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Application of multi-agent planning to the assignment problem

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Abstract

Nowadays, a globalization of national markets requires developing the flexible and demand-driven production systems with new innovative concepts of management, information processing, production scheduling and planning. The presented work focuses on the low-level planning, where the multi-agent solution towards a ''job-machine'' assignment is considered. The main point of the discussion is the flexibility of planning systems ensured by the concept of agent's ''roles'' and ''emergencies''. Depending on the state of ''emergency'', the system receives stepwisely additional degrees of freedom to adapt the planning to the changing conditions of the manufacturing floor. The distributed constraint satisfaction and optimization approaches, underlying the suggested method, as well as activities of rescue agents, are described in the form of Petri networks providing both the conceptual notions and main details of implementation.

Keywords: Flexible manufacturing system; Process planning; Multi-agent systems; Petri networks; Distributed optimization

1. Introduction

In the modern world, competition among international suppliers and globalization of national markets requires production systems that can successfully operate in this global and quickly changing market (e.g. [1]). From this viewpoint there are several requirements that should be satisfied by these systems. Firstly, the time needed from development of a product to its serial production should be essentially shortened. Secondly, manufacturing systems should become oriented to a multitude of parts and variants of customer requirements. This means a product will be fabricated in small series with different consumer properties, like color, equipment and so forth. Moreover, a product should often be fabricated on the demand of a client with a unique specification [2], achieving the aim of mass customization [3]. All these requirements may only be satisfied by flexible, quickly reconfigurable production systems. Not only the physical fabrication should be flexible (equipped with e.g. reconfigurable machinery), but also all operational, executive and developing processes of modern production systems. For such a factory a completely new structure, new organizational principles and, correspondingly, new software and hardware instruments should be developed [4].

Taking into account a spatial distribution of manufacturing elements and the requirement of flexibility to the whole system, the concept of autonomous

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agents has found some applications in this field [5]. Moreover, the following applications have been taken into account:

- Activity of agents is a result of the group behaviour that bases on different forms of negotiations among agents. Because of this specific form of ''programming'', the problem solving (decision making, planning, etc.) in a multi-agent system (MAS) has essentially more degrees of freedom, than in traditional centralized systems. The negotiation-based MAS planning system becomes more flexible and, in this way, more ''stable'' to different predicted and (sometimes unpredicted) disturbances, e.g. machine failures, technological changes etc.
- There is a trend to equip processing elements (processing machines) with some degree of autonomy and ''intelligence'', allowing them to react to short-term disturbances, perform self-maintenance and integrate to autonomous manufacturing. This trend corresponds to the agent concept, in this way the processing element becomes an agent.
- In some situations (e.g. hazardous and dangerous environments) a human worker needs to be replaced in modern manufacturing. The replacement element should have a behaviour similar to human, i.e. it should be autonomous, make decisions and communicate with human or non-human workers.

Application of the agents to manufacturing requires also a development of new approaches towards typical problems of multi-agent technology, such as distributed problem solving, planning or collective decision making [6]. The following agent-oriented application is addressed to the lowest level of manufacturing architecture, where the low-level jobs (for example ''to produce one workpiece with a defined specification'') should be assigned to available machines. The aim is to generate this assignment via agents that represent different factory departments as well as processing elements.

The remainder of this work is structured in the following way. Section 2 describes the assignment problem from the manufacturing side. This section is concluded by a formulation of constraints needed for the next steps. Section 3 is devoted to the agent-oriented solution of the assignment problem. The main point of this section is focused on the flexibility of MAS and on the methods that allow it to be achieved. Several remarks about agent-based optimization are brought out in Section 4. Finally, two issues concerning disturbances and executing the planning approach are summarized in Section 5.

2. The problem of assigning jobs to machines

The assignment problem is often encountered in manufacturing. It is a part of Operations Research/Management Science (OR/MS), where the flow-shop and job-shop problems with deterministic, stochastic, one-step or many-steps characters are distinguished [7]. Generally, the assignment problem can be classified into scheduling, resource allocation and planning of operation order (e.g. [8]). This is a classical *NP*-hard problem, there are known solutions by combinatorial optimization [9], dynamical optimization [10], evolutionary approaches [11], constraint satisfaction and optimization [12] as well as discrete dynamic programming [13]. However, these methods are developed as central planning approaches, the distributed or multi-agents planning for the assignment problem has in fact not been investigated (overview e.g. in [14]).

Manufacturing of a workpiece consists of different steps and requires a corresponding plan that is known as process planning. The process plan (PP) includes a technological working plan and manufacturing control. The first from them defines how to manufacture the workpiece whereas the second determines available machines and production timing. Because of the separation between these branches, especially because of their sequential execution, today's concepts for process planning are not able to react reasonably to disturbances like machine malfunctions or changes of production order. One way to solve this problem is to develop a rescheduling tool allowing a worker to adapt the generated plan to the actual situation on the shop floor. A very promising concept exists that is based on an integrated information model, which enables rescheduling in the case of disturbances or plan variances [15]. In order to make the process planning more adaptable and to improve the reaction time to disturbances, it is reasonable to incorporate both parts of PP into a so-called sequence plan.

Implementation of the sequence plan needs a new approach to process planning in order to better adapt a