A MultiCriteria Group Decision Support System for Industrial Diagnosis

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Abstract. The diagnosis is a research key element to improve business performance. However, the diagnosis methods do not possess a unique and universal aspect in a context where diagnosis diversity and complexity are increasing. Thus, there is, currently, no susceptible diagnosis method which ensures the relevance, efficiency and effectiveness of maintenance in all circumstances. The work presented in this article aims to eliminate or at least lessen the impact of unsuccessful attempts of the diagnosis tools development on the good functioning of a company. The development of the multicriteria group decision support system for diagnosis assistance (DIAG-GDSS) is an answer to the problem; it is a collective decision-making tool for the choice of the most relevant diagnosis method.
On the basis of a set of criteria and diagnosis methods, carefully selected and implemented , the developed tool allows:

- to assist decision makers in maintenance, according to their preferences often conflicting, to adopt a diagnosis method;
- to make a quick and efficient diagnosis using the developed methods.

In order to meet this group decision where different viewpoints are considered, we propose a multilateral negotiation protocol, coupled with a multicriteria method namely ELECTRE III. This protocol features a coordinator agent and a set of participating agents, trying to find a compromise that best meets all the decision makers.

Keywords: group decision support system, multiCriteria analysis, diagnosis, multi agents system, negotiation protocol, ELECTRE III.

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1 Introduction

In maintenance field, we need to be able to prevent production inability, rather than seek to produce more. It is therefore to maintain the total stock of equipment used in production. Maintenance includes the functions of detection, interpretation and decision performed by a diagnosis system which constitutes an important part of a maintenance system. Indeed, the problem of diagnosis is actually linked to that of maintenance. The latter involves various factors; they may be economic (cost of maintenance over the expected gain), human (skills, personnel training) or industrial (turf skills, industrial competition) which are difficult to assess.
Nowadays, all manufacturers are interested in new technologies enabling them to improve diagnosis and enhance their competitiveness. Indeed, reducing commissioning time, optimizing uptime and the requirements of availability constitute common concerns to almost all sectors whether in transportation, aviation, space, energy, environment, food or health.
Giving the important role of diagnosis in maintenance, the relevance of the diagnosis system is a factor affecting the relevance of a maintenance system. For this purpose, diagnosis methods are numerous: each of these methods aims to solve diagnosis problems differently

and tries to meet users' expectations in a better way. Faced with this plurality of methods, the choice of the diagnosis method the most relevant and suitable to the issue is a very complex problem. In this context, research on the topic of relevance of diagnosis methods for maintenance is largely motivated by the lack of tools. This is in order to compare these methods for optimization of maintenance that is penalized. Offering companies a way to select the diagnosis tool, for implementation or adoption, represents a significant financial gain in a competitive environment. Thus, ensuring to the company that the proposed tool is the most suitable requires putting in place means to identify the needs for each decision-maker according to a variety of criteria.
The current study takes in account a problem related to investment in industrial maintenance. The proposed methodology ensures the development of a Multicriteria collective decision support system trying to bring a conscious, clear and rational solution for the problem of diagnosis methods choice in a multicriteria and multi participant's context.
In this research context, the proposed group decision support system **DIAG-GDSS** uses the benefits of Multi Agents Systems (MAS) to represent the diversity of actors involved in the diagnosis decision, their behaviors as well as interactions. They are very suitable for modeling complex entities which can cooperate, collaborate or negotiate to reach an agreement.
We endow the module MAS by a negotiation protocol based on mediation. This protocol features a coordinator (initiator) agent which is responsible for the smooth conduct of negotiation and a set of participating agents. The agents represent the different entities impacted by the decision in terms of diagnosis.
Multicriteria analysis allows classifying the different diagnosis methods, according to their relevance, respecting different points of view, often conflicted, of the different decision makers affected by the group decision. The proposed interactive tool also allows an implementation of the diagnosis tool chosen after negotiation within the company which is the subject of study.
After presenting some elements of reflection to introduce the context of our study and highlighting the problems associated with diagnosis systems, we propose in Section 2 a classification of the diagnosis methods. Section 3 gives a quick preview on the studies of diagnosis and issues related to this topic. Our contribution is described in its whole in Section 4 and Section 5 is devoted to a state of art of negotiation in Multi Agents System (MAS). Section 6 describes the proposed group decision support system DIAG-GDSS and the MAS component is described in detail, in the same section. Section 7 deals with the procedure of use of the proposed tool and Section 8 is devoted to the experimentation of this tool through an application on an industrial production process. This case study constitutes a first validation step. Finally, we conclude the paper, in Section 9, and give some perspectives.

2 Classification of the Diagnosis Methods

The interpretation of the term "diagnosis" has much significance according to the addressed field [31].
AFNOR **(Standard NF X 60-010)** defines the diagnosis as the identification of the probable cause(s) of failure (s) using a logical reasoning on the basis of a set of information which is obtained from an inspection, control or test.
There is a great variety of diagnosis methods; some of them are specific and appropriate to the industrial sector. The selection of the most appropriate diagnosis method to a given industrial system can be done only after a census of the needs and the available knowledge. In this section, we present briefly the main methods which meet at least one of the diagnosis process functions: the detection function, the localization function and the identification function, classified mainly according to the type of the used knowledge [31].

