MULTI AGENT MODEL TO CONTROL PRODUCTION SYSTEM

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ABSTRACT.

The need of adaptability of production structures is continuously increased due to decrease of product life cycle and increase of the competition. The efficiency of a production system is now described not only in term of time cycle, due date, inventory level, but also in term of flexibility and reactivity in order to integrate the evolution of the market. Current methods for real time control of production system do not provide sufficient tools for an effective production activity control. The origin of such a problem is at the level of existing control structures. This work details the design of a production activity control system based on distributed structure. The structure is based on the distributed artificial intelligence concepts. After having introduced the context and reasoning work, we describe the different parts of our multi-agent model. Lastly, we illustrate this approach on a practical example of production cell.

1. INTRODUCTION

Evolution imposed by the "globalisation" of economic activity and the constraints related to environment require the development of theories, methods and models to promote an innovating approach to design a production activity control putting man and his environment at the centre of the reflexion. The work of researchers undertaken since ten years within the national or European context, often within a disciplinary framework, contributed to a progression of the productivity and quality. They also made it possible to reach a better knowledge of the factors which are at origin of this progression. however these results, are insufficient face to current and future challenges that asks the organization of companies, the evolution of society and economy and emergence of new technologies.

Flexibility, reactivity, and agility have become unavoidable qualities for many companies, which are confronted with ever more demanding constraints of quality and real time that are both varied and fluctuating. Indeed, the new manufacturing methods, in particular the production constrained by the demand (PULL), implies that at the level of production control, companies switch directly from a logic of «projected planning» to a logic of «just in time», directly led by the customer and the product in a process of development. It results from this a new challenge for these companies, which must install modular and flexible production equipments with a control system able to manage them. The latter must, on the one hand, be able to adapt to the heterogeneity of available equipment (API, Computers, Automatically Programed machine-tools, robots, etc.), equipment, which can be substituted, deleted, or reconfigured, according to needs. On the other hand, it must be sturdy when confronted with different malfunctions and distruptions, which can affect it. The control system is also inseparable from human beings, whose decisions and global vision lead to a well run system [FOX 92] [NOR 94], and from the company that placed the order, who nowadays is strongly and directly involved in the supply chain [MAS 99].

The problem of production systems control can be set out in the following way: how can we ensure that a group of elements from different origins are able to follow their goals, in agreement with the aims of the company? The main difficulty is to find a compromise between, on the one hand, maintaining the relevance outside the company through to the determination of clear performance criterions and on the other hand, to deal continually with the internal coherence of the collective actions.

The development of these system of control remains very complex because of the great amount of data to process and the decisions to take, without forgetting constraints of real time and the need to communicate with equipments in the shop and other functions within the company. Therefore, in order to answer simultaneous needs of reactivity, flexibility and robustness, a lot of researchers have neglected the prearranged, centralized and hierarchized structures to try to implement distributed structures. Control system is distributed between several decision-making centers, all of which have a degree of autonomy and cooperation and communicate with each other in order to well conclude the planned production. In this context, the approaches allowing self-configuration or configuration of a system are regarded nowadays as a major improvement. A recent study [KOU 02] shows that the multi-agent systems and the underlying emergent approach constitute actually one of the important research issue in the domain. The second section introduces the approach with the main principles of reactivity, distribution and emergence for production activity control, the third section presents models for the modelling of multi agent systems. Finally, we will illustrate our approach by a concrete example in order to explain better the different mechanisms that were used at the time of the controlling production cell.

