Resource Allocation Process Using Multi-Agent Systems

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Abstract. The study intends to contribute to the MAS (Multi-Agent System) research in different application domains, highlighting the positive impact of the MAS and fostering the development of such applications in industries. This paper describes the development of a MAS to plan the allocation of resources in a case study: the allocation of biscuit package machines by a company in Santa Cruz do Sul. The simulation and evaluation of the agents in this environment contribute to improve the control of industrial processes and to achieve the objectives, time restrictions and global costs of the production system. An example of the use of these criteria in a game prototype is described, as well as the results achieved.

Keywords: Resource Allocation Process, Multi-Agent Systems.

1 Introduction

In order to fulfill new demands of manufacture systems, resources must available so that the process can take place. The complexity of planning a production line is in finding the ideal usage of resources. A multi-agent system (MAS) can be a solution to the automation of such processes of resources allocation, using intelligent agents that interact with each other and with the environment [7]. The agents are able to look for solutions, so there can be higher control during tasks and procedures of a given process, which makes resources allocation more efficient.

According to [1], manufacture systems based on autonomous agents are manufacture resources individually controlled by agents. The application of agents in industrial environments makes possible to define a strategy, thus allowing planning of the resources usage so that the demands of the production activities can be fulfilled in a decentralized and distributed way. They also contribute effectively with means to reach objectives, deal with temporal restrictions and global costs of the entire production system, and to provide consistent specification of the functional and organizational structure of a production sector.

This study intends to contribute to the MAS research in different application domains, highlighting the positive impact of the MAS and fostering the development of such applications in industries.

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The paper presents a model of a MAS that would be able to solve problems found in a biscuit company: the set up of biscuit packing machines and planning of biscuits weekly production.

This paper is organized as it follows: section 2 presents some considerations and features of the resources allocation planning in a manufacture system. Section 3 presents the proposal and development of a MAS in the solution of a resource allocation problem. Section 4 presents the MAS implementation in an environment that simulates the production, and the results of experiments. Finally, the conclusion is about the agents' role in the production planning process.

2 Resources Allocation

Production resources are machines, equipments and workmanship that take part in the productive system [3]. During the productive process, there is material consumption and usage of production resources. In order to fulfill new production demands, one must observe if there are enough available resources for that end, considering capacity limits, time required in each activity with relation to resources used, time for resources preparation, due dates of each item and a temporal synchronism in the allocation of such resources [4].

According to [2], there are some advantages that result from the planning of resources allocation, such as: quality improvement − so that the company can be aware of which resources are suitable for certain activities; time availability − reducing waiting time of each item that will be processed by a production resource, thus affecting the final product total time of production; productive capacity − the company will be aware of the productive capacity of each resource in what concerns the time interval available for its allocation in productive activities; the company will be able to know if there is capacity to respond to new demands for the company's products.

The complexity of production planning is in trying to find the best resources allocation in every step of the process so that current demands can be fulfilled [6]. Thus, it is necessary to decentralize decisions in the resources allocation, this way each participant decides when and where local resources will be used. A MAS can be used as an alternative to this issue.

The use of agents responsible for the resources allocation can be able to reverse disturbances that may happen in a productive process (lack of resources, production increase) in time, thus avoiding rescheduling of deliveries already programmed and troubles in the next production activities.

3 Resources Allocation Using MAS

In this section we present some points related to the development of a MAS in problem-solving of resources allocation.

3.1 Case Report

The production environment chosen was a traditional food company (biscuits production) from Santa Cruz do Sul, in the state of Rio Grande do Sul, Brazil.

We carried out several interviews and visits on the shop floor in order to identify the resources of the production line that would be most adequate and profitable to the application of a MAS. Based on knowledge about the activities of the company's production line, we realized that among all resources, the packing machine represented the major critical point.

In the company reported in this study, the packing machine for biscuits packs containing 135 g was the same used for 100g packs, because there was no physical space for both of them. There is one 100g packing machine and four 135g packing machines working in the sector and another on stand-by (which can both work to pack 100g or 135g), which is used when the production must be increased.

By using the information collected with workers and chiefs of the production sector we could identify the problem to be approached: to control and make warnings when packing machines should be set up, aiming at reducing the number of weekly switches from 135g to 100g or from 100g to 135g and helping in decision taking about the best time to perform the set up.

3.2 Proposal of a MAS for the Control and Set up of Packing Machines

Taking into account that the exchange of packing machines elevates costs and generates extra work we built a MAS model in which agents' role is to warn when the packing machines should have their function changed from 135g to 100g packing or vice versa.

The model we propose has six agents: four packing machine agents of 135g, one of 100g and a stand-by. The 135g and 100g agents represent the five packing machines that are allocated in the company's production line and the stand-by agent represents the stand-by machine can be used to substitute another machine. These agents control the machines production, with the goal of planning and warning the set up time [5]. The agent's internal architecture contains modules that are responsible for the perception mechanisms, knowledge, reasoning, planning and communication, as Figure 1 shows.

