NEGOTIATION STRATEGY FOR A DISTRIBUTED RESOLUTION OF REAL TIME PRODUCTION MANAGEMENT PROBLEMS

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ABSTRACT

Real world manufacturing environments are highly dynamic because of frequently changing situations. Deterministic mechanisms using a centralized control mechanism cannot handle the system dynamics. Agent-based approaches are particularly suitable for dynamic manufacturing scheduling. This paper proposes a negotiation approach based on multi-agent system for complex manufacturing systems. The local scheduling and control function in dynamic distributed environment is addressed by a new negotiation protocol based on a hybrid model. The agent negotiation protocol that we have developed facilitates the establishment of the solution program in real time on the basis of hybridization between the Contract Net Protocol and a particular approach which is based on artificial intelligence. The purpose of this protocol is to assign operations dynamically to the production system resources in order to accomplish the proposed task. The article describes the common resource sharing through a number of scenarios of negotiation between the initiator agents and participants; this description treats the cases of conflicts, renegotiation and waiting.

Keywords: *Multi Agent System, Negotiation, Decision Support System (DSS), Dynamic Scheduling, Contract net Protocol, ISP (Integrated Station of Production).*

1. INTRODUCTION

We find three issues central to constructing frameworks for distributed problem solving:

(i) The fundamental conflict between the complete knowledge required to ensure coherence and the incomplete knowledge inherent in any distribution of problem solving effort,
(ii) The need for a problem solving protocol, and
(iii) The utility of negotiation as an organizing principle [5].

Recently, agent technology has been considered as an important approach for developing industrial distributed systems. It has particularly been recognized as a promising paradigm for next generation manufacturing systems [7].
In distributed intelligent manufacturing systems, agents can be applied and implemented in different ways, the most interesting for our study are:

(i) Agents can be used to encapsulate manufacturing activities in a distributed environment by using a functional decomposition approach. Examples of such functional agents include order processing, product design, production planning and scheduling and simulation.
(ii) Agents can be used to represent

Negotiation partners, either physical plants or virtual players; they also can be used to implement special services in multi agent systems like facilitators and mediators. A good discussion on agent technology can be found in [7].

Yee-Ming and al [2] developed a collaborative framework of a distributed agent-based intelligence system with a two-stage decision-making process for dynamic scheduling. Many features characterize the framework; more precisely the two-stage decision-making process, the fuzzy decision-making process and the compensatory negotiation process are adequate for distributed participants to deal with imprecise and subjective information, to conduct practical operations.
In [14] Yan and al present a multi agent system that is an implementation of a distributed project management tool. Activities, resources, and important functions are represented as agents in a network. They presented methods to schedule activities and resolve resource conflicts by message exchanging and negotiation among agents.

In [9] Sousa proposed holonic architecture for the dynamic scheduling of manufacturing systems. It also

presented a negotiation protocol based on the contract net protocol and was suitable for the dynamic scheduling of manufacturing tasks.

Our research concerns the definition of an assistance dedicated to the supervisor agent in the problem formulation and problem solving phases. The first aim is to provide assistance tools to the decision makers by introducing a negotiation coordinator *agent.* Secondly, it aims to generate several negotiation agents in order to solve a conflict; it operates in the problem resolution phase.

The paper is organized as follows: in Section2, we describe the DSS architecture. In Section 3, we detail negotiation protocol between agents. Then, we discuss, in Section 4, the different stages of decision making process which are adopted by the agents to determine how to perform dynamic scheduling on the basis of compensatory strategies.
Some conclusions and suggestions for future-studies are provided in the final section.

2. DSS ARCHITECTURE

The role of the decision support system (DSS) is to provide a decision-making support to the actors in order to assist them during a crisis case [4]. The DSS allows also managers to anticipate the occurrence of potential incidents thanks to a dynamic and a continuous evaluation of the current situation.

The DSS architecture is composed of several modules. Each module has its own functionalities and objectives [10], [11] and [12]. The analysis and reaction module is developed thanks to a multi-agent technology. As shown in Figure1. The agent based system is decomposed into a supervisor agent and several ISP agents. Each ISP agent has the possibility to use resources.

