A Preventive Interaction Model Applied to the Management of Spare Parts

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Abstract: The paper proposes some agent-based approach to support the management of spare parts using e-environment. In this approach, we show how to describe an extended enterprise using an organisation model and how to manage the shared resources of the different sites by defining an interaction model. Indeed, an internal architecture of each site based on Multi-Agent System (MAS) foresees a dedicated cognitive agent, whose role is to watch, and even to warn, the cases of under-storage and on-storage of the articles. This operation is done on the basis of the previous consumption. The global architecture ensures the emergence of a balancing of articles availability, capable to avoid situations of going beyond of threshold of storage.

Key words: cooperation, e-maintenance, extended enterprise, Information System, load balancing, management of resources, multi-Agents system, prevention, spare part.

1 Introduction

The study of multi agent systems (MAS) focuses on systems in which many intelligent agents interact with each other. The agents are considered to be autonomous entities, such as software programs. Their interactions can be either cooperative or selfish. That is, the agents can share a common goal.

Contrary to downward approach known as conventional static approach, modelling a complex problem in MAS is to start from distributed simple tasks with local objectives, until reaching the emergence of a global solution Fig.1, [9].

This study wants to be a contribution to model, by the approach of the MAS, the optimal management of the distributed resources using a preventive policy being able to bring to the wide company a gain of cost, continuous and optimal availability of the spare part.

Our step consists in working on a model of organization which answers best the correct operation of the problem arising i.e. the optimal management of the spare parts.
Moreover, a model of organization is related to a model of interaction which is necessary to develop and well validate.

2 Classification of spare parts

Review The management of an article is specific to the class to which it belongs. The politics of reorder results from this narrowly. It is according to this classification that the answers to the questions what, when and How much to reorder, must be found.

The classification of the articles in general and the spare parts in particular can be carried out according to several criteria: the price, used quantities, frequencies of use, minimal quantities of purchase, deadlines, impacts in the event of unavailability, etc. The classification known as of ABC, based on the principle of 20/80 of Pareto is given as follows:

- ✓ Class A, articles with slow rotation (SMI): Very expensive, rare articles, long delays. They must not be available on all stores of maintenance.
- ✓ Class B, articles with middle rotation (NMI): Fairly expensive articles, uncertain availabilities on the market. Must be in very particular and accessible sites, at the appropriate moment, for the set of the sites of the extended enterprise.
- ✓ Class C, articles with fast rotation (IMF): Current articles, generally little dear. They may be available in all stores of the sites, but in optimal quantities.

The management of an article is specific to the class to which it belongs. It is according to this classification that the answers to the following questions must be found:

- ✓ What to restock?
- ✓ When to restock?
- ✓ How much to restock?

The policy of storage and reorder of an article of a site especially depends on its classification.

2.1 Extended enterprise

The architecture of an extended enterprise may be viewed as a composition of N sites. Each of them can be composed of one or several other under sites.

The articles of the class C can be found in all the sites, but the articles supposed to belong to the classes B and C can be available in particular sites, considered significant by the managers of the extended enterprise.

The principle is to maintain a balancing between all sites and for all articles of which each of these sites has need. With this intention, it is a question of finding the adequate solutions in order to warn and possibly to avoid an unbalance of these resources in a multi-sites context and subject to several constraints of the offer and demand of every site in addition to the constraints imposed on the spare parts.

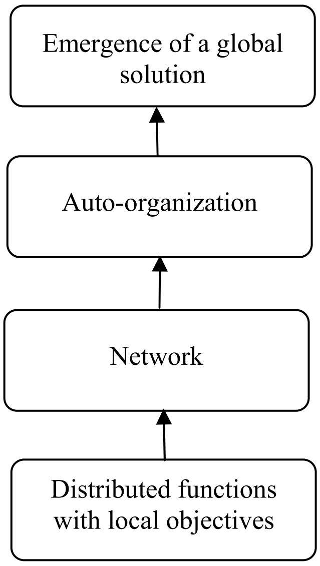

Fig.1: Dynamic Approach based on the interactions

3 Agent based modelling

As shown previously, the architecture of an extended enterprise is distributed and composed of N sites that are all concerned by the use of spare parts:

1. Every site is autonomous by the policy of preventive management of the spare part on its level.
2. The interaction between the sites of the system is obvious, in order to achieve a balancing concerning this resource, especially by cooperation.
3. The objective in our case is a balancing of resources of the system, that requires an approach based on :

    - ♦ Cooperation between the sites, for the emergence of the solution that is the balancing of resources of the extended enterprise.
    - ♦ The dynamics of the system, balancing continues with the passing of the time.

All these features allow us to model the problem by using the architecture of MAS that adapts efficiently to this kind of architecture.

3.1 Agent and MAS [6]

An agent is a software entity, located in an environment, equipped with an autonomous behaviour enabling him to reach, while interacting with this environment, the objectives which were assigned to him with its design.