2.1 Methods of Diagnosis by Modeling

These methods are founded either on equations governing the internal phenomena of the system or on cases reflecting the system functioning modes. The associated models require a thorough knowledge of the system operation, and gather mainly in three main families: physical models[7], meta-models (FMEA Method (Failure Mode and Effects Analysis) , HAZOP method (HAZard and OPerability stydy), Ishikawa diagram, failures trees, events trees, ...) and macro-states graphs [5] (Petri Networks and Hidden Markov Models).

2.2 Diagnosis Methods by Data Analysis

When knowledge over the system be diagnosed is not sufficient and the development of a process knowledge model is impossible, the use of methods based on data analysis can be considered. This is the case of probabilistic methods for predicting length of life, matching matrix, support vector machine (SVM), neural networks and pattern recognition, etc. The latter have been, successfully, used in the field of diagnosis [28] [9].

2.3 Diagnosis Methods by Artificial Intelligence (AI)

The diagnosis systems using artificial intelligence tools are designed to formalize and to model knowledge providing mechanisms to exploit them. Compared to other methods where a priori quantitative or qualitative knowledge about the process is required, in the methods of AI, a large amount of data stored on the functioning system (normal and during failures) is required. There are two main approaches: Probabilistic Model-based approaches (Bayesian Networks) [16] and inference Model-based approaches (Case Based Reasoning and Expert Systems).

3 Related Research Works in Diagnosis

A lot of great and innovational contributions in diagnosis have been published. We can quote in a non exhaustive way the work of Hernandez [13] who worked out a diagnosis system by neural networks applied to the detection of the automobile driver hypovigilance; Dubuisson [9], who worked on the theory of the diagnosis containing models, the diagnosis by pattern recognition, and the neural networks; Bellot [1] who tried out the Bayesian networks for the diagnosis applied to the Telemedicine, Bourouni [3] who developed an assistance tool of the maintenance diagnosis based on the dominant modes of failures by exploiting the approach expert system, Djebbar [8] who approached the diagnosis making of hepatic pathologies by using two approaches: the Case Based Reasoning and the Bayesian Networks.

More recently, we find the works of Khemliche [17] and [20], who used the bondgraphs for the installation of diagnosis assistance tools. Theilliol [29] who exploited the methods of diagnosis containing models for the monitoring of industrial systems, Greziac [14] who implemented a new approach of *"diagnosis machine"* based on the execution of a structural model called *"Automatic Diagnosis"*, Kiener [18] who proposed an implementation of neural networks for the diagnosis on coprocessor; Sabeh [25] who detailed the general principles of diagnosis systems in the case of the monitoring of the loop of gases in an overfed diesel engine with direct injection. Lastly, we can quote Chanthery [4] who chose an embarked architecture for the modeling and the integration of the active diagnosis.

Various projects exist in the literature regarding the decision support in diagnosis, we cite mainly the Project HEROS; its goal is to provide doctors, participating to Multidisciplinary Consultation Meetings, a support system for group decision making (GDSS : Group Decision Support System) to take diagnosis and therapeutic decisions [21].

4 Our Contribution

The purpose of this study is to provide a response to the performance of maintenance systems. Thus, in this paper, we propose a methodology to justify the profitability of a maintenance project and guide the user in choosing the most relevant diagnosis method. The proposed tool **DIAG-GDSS** (**DIAG**nosis **G**roup **D**ecision **S**upport **S**ystem), on the basis of a multicriteria group decision approach (collective), determines the most appropriate method of diagnosis to be implemented at an industrial company which focuses mainly on the processing of semi-finished products into finished products.

DIAG-GDSS takes into account the specific and divergent interests of the various decision makers to reach an acceptable agreement.

The main objective of this work is to offer the company a way to indicate the diagnosis method to be applied. Thus, each decision maker must establish a ranking and a prioritization of the different diagnosis methods, according to their relevance, relatively to well defined criteria, while respecting its preferences using the multi criteria method ELECTRE III [2]. The final choice of the diagnosis method, in this decisional situation, is made after a negotiation process according to the protocol that we propose.

In this version of our tool, we developed 10 diagnosis methods which enabled us to capitalize expert's knowledge. Each method provides, by the adopted approach or the used step, more to the diagnosis methodology.

5 Reaching Agreements in MAS: State of Art

One of the major problems faced by multi-agent systems is that of reaching agreement in a particular problem, each agent is supposed having a preference on contracts or possible agreements. The agent then sends messages in order to reach an agreement that can arrange everyone. But the agents face a dilemma: on the one hand, they want to maximize their own utilities, and on the other hand may fail negotiation and miss the agreement that can satisfy everyone. In MAS, among the most used techniques to reach such agreements, there are mainly auctions [30], voting systems [26], negotiation [12], and argumentation [15].

In MAS, negotiation is a key form of interaction that allows a group of agents to reach a mutual agreement regarding their beliefs, goals or plans. It is the predominant tool for solving conflicts of interests. Generally speaking, there are various protocols of negotiation in

MAS applications, the most used ones are [30]: Monotonic Concession Protocol, One Step Protocol, Contractual protocols (the Contract Net Protocol, the Extended Contract Net Protocol).

6 DIAG-GDSS Description

The originality of our approach is due to the simultaneous use of a MAS and a DIAGNOSIS system. The literature offers few examples of this type of coupling. For simplicity, we choose a loose coupling (or weak coupling [1]) between the two components which remain independent and communicate only by exchanging data [10]. Thus, the features of the two systems are different. Let us detail the two modules:

6.1 The Diagnosis Module

The advocated approach is generic; the diagnosis vision is supported by the DIAGNOSIS Module. The latter, after identifying the various diagnosis methods and the different criteria, provides the performance matrix using several evaluation methods and simulation functions. This matrix is injected into the MAS module and analyzed by the multicriteria analysis engine ELECTRE III in order to generate different preference vectors according to each decision maker, then the MAS provides a negotiation process to reach an agreement.