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2. PRESENTATION OF THE APPROACH

2.1. Principles: Reactivity, Distribution and Emergence

The control of the production systems is synonymous with the action to run, to guide and to assure the pertinence and coherence of a system in a given environment. The controlling can be considered as the art to adapt permanently the objectives of a company at the evolution of the environment through to the analysis of constraints and opportunities. This activity is made delicate at the same time by the combinatory aspect related to the organization of production, the multi-criterion aspect of decisions taken and finally, the management of uncertain data, inside as well as outside the production system. In order to better determine these problems we propose to use a reactive operational approach, distributed and emergent. The reactive propriety is to be used for adapting the command to the different variations and disruptions of the system and its environment. The approach is distributive since it is made up of autonomous entities in order to give more flexibility. The approach is emergent in that the performance of the system is not globally planned, but the global plan will emerge from the dynamics of the interactions in real time between the entities (dynamic planning), using multi-agents technologies. In this way, it is not necessary for the system to alternate between planning and execution, but its behaviour is elaborated from competitive decision of the entities.

2.2. General Approach

Production system is a system (set of material or abstract elements in interaction) realizing production activity, which means transforming raw materials or components to finished product. In order to conclude this operation of transformation, the production system uses a set of resources such as machines, operators, stocking area, industrial tools. From this definition, a distributed, reactive, and emergent model to control the production system will be proposed. This model based on multi agent approach. This approach was chosen because a lot of works and applications were done in the domain of distributed control. The reader can find a study and review of this work in [KOU 02][PAR 98][SHE 99][BUS 01].

Within this approach, a control process is associated with each resource and for each product present in the production system. Each process will be modeled by an entity. Each entity of the production system is represented by an autonomous agent which has individual behavior and the capacity to make it's own local decisions. These agents gather the functions of action, decision and communication, as well as a local knowledge base. Each product is able to communicate and negotiate with the other agents to organize, plan and control the system of production. The products agents require services of the resources agents, which can accept or refuse these services. A population of resource agents and a population of product agents will be obtained.

Human operator is present in the production control loop by means of interface agent, which enables him to communicate with the other agents of the system.

The system consists of three types of agents : product agents, resources agents and operators agents. In this approach the decision is distributed between all the agents, it is a team of agents in which there is no order relation. Only cooperation links exist. Each agent takes his decision cooperating with his neighbours in order to conserve the global coherence of the decisions and to respect the objectives fixed to the system. The advantage of this approach is its simplicity, flexibility, reactivity, its tolerance of faults, and its robustness. This system is able to adapt quickly to disruptions no matter if their origins are internal or external to the system.

3. MULTI AGENT MODEL

A multi-agents system is commonly characterized by: some agents, an environment, an organization and one or more interaction models. The Parunak model has been chosen [PAR 97] to specify environment, agents and the coupling between them. But this model does not describe organizational aspect and agent behavioural. On this subject, much of works use the concept of role, abstraction of a function, a service or a behaviour. The model of interaction being based then on the relations between these roles [CAS 00]. Among those, we have chooses AALAADIN model (Agent groups role). In this last, the agent is a communicating autonomous entity, which plays roles within different groups. An agent can have several distinct roles within several groups and the same role can be hold by several agents, which makes possible the heterogeneity of the situations of interaction [GUT 00]. There is no constraint or pre required on internal agent architecture and does not define a particular model to describe the agent behaviour. The agent behaviour can be produced by multiple ways: tasks made up of primitives then started by stimuli, sorters system, Petri nets [FER 95], but to create agents which can adapt, will consist first and above all to make evolve their behaviours, in all their complexity. To tackle this problem, we should use an approach that allows the evolution of agent behaviour. Work of Picault and Landau [LAN 01] encouraged us to produce agent behaviour, by using a structure of oriented and stamped graph named ATN (Augmented Transition Network).

3.1. Basic Model of MAS

A multi-agents system according to Parunak can be defined like a triplet: a set of agent, an Environment, and a coupling, which defines the bond between them, we will not detail this model here, the reader can find it in [PAR 97].

3.2. Organisational Model

The dynamic aspect is very important in this approach because it ensures the emergence of the overall plan. The team was interested in specifying the system using a methodology and modelling based on organisational notions dedicated to the multi agents system stemmed from Aalaadin [GUT 00]. This model is based on the notion of agent-group-role. A group is seen like a usual MAS and in our case we identified four groups:

- Products agents group,
- Resources agents group,
- Operators agents group,
- A group associating a product agent with the resources agents necessary to its transformation.