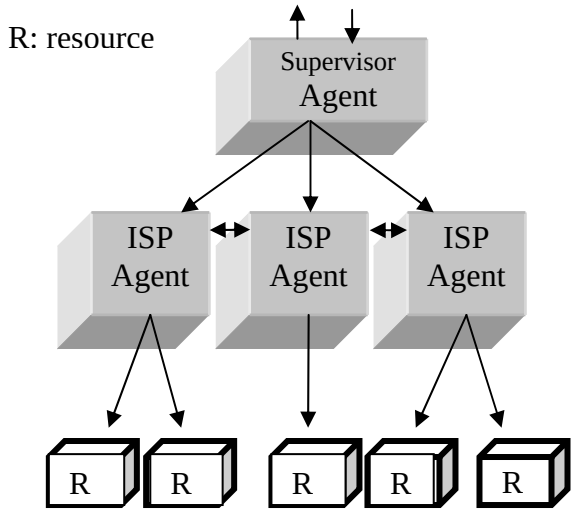

Figure1. Modelling of the distributed and supervised piloting structure by the multi agent model

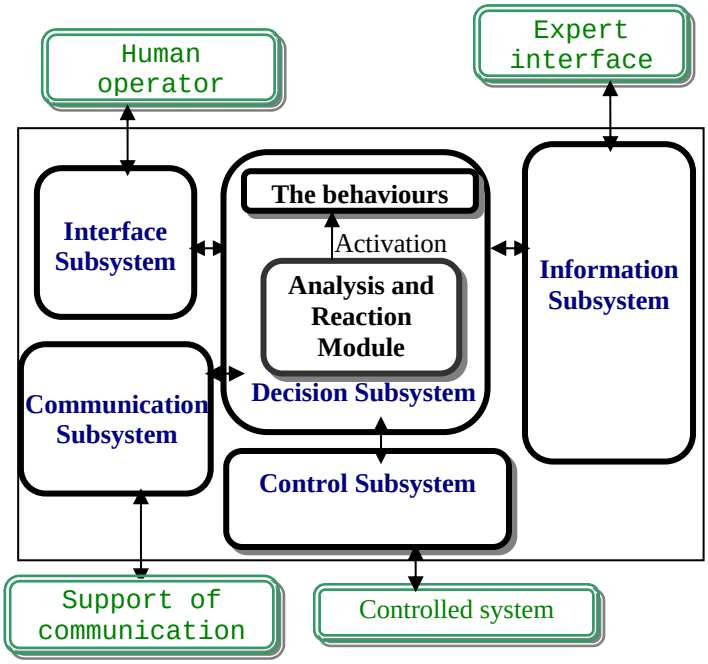

Figure2. A Supervisor Agent Structure.

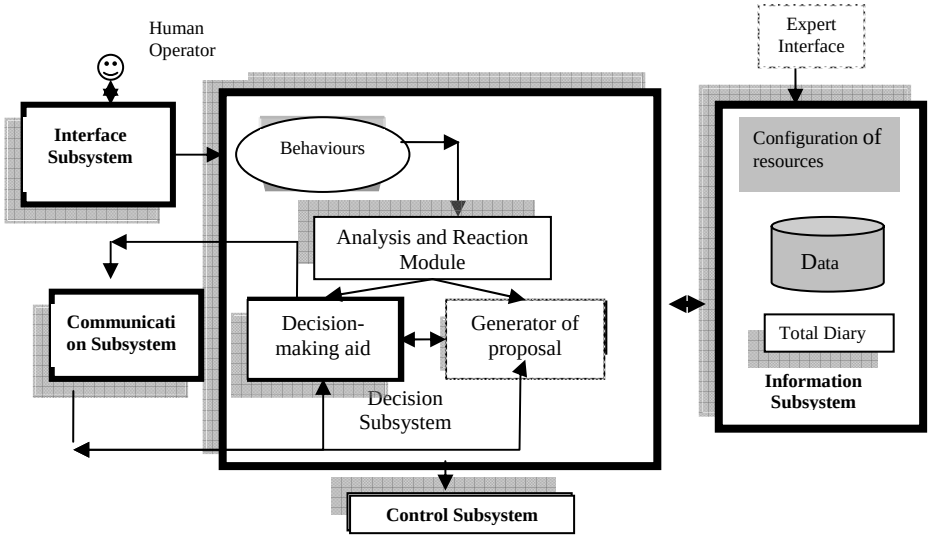

Figure3. Structure of negotiation Agent (ISP)

3. THE NEGOTIATION AID

3.1. INTRODUCTION

In multi-agent systems, negotiation is a key form of interaction that allows a group of agents to reach mutual agreement regarding their beliefs, goals, or plans [3]. Also, it is the predominant tool for solving conflicts of interests. The area of negotiation is broad and is suitable for use in different scenarios [6]. Jennings in [1] identified three broad and fundamental topics, negotiation protocols, objects, and strategies, for research on negotiation.