6.2 The MAS Module

This component aims to represent the different actors which have their own objectives, decision strategies and preferences.
Multi Agent technology has, already, proved its worth in many areas. It is especially invited in the implementation of collective decision-making (multi decision makers) applications because of the facilities which are provided.
For modeling preferences, we use techniques of multicriteria decision support methodology. The latter allows the construction of appropriate tools and is able to replace a decision maker on complex problems.
We delegate to MAS, the selection of the elected resource according to a negotiation process; the chosen diagnosis method will be implemented. To cope with this group decision, it is necessary to go through a negotiation procedure to reach a beneficial consensus. To this end, we endow the MAS with a negotiation protocol based on mediation involving two types of agents:

[1] The best known types of coupling two systems are: the tight coupling (or strong coupling), the loose coupling (or weak coupling), the cooperative direct coupling and the cooperative indirect coupling

1. the coordinator agent (initiator or manager): is the agent responsible for managing the negotiation, modifying the contract and choosing the final elected resource.

2. the participant agents (contractors): these are agents involved in the; the goal of each agent is that its favorite resource is chosen.

It is essential that participant agents go through a negotiation phase, according to a well-structured protocol, in order to reach a beneficial agreement to the group. The negotiation takes place between the coordinator agent and all the participant agents (this is a negotiation from 1 to n agents). Figure (1) shows an overview of DIAG-GDSS.

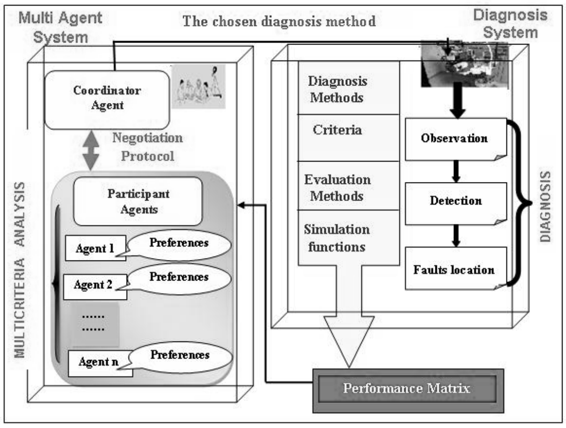


Figure 1: DIAG-GDSS: An overview

6.2.1 Modeling Agents

The agentification is an important aspect of a MAS designing. It strongly influences the performance and efficiency of the system to solve a problem. In litterature, there are a multitude of methodologies offering an important interest for MAS in an organizational perspective [10] as Gaia, voyelles, ingenias, Aalaadin, ...
Our proposal, for the modeling agents, is based on the methodology Aalaadin [11] exploiting the concepts of agent, group and role to define a real organization.

6.2.2 The Phases of Negotiation in the Proposed Protocol

The current negotiation protocol is, largely, based on the Contract Net Protocol [6]. It is characterized by a series of messages exchanged between the coordinator agent and the participant agents. It proceeds in five phases: an initialization phase, a proposal phase, an evaluation phase, a modification phase and a final decision phase.

1. **The initialization phase:** this phase is synonymous of the beginning of the negotiation process. Participants are asked to express their preferences concerning the different resources. Each agent establishes a classification of resources (methods of diagnosis) from the best one (the most beneficial) to the worst one, according to a set of criteria by using the multicriteria method ELECTRE III [19].

2. **The proposal phase:** during this phase, the coordinator agent proposes a deal to all the participants on a given resource. They will either accept or reject the contract with reference to their vector of preferences, previously constructed in the initialization phase.

3. **The evaluation phase:** when the coordinator receives all the answers of the participants concerning the proposal of the contract, it accounts the number of the participant agents having accepted its proposal. If this number is greater than or equal to a given threshold, then the negotiation is successful. If not, he must carry out a modification of the deal.

4. **The modification phase:** during this phase, the coordinator is brought to make a modification of the contract while taking as a starting point the proposals of the agents. It must establish a synthesis from what it has received during the evaluation phase and then returns to the proposal phase.

5. **The decision phase:** this is the last phase of the suggested protocol. It signifies the end of the negotiation process. A decision is taken by the coordinator according to the participants answers concerning the proposals which it has made.

6.3 Characteristics of the Proposed Protocol

During the negotiation process, many fundamental aspects must be taken into account, such as:

- the language used by the agents to exchange information during the negotiation (primitives and strategies);
- the objects of negotiation;
- the strategies adopted by the different agents;
- the cardinality of the negotiation.

In what follows, we present the main characteristics of the proposed negotiation protocol.

6.3.1 The objects of negotiation

Resources are the objects of negotiation, they can be either personal or shared. In our case, they are common resources (the diagnosis methods).

6.3.2 The cardinality of negotiation

It is an important concept for the MAS. The question is how agents negotiate among themselves. Our protocol allows the coordinator to propose a deal to a set of participants; it is a negotiation from 1 to n agents. item

6.3.3 The primitives of negotiation

In order to lead a negotiation process to its term, it is necessary to define specific primitives to the coordinator and other specific primitives to the participants.

