Agent-Based Enhancement of Legacy Manufacturing Planning and Control Processes

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ABSTRACT: Nowadays, the industrial company are attached with a very competitive and Highly dynamic Environment that require a rapid reaction in order To avoid the accumulation of defects in the execution plans and to ensure a better control of the manufacturing and supply plans while communicating the real-time situation to the customers vis-à-vis their orders. In this paper we propose a multi Agents system that enhances the capacity of manufacturing legacy systems for maintaining an updated planning according to real-time situations. The proposed system will be integrated with the legacy system and add to it new capabilities such as autonomy, speed, decision making support and intelligence. The logic and the architecture of the system were inspired from the human organization and behaviours adopted in manufacturing planning and control activity.

KEYWORDS: Multi-Agent System; Legacy Systems; Manufacturing Planning and control; Interaction Protocol

1. INTRODUCTION

Nowadays, industrial companies know a very competitive and highly dynamic environment: changing bank rates; changing political situations; materials do not arrive on time, power supplies breakdown, production facilities fail, workers' absences; dealing with new orders, changing or cancelling existing orders [1].

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Dynamic changes influencing the validity of schedules have been classified into two categories [2]: i) resources related, which implies failure on production resources: machine breakdown, workers' stat, and supplying failure : delay in the arrival or shortage of materials, defective material (material with wrong specification), etc ii) Jobs related, which include the disrespect of the task deadline (earliness and lateness), customer's order change : new job, job cancellation, due date changes, change in job priority, changes in job processing time, etc. These unexpected changes may cause a modification in the scheduled plans, and a previously feasible schedule may turn infeasible when it is released to the shop floor. The relevant issues in this situation are: how to improve the control system to detect the influencing changes in an earlier time, and how to react in order to preserve the stability and consistency of schedules with the production. The first issue is the responsibility of the Information system (IS) that must be aligned with the business. We must add the necessary functionalities for the collection of new resulting information from business operations and those which allow diffusing the right information to the right place at the right time. In this issue different techniques are used according to the environment and the nature of implicated entities. For example in [3][4], radio frequency identification (RFID) technology has been used in order to facilitate the production data capture. The second issue refer to what is called in the literature as dynamic scheduling, real-time scheduling and online scheduling. For this aim many model and methods are proposed in the literature, among them we find the multi-agent based model.

Agents and similar concepts were welcome in manufacturing because they helped to realize important properties as autonomy, responsiveness, redundancy, distribution, and openness [5]. Agent technology also has been considered as an important approach for developing distributed intelligent manufacturing systems [1]. In [6] a Multi-Agent System (MAS) has been defined as a network of problem solvers that work together to tackle problems that are beyond their potentials.MAS architectures for Planning and scheduling aim to guarantee interoperation of all the relevant entities in the supply chain. This allows a direct flow of information in the chain, making planning decisions fresher and more reliable [7]. Many projects and researches have adopted the use of MAS in manufacturing systems especially in dynamic

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manufacturing planning, scheduling and control systems. References [1][5][7][8] present surveys of proposed approaches based on agent paradigm.

However, as it is mentioned in [8][9], the adoption of these concepts by industry is very slow and extremely rare. According to our point of view the reason is in the strong and solid relationship and trust that has grown over time between the users and the adopted legacy systems, this is natural, the majority of works presented above don't take into account companies existing legacy systems. We think that changing technology and systems beyond the company must be taken step by step and the new adopted systems and techniques must be integrated with the existing one.On the scope of this paper, the Planning activity aims to determine the position of customer orders in the production horizon taking into account orders priority, production capacity, the work in progress and other continuously updated information present inside the manufacturing system and in the supply chain. A schedule determines how the planned orders will be realized in the time. It determine the detailed fabrication plans that must be ensured by the production resources, including assignment of workers, sequencing, and timetabling of the production operations on the available resources, taking into account the necessary real-time information. In reality, planning and scheduling are strictly dependent [7]. In fact we can't validate a global plan without checking its feasibility in the operational level. The control activity consists of monitoring the execution of planned tasks, Procurement and outsourcing plans, it checks the respect of fabrication plans allocated to the different resources. This activity is based on a strong interaction with the operational manufacturing system in terms of communicating new directives and in term of collecting new information concerning the work in progress and the current resources situation.