The protocol of the agent negotiation that we have developed facilitates the establishment of the program in real time of solution on the basis of hybridization between the Contract Net Protocol and a particular approach which is based on artificial intelligence.

3.2. CONTRACT NET AND NEGOTIATION POLICY

The contract Net protocol was one of the first solutions to the task assignment problem which a set of problem resolvers [5] generally faces. In this protocol, the agents can take role either: manager or contractor. The agent which should carry out a given task (the manager) starts first breaking up this task into several other tasks. The agents who receive an announcement of the task to be achieved may make a proposition which should reflect their capacity to fill this task. The manager gathers then all the received propositions and allocates the task to the agent which has made the best proposition.

The contract Net protocol is a model where only the manager emits propositions. The contractors can only make an offer but not counter-propositions. On the other hand, our proposition includes a process to consider the opinion of contractors, so as to find more quickly a common accepted solution [13].

Whenever a task (problem) comes to the negotiation agent coordinator, it is decomposed into subtasks (sub-problems). Subsequently, the coordinator invites potential ISP agents which possess the capability to solve the problem. Meanwhile, ISP agent analyzes the tasks and prepares bids accordingly.

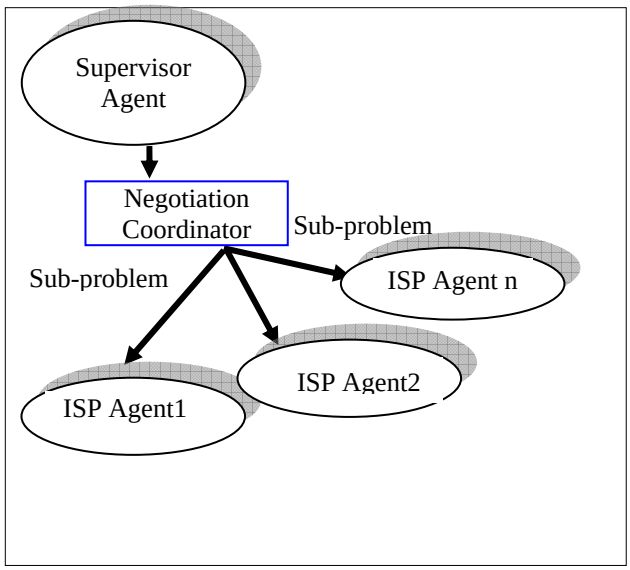

Figure4. Negotiation Protocol

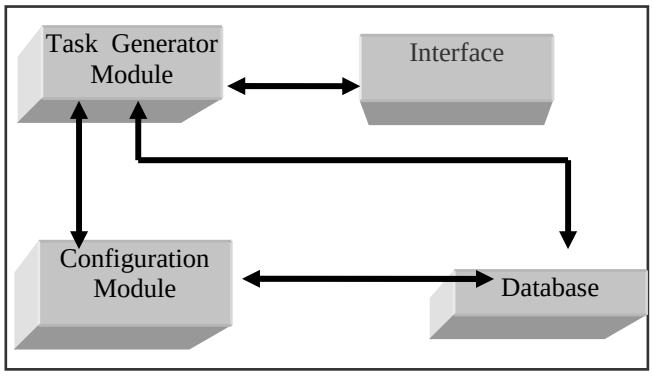

Figure5. Architecture of Negotiation Coordinator Agent

3.3. STRUCTURE OF THE NEGOTIATION AGENT COORDINATOR

As described in Figure5. the negotiation agent coordinator includes several types of functional modules such as: the task generation module, configuration module, a database and an interface. The generating task module is the core of this architecture; its role is to break up a complex problem into sub-problems. By its participation, it offers a valuable assistance to the supervisory agent. That is, it reduces its function of handling a problem which has occurred during the production. The negotiation agent coordinator analyzes the input events and assigns them in the form of tasks to ISP agents. The configuration module allows carrying out relevantly the distribution of sub-problem resolution tasks to the set of ISP entities from all the data and parameters on the tasks (data resulted from the problem formulation phase).
The configuration module ensures the management of the multiple negotiation steps and synchronizes the various results obtained. Finally the interface module manages the information exchanges between the agent coordinator and the other agents.