3.2.1 Products agents

Each product agent has its own procedure (range), these agents are created as soon as product enters in the production system and destructed at the end of treatement. Several product agents can be find in the production system at the same time. The role of the product agents is to plan and to control the product in the production system in order to process all the treatments dictated by the procedure, respecting the time price and quality constraints

3.2.2 Resources agents

These agents control the resources of the production system, (for example: machines, robots, conveyor). In the production system resources agents can be find from the same type which has to cooperate each other in order to avoid conflicts. The role of the resource agents is to process the treatment and task over part respecting the time constraints.

3.2.3 Operators agents

The interface agent is designed to interpret the human operator's messages in order to configure the system and send back the interactions between the resource and product agents to the operator. The role of this agent is:

- To introduce new constraints on the resources or on the product.
- To favour the production of a product compared to another product.
- To add new data and external information.
- To release (the start and the stop of the system).
- To support simulation process, to introduce breakdowns on the resources, and to follow the behaviour of the system

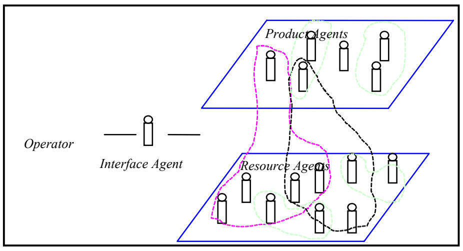

Fig. 1. : Organisational structure of the multi-agent system to control the production system.

3.3. Interaction model

The aim of the interaction model is to show and explain knowledge exchange, to resolve problems of conflict, to cooperate in order to reach their objective. this part presents the basic communicating system and negotiating process.

3.3.1 Communication system

The communication is a fundamental point of the multi-agent system. It is not reduced at data exchanged systems, but it's matter of an intentional act, which finds an expression in a modification of the agent knowledge. FIPA (Agent Communication Language) has been used; it is a high level of communication language and protocol, message oriented, independent of the syntax and semantic of the content (ontology). It is even independent of message transport mechanisms (ex: TCP/IP, SMTP, IIOP, HTTP…) and high-level protocol of negotiation (ex: Contract-Net). ACL is based on primitive of communication called "act of communication"[FIPA 00037].

3.3.2 Negotiation system

The aim of a negotiation process is the modification of the agents local plans to reach a consensus upon execution of the tasks in the system. The negotiation is essential for this particular system. The well known contract-net protocol (CNP) [SMI 81] was chosen as model of negotiation.

3.4. Process Model

Behaviour (process model) of agents are descrided using an oriented and stamped graph structure named ATN (Augmented Transition Network). At the beginning these graphs were used within the context of language processing [WOO 70] [WIN 83], and at a later stage, they were used to describe agent's process [GUE 96]. The ATN are constituted of nodes linked by arcs, which can be stamped by a whole set of conditions and list of actions. The choice of ATN is not by hazard but to produce the behavioural graph automatically using genetic algorithms [LAN 01].

3.4.1 Behavioural Model of the Agents

As we have indicated previously, the behaviour of the agents are described by ATN graphs. The behaviour graph of an agent has a direct node of departure (called start), and a final node (end). The other nodes are linked by arcs, which can be associated by a whole range of conditions and by a sequence of actions. Our agents are initialised at the beginning. Also the agent activity consists for each node:
- To select between the arcs from the current node, the ones which are crossed, that is to say either without conditions or whose conditions are checked simultaneously.
- To chose one of its arcs randomly.
- To cross it (to take up on a node where it ends up) after having possibly realized actions linked at the arc in the order.

The agent searches continuously to get from one node to another, if no arc is surmountable, it stays in the first state, and will try again to the next step. It changes in a waking state when it is situated on the node called end and stops acting.

It can be noticed that two agents, which have a common ATN, can adopt very different behaviours (from the same abilities of reception and actions), in the situation when they can use different arcs if they are situated in the same conditions.