2. ANALYSIS and DESIGN of our MULTI AGENT SYSTEM

Our system knowledge and reacting mechanism was taken from the human experiences in processing difficult situations it encounters while operating. In fact, when we think of humans as intelligent beings we often refer to their ability to take in data from their environment, understand the meaning and significance of the information, and then act appropriately [10]. This is exactly what cognitive agents and MASs are expected to do. For the construction of our MAS we used a methodology proposed in [11] adapted especially for the development of multi-agent systems using the JADE (Java Agent Development Framework) platform which complies with FIPA specifications (Foundation for Intelligent Physical Agents) [12].The analysis of the system goal and use cases has led us to propose a set of agents types associated with the subsequent main tasks of the system: a) sensing new orders, b) Kept in touch with the customers to sense the changes in orders, c) negotiate orders deadlines while doing dynamic planning, d) dynamic planning and scheduling, e) selecting the best suppliers and outsourcing, f) keeping outsourcing and suppliers' lead times under strict control, g) Maintaining a real time virtual view of the state of shop floors and of the work in progress h) Searching for local solution for recovering lost production time.

Table 1 exposes the types of agents included in the system and the responsibilities of each one.

Table 1: The responsibilities of the system's agents

Agent Type	Roles
Notifier Agent	- Check the legacy system database For new order, - Notify Commercial-agent if new order founded
Commercial agent	- Check for inventory - Validate new plans (By collaborating with the human commercial manager) - Request the planner-agent for new planning operation
Planner-Agent	- Request for possible delivery time of materials and outsourced product Request for possible augmentation in shop floor capacities - Execute new planning simulations by taking into account the new shop floor situation and the new requested information - Publishing new plans
Shopfloor Agents	- Collect information about the progression of work and resources situation - Update Information about the production capacity of the ShopFloor - Communicate new directives to workers. Ask the shop floor responsible for possible additional capacity
Controller Agent	- Request for new situation in work progression and delivery time - collaborate with supply-service-agent, shopfloor-agents and outsourcing-agent to

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	resolve appeared problems in the scheduling level only Notify the planner agent about new critical situations
Supply service Agent	- Searching new suppliers - Create new outsourcing-agent according to new outsourcing offer - Applying new orders - Creating and killing supplier agents - Select suppliers
Supplier Agents	- follow the concerned material orders by interacting with the supplier IS, - Notify the controller agent if it predicts a delay in delivery times. - Request the supplier IS for deadlines
Outsourc ing agents	Request for deadlines of outsourced semi-finished product - Making new outsourcing orders - follow concerned outsourcing orders by interacting with the IS of the outsourcing company - Notify the controller agent if it predict a delay in delivery times
Business Manager agents	- Notify the customer in relation with progress and deadlines of its order - Request the controller agent about the progression of work and material delivery concerning their followed order
Data- Integrato r agent	- performing database schema integration - Make data transfer from the Legacy Database to the MAS Database (plans , bill of material, manufacturing range, order details, manufacturing resources, capacities) - Updating the Legacy Database with new data concerning, changes in plans, new supplement work new state of the work in progress ...

3. POSSIBLE INTERACTION MODES

Figure 1 shows the different modes of interaction that the agents of the system may play.

a) Agent to agent interactions : Figure 1(a) illustrate agent to agent interaction made up of FIPA conversations, composed of a series of FIPA-ACL messages (Agent communication language) associated with the same ontology that guarantees the consistency (an expression has the same meaning for all the agents) and the compatibility of exchanged message content [13]. This kind of interaction is based on the well-known model of actors, where agents interact with each-other by messages. This model is suitable for our system, as the implicated agents have different profile and role and handle different tasks. Besides, as the interaction is limited to pairs of agents, communication cost is reasonable. We note that the communication ontology proposed in Figure 2 contains only data that make message content meaningful, but when doing its action, responding to a message, the agent can refer to the system database (MAS DB) that contains all the required data, for example: when commercial-agent sends the message : request (schedule_order(Order : id Str17-01)) to planner-agent which is a request for performing the action schedule_order for the new customer order identified by the code Str17-01, the planner agent will do the action of scheduling using data saved in MAS DB about the detail of order Str17-01, current schedules, the capacities and situations of machines and other data, after that it saves the result (new schedules) in the database and replies to commercial agent with an inform message that indicates the successof the operation and that the new schedules are waiting for validation. The MAS DB is also used as intermediate structure for sharing data between system's agents.

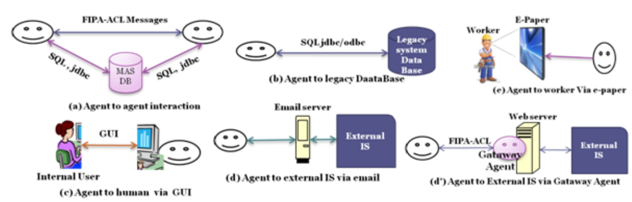

Figure 1: Possible Interaction modes

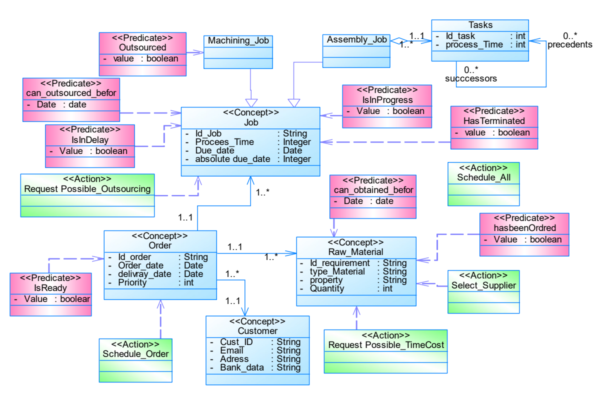

Figure2. The Message Content Ontology

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b) Agent to Legacy system Data Base: see the responsibilities of Data-Integrator Agent in Table1

