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Comparison of negotiation protocols in dynamic agent-based manufacturing systems

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Abstract

This paper proposes a negotiation methodology based on multi-agent system for heterarchical and complex manufacturing control systems. This approach has been selected to implement new paradigms based on "co-opetition = co-operation + competition" in order to improve the "production on demand" and reaction capabilities of distributed production systems related to the net-economy. Agents may represent products and resources of the system. The local scheduling and control functions in dynamic environments is addressed by a new negotiation protocol between agents based on the "request session" principle for cooperation and on the game theory approach for competition.

Keywords: Production and management control; "Co-opetition"; Multi-agent systems; Negotiation protocol; Game theory

1. Introduction

The application of multi-agent systems based on the concept of distributed artificial intelligence is considered as being one of the most promising control architectures for next-generation of complex production systems, specifically in a dynamic environment (failed resources, disturbances, etc.). In particular, very attractive solutions and efficient issues are expected in the domain of local planning, and execution control, to improve the conventional supply chain management; here, the usual production system management consists, in a set of separate and heterogeneous application software packages, such as Enterprise Resource Planning (ERP), Manufacturing Execution System (MES), Supervisory Control And Data Acquisition (SCADA), etc. These tools are not able to cover satisfactorily the constraints required by the new challenges of the economy such as networked enterprises, production on demand or mass

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customization, with the high reactivity of the E-business. With regard to this situation, new paradigms have to be introduced (e.g. auctions, dynamic products and processes reconfiguration) which can be implemented only through an adapted and consistent technology. In this paper we will indifferently address the term of manufacturing system (MS) or production system (PS), which is an extension of the MS concept. In multi-agent manufacturing systems, agents may represent single resources (a work cell, a machine, a tool), workers involved in a process, etc. as well as products, customers or providers. Altogether, they perform individual tasks, in interaction between them, in order to fulfil production functions (such as procurement, local planning, task assignment, scheduling execution control, or even distribution). Architectures commonly studied in a multi-agent approach mainly comprise hierarchical and heterarchical structures. In a hierarchical architecture, there are multiple levels of master/slave agent type relationships. Here, in a heterarchical architecture, agents communicate on a "peer-to-peer" mode, without any predefined master/slave relationship. This core notion of the heterarchical control architecture is the follow-on of full local autonomy and co-opetition approaches "co-opetition = co-operation + competition" (Brandenburger and Nalebuff, 1996) used to perform global decision-making. Only heterarchical control architecture will be considered here.

This paper is organized as follows: in Section 2, we are reviewing some algorithms involved in distributed manufacturing control system; they are a theoretical basis to design and develop our monitoring and control system. In Section 3, an example of the architecture intended to be used is presented; it is in connection with the so-called PABADIS European IST project (IST-#60016: "Plant Automation BAsed on DIstributed Systems"). Section 4 will be devoted to the description system modeling approaches and associated mechanisms. Section 5 details negotiation protocols between agents, which are proposed to solve the problem of local scheduling and resource allocation. In Section 6, implementation and some experimental results are discussed. Section 7 is a summary of the paper. Finally a glossary of the abbreviations used in the paper is proposed.

2. Main algorithms involved in distributed manufacturing control system

This section briefly reviews some various algorithms, concepts and protocols to be applied in distributed and complex manufacturing control systems. They are intended to enable a better understanding and consistent design of the new agents technology based paradigms; they also enabled to design and to enhance the reasoning and decision-making capabilities to be introduced at agent level.

2.1. Dispatching and sequencing

Dispatching rules are widely used in manufacturing, due to their simplicity, efficiency and their nature related to on-line algorithm (Holthaus, 1997). These rules, usually associated with sequencing, only require local information for the decision-making; thus, they are straightforward to distribute across a heterarchy. For most of these kinds of decisions, the system scales sub-linearly since the addition of an agent does not effect dispatching decisions at other agent's level (Baker, 1998). Dispatching with priority rules is the best-known heuristic for scheduling. Using dispatching rules, local schedules can be produced almost instantaneously. Flexible and distributed manufacturing and assembly systems are the best candidates involved by their implementation. Also, dynamic process and products reconfiguration are allowed.

2.2. Scheduling

Scheduling is an optimization process where limited resources are allocated over time among both parallel and sequential activities (Zweben and Fox, 1994). It is a difficult and complex problem solving, particularly when it takes place in an open, dynamic environment. Scheduling problems in theory, are dynamic in nature, such that new orders are received continuously, while operations