1. **Coordinator primitives:** the messages sent by the coordinator are aimed at all the participant agents, three primitives of negotiation are associated with the coordinator:
   Request (): the coordinator sends a message to the participants in order to indicate the beginning of the negotiation process;
   Propose (): the coordinator proposes a contract to the participant agents concerning a given resource;
   Confirm (): the coordinator sends a message to all the agents informing them that the negotiation is a success and that the resource was found.

2. **Participant primitives:** the messages sent by the participants are solely aimed to the initiator. The other participants are not informed of these messages. Three negotiation primitives are associated with the participant:
   Inform(): after establishing a storage of the resources from the best to the least good. Each participant indicates to the coordinator that it can make them a first proposal;
   Accept (): through this message, the participant answers the proposal of the deal made by the coordinator. Each participant indicates, by this message, to the initiator that it accepts the contract;
   Refuse (): the participant indicates to the coordinator that its proposition is refused. The deal can not be concluded in its current form and should be modified.

In order to represent the interactions between the coordinator agent and the participant agents, we opt for the

use of the UML sequences diagram, often used to describe the interaction of different agents.
Figure (2) represents the various primitives associated with the different agents via an UML diagram.

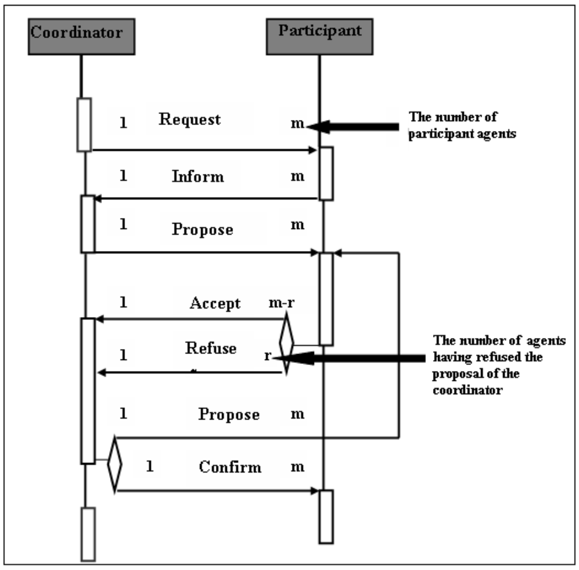


Figure 2: UML Sequences diagram of the proposed negotiation protocol

6.3.4 The Agents Strategies

The suggested protocol distinguishes two roles: coordinator and participant. The negotiation strategy is not the same; it differs according to the role of the agent. Thus, there are two types of strategies:

1. the coordinator strategy allows it to modify a contract if the participants have not rather been numerous to accept it;

2. the participants strategies allow them to establish their preferences, accept a contract or refuse it.

- **Participant Strategies:** we associate with each participant agent three strategies:
  1. Strategy of establishing preferences: each participant must establish a classification of the resources from the best (the most beneficial) to the least good referring to a certain number of criteria. For that, it exploits the advantages offered by the multicriteria decision making method ELECTRE III [23], [22]. When each participant has established its preference vector, it associates with each resource a row. The resource classified first will have a higher row representing the preference of the participant at the first round. This ranking is, each time, decremented by 1 for the following resources.
  2. Strategy of acceptance: the negotiation can proceed in several rounds, until a compromise is found. In each new round, the participant receives a new proposal. If it corresponds to its preference at the round t, it accepts this proposal. Otherwise, it checks whether the proposition corresponds to one of an earlier preference. If it is the case, it accepts the contract indicating its actual preference.
  3. Strategy of refusal: when the participant receives a proposition which corresponds neither to its preference at round t, nor to other earlier preferences, it refuses it and makes against the proposal which corresponds to its preference at round t.

- **coordinator Strategy:** we associate with the coordinator only one strategy used at the time of the modification phase.
  Strategy of modification: when the participants are not rather numerous to accept the coordinator's proposal, the latter is obliged to modify its contract for the next round while taking as a starting point all the modifications sent by the participants at round t , in order to find a new possibility for the contract. For that, the coordinator associates a score $SCORE(R_i)$ with each resource R_i (i= 1,.. n) which takes into account the weight of the participant agent as well as the ranking of the resource in the vector of preferences of this agent. As in the method of scorages [10], the resource which has obtained the highest score at round t, will be the winner resource and the coordinator will propose it in the new contract. This score is updated each time the participants have been less numerous to accept the contract. $SCORE(R_i)$ is given by the following equation :

$$SCORE(R_i) = \sum_{j=1}^{m} WEIGHT(participant[j]) \\ *ROW(R_i, participant[j])$$

  - n, m: the number of resources and decision makers respectively;
  - WEIGHT(participant [j]): to each participant j, we associate a different weight, since in reality, the Project Engineer, for example, does not have the same weight that the Finance responsible at the time of a group decision out of diagnosis.
  - $ROW(R_i, participant[j])$: the row associated with the resource (action) i by the par-

ticipant j in its vector of preferences (sorting provided by ELECTRE III);

7 DIAG-GDSS: Functional Architecture

The procedure for using the tool DIAG-GDSS operates in two main phases: a phase of group decision support and a phase of diagnosis (concretization of results).

7.1 The Phase of Group Decision Support

This phase of the current approach corresponds to the structuration and exploitation of the decisional model.

7.1.1 Structuring the Decisional Model

This phase aims to identify the problem and the fundamental choices on how to approach it. It aims, also, to formalize three basic elements of the decisional situation:

1. **Identify actions (resources):** the identification of all the potential actions is a very significant step in any decision support approach, especially when the multicriteria analysis method proceeds by partial aggregation. It is very important that the set of all the actions is complete because its modification during the analysis can cause a recurrence of multicriteria analysis.