3.4. THE ROLE OF SUPERVISORY AGENT IN DECISION-MAKING [12]

The entity supervisor has a set of behaviours to achieve its task: (see Figure2. above)

• **The First supervisor agent behaviour:** is used to search the most satisfying resource for the production objectives.
• **The Second supervisor agent behaviour:** aims to seek the best agent of substitution for a reassignment operation (in the event of a local reassignment failure).

3.5 THE ROLE OF ISP AGENT [12]

The negotiation agent carries out a continual analysis of messages received by the other agents, through its communication interface; it also activates the behaviours corresponding to the received events. Thus, the state of operations is updated. The behaviours (see Figure3. above) are:

• **The First ISP agent behaviour**: aims to manage the queue of the agent and select the next operation to be carried out.
• **The Second ISP agent behaviour**: corresponds to the allocation process and aims to search for the next best production agent to treat the following operation of the current work.
• **The Third ISP agent behaviour**: allows the search for a substitution machine among those that it controls (the best). This behaviour is developed for reassigning operations which follow a failure.
Each negotiating agent equips decision subsystem with additional models such as:

- The proposal generator constructs a proposal for a given task according to the initial parameters and the user's preference and interest. A proposal indicates a definite value for each negotiation attribute.
- The decision making aid is applied when each agent evaluates the alternative solutions using a multi-criteria decision making technique. In our system, Electre III is used for this purpose. It considers all related attributes of the given task and gives a utility assessment to represent the satisfaction level of a proposal.

4. THE NEGOTIATION PROCESS

The negotiation protocol that we propose is characterized by a succession of messages exchanged among the agents; it is divided into four phases (Figure4. describes the negotiation protocol):

1. Decomposition of the problem: when a problem (conflict) occurs, the supervisory agent transmits this problem to the negotiation coordinator agent which transforms it into a set of sub -problems.

2. Distribution of "sub - problems": the message is sent by the manager to all agents that are considered able to carry out the task; it is sent to all agent systems. From the task description, the contracting agents build a proposition that they send to the manager.

3. Finding the solutions to the "sub-problems": The creator of agent _N creates the negotiation agents to launch the process which is divided into three phases:

3.1 The proposition phase (the proposition generator): This phase is the first phase of our protocol, it initiates the negotiation. It includes the contract proposition by the initiator to the participants and the

collection of answers of each participant. Each participant can either accept, or refuse the proposition. Where each negotiation agent has a knowledge base and the language acts which are necessary for the agents to make evolving their knowledge,

3.2 The conversation (communication) phase: by proposing amendments which are then exchanged among the agents. These agents could accept or push back a proposition (offers).

3.3 The decision (local decision-making) phase which allows the agents to infer their decisions according to the knowledge obtained from the other negotiation agents. This phase leads either to the confirmation or cancellation of contract.

4. Solution (Answer): the evaluation agent gathers all its received propositions and chooses the best proposition.

4.1. CONVERSATIONS

A well-conducted negotiation process among agents necessitates defining several negotiation primitives among the agents. A general description of interaction between an initiator agent and participant agent is given in Figure6.

The initiator has four negotiation primitives:

Proposes, asks for modification, confirms and cancels.

- ***To propose (contract):*** it is the first primitive which the initiator sends to the participants in order to propose a contract to them.
- ***To ask for modification (contract):*** this message indicates to the participants that the contract cannot be concluded in its current form and that it should be modified.
- ***To confirm (contract):*** this message indicates to the participants that the contract is confirmed. The negotiation is a success.
- ***To cancel (contract):*** this message indicates to the participants that the contract is cancelled. The negotiation fails.

The participant has three negotiation primitives: Accepts, refuses, and proposes modification (list of modifications).

- ***To accept (parameters)***:

This message answers the proposal for a contract made by the initiator. The participant indicates by this message to the initiator that it accepts the contract as such. There can be parameters if the contract is partially concluded. This parameter can also be used to carry out a counter proposal.