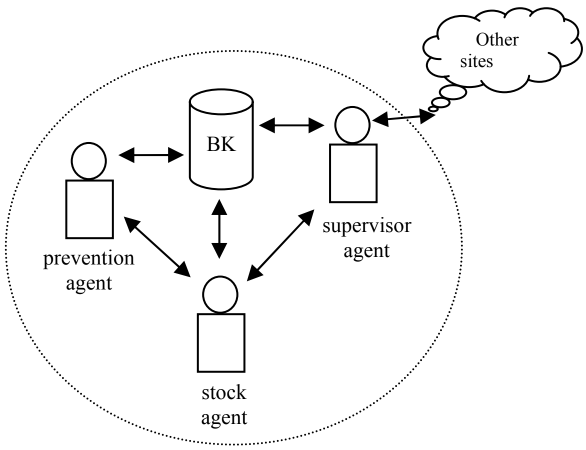

Fig.2: Structure of the agents representing one site.

Therefore, a MAS is a set of agents answering the architecture of a given system, obeying a model of organization, and on the basis of an interaction model between the agents of this system, activate for the emergence of the required global solution.
The main features of the pair (agent - MAS) are: organization, autonomy, interaction and objective. These features constitute the reason of the dynamics of the system so that it filled the required objectives.

3.2 Architecture of the system

Different tasks are considered in our application. To ensure an optimal repartition of the roles of each task within each site, we opted for the definition of the three agents: supervisor, prevention and administrator of stock.

3.3 Description of the agents of the site

3.3.1 Supervisor agent

It is the main agent of the system associated to a site; its role is the management and the control of the working of the system. The supervisor describes the set of the objectives of the system and observes its state. The supervisor agent communicates the incoming and retiring quantities of articles. He also throws the requests of acquirement and offer of the Spare part. The supervisor ensures the communication with other sites. It plays the role of an interface according to following script.

// I am the interlocutor of the site S_p
DO_IN_ PARALLEL {
IF "I receive an offer of S_m for the article N° k" {
// I enter in negotiation with S_m
}.
IF "I receive a demand of S_m for the article N° k" {
// I enter in negotiation with S_m
}
}

3.3.2 Prevention agent

The prevention agent is an intelligent agent, provided with the capacity to decide according to its basis of knowledge (BK), to foresee and then to indicate to the supervisor agent, the cases of under-stock or on-stock of spare parts quantities. This agent studies the operations of prevention using algorithms that calculate the previous consumptions $P_{k,m,prev}$ and the time of stock rupture $T_{rupture}$. These algorithms may include other criteria's as MTBF (Mean Time Between Failures), failure rate or MTTR (Mean time To Repair).
The Fig.3 shows an example of consumption of an article *k*, of class C, within a site *p*.

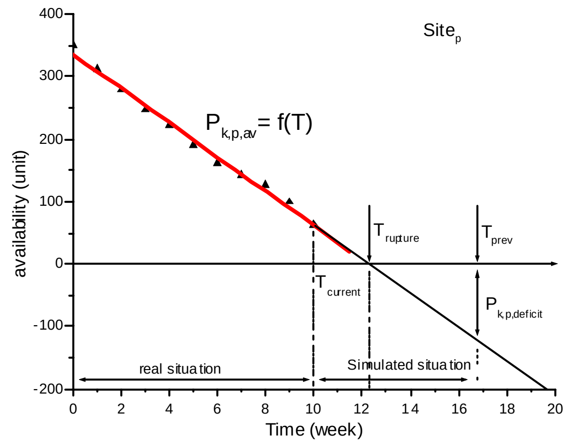

Fig.3: Example of consumption

In this case, the consumption law may be represented by a linear function as:

$P = aT + b$ with a and b to be calculated.

The previous consumption $P_{k,m,prev}$ and the time of stock rupture $T_{rupture}$ are determined as follow:

$$P_{k,p,prev} = aT_{prev} + b$$
$$T_{k,p,rupture} = -b/a \text{ when } P_{k,p,prev} = 0$$

We will see in the section 6 a simulation of a balancing problem of resources based solely on the criteria of availability and the corresponding script.

3.3.3 Manager stock agent

It is a reactive agent deprived of all shape of intelligence; its role is a classic management of stock as the consultation of the data basis and its update. This agent receives orders from the supervisor agent.

3.4 The Coordinator Agent of a Group

Every site is represented by its supervisor; it is the interlocutor of the other sites of the system. An agent representing a group of sites is called Coordinator of the Agents of the Group and is baptized *CAG*.

It receives all requests emanating from supervisors of the group; it is a shape of real estate agency regrouping all information on the offers and the demands of the agents of the group.
In case, where the request finds a favorable answer at this *CAG*, this last puts in contact the concerned agents, in order to enter in direct negotiation.