2. **Identify criteria:** the list of criteria obtained by aggregating the corresponding factors (sub-criteria) should be as complete as possible. These criteria must be related to constraints and objectives used in the generation activities. The family of the most relevant criteria must verify the conditions of exhaustivity, consistency and independence [23].

3. **Identify actors (decision makers):** the concept of actor refers to a concrete entity, localized (in a context). It is a unity of individual or collective decision, which can allocate resources, purposes and strategies[2]. The multiplicity of actors makes negotiation difficult since we have on one side the strong actors with a significant power and on the other side weak actors who have more difficulty defending their interests.

7.1.2 Exploiting the Decisional Model

In this phase, every actor will be modeled as an agent to which is associated a weight expressing its importance and its authority scope in the group decision. All agents have access to the performances matrix managed by the diagnosis component to determine their vector of preferences by exploiting the multicriteria method ELECTRE III. After several rounds of negotiation under the proposed protocol, the participant agents arrive to a consensus that satisfies all the concerned parties (or part of them) in the final agreement.

7.2 The Phase of Diagnosis

This phase is essentially the result of acceptance, it includes the implementation of the group decision and the control of the solution. In this last phase, after introducing the data of the industrial process, we can carry out the diagnosis through the elected diagnosis method.The main phases of DIAG-GDSS are designed in Figure (3) and Figure (4) summarizes how DIAG-GDSS operates.

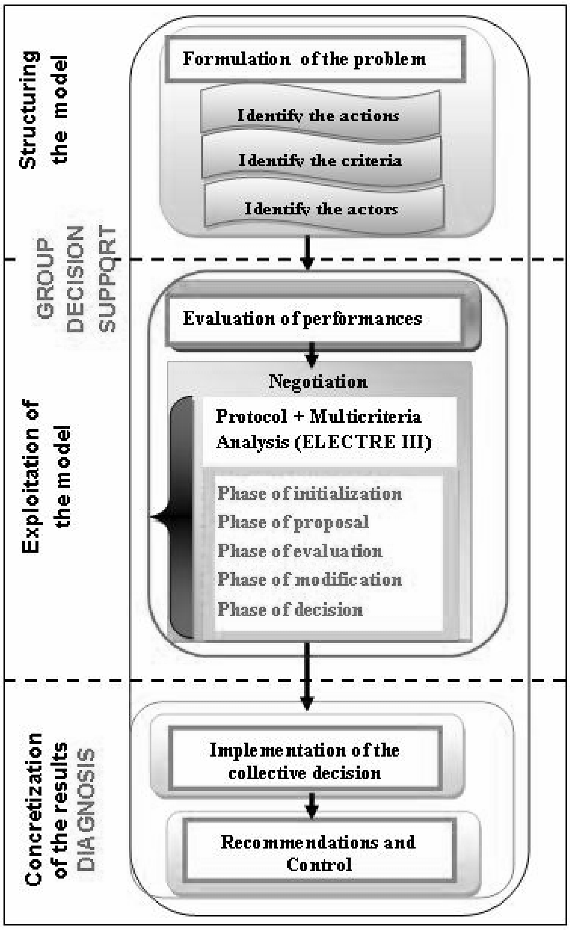


Figure 3: DIAG-GDSS: Functional architecture

[2]We can identify two main types of actors: individual and collective. Collective actors are groups or organizations.

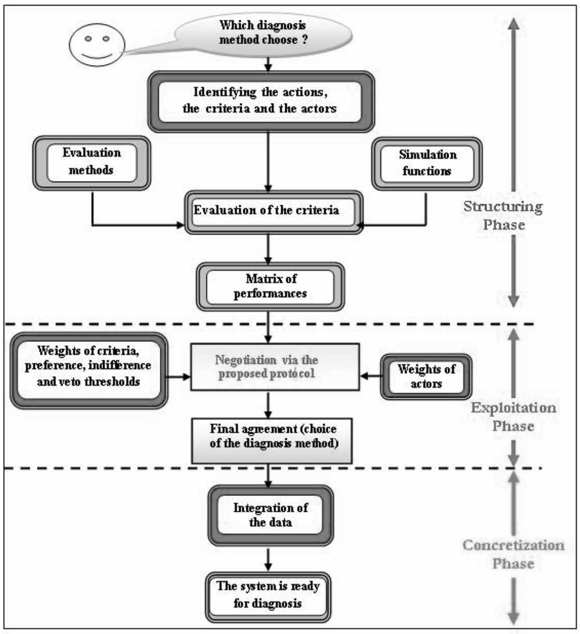


Figure 4: Functioning of DIAG-GDSS

8 Case Study: Experimental Results

The development of a multi-agent module is a complex problem. Therefore, it is preferable to use an existing multi-agent platform that we adapt to our needs. The modules MAS and Diagnosis communicate with each other through shared data.

8.1 The addressed Problem

The implementation of the proposed group decision support process is accompanied by an application on a company test. The objective of this simulation exercise is to support the proposed methodology by a confrontation with the available tools and data. In addition, testing DIAG-GDSS on an existing case (with real data) allows the validation of our proposal.
The study carried out was tested on a production process of an Algerian company of steel industry **"ANABIB"**. For the sake of efficiency, we chose the most critical equipment of this company. It is about a machine which, starting from a **steel coil**, gives **"tubes"**. It ensures the operation of forming and welding. This enabled us to show the effectiveness of this type of tool in terms of availability and reduction of the downtime of the machines. The stages to be followed, are described in the next sections.