- ***To refuse***: this message answers the proposal for a contract made by the initiator. The participant indicates to the initiator that it refuses the contract.
- ***To propose modification (list of modifications)***: this message answers a request for modification on behalf of the initiator. The participant sends to the initiator a possible list of contract (counter-proposal) modifications. The number of modifications contained in the list is a parameter of the negotiation. This list can be empty if there is not a possibility of modifications.

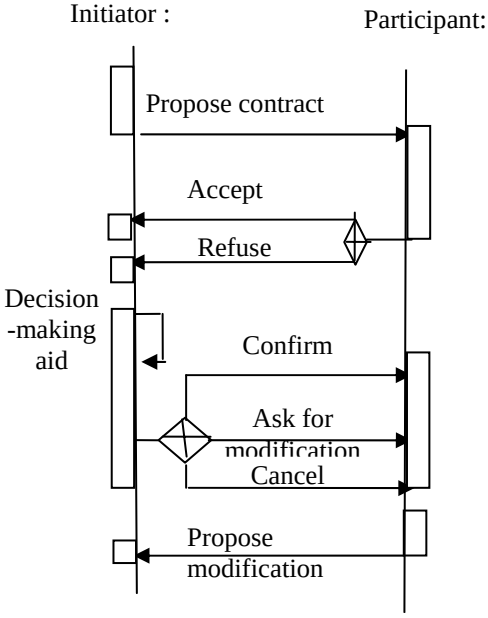

Figure6. Graph of interaction between an initiator agent and a participant agent

During the negotiation process, there may be a participant who does not answer the initiator proposition, because either it is absent or a failure has occurred. The negotiation then should not be blocked; the initiator considers a default response for the participants.

The negotiation protocol defines the interactions and rules between ISP agents in the negotiation. The protocol used is represented as a sequence diagram of agent unified modeling language (AUML) as shown in Figure6.

4.2. DISCUSSION

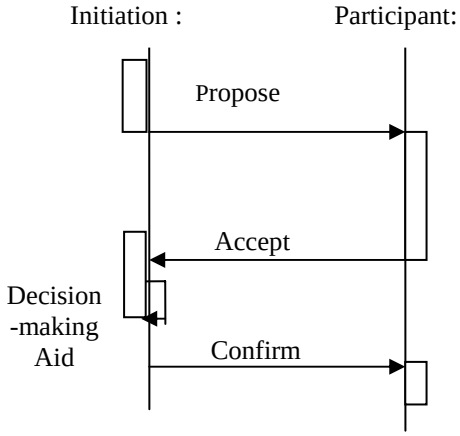

Figure7. Graph of negotiation between an initiator agent and a participant agent.

