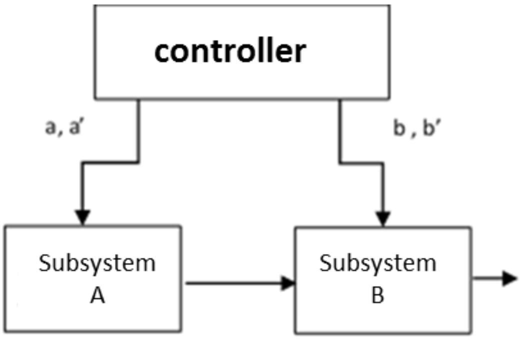
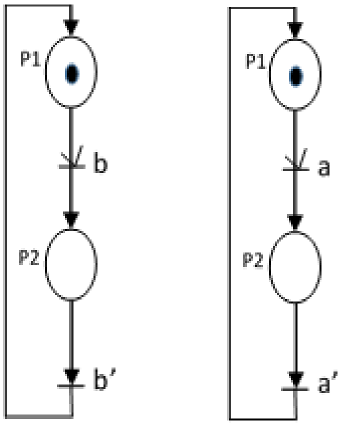


Figure 3: Example of a system composed of two subsystems

The desired functioning by the controller is: G = {<b>, <a> <b '>, <a'>}, this sequence of events begins with the transition b, followed by the transition a, followed by b', and at the end the transition a'. Figure (5)

The modeling of the desired functioning by controller with Petri nets is given in Figure (6) .this modeling includes normal and faulty system behavior. Defects transitions will be noted along the paper by f.



(a) (b)

Figure 4: local models of subsystems A and B established by Petri net

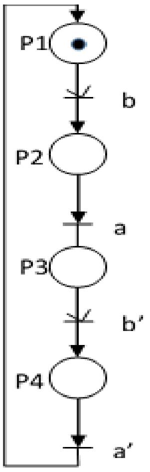


Figure 5: the model of local controller established by Petri net

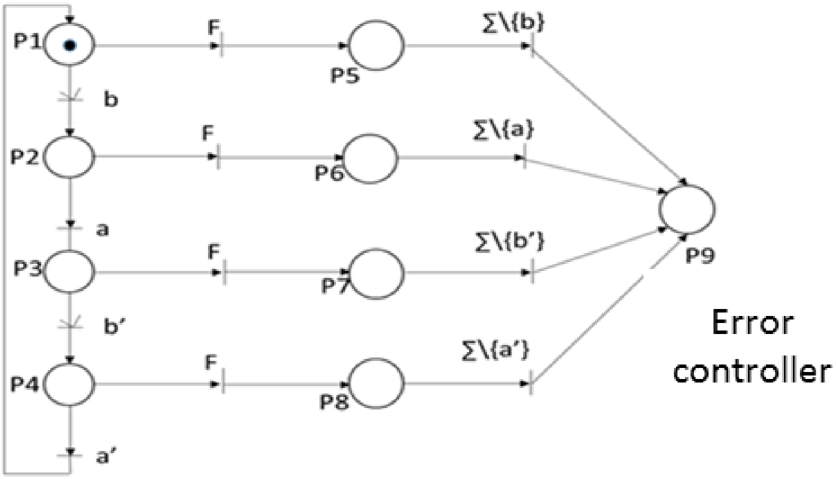


Figure 6: the local model of the controller with the normal and faulty behavior

The construction of the local diagnosticians of the two subsystems A and B is given in Figures (7) (8):