8.2 Definition of Actions

Potential actions [3] are all diagnosis methods which are susceptible to meet the goals of a diagnosis system for maintenance, while respecting the imposed constraints and undertaking a technical study of each method.
The actions correspond to different diagnosis methods that we have implemented and must be negotiated in order to help the decision makers to choose the method that will be maintained for diagnosis. This is by considering a set of criteria and taking into account the subjectivity of the several actors implied in this project.
In the present study, and given the invested area (the industrial diagnosis), we opted for the following methods: **Act1:**Model-based Diagnosis, **Act2:**Pattern Recognition Method, **Act3:** Expert Systems, **Act4:** Neural Networks, **Act5:** Petri Networks, **Act6:** Markov Chains, **Act 7:** Failure Mode and Effects Analysis (FMEA), **Act 8:** Failures Trees, **Act 9:** Bayesian Networks, **Act 10:** Case Based Reasoning.

8.3 Identification of Criteria

The identification of criteria for choosing a diagnosis method must be based on the exhaustive list of constraints and objectives of the diagnosis system in maintenance. Setting goals is an essential step that allows defining the most relevant criteria to our study, acceptance levels of the diagnosis results, and therefore the relevance of methods and tools.
Indeed, a criterion is a translation of an objective or a portion of an objective (respectively a constraint) into a quantifiable element quantitatively or qualitatively.
In the current study, choosing the most relevant diagnosis method, takes into account a family of criteria. To give our study genericity following the methodology of diagnosis aid, the criteria used in our study were developed using experts from the company [27]. These criteria are:

- **Crt 1:** Response time
- **Crt 2:** Measures variations robustness
- **Crt 3:** Modeling errors robustness
- **Crt 4:** Prediction capacity
- **Crt 5:** Development cost
- **Crt 6:** Accessibility level
- **Crt 7:** Ease of knowledge exploit

[3] In the multicriteria decision aid methodology, the action is a possible solution for the decisional problem; it is synonym of the term resource in the MAS vocabulary.

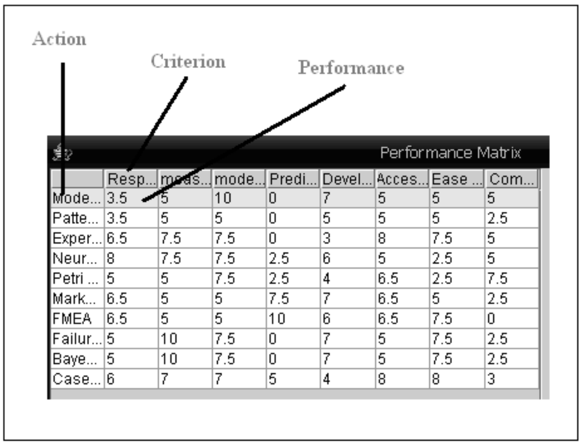
- **Crt 8:** Complex systems adaptation

8.4 Evaluation of Performances

We focus, in this section, on evaluating the performance of each possible and potential diagnosis method according to each criterion:

- If the method performance is high, this method is preferred;
- Performance evaluations can be performed with various methods: analytical formulas, measuring instruments, human experts, ...
- If the evaluation criterion is not measurable by an analytical formula or is not objectively measurable, an evaluation or score can be performed on a scale or finite set of values.

The definition and assessment of the identified criteria according to different actions generate the matrix of performance, illustrated in Figure (5). This matrix is managed by the diagnosis component.



	Resp...	meas...	mode...	Predi...	Devel...	Acces...	Ease ...	Com...
Mode...	3.5	5	10	0	7	5	5	5
Patte...	3.5	5	5	0	5	5	5	2.5
Exper...	6.5	7.5	7.5	0	3	8	7.5	5
Neur...	8	7.5	7.5	2.5	6	5	2.5	5
Petri ...	5	5	7.5	2.5	4	6.5	2.5	7.5
Mark...	6.5	5	5	7.5	7	6.5	5	2.5
FMEA	6.5	5	5	10	6	6.5	7.5	0
Failur...	5	10	7.5	0	7	5	7.5	2.5
Baye...	5	10	7.5	0	7	5	7.5	2.5
Case...	6	7	7	5	4	8	8	3

Figure 5: The matrix of performances

8.5 Identification of Decision Makers

In this study, the different decision makers involved in the group decision are:

- **Decision maker 1:** project Engineer
- **Decision maker 2:** company Manager
- **Decision maker 3:** finance responsible
- **Decision maker 4 :** diagnostician exhibitor (the person offering the diagnosis service)
- **Decision maker 5 :** machinery manager (the person who manages the machines and gives its opinion on the consistency of diagnosis with the machinery operation)

Each Decision maker is represented by an agent; the generation of agents is performed using the platform MAS JADE (JAVA). We attribute to each participant agent, a weight expressing its importance in the negotiation. The weights of various actors, reflecting a maximum of reality, are given in Figure (6).