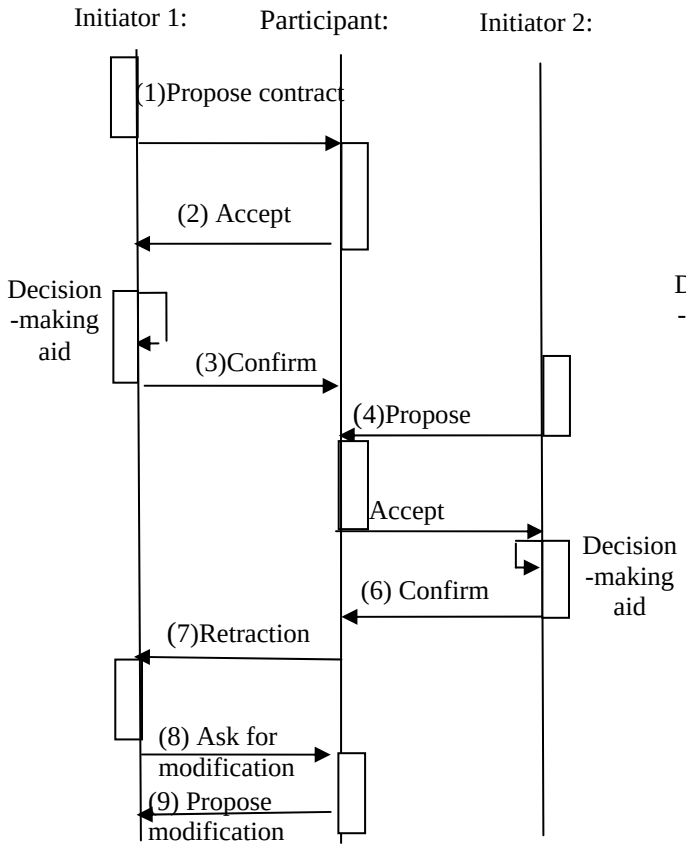

Figure8. Graph of common negotiation with renegotiation

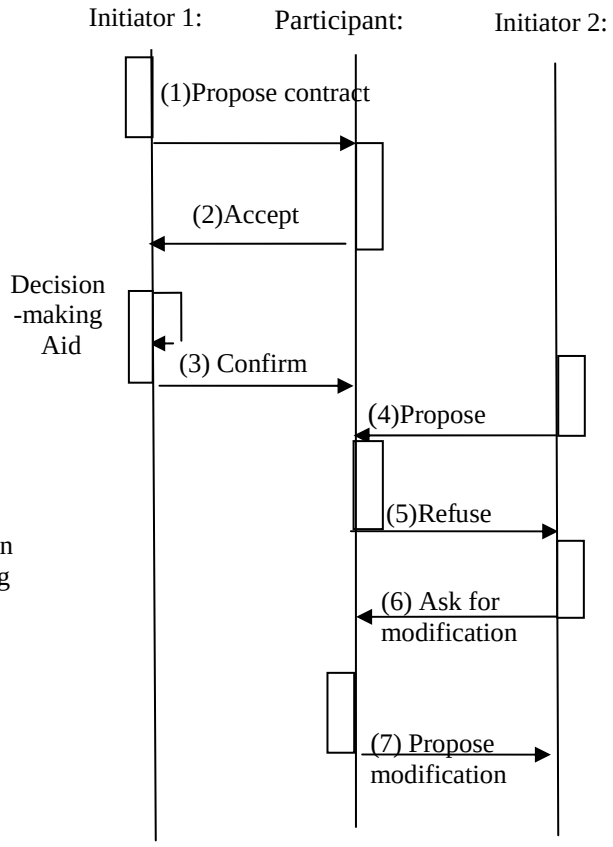

Figure9. Graph of common negotiation with conflict

- Let us deal with Figure7. ; It represents a simple example of negotiation utilizing two agents: the initiator and the participant. The initiator creates the *contract* and sends the message *propose contract* to the participant. The latter receives the contract, studies it and sends the message *accept* to the initiator to inform it that it accepts the terms of the contract. The initiator makes the decision of contract confirmation and sends the message *confirm* to the participant.

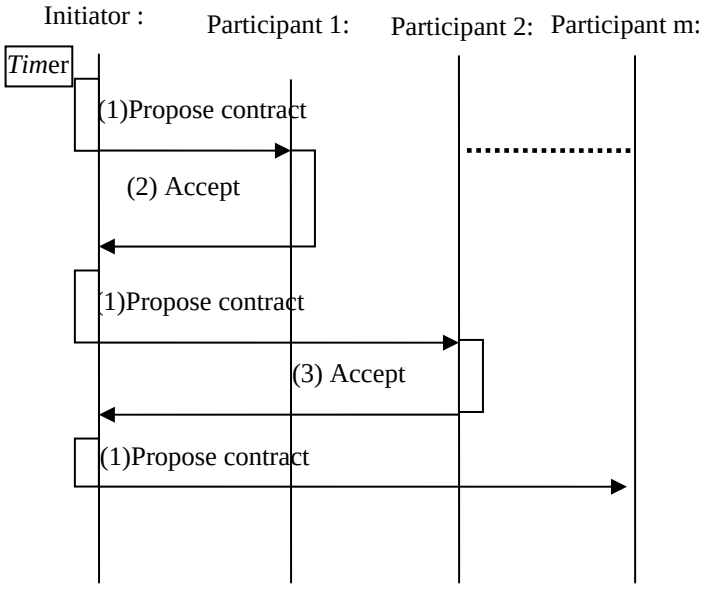

Figure10. Graph of negotiation between an initiator agent and m participant agents

- Let us study the example of Figure8. , initiator 1 proposes a contract to the participant who accepts and thus the contract is confirmed. Initiator 2 proposes in its turn a contract to the participant for the same resources which are in conflict with the previous one. The participant

then decides to accept the contract, sends consequently a message *accept* to the initiator 2 and a retraction to initiator 1. Thus, initiator 1 starts a contract renegotiation with the participant.

