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Manufacturing resource combinatorial optimization for large complex equipment in group manufacturing: A cluster-based genetic algorithm

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ABSTRACT

To address manufacturing resource combinatorial optimization (MRCO) for large complex equipment in group manufacturing and provide high-quality manufacturing resource, a multi-objective optimization model and heuristic approach are investigated in this study. First, considering the extensive manufacturing resource, a four-tuple model with use-cost, trading period, credibility and resource consumption for manufacturing resource clustering is proposed, as well as MRCO model associated with the four indicators. Then, an improved cluster-based genetic algorithm (CGA) has been carried out with a fuzzy c-means algorithm (FCM) for manufacturing resource clustering. The proposed algorithm uses a fuzzy analytic hierarchy process (FAHP) to successfully determine the priority weights of multi-objective. Finally, a case study and comparison of performances with simple genetic algorithm (SGA) and non-cluster-based genetic algorithm (Non-CGA) are presented. Experimental results show the proposed method is more preferable in optimal solution searching and more efficient as the dimension of problem increases.

1. Introduction

Manufacturing enterprises are imbalanced between manufacturing resource (MR) and capacity in the increasingly intense market competition, which leads to the shortage or idle of MR [1]. Therefore, some manufacturing enterprises set up a new group manufacturing company through combination and restructuring. Generally, with the development requires, the branches of group manufacturing are established in different regions and operated independently. However, the intensified market competition has made these companies merge together to found a group manufacturing company especially since the economic crisis [2]. Although these companies are around in different regions, they belong to the same group manufacturing company. Hence, as an advanced organization of networked manufacturing, compared with Virtual Enterprise or other organizations in networked manufacturing, group manufacturing organize the members together not for fulfilling a customer order but for improving the overall effectiveness and competitiveness of group manufacturing. Group members operate independently with clear property rights and higher sharing ability of MR. As shown in Fig. 1, they not only take orders independently, but also share orders, devices, material resources, and suppliers, etc., in the uniform network platform.

MR management is the core of project management in manufacturing enterprise, while manufacturing resource combinatorial optimization (MRCO) is among the top challenges in MR management [3,4]. In recent years many efforts have been made aiming to resolve the problem of selecting a group of MR to provide service for order with considering multi-objectives, such as the lowest cost, the shortest manufacturing cycle and the maximum delivery rate [5,6]. MRCO results in a series of benefits, including cost reduce, process control and order delivery guarantee. The methodology of MRCO has being applied increasingly in today's manufacturing environment. Actually, the manufacturing process of order task is mainly the service of MR [7]. MRCO is essential for manufacturing enterprises to execute effectively with lower cost and better service. Linear programming [8–10] and heuristic algorithms [11–13] are usually used to solve the MRCO problem.

Large complex equipment (LCE) manufacturing is a supporting industry in equipment manufacturing [14]. LCE is a kind of technological systems with long processing cycle, high complexity and great value of MR, which are produced as customized, one-off or small batched capital goods items, such as aircraft engines, offshore oil equipment and cement equipment, distinct from mass-produced commodity products such as cars, semiconductors, and consumer electronics [15]. The customer individual requirements,

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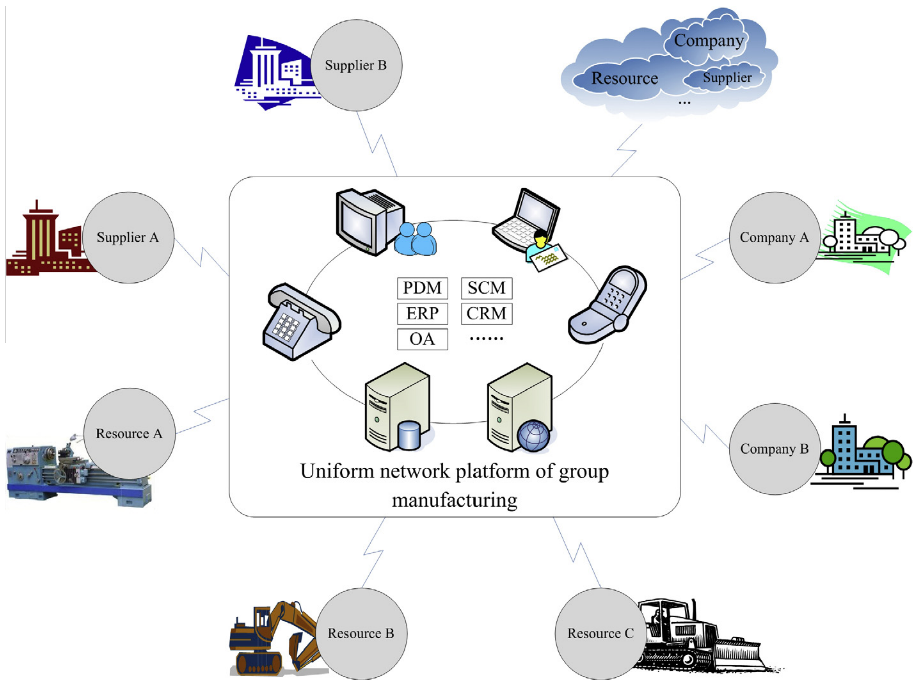