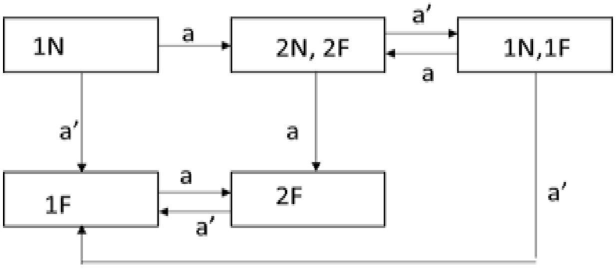


Figure 7: Local diagnostician of subsystem A

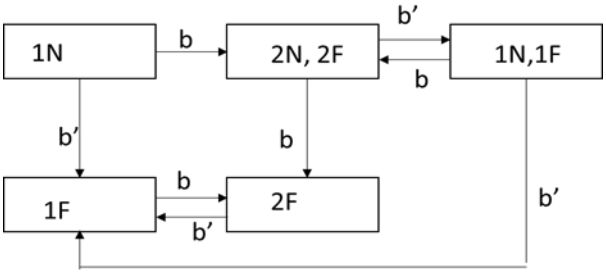


Figure 8: Local diagnostician of subsystem B

The figures (7) and (8) show that local diagnosticians D1 and D2 contain states 'Fi uncertain'. Therefore these diagnosticians are not co-diagnosable, hence the necessity to use a global model of the system to eliminate indecision states.

MODELING APPROACH BY THE PETRI NETWORK AND INTERNAL SUCCESSION EVENTS

In this paper an approach of local models based on Petri net is proposed in order to obtain a decentralized co-diagnosable diagnosis, without the use of a global model but by the use of internal succession events.

In this approach the system is decomposed into a set of interconnected components, and constituted of observable events (observable transitions) and internal succession events (unobservable transition). Figure (9)

For each component i, we build a set of observable events which contains (n) events, and a set of internal succession events which also contains (n) events. So, ∑i= ∑io+∑isi

Whence Σi is a set of events of a subsystem i, Σio is its set of observable events, and Σisi is its set of internal succession events.

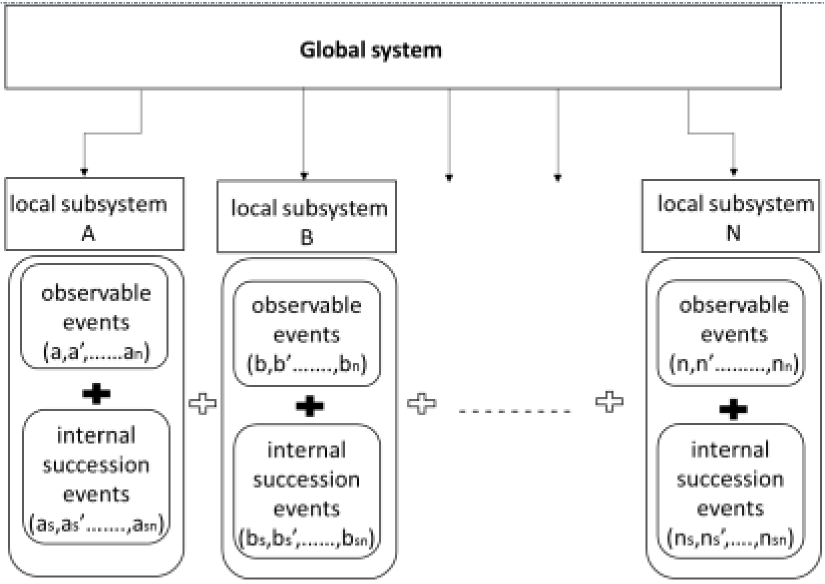


Figure 9: global system divided into N subsystems

- **Example:** Consider the example of two subsystems A and B:

For the subsystem A, we have built two observable events $\Sigma Ao = \{a, a'\}$, and 2 internal succession events $\Sigma Asi = \{as, as'\}$.

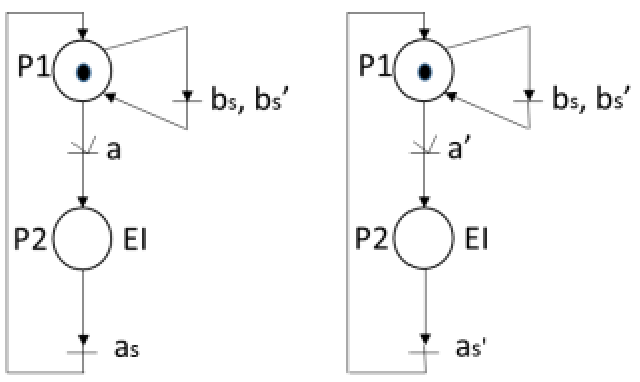
The same for the subsystem B, which was built two observable events $\Sigma Bo = \{b, b'\}$, and 2 internal succession events $\Sigma Bsi = \{bs, bs'\}$.