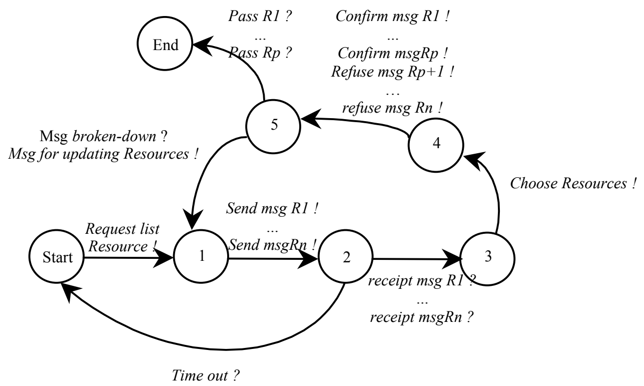

Fig. 2. ATN of the product agents

Table 1. The actions and the conditions of product agent

Action !	Condition ?
Ask a call for proposals !	Recept msg ?
Chose proposal !	Msg pane ?
Send confirm msg !	Blank pass all resource ?
Send refuse msg !	Time out ?
Update list of resources !	

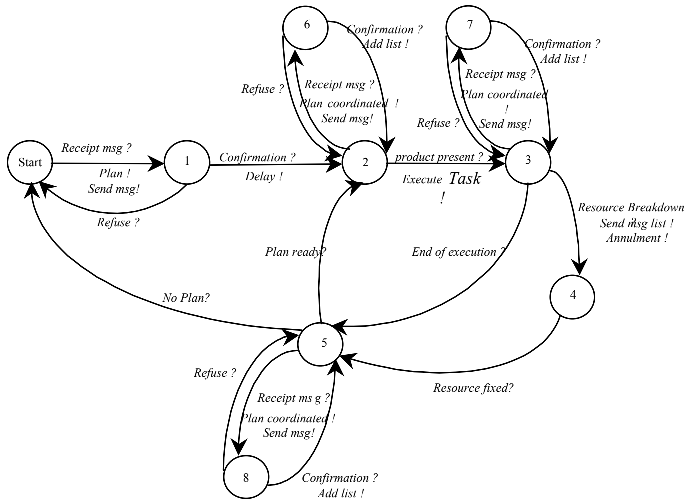

Fig. 3. ATN of the resource agents.

Table 2. The actions and the conditions of resource agent.

Action !	Condition ?
To Plan !	*Recept msg ?*
Send msg!	*Recept msg refuse ?*
Delay!	*Recept msg confirmation ?*
To execute!	*Plan Ready ?*
Follow up!	*No plan ?*
Send msg to cancel contracts!	*Resource Fixed ?*
	End of Execution ?
	Resource failure ?

4. ILLUSTRATION BY AN EXAMPLE

To test the approach, a simulator of a production cell was chosen. The main objective is to control this cell in real time. In addition to reactivity, robustness, and efficiency, we test the coherence of the overall plan, which emerge from local agent plan. Even the feasibility of the approach will be test.

4.1. Presentation of Example

4.1.1 Description of the Production Cell [LOT 96]

The production cell is equipped with two conveyors belts, four processing units and two portals with a traveling crane. The conveyor belts carries the blanks in only one direction, from left to right. At the end of the feed belt, there is a light barrier and a code reader. The deposit belt contains a light barrier at it's beginning. The processing units are equipped with two sensors, one sensor which reports whether the unit is occupied or not and the second sensor which indicates whether the unit is working or not. There is two type of processing unit type 1 (drill or press) or type 2 (oven). Both traveling cranes can reach all four processing units and can be moved in three directions.

Blanks are introduced to the system via the feed belt, whenever a sensor reports a blank the belt must be stopped. Then, the blank is positioned directly in front of the bar code reader. Blanks have a bar code which contains information about the procedure for there processing. It tells which type of processing unit must be used and determines whether the processing order is correct or not. Additionally, there may be time constraints, which limit the time that can be used for processing the blanks. An additional time constraint gives a maximum limit on the total time a blank may spend in the whole system. The code reader transmits the information after having read it from each blank. The type of return value of the bar codes is tupel $\left\langle n, \left\langle \min_i, \max_i \right\rangle_{i=1}^{n}, r, t_G \right\rangle$ which tells how the blank must go through the system and gives time constraints.