Fig. 1. The operation of group manufacturing.

complicated structures and parts, single or small batch production are main characteristics of LCE manufacturing which leads to a more complex resource management in resource selection, cost and delivery control [16]. Supposing a LCE has m sub-tasks to manufacture, and the MRs for each sub-task can choose n MRs in group members, then the choices will be reached to m^n with a geometric increase. However, when the scale of sub-tasks and MRs get bigger, it is inefficient to choose a more appropriate one by comparing each MR with unit price or quality. The MRCO for LCE in group manufacturing (MRCO-LG) is a NP-hard problem which is different from classic MRCO in two major aspects. First, the highly complexity of equipment results in various requirements of MR, while there is a large number of similar MR to be chosen for each kind of required MR in group manufacturing. Second, LCE has been divided into different components and organized the complex manufacturing network which collaborative manufactured by group members. In order to allocate better MR for LCE, MR management has more demands with multi-components, multi-participants and multi-resources in the extensive MR environment for group manufacturing.

This research aims to improve the efficiency of MRCO-LG and propose a suitable solving method. In this so-called MRCO-LG, customer orders are decomposed into different sub-tasks, and MRs for each sub-task is different. The group members are collaborative to complete manufacturing process of LCE with more suitable MR. Hence, it is necessary to classify MR by different factors and this paper proposed with fuzzy c-means algorithm (FCM). In this paper, a heuristic approach using a clustering algorithm and an improved genetic algorithm with cluster-based is proposed to resolve such problem. Experimental results have shown that the proposed approach is able to support for MRCO problem.

The rest of this paper is organized as follows. In Section 2, the literature review is outlined. The multi-objective MRCO model has been proposed in Section 3 and a cluster-based genetic algorithm solution is presented in Section 4. The numerical results have been carried out with comparison experiment and analysis in Section 5. Finally, the paper ends up with some conclusions and future works in Section 6.

2. Literature review

There are lots of researches have been made towards MRCO. After reviewed the literature, we classified into three separate but relevant research streams: MRCO with resource-constrained (MRCO-RC), MRCO in networked manufacturing (MRCO-NM) and MRCO for LCE (MRCO-LC). The characteristics among MRCO-RC, MRCO-NM, and MRCO-LC are summarized in Table 1.

2.1. MRCO-RC

Resource-constrained model is a classic research area where considerable researches have been conducted. Chen et al. [17] used delay local search rule and bidirectional scheduling rule for an improved particle swam optimization approach to solve resource-constrained scheduling problem. Correia and Saldanha-da-Gama [18] used a mathematical programming modelling framework to solve the cost-oriented multi-skill project scheduling problem. Bianco and Caramia proposed a Lagrangian relaxation based lower bound in [19] and an exact algorithm in [20] to minimize the completion time of a project under resource constraints and feeding precedence relations. Hegazy and Kassab [21] proposed a new approach by combining a flow-chart based on simulation tool and a powerful genetic procedure for resource optimization. Chaharsooghi and Meimand [22] investigated a modified ant colony optimization algorithm to solve the multi-

Table 1
Literature review of MRCO.

	MRCO-RC	MRCO-NM	MRCO-LC
Optimal object	Decomposed task	Decomposed task	Equipment
Task Complexity	Lower	Medium	Higher
Optimal participants	Inner-enterprise/multi-enterprises	Supply chain	Supply chain
Resource scale	Limited	Mass	Mass
Allocation difficulty	Easy	Difficult	Difficult

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