The communication between these two local subsystems is done in the following way:

Internal succession events leaving (output) the subsystem A, will be the internal succession events entrants in (input) the subsystem B: $\sum isi\ (out) = \sum j\ si\ (in)$, and reciprocally see Figure (10).

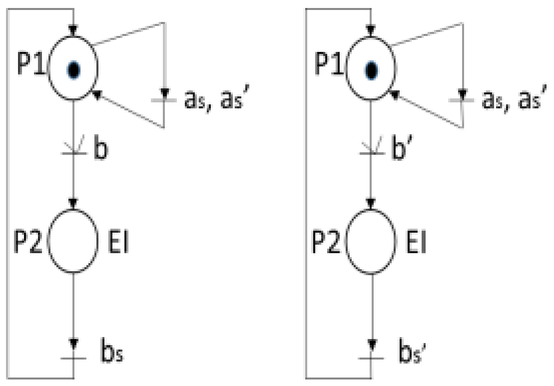
- $\sum Asi(out) = \{as, as'\} = \sum Bsi(in)$
- $\sum Bsi(out) = \sum Asi(in) = \{bs, bs'\}$

Thanks to these internal succession events, the subsystem A will be able to take the next transition of the subsystem B, respecting the desired functioning by the controller. Similarly, subsystem B will be able to take the next transition of the subsystem A, respecting the desired functioning by the controller.



(A1) *(A2)*

Figure 10: internal succession model of the subsystem A



(B1) *(B2)*

Figure 11: internal succession model of the subsystem B

Internal succession models (A1, A2) and (B1, B2) of subsystems A and B are built at first, to build local diagnosticians models A and B.

In B1, the transition (b) leads the subsystem in place P2 which corresponds to an unstable state (EI), the latter will be stabilized by the transition (bs). The transition (bs) stabilizes the unstable state EI, and activates at the same time the process of subsystem A1. The occurrence of the transition (as) in A1 will trigger the process of the subsystem B2, and the occurrence of the transition (bs') in B2 will trigger the process of the subsystem A2.
These internal succession transitions allow to obtain the desired functioning by the controller: G = {<b> <a>, <b '> <a'>}. Each observable transition of this sequence of events leads the system to an unstable state, which is stabilized by an internal succession transition, see Figure (12).

Following the occurrence of an observable transition in a component i, decisions will be calculated based on the use of local models. Finally the decisions of local diagnosticians are summed to calculate the global model for diagnosis which should be equivalent to the diagnosis decision obtained by the centralized diagnosis structure.