The bar Code :

n : number of type of processing units
$\min_i$:Minimum processing time in seconds, machine type i
$\max_i$:Maximum processing time in seconds, machine type i
r : Indicates if there is an order during processing
t_G : Maximum time in secs, in the whole system.

4.1.2 Processing Problem

Our multi-agents system must control production cell in real time, solve the problem of conflict between the resources and avoid the collision between the two gantries (cranes). The agents must respect the procedure of treatment delivered by the code bar (order, and maximum duration that the blank should not exceed in the system, and each type of machine). To establish these agents, we use the last version of JADE (Java Agent DEvelopment framework). The main objective is to prove the coherence of the decision of each agent.

4.2. Functioning and Application of the Approach

Agents model the blanks and the machines of the system. As soon as the blank arrives in the entry conveyor, the blank agent is created through an event caused by a light barrier sensor. The reader of bar code agent sends the procedure (range) to the blank agent, from this location the blank agent negotiates using the Contract-Net [FIPA 00037].

4.2.1 The Negotiation Between Blank and Resources

Firstly the blank agent makes a bid to the machines agents in order to fulfil the procedure. According its capability each machine agents propose one bid, which specifies a starting date for the task and a list of tasks already scheduled on the machine. The blank agent analyses bids and chooses the machines, which propose the weakest date (the smallest date). All that is done, before the blank quits the entry conveyor and before that the blank suffers the treatment. As soon as the success of the negotiation we pass to the execution of the task planed, at the end of the execution, the blank agent is destroyed by the exit conveyor agent. The global plan for the treatment in cell emerges from an organised plan by each blank agent.
In the case of a breakdown or perturbation, the blank agent cancels the contract and tries another new proposition with new bid in order to follow the treatment.

4.2.2 The Coordination Between Resource Agents

The resource agents can coordinate their plan before giving the proposition to the blank agent in order to respect the constraints, for example collision between cranes.

4.2.3 The Coordination Between Blank Agents

To respect the production delays of some products, the system has to adapt and favour certain products; in that case, the blank agents must coordinate their plans and exchange them. The priority blank agent sends messages to the other blank agents, which are in the system, and negotiate, if possible, respecting the range constraints, of passing into resources before the others. In that case, the agents already in the system cancel contracts with some resources to leave a place for the priority blank agent.

5. CONCLUSION

In this paper, we have presented the modeling of multi-agent systems for controlling production systems. This approach is motivated by the evolution of production methods and increasing complexity of products, which have in consequence raised complexity of the production activity control. The evolution towards to the notion of (virtual factory) does become worth this trend. That leads the traditional methods of optimization to the combinatory explosion of calculation. Associating an entity to every element in interaction, the multi agent approach allows us to substitute the explicit coding of the complete set of interaction by its generation at the execution time. That reduces drastically the quantity of coding at the production stage and so, the cost of developing the system. That is why this approach nowadays constitutes one of the most important research issue in the domain.
Considering the previous remarks, this work emphasizes the viewpoint that lead to consider complex activity as a consequence of agent‘s interactions instead of being the result of complex agent-thinking mechanisms. The originality of approach is to try to integrate different existing models in order to provide a complete model adapted to this problem. This allows us to describe all the aspects of a multi agent system: the agents, their behaviour, their organization, the environment in which they evolve, and the way in which they communicate to realize collective actions.
The realized work opens the way to several perspectives about:

1. The evolution of models of behaviour: utilization of ATN allows us to plan the automatic generation and adaptation using the Picault Landau ‘s works based on an evolutionary approach,
2. The resolution of the problem of the follow-up and possibly of recovery while a degraded functioning of the production system.
3. The resolution of the agent autonomy problems compared to the global coherence of the system.

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