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Team formation based on group technology: A hybrid grouping genetic algorithm approach ☆

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ABSTRACT

This paper presents a new model for team formation based on group technology (TFPGT). Specifically, the model is applied as a generalization of the well-known Machine-Part Cell Formation problem, which has become a classical problem in manufacturing in the last few years. In this case, the model presented is especially well-suited for problems of team formation arising in R&D-oriented or teaching institutions. A parallel hybrid grouping genetic algorithm (HGGA) is also proposed in the paper to solve the TFPGT. The performance of the algorithm is shown in several synthetic TFPGT instances, and in a real problem: the formation of teaching groups at the Department of Signal Theory and Communications of the Universidad de Alcalá in Spain.

1. Introduction

Correct management of their human resources is one of the key factors in the success of many companies and organizations [1–22]. There are many different problems related to human resources that have been previously tackled in the literature: formation of project management teams [10,11], formation of multi-functional work-force teams [15,14], task force teams organized by companies in order to carry out certain tasks [2], or student-teams for improving the learning process [23,24]. The objective in the majority of these problems, in terms of the expected performance of the team, is to select a (some) leader(s) (project manager, task force chief, etc.) and team(s) members from the available staff [10]. Specifically, at teaching or R&D-oriented institutions, such as universities or research institutes, the staff is usually organized in teams at the outset (departments, research groups, teaching groups, etc.), which have an enormous influence on the performance of the entire organization [10]. Unlike the problems mentioned above, in the majority of cases, the organizational teams in this kind of institution do not require a leader: the final objective of grouping the staff is to specialize groups