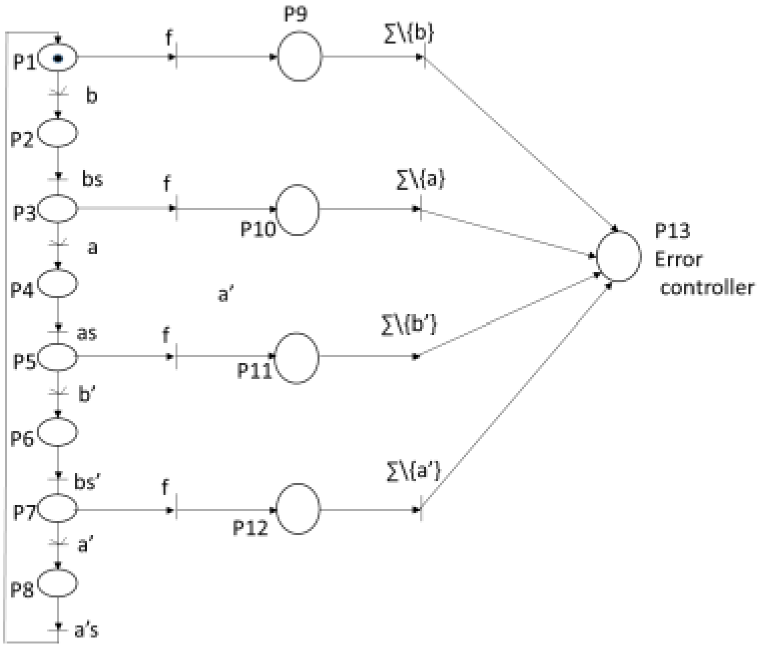


Figure 12: Controller model

After constructing the model of controller that includes normal and faulty states; local models of each subsystems should be established in order to build their local diagnosticians.
Local diagnosticians of the subsystems A and B are formed by the interaction of several states

_ ED and ED ': desired states _EI: unstable states _ EC: controller error

Each state corresponds to a set of places of Petri network, with different labels according to their modes of operating:

_N: normal state _N*: unstable normal state _F: Fault state _F *: unstable fault state

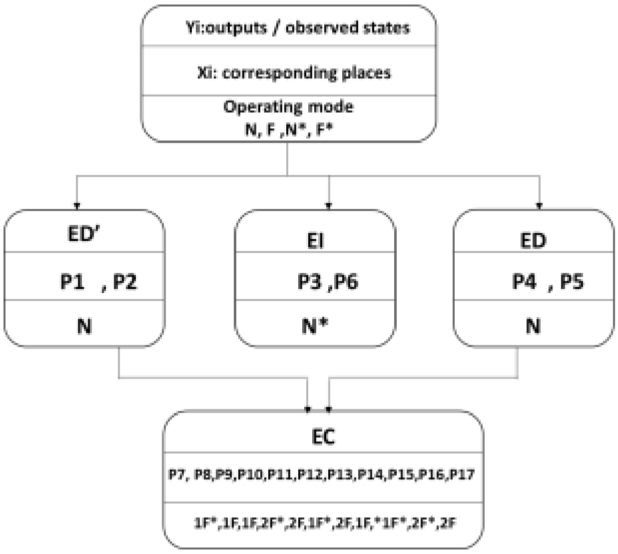


Figure 13: Local diagnostician D1 of the subsystem A

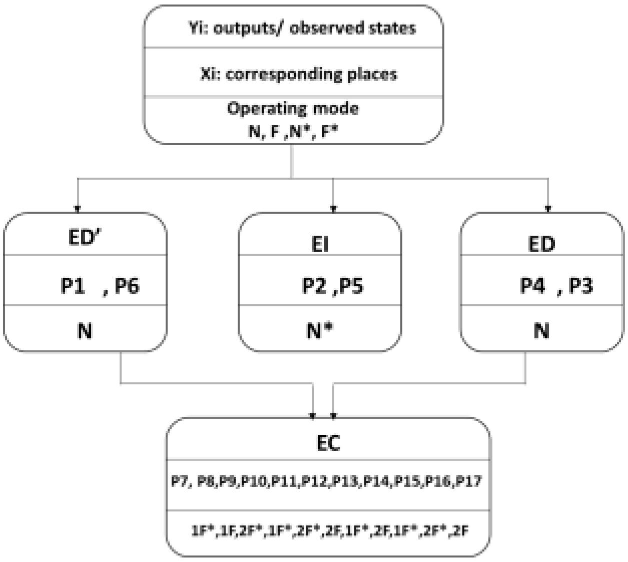


Figure 14: Local diagnostician D2 of the subsystem B

At the end, we must calculate all local decisions observed following the occurrence of an observable event, for each local diagnostician. This will generate the paths that constitute sequences of events.
Figures (15) (16) show local diagnosticians of A and B obtained following the occurrence of the observable transition (a ').