Decision Maker (Agent)	Weight
Diagnostician Exhibitor (DE)	11
Finance Responsable (FR)	20
Company Manager (CM)	27
Project Engineer (PE)	15
Machinery Manager (MM)	17

Figure 6: The weights of several agents

8.6 Definition of Subjective Parameters

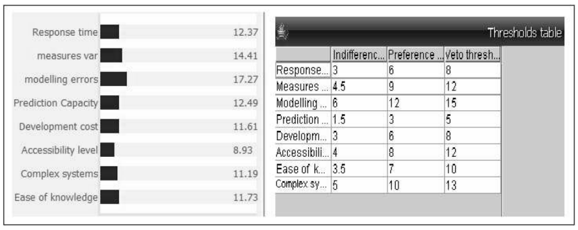
Each agent will make its vector of preference where it classes resources from the best ones to the worst according to the identified criteria. To achieve this goal, it uses the multicriteria analysis method ELECTRE III. To be conducted, this method introduces some subjective parameters. In the following, we show how DIAG-GDSS assigns values to these parameters.

1. **Weight:** is a number $\omega_j, \{j = 1, 2, ..., m\}$, m designates the number of criteria) assigned to each criterion, according to its importance regarding other criteria. It is not always easy for the decision maker, to articulate the assessment of the relative importance of each criterion. To assign a value to this intra criteria parameter, we used the Saaty scale. The latter allows evaluating various criteria and ordering them according to their relative importance. The scale of Saaty is based on a mathematical model developed by Thomas Saaty [24]. After comparing sequential pairs of criteria (each criterion is assessed on all the others in a series of comparisons), we ask the user to order on a scale

from (-9 to 9) the relative importance of one criterion.

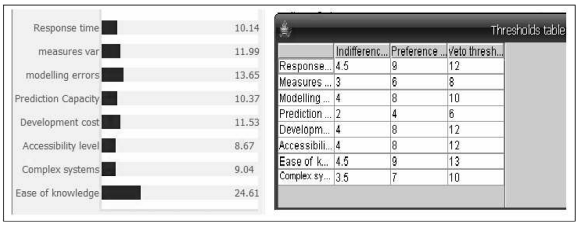
2. **Thresholds:** In our study, thresholds of preference and indifference p_j and q_j on the criteria j , respectively, are chosen on the basis of values assigned to data uncertainties. For example for an uncertainty of 20:
   $p_j = 2 * 20/100 * max(i, k)[g_j(a_k) - g_j(a_i)]$
   $q_j = 20/100 * max(i, k)[g_j(a_k) - g_j(a_i)]$
   Where
   $g_j(a_i)$: the performance of action a_i according to criterion j.
   $g_j(a_k)$: the performance of action a_k according to criterion j.
   The veto threshold $\nu_j$is also determined by the values assigned to data uncertainties. For example for an uncertainty of 20, ν_j is given by:
   $\nu_j = 3 * 20/100 * max(i, k)[g_j(a_k) - g_j(a_i)]$; q_j < p_j <ν_j

In this case study, the values of the subjective parameters expressed by the agent **Diagnostician Exhibitor** and the agent **Project Engineer** are given in Figures(7) and Figure (8), respectively:



	Indifferenc...	Preference ...	Veto thresh...
Response...	3	6	8
Measures ...	4.5	9	12
Modelling ...	6	12	15
Prediction ...	1.5	3	5
Developm...	3	6	8
Accessibili...	4	8	12
Ease of k...	3.5	7	10
Complex sy...	5	10	13

Figure 7: Subjective parameters expressed by the agent Diagnostician Exhibitor

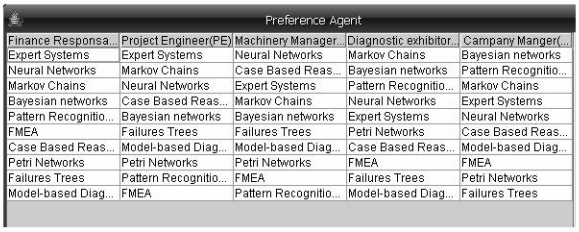


	Indifferenc...	Preference ...	Veto thresh...
Response...	4.5	9	12
Measures ...	3	6	8
Modelling ...	4	8	10
Prediction ...	2	4	6
Developm...	4	8	12
Accessibili...	4	8	12
Ease of k...	4.5	9	13
Complex sy...	3.5	7	10

Figure 8: Subjective parameters expressed by the agent Project Engineer

8.7 Simulation of the Negotiation

The ranking of the diagnosis methods made by each agent (establishing the vectors of preferences) using the multicriteria analysis method ELECTREIII is illustrated in Figure (9).


Preference Agent

Finance Responsa...	Project Engineer(PE)	Machinery Manager...	Diagnostic exhibitor...	Campany Manger(...
Expert Systems	Expert Systems	Neural Networks	Markov Chains	Bayesian networks
Neural Networks	Markov Chains	Case Based Reas...	Bayesian networks	Pattern Recognitio...
Markov Chains	Neural Networks	Expert Systems	Pattern Recognitio...	Markov Chains
Bayesian networks	Case Based Reas...	Markov Chains	Neural Networks	Expert Systems
Pattern Recognitio...	Bayesian networks	Bayesian networks	Expert Systems	Neural Networks
FMEA	Failures Trees	Failures Trees	Petri Networks	Case Based Reas...
Case Based Reas...	Model-based Diag...	Model-based Diag...	Case Based Reas...	Model-based Diag...
Petri Networks	Petri Networks	Petri Networks	FMEA	FMEA
Failures Trees	Pattern Recognitio...	FMEA	Failures Trees	Petri Networks
Model-based Diag...	FMEA	Pattern Recognitio...	Model-based Diag...	Failures Trees

Figure 9: Vectors of preference of each agent using ELECTRE III

Before starting the negotiation process, it is necessary to fix an acceptance threshold[4]. In our study, it is set at **(70%)**. As soon as the participant agents receive the message **Confirm** (synonymous with the end of the negotiation), the ultimate resource chosen has been found. Incorporating features of the module MAS, the different messages exchanged during the negotiation process are shown in Figure (10).
After several modifications of the contract and at the fourth round, the decision makers arrive at a consensus, the selected resource is **Act3 (Markov Chains)** with an acceptance rate of **77%**, Figure (11).