Through the perception module the agent receives information from the environment (the human agent – user – imports data from orders), realizes changes in the environment, receives a positive or negative feedback from the user and instructions. Perception is the source of the agent's knowledge.

The knowledge module stores information that the agent has about the environment, such as: capacity of packing machines production per hour, minutes worked per week, idle minutes per week, name of the client responsible for the order, selling dates, and others.

The reasoning module analyses and processes information taking into account the agent's perception and knowledge. The agent makes many calculations through the reasoning module and the results from such calculations are sent to the planning module. Examples of calculations performed are: calculating the amount of 100g biscuits sold per week; calculating the mean capacity of the weekly production.

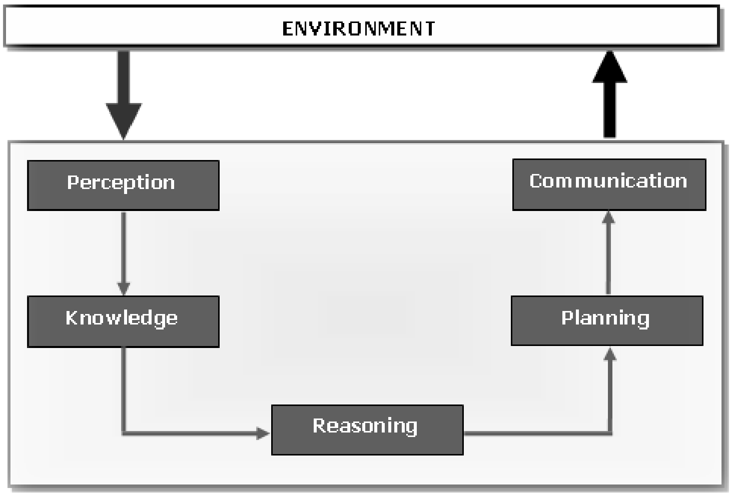

Fig.1. Agent's internal architecture

The planning module receives information processed in the reasoning module, comparing all these information and deciding for the best behavior. The planning module schedules plans and, if required, performs and reviews such plans. It sends the messages that must be sent to the environment to the communication module. Examples of plans performed are: Check the necessity of setting up the packing machines − from 100g to 135g or from 135g to 100g; checking if there are conditions to respond to the expected weekly demand. As to the production capacity of the company's resources for the weekly production, the company only assesses the production capacity of the packing machines and not of all resources, because they represent the critical point of the production sector.

The function of the agent's communication module is to send and get messages from the environment, as, for example: message sent − warns if it necessary to set up the packing machine during the week.

The agents are responsible for choosing the best way to perform the activities they are assigned, aiming at reaching the objective of decreasing the number of packing machines set ups and avoiding pending processes caused by such processes.

This way, the strategic objectives of the organization towards production are reached after an analysis an organized planning of the resources allocation process using the MAS.

4 Implementation of a Simulated Production Environment

Figure 2 shows the system menus. The human agent uses the system to inform data (knowledge) so that the agent performs his processing (reasoning), in order to provide and visualize actions to be taken concerning the weekly production process.

The simulation environment was implemented with the phptriad package, PHP programming language and Mysql database. For data management in the database we used WinMySQLAdmin and DBDesigner.

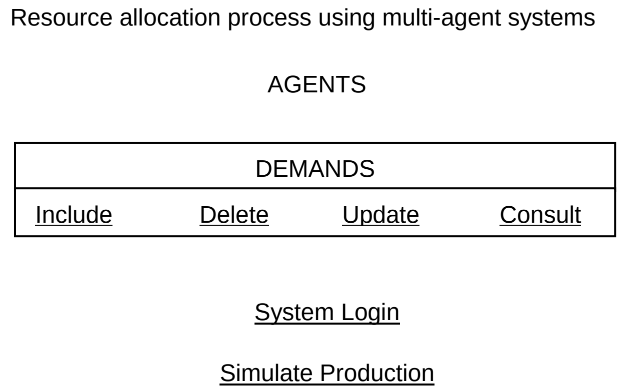

Fig.2. System menus

Below we present the features of the simulation developed.

4.1 Prototype Description

In order to evaluate the agent's behaviour, comparisons were made after the simulation of a real situation, with basis on observations made at the early stage of this study (in the shop floor), with the agent's planning simulation.

Figure 3 shows the weekly production planning using the agent. The agent passes several information to the human agent, such as:

- it is possible to accomplish the 100g biscuits production;
- it is impossible to accomplish the 135g biscuits production with 40 work hours;
- it is possible to set up packing machines from 100g to 135g;
- the amount of packs sold and the amount of packs that could not be produced in the previous week;
- the mean production capacity of 100g biscuits was 94,007 and of 135g was 355,423;
- how many work hours are necessary to reach the targeted production;
- hours available to produce during the week;
- overtime work with no machines set up using resources from the stock;
- amount of packs that can be produced to be stored;

• amount of packs that can be produced added to the stock;

• packs that lack to reach the 135g biscuits production using the stock (they can be produced in the following week);

• packs to be produced after switching the 100g machine by the stand-by that produces 135g packs after 1-hour set up;

• overtime work to reach the production of 135g with five baling machines producing 135g packages after 1-hour set up;

• total of overtime work hours to reach the production of 135g packs with 1-hour set up included.