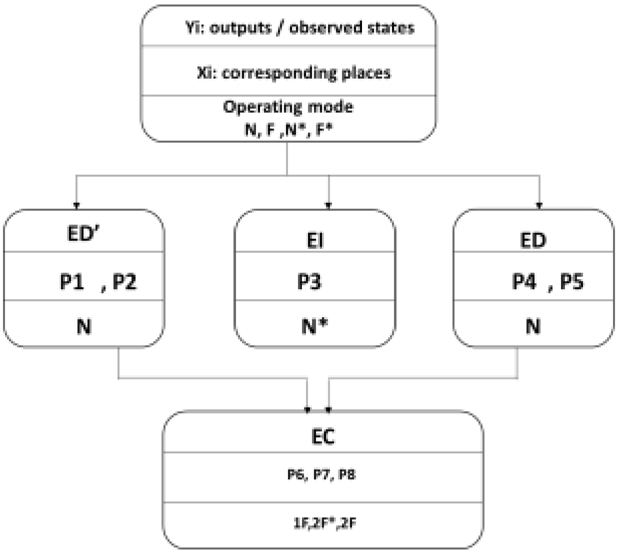


*Figure 15: Local diagnostician of the subsystem (A)
following the occurrence of observable transition (a')*

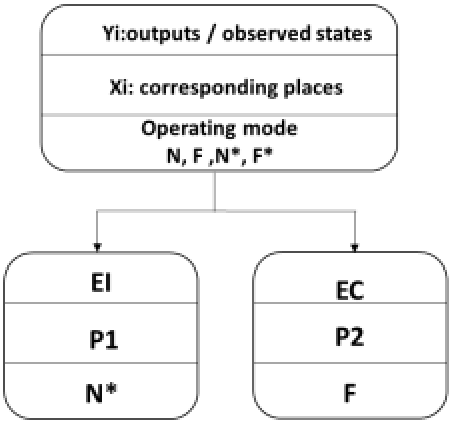


*Figure 16: Local diagnostician of the subsystem (B)
following the occurrence of observable transition (a')*

Following the occurrence of an observable transition in a subsystem, local decisions are calculated based on the use of local models. Finally the decisions of local diagnosticians are summed to calculate the global diagnosis model which must be equivalent to the diagnosis decision obtained by the centralized diagnosis structure.
Figure (17) shows the diagnostician obtained by the summation of two diagnosticians A AND B. the place P1 of the diagnostician corresponds to a normal state N (1N, 1N), the place P2 corresponds to an uncertain unstable state F (2F *, 1N), and the place P3 corresponds to a certain state F (2F, 1F).

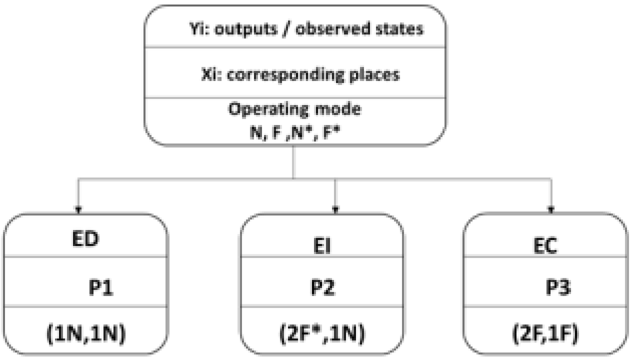


Figure 17: global diagnostician obtained by the summation of two diagnosticians A AND B

After the elimination of uncertain unstable state F, the final diagnostician is obtained, see Figure (18) .the final obtained diagnostician contains only the normal states N and the faulty states F. consequently there was obtained a global model for diagnosis, equivalent to the diagnosis decision obtained by the centralized diagnosis structure, by eliminating indecision states, without the use of a global model.