In this case study, given that the decision provided by DIAG-GDSS is the use of Markov chains as a diagnosis method. A modeling of the production process is possible using the interface "expert" . The latter gives the possibility to capture various data regarding the production process, namely: the name of the machine, the causes of failures, the vector of initial probabilities, the transition matrix A, effets of failures and the matrix of observation B.
After modeling the process, it is possible to make a diagnosis by accessing to the interface "user".

9 Conclusion

The relevance of each method of diagnosis, in the context of maintenance activity, differs from one system to another. The different existing methods have advantages and disadvantages of implementation and operation. Given the plurality of diagnosis methods, decision makers in maintenance are often faced with difficult choices. Their decisions should ensure the rele-

[4]Maximum of agreements necessary for the acceptance of a contract

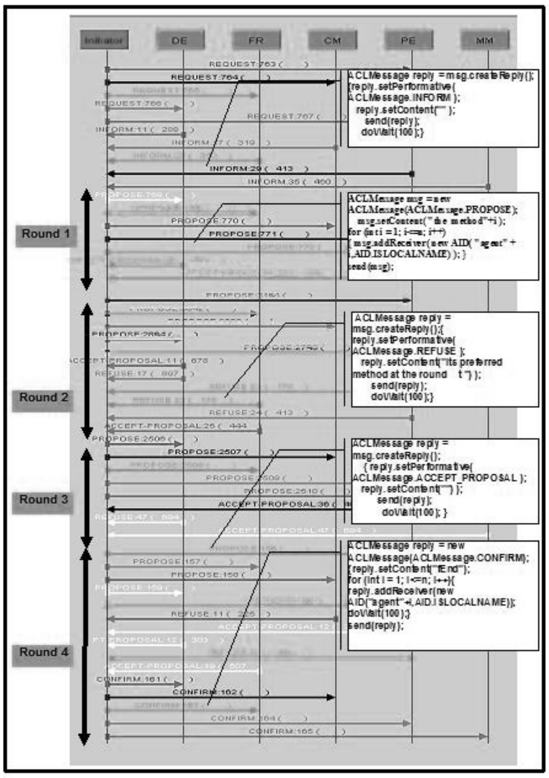


Figure 10: Viewing exchanged messages during the negotiation process via the Sniffer of JADE

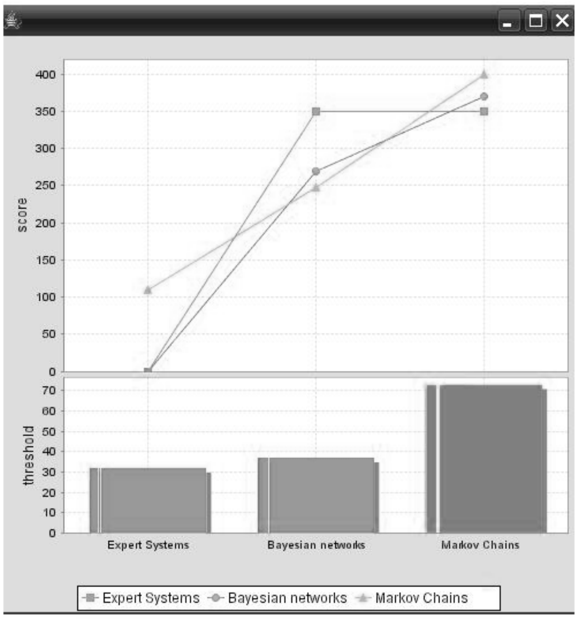


Figure 11: Simulation of the negotiation process

vance of the chosen method according to the objectives to be achieved by each of them.

Although the choice of the method, in some cases is predictable, in other cases it is more complex, involving multiple decision makers with conflicting objectives and based on very heterogeneous criteria.

The objective, we have pursued throughout this paper, is to propose a group decision-support process for facilitating the choice of a diagnosis method through the integration of a multicriteria approach in a negotiation protocol implemented in a multi-agent system.

Thus, we have initiated in the framework of decision support in diagnosis a new approach combining multicriteria analysis with models based agents to treat the multiplicity and diversity of actors in a diagnosis project.

Through this article, our effort has focused on the proposal of a multicriteria group decision support system that meets a primary objective and a specific objective, respectively:

- the representation of the multiplicity of decision makers in maintenance, their diversity, their behavior and their interaction in order to select the diagnosis method which is the most appropriate to the context of the company.
- the development of different approaches we have used to model a system of diagnosis.

An application in the industrial field has been proposed, and has served as a basis to demonstrate the feasibility of such an approach.

To consolidate the contribution of different diagnosis methods integrated into the tool DIAG-GDSS, we have developed a negotiation protocol incorporating a multicriteria analysis method, more specifically ELECTRE III. The latter allows each actor of maintenance, with its own preferences, to make a classification by level of relevance using different criteria.

We end here by evoking the different perspectives of research that we plan to address in the future:

- extending the model of agents allowing them to change their goals according to new information they receive: developing a protocol of negotiation based on argumentation;
- integrating other strategies of negotiation between different agents.

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