It is possible to accomplish the 100g biscuits production in the week!!
It is impossible to accomplish the 135g biscuits production with 40 work hours in the week!!
It is possible to set up packing machines from 100g to 135g!!!

	Sold packs	packs that could not be produced in the previous week	Amount of packs to be produced	Production capacity (hour)	Production capacity (week)	Packs in stock
100g	90.000	0	90.000	2.350	94.007	80.000
135g	490.000	0	490.000	8.885	355.423	90.000

	Amount of packs produced added to the stock	Work hours to reach the production	Available hours	Overtime work with no machines set up using resources from the stock	It is possible to produce to stock
100g	174.007	4.3	35.7	----------	84.007
135g	445.423	45.01	-------	5.01	----------

Packs that lack to reach the 135g biscuits production using the stock (they can be produced in the following week)	Packs to be produced after switching the 100g machine by the stand-by that produces 135g packs after 1-hour set up	Overtime work to reach the production of 135g with five baling machines producing 135g packages after 1-hour set up	Total of overtime work hours to reach the production of 135g packs with 1-hour set up included
44.576	35.691	**3.27**	**4.27**

Fig.3. Planning the weekly production with an agent

By planning the weekly production with an agent it is not necessary to make the machines set up, at a maximum, one set up during the week is required to reach the intended production. Moreover, the agents provide the system's administrator with other important information about production planning.

Such information can be used for comparisons between the production without the agent. Figure 4 shows the real weekly production without the agent.

Figure 5 shows some comparisons between production with and without the agent (real production).

Weekly production with agents can be more profitable specially because there were no 100g machine set up, and only a set up of 135g packing machine during the week (the machines set up time lasts one hour), while without agent set ups could come to six. This situation shows that the company gains 6 production hours per week when using agents, weekly producing 7,050 100g packages and 6,664 135g packages more than without agents. Another advantage is the reduction in the number of overtime work to reach the targeted production.

The results obtained with the agent is due to the organized production planning, which is based on calculations and crossing of information that are relevant to the system. Observations about comparisons between the weekly production with the agent and the real production without the agent show the importance of the agent's inclusion in this productive system.

Work hours in the week	How many packing machines changes in the week	Real workhours 100g, without packing machines changes	Real work hours 135g, without packing machines changes
40	6	37	37

	Sold packs	packs that could not be produced in the previous week	Amount of packs to be produced	Production capacity (hour)	Produced Packs	Packs in stock	Amount of packs produced added to the stock
100g	90.000	0	90.000	2.350	86.957	80.000	166.957
135g	490.000	0	490.000	8.885	348.759	90.000	438.759

Fig.4. Real weekly production without the agent

	Produced packs	Amount of packs produced added to the stock	Amount of packing machines changes
With agent 100g	*94.007*	*174.007*	*0*
Real production 100g	86.957	166.957	3
Diference 100g	7.050	7.050	3
With agent 135g	*355.423*	*445.423*	*1*
Real production 135g	348.759	438.759	3
Diference 135g	6.664	6.664	3

Fig.5. Comparisons between production with and without the agent

5 Conclusion

The MAS development for resources allocation using agents in the production environment was aimed at providing an adequate control of the industrial process of a factory.

In order to define a case study that would adequately fit the objective of the present study we studied the company's environment, so a problem in the production sector could be identified. Then, we identified how agents could control the decrease of packing machines exchanges and weekly biscuits production planning.

By using a simulated environment we could assess the way how agents acted in the company's production planning process and showed the benefits of incorporating agents to this process, such as:

• reduction in the number of weekly set ups of 135g packs to 100g packs or vice versa, thus avoiding pending processes that resulted from such switch;

• help in deciding the machines set up time;

• delegation of functions to agents, as the weekly production planning, which were earlier performed by workers during long meetings;

• generation of as many simulations as necessary to arrive to the weekly production planning expected by the company;

• help the company to control production so that the delivery date scheduled with clients is maintained, which contributes to the image of the company in the market;

• increase in the production resulting from hours gained with the reduction of machines set ups, which results in benefits increase as well.

The present study shows that the process for resources allocation using MAS allows the strategic planning of resources consumption that can fulfill demands, presenting mechanisms to balance the use of productive resources and rules that guarantee the accomplishment of the commitments undertaken with clients. The agents responsible for the resources allocation can be able to reverse disturbances that may happen in processes as rescheduling of deliveries already programmed, troubles in the production activities and also avoid problems with the next productive activities which are under the agent's responsibility. This way, the agents provide stability in the programming of production and deadlines.

The present work has demonstrated the advantages of adequately using a MAS in a domain of production planning and its positive impact, thus trying to foster the construction and utilization of agents-based applications in the industry.

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