- Another situation can be presented (see Figure9.) and displays the conflict of the use of common resources. Initiator 1 proposes a contract to the participant who accepts it. Initiator 2 proposes to the participant a contract which is in conflict with the previous one. The participant then refuses this contract, initiator 2 can only ask for one counter-proposal of the participant. According to the latter, initiator 2 proposes a new contract to the participant.

- To show the utility of a reply delay, the example quoted in Figure10. Is studied. Here, the initiator proposes a contract to m participants: only two of them answer (refuse the contract). After the period expiration by Timer (for example 1 minute) while the other participants have not answered yet. The initiator considers the response default for these m-2 participants. On the whole, there are thus m-2 acceptances and 2 refusals. The contract is thus confirmed.

The negotiation protocol that we have elaborated takes into account the cases of counter-proposition renegotiation and formulation. The negotiation agents have a robust architecture based on a reasoning mechanism. The decision-making module described in Figure6. gives to the negotiation agents decision-making capacities in order to resolve most of the conflict situations.

4.3 EXAMPLE OF APPLICATION

We use the resource allocation problem to demonstrate how the agents solve problems by interactions among agents. A company wants to produce a special computer installation with its own hardware and software for a customer. The following print screens show several steps of the simulation: the declaration of resources, the criterion formulation, the simulation and finally the variation of the cost criterion.

Figure11. Choice of components.

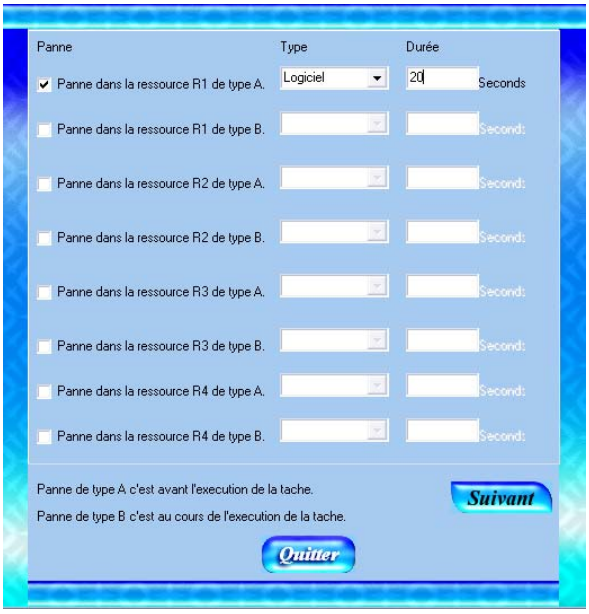

Figure12. Simulation of breakdowns

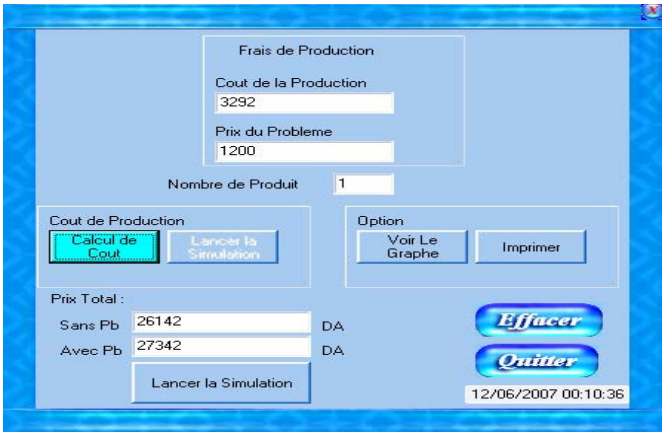

Figure13. Variation of cost criterion according to time resolution

5. CONCLUSION

The negotiation is increasingly used in the multi-agent systems against the conflicts. It can take various forms, from the simplest negotiation to be taken or left to the most complex implying counter-proposals. We have showed in this article the interest of a negotiation strategy using a hybridization of the protocol contract Net and an approach based on the artificial intelligence. Our proposal of a negotiation protocol has several objectives, with generics, flexibility, automation and portability of the message sending. We have provided a platform using the language acts inspired by the ACL. One of the future perspectives in this work lies within the scope of elaboration of an automatic algorithm of Electre III in order to obtain results to sensitivity analysis. The application carried out with JAVA relates to the implementation of decisional model which is reproduced on a multi-agent model and uses a negotiation protocol.

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