Coordination policies to support decision making in distributed production planning

G. Lo Nigro[a], S. Noto La Diega[a], G. Perrone[b],*, P. Renna[b]

[a] *DTPM, University of Palermo, Viale delle Scienze, 90128 Palermo, Italy*
[b] *DIFA, University of Basilicata, C.da Macchia Romana, 85100 Potenza, Italy*

Abstract

Distributed production networks are considered organizational structures able to match agility and efficiency necessary to compete in the global market. Performances of such organization structures heavily depend on the ability of the network actors of coordinating their activities. The research proposes to model and design coordination problems within production network by using the Multiple Agent Technology. In particular, the paper proposes new strategies for coordinating production-planning activities within production networks. Such models have been developed and tested by using a proper simulation environment developed by using open source code and architecture.

The results of the research can be located at two levels: (a) concerning the specific coordination problem addressed, the research provides some insights to make decisions about the choice of coordination approaches to be used in distributed production planning problems; (b) at more strategic level, the paper shows how Agent Technology and discrete event simulation can be used to build up efficient coordination structures for production networks.

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1. Introduction

Market globalization requires companies to operate in a wide and complex international market by matching agility and efficiency. This can be achieved either by splitting geographically the production capacity or by working together in supply chain organization involving several independent entities.

In both cases, companies need to be able to design, organize and manage distributed production networks where the actions of any entity affect the behavior and the available alternatives of any other entity in the network [1].

Basically, two approaches are available for managing complex distributed production networks: a centralized approach, where a unique entity (the planner for instance) has got all the necessary information to make planning decisions for the entire network; this is the case, for instance, of the approach suggested by several ERP vendors with their advanced planning and scheduling (APS) tools. On the other hand, a decentralized approach can be used; in this case, each entity in the network has the necessary information and knowledge to make autonomous planning decisions, while, the common goal is reached through a cooperation among all the network actors.

It has been quite acknowledged that, while centralized approaches are theoretically better in pursuing global system performance, they have several drawbacks concerning operational costs, reliability, reactiveness, maintenance costs and so forth [2].

This is the reason why several authors propose to use decentralized approaches for distributed production planning. However, when it comes to manage complex distributed systems, questions may arise about what kind of technology and approaches should be used to assure the necessary effectiveness and efficiency of distributed systems. As far as the technology is concerned, multi-agent system (MAS) technology seems to have demonstrated its suitability. MAS, indeed, as branch of distributed artificial intelligence (DAI), is a

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*Corresponding author. Tel.: +39-971-205143; fax: +39-971-205160.

E-mail address: perrone@unibas.it (G. Perrone).

technology based on autonomous and intelligent agents cooperation; the term agent represent an hardware or (more usually) software based computer system that has the properties of autonomy, reactivity, pro-activeness, and proper knowledge belief. Then, MAS is the logical framework for developing distributed applications, and this is particularly true in Distributed Production Planning problems.

The suitability of MAS in supporting production networks modeling and management is testified by several research contribution; among them, Swaminathan et al. [3] have used multiple agent networks for modeling supply chains dynamics; Parunak and Vanderbok [4] have proposed an agent architecture consisting of three kinds of intelligent and autonomous agents called company agents, production planning and inventory control agents, and shipping agents for virtual enterprises (VEs) supply chains management; Brugali et al. [5] have proposed the use of mobile agent technology to implement supply chains networks; Gjerdrum et al. [6] have applied multi-agent modeling techniques to simulate and control demand-driven supply chain network system; Zhou et al. [7] have presented the result of the ESPRIT Project 20544, entitled X-CITTIC, where they have developed an object-oriented technology to support production planning and control in VEs.

Of course, MAS is just an enabling technology that can be successfully used to build distributed systems up, but such technology has to be associated with a proper mechanism allowing agents to cooperate each other in order to reach a common goal. As a matter of fact, Kraus [8] stressed the importance of proper coordination mechanisms within the production networks, in order to guarantee goals achievement; in particular, the author stressed how cooperation not merely coordination may actually improve the overall behavior of the system. Wu et al. [9] have also stressed how the coordination problem is even more critical when it concerns production planning activities; in particular, they remarked how one of the main issues in developing network enterprise applications concerns the coordination of production across multiple facilities, and its integration with the customer requirements.

Fortunately, the fast growing of networking technologies allows implementing such distributed systems with relatively low simplicity. In fact, the integration of the Internet, with the World Wide Web allows the development of Business-to-Business (B2B) applications able to provide the customer with true added value services. As an example of this possibility, Cantamessa and Tung [10] have proposed to use B2B approaches to model inter-firm negotiation upon requests for quotation, and the resulting tool wants to be a support instrument in the cumbersome business opportunities that can occur in a B2B environment.

However, B2B investments are extremely risky for the firm, because they require high investments and new knowledge acquisition for manufacturing firms (Nembhard et al. [11]). Because of that, enterprises often require a preventive test about the goodness of such approaches. In industrial engineering simulation is usually acknowledged as the most reliable tool for testing production systems performances. Nevertheless, not so many tools are available to model and simulate multi-agent based systems.

This research investigates the use of agent technology in managing distributed production networks; in particular, the main motivation of the paper is to put into evidence how several coordination strategies can be conceived within the same distributed planning framework and how each one of them can lead to different global performances; therefore, the research suggests to use discrete event simulation as a tool for choosing the most fitting coordination policy. Furthermore, it will be demonstrated how it is possible to reduce time and investment cost of ICT agent based applications, by developing a simulation environment that can be reused, after the design and testing phase, to build the real decentralized application.

In order to achieve this goal, the authors have focused their attention on one of the most complex problems in distributed production networks, that is the production planning problem. Indeed, in very turbulent Make To Order (MTO) markets, the output of the production planning activity determines the variables involved in the response offered to the customer order request. Thus, in these markets, it becomes very strategic to plan the production in a quasi-real-time fashion. In particular, the paper focuses the production-planning problem in a multi-plant environment. In particular, it aims at exploring what kind of coordination policy is more suitable to achieve company's goals in a multi-distributed production environment.

The paper is structured as follows: Section 2 reviews the literature in the multi-facility production planning area; Section 3 points the problem framework out, while Section 4 introduces the proposed coordination policies that is a competitive (Section 4.1) and a cooperative approach (Section 4.2); in Section 5, the simulation environment used to develop and test the network is discussed, while in Section 6 a numerical example has been developed, tested and discussed, and finally conclusions and further researches in this area are drawn in Section 7.

2. Multi-facility production planning: a literature review

A multi-facility production planning problem can be formulated as follows: given an external demand for items over a time horizon and a set of facilities able to