3.4.1 Negotiation on the Network

The *CAG* detains all information concerning the surpluses and the deficits of the different articles used by the members of the group and send periodically to their supervisor:

- The $P_{i,p,surplus}$ with $i \in E_p$ and E_p represents the set of the articles, in surplus, associated to the *p* site,

- The $P_{i,p,deficit}$ with $i \in E_p$ and E_p represents the set of the articles, in deficit, associated to the *p* site,

With $(E1\ U\ E2\ U. . .\ \ U\ E_N) = E$ and *E* is the set of the articles of the system.

The role of a CAG_m associated to a group of sites $(S_1, S_2. S_p,...)$ is the coordination and the receipt of the needs, in quantity of articles, of the different sites of the group, $P_{k,p,surplus}$ surpluses and $P_{k,p,deficit}$ deficit for every *k* article.
It classifies these needs; optimize the costs for every article and answers to the claimants, according to the following script:

```
// I am the Sript of the CAGm
{
    Receive_offers_of_calls ()
    Optimize_costs ()
    Classify_offers ()
    Answer_requests_emanating_some_sites_according_to_the_best_cost ()
}
```

3.5 The Inter-group Coordinator Agent

The communication between the different groups is ensured by an Inter-group Coordinator agent, that we called *CIG*.
Its role is the contribution to the establishment of the balance of the loads, once this balance reached; it has to supervise it, which means to avoid the unbalance.

4 The organization model "AGIRAT"

The model that we developed is baptized "AGIRAT"; it's characterized by the following elements:

Agent: it is the basic conceptual entity of our organization. For the moment a site is represented, with respect to its environment, by the supervisor agent. And the site itself can have an internal structuring MAS or other. Consequently, an agent is:

- Autonomous,
- Communicating,
- Distributed,
- Have an objective,

Group: it represents the organization of the agents in a group according to very established criteria.

Interaction: All the system is based on the interaction between entities, without interaction, the system is static.
Role: Every agent has a role in relation to its existence, but executes one or several tasks at one moment $T_{current}$.

Authority: the authority is the rule that governs the organization. The interest of the *CAG* group for example must pass before the interest of the agent, and the one of the *CIG* before the one of the *CAG*. On this basis, a strategy of the whole can be applied.

Task: that is the subdivision of the role in sequences of tasks (in sequential or in parallel), it is the atomic element in relation to the conceptual MAS.

5 The interaction model

The interaction model that we proposed in (Fig. 4.), is similar to that of the estate agencies where, the agency is intermediate and plays a role of negotiation between sellers and purchasers while valuing all propositions and presents, in principle, the best opportunities to its customers.
In our case, the CAG_m plays the role of this agency according to this script:

1. The CAG_m periodically receives all information from the sites of its group: levels of stock $(P_{K, J, surplus})$ to offer and $(P_{K, J, deficit})$ to require.

2. This last values all propositions and establishes the best costs for every article *k*.

3. The site S_i wants to acquire a $P_{k,i}$ quantity or to offer a $P_{k,i}$ quantity, emits its desire to its CAG_m.

4. The CAG_m already knows the site that proposes the optimal cost, and then sends him a message of proposition. In case of unavailability of article within the group, the CAG_m associated with the group must call upon other sites of other groups via the Inter Group Coordinator agent (CIG_p).

5. And 6. Negotiation between the sites S_j and S_i on the cost of the quantity of article *k* until signature of the contract.

6. In any case, the CAG_m must be informed of the exit of the negotiations and in case of disagreement; he proposes the offer to another site by re-applying the practicum's (1 to 6) again.

This operation occurs again until signature and realization of a contract.

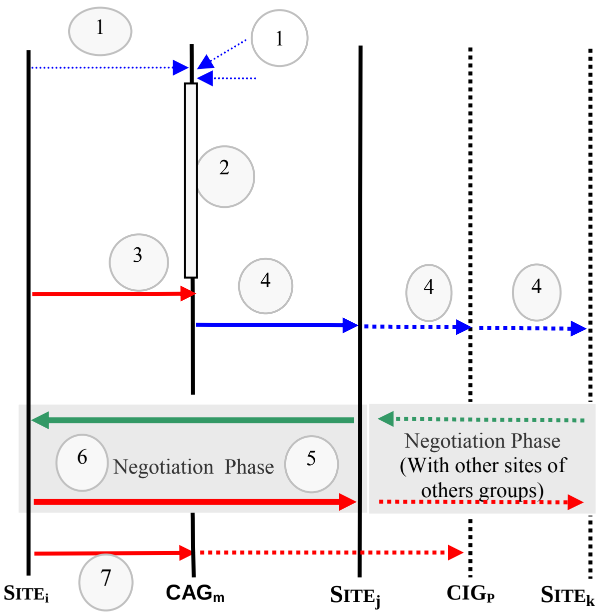

Fig.4: Interaction Model

6 Case study

6.1 Principle

Consider a system with two sites S_1 and S_2. S_1 has the articles P_1 and P_2, with respectively P_1+ and P_2- quantities. S_2 has some same articles but with P_2+ and P_1 - quantities.