c) Agent to internal user via graphical user Interfaces Figure1(c)

d) Agent to external Information systems of suppliers, Customers or outsourcing companies: in this case the communication can be held by email messages Figure1(d) or basing on a gateway agent that implement a servlet integrated with a web application Figure1(d').

e) Agent to workers via electronic paper Figure1(e): the concept of ePaper can be defined as a display technology that simulates the appearance of text written on a traditional physical paper [14], we propose to install an ePaper in big format beside each workstation, used to display the right information at the right time concerning the job to execute.

We must note here that the Interaction with external resources implies non controlled response time and successive interactions can start while the current one has not yet been completed. Therefore the agents must implement strategies for managing their interactions and operations, so each agent possesses his own notebook for planning and managing its interactions.

4. SCENARIOS

The functioning of the system can be summarized with the following main scenarios:

i) Processing New Customer Order: this scenario implicate all the system Agents, It is triggered when a new order is passed and validated in the ERP system, a validated order means that the corresponding project were analyzed and designed and all corresponding details (bill of material and manufacturing range) are saved in the ERP database.

ii) Reacting to detected non-compliance with delivery deadlines: supplier and outsourcing agents communicate periodically with their corresponding supplier and outsourcing companies for ensuring the respect of delivery deadline. The feeling of a problem will trigger this scenario.

iii) Reacting to detected failure in realizing execution plan: These scenarios are reached with complex Interactions among system agents and implicate some other sub-scenarios represented with less complex Interactions:

- Request for Information about resources implicated for processing new customer Order, initiated by planner Agent and implicates SupplyService Agent, ShopFloor Agents and outsourcing Agents.

Publishing new plans, initiated by the commercial agent and Implicates Supply-Service Agents for making material orders, Shopfloor Agents for lunching the execution plan, the Outsourcing agents for making orders, the business Manager Agents for informing the customers and the data-Integrator Agent for updating the Legacy Database.

Request for Possible prices and supply time concerning a list of materials and components, initiated by Supply service Agent and implicates the Web Crawler Agent that surfs the web for new offer.

In Figure 3 we present an interaction diagram of the "Processing new customer order" scenario, using the original Unified Modelling language (UML) sequence diagram instead of AUML (Agent Unified Modelling Language) which is an extension of UML for agents and MAS modelling [15]. We present each agent role in a separate life cycle, and using parallel and conditional fragments for modelling concurrent threads and decisions [16,17]. We also used reference fragments (e.g. *"ref: publishing new plans"*) to refer to a sub-process that will be modelled on another diagram, which makes the main diagram more legible [18].

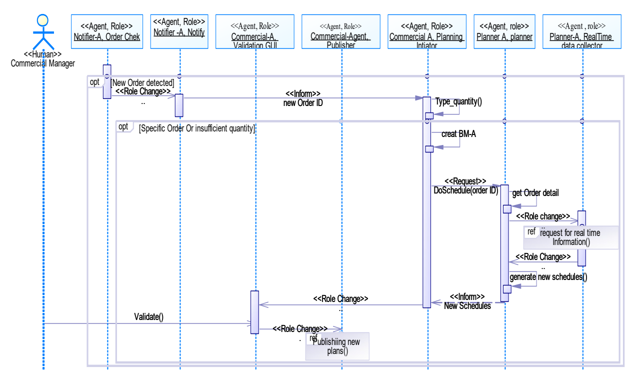

Figure3. Processing New Customer Order

5. CONCLUSION

In this work, we presented a multi-agent system that simulates human behaviours and organization concerning decision making on online manufacturing planning with its reaction to different situations. All the different possible interactions between agents are described. We think that once the system is developed it can be perfectly used because it supports the legacy system in which it is integrated. It can be executed

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along with the traditional processes while ensuring data consistency. In fact, one originality of our proposal is the harmony and integration of existing legacy systems with the new architecture we suggest.

History can help the system to be smarter, it can evaluate some factors like supplier confidence, effect of some situations, bottlenecks, customer preferences and others.

The MAS presented promotes a gradual evolution of the manufacturing systems and can be adapted easily to different models of it, by adding some types of agent or by changing some behaviors and interaction mechanisms. This flexibility added to other characteristics is the reason that makes agents technology a promising tool for Industry 4.0.

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