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Application of genetic algorithm to computer-aided process planning in distributed manufacturing environments

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Abstract

In a distributed manufacturing environment, factories possessing various machines and tools at different geographical locations are often combined to achieve the highest production efficiency. When jobs requiring several operations are received, feasible process plans are produced by those factories available. These process plans may vary due to different resource constraints. Therefore, obtaining an optimal or near-optimal process plan becomes important. This paper presents a genetic algorithm (GA), which, according to prescribed criteria such as minimizing processing time, could swiftly search for the optimal process plan for a single manufacturing system as well as distributed manufacturing systems. By applying the GA, the computer-aided process planning (CAPP) system can generate optimal or near-optimal process plans based on the criterion chosen. Case studies are included to demonstrate the feasibility and robustness of the approach. The main contribution of this work lies with the application of GA to CAPP in both a single and distributed manufacturing system. It is shown from the case study that the approach is comparative or better than the conventional single-factory CAPP.

Keywords: Computer-aided process planning; Distributed manufacturing system; Multiple factories; Genetic algorithm

1. Introduction

Increasing product varieties, product customization and a shorter lead-time are the key challenges for a manufacturing company. The existing manufacturing systems cannot adequately conform to these requirements because of their inflexibility and deterministic approaches to decision-making in a stochastic environment, and insufficient communication and exploitation of expertise. In order to meet new challenges, a shift of the manufacturing paradigm from deterministic to a new manufacturing perspective is needed [1]. Several influencing approaches are emerging, such as the fractal factory [2], bionic manufacturing systems [3], holonic manufacturing systems [4], distributed manufacturing systems [5], etc. Much investigation and study [6,7] has proven that distributed manufacturing enables the enterprises to achieve better product quality, lower production cost and reduced management risk. This paper proposes and develops a genetic algorithm (GA) for solving the computer-aided process planning (CAPP) problem based on the concept of distributed manufacturing.

A practical industrial environment exhibits a high degree of complexity where multiple alternative process plans exist, and obtaining an optimal or near-optimal process plan has long been a difficult task in the manufacturing research community. Traditional CAPP systems aim to obtain optimal machining processes, machines and tools capable of performing specified operations from a single job shop having limited available manufacturing resources. However, in a distributed manufacturing environment, there are other available factories capable of performing a task, and it is possible that one of them may provide a more efficient and better process plan. Therefore, developing a CAPP system, which can produce optimal process plans in a

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distributed manufacturing environment, is the main objective of the present study.

Manufacturing systems are complex in nature and difficult to optimize using conventional techniques. Evolutionary algorithms, which mimic living organisms in achieving optimal survival solutions, can often outperform conventional optimization methods. In the past two decades, GA has been widely applied to solve optimization problems. The first application of GA goes back to the 1960s, but only by the end of the 1980s, due largely to Goldberg's [8] studies, its application became prominent in the engineering community. Since then, GA has become an optimization technique for solving complex manufacturing problems, such as job shop scheduling and process planning. Because process planning is a NP-hard problem [9], some global search techniques must be applied. In this research, GA is chosen for solving this optimization problem. Automated processing planning based on GA and/or simulated annealing have been reported in [10–12]. However, most of the reported work and case studies dealt with the process planning of a single factory that manufactures the components under the same environment.

2. Genetic algorithm

2.1. Distributed manufacturing systems

As depicted in Fig. 1, in a distributed manufacturing environment, factories possessing various machines and tools are at different geographical locations, and different manufacturing capabilities are often selected to achieve the highest production efficiency. When jobs requiring several operations are received, feasible process plans are produced by available factories according to the precedence relationships of those operations. Manufacturing operations can be performed by different machines and tools located at different locations. The final optimal or near-optimal process plan will emerge after comparison of all the feasible process plans.

2.2. Representation of process plans

When dealing with a distributed manufacturing system, a chromosome not only represents the sequence of the operations but also indicates which factory this process plan comes from. Therefore, the identity number of the factory will be placed as the first gene of each chromosome no matter how the other genes are randomly arranged. Every other gene comprises operation ID and corresponding machine, tool and tool access direction (TAD), which will be used to accomplish this operation. As a result, a process plan will be represented by a random combination of genes. Fig. 2 shows the representation of a six-operation process plan. '001' is the factory ID, 'Op4' represents operation 4; M-02, T-04 and $+x$ in the second row represent the machine, tool and TAD, respectively, that will be used to perform operation 4, so are the other columns.

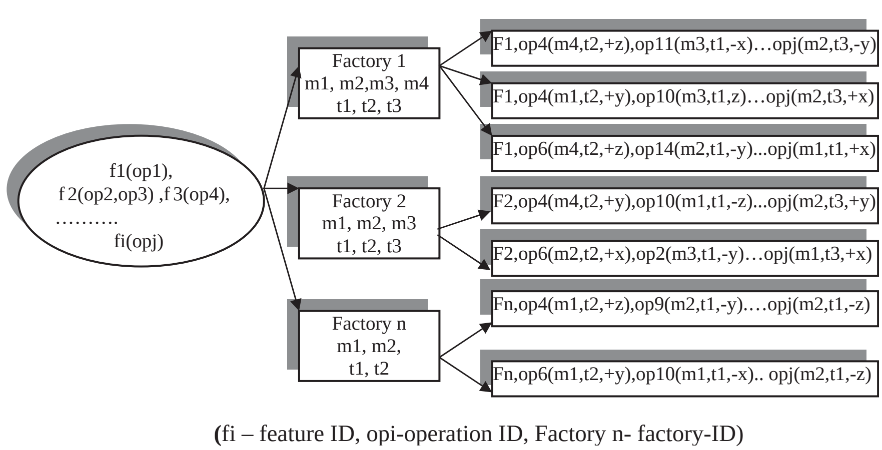

Fig. 1. Description of a distributed manufacturing system.

	Op4	Op1	Op5	Op6	Op3	Op2
001	m-02 t-04 +x	m-03 t-02 -y	m-02 t-03 +z	m-01 t-02 -x	m-03 t-01 +x	m-01 t-04 -y

Fig. 2. Representation of a process plan.