In order to balance the two sites in these resources, S_1 must send to S_2 a quantity of P_1, according to conditions put by S_1 and accepted by S_2, and can receive from P_2 according to other conditions.

In what follows, we will take in consideration, the availability criteria of the article within the group.

6.2 The Script of Prevention Agent

On the basis by what preceded, we can announce the following script of the prevention agent:

// Script of the prevention agent of the site S_m
FOR each period T {
FOR each article $k \in S_i$ {
Determine_T_{Prev} ();
IF $P_{k,m,prev} < 0$ {
Calculate $T_{Rupture}$ ();
// I want to avoid the understocking
// before $T_{rupture}$
Send (*supervisor*$_i$, $P_{k,m,prev}$, *demand* , $T_{rupture}$)
}
ELSE
IF $P_{k,m,prev} > 0$ {
// I can offer from $T_{current}$
Send (*supervisor*$_i$, $P_{k,m,prev}$, *offer*, $T_{current}$)
}
}
}

6.3 Simulation

In Fig.5, we show the previous consumptions of the sites S_1 and S_2 at $T_{current}$.

The under-stockings of the product *k* will arrive for the sites S_1 and S_2 at:
$T_{k,1,rupture}$ = 2,24 weeks when $P_{k,1,prev} = 0$, and
$T_{k,2,rupture}$ = 8,87 weeks when $P_{k,2,prev} = 0$

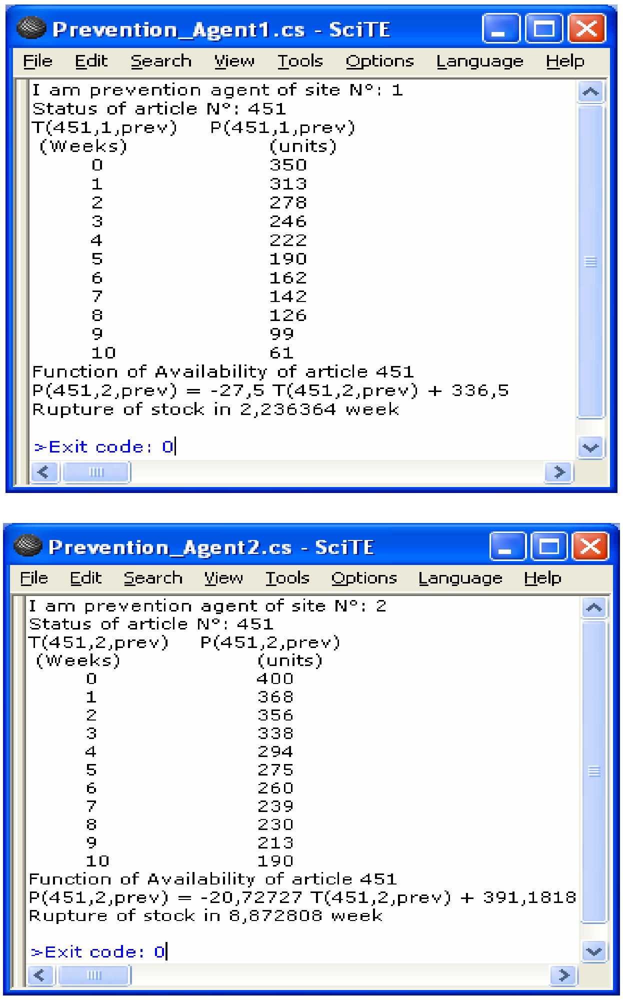

Fig. 5: Simultaneous execution of two prevention agents of two sites.

If the reorder must be done between the 3rd and the 8th week, that can affect the site1 negatively, because its under-stocking in this article is two weeks. Therefore, a negotiation between the two sites seems to be necessary.

7 Conclusion

We presented a model of MAS organization, associated to a model of interaction between agents of the system.

Considering the importance of the spare parts of an extended enterprise, we showed how to carry out a balancing of resources in order to avoid falling into abnormal situations and to exceed the thresholds tolerated in on-storage or under-storage, for each site.

A real game of data, of articles belonging in the class C, has been tested on a distributed application, written in Java language, and has been validated on a local area network, using the sockets as middleware.

The work presented in this paper is part of the European project PROTEUS that aims to integrate multiple services within a generic platform for e-maintenance.

In perspective, the MAS modelling proposed in this paper may be extended to the Ants Systems, for the optimal research, in terms of availability and in cost, of one or several articles on the Web, where the number of sites is unknown in advance, and where the problem is not determinist.

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