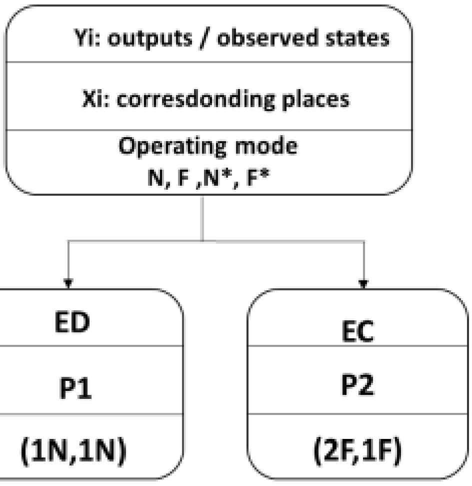


Figure 18: Final diagnostician without the use of a global model

- **Findings of approach**

To apply the proposed approach for a real and complex system, follow these steps:
1- Decentralize the global system into (n) subsystems.
2- Build for each subsystem a set of observable events Σio, and a set of internal succession events: Σisi: Σi = Σio + Σisi.
3- Build the internal succession models for each subsystem (n).
4- Build the desired model of the controller.
5- Build the local diagnosers of each subsystems.
6-Build local simplified diagnoser of each subsystems, following the occurrence of an observable event.
7- Construct the global diagnoser by summing the (n) local diagnosticians and eliminate the indecision states.

CONCLUSION

The approaches of construction of a decentralized diagnostic module existing in the literature, are all based on the use of a global model to verify the co-diagnosability of decentralized diagnosis structure obtained, and eliminate indecision states.

The approach proposed in this article, allows the verification of the co-diagnosability of decentralized diagnosis structure of discrete event systems, without the use of a global model, through local diagnosticians built by network Petri, and the succession of transitions, to obtain a global decision equivalent to the centralized decision diagnosis.

The proposed approach represents a solution to the problem of the use of global model in the case of complex systems. In future work, the proposed approach will be implemented to develop local diagnosticians which consider the notion of time. For it, using timed Petri networks will be considered.

REFERENCES

[1] A. Philippot, "Contribution au diagnostic décentralisé des systèmes à événements discrets: Application aux systèmes manufacturiers," Université de Reims-Champagne Ardenne, 2006.
[2] M. Sampath, R. Sengupta, S. Lafortune, K. Sinnamohideen, and D. Teneketzis, "Diagnosability of discrete-event systems," Automatic Control, IEEE Transactions on, vol. 40, pp. 1555-1575, 1995.
[3] P. Marangé, A. Philippot, J.-F. Pétin, and F. Gellot, "VERIFICATION DE LA DIAGNOSTICABILITE PAR MODEL-CHECKING," in MOSIM, 2014.
[4] B. Liu, M. Ghazel, and A. Toguyéni, "Évaluation à la volée de la diagnosticabilité des systèmes à événements discrets temporisés," Journal Européen des Systemes Automatisés, Edition spéciale MSR, vol. 13, pp. 227-242, 2013.
[5] S. Jiang, Z. Huang, V. Chandra, and R. Kumar, "A polynomial algorithm for testing diagnosability of discrete-event systems," Automatic Control, IEEE Transactions on, vol. 46, pp. 1318-1321, 2001.
[6] S. Jiang and R. Kumar, "Failure diagnosis of discrete-event systems with linear-time temporal logic specifications," Automatic Control, IEEE Transactions on, vol. 49, pp. 934-945, 2004.
[7] W. Qiu and R. Kumar, "Decentralized failure diagnosis of discrete event systems," Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on, vol. 36, pp. 384-395, 2006.
[8] A. Schumann and Y. Pencolé, "Scalable Diagnosability Checking of Event-Driven Systems," in IJCAI, 2007, pp. 575-580.
[9] J. Chen and R. Kumar, "Decentralized failure diagnosis of stochastic discrete event systems," in 2013 IEEE International Conference on Automation Science and Engineering (CASE), 2013, pp. 1083-1088.
[10] M. Sayed-Mouchaweh and E. Lughofer, "Decentralized fault diagnosis approach without a global model for fault diagnosis of discrete event systems," International Journal of Control, vol. 88, pp. 2228-2241, 2015.
[11] A. T. Sava, "Sur la synthèse de la commande des systèmes à évènements discrets temporisés," Institut National Polytechnique de Grenoble-INPG, 2001.
[12] J. Pradat-Peyre, "Spécification et vérification des problèmes concurrents: Vérification avec les réseaux de Petri et les réseaux de haut-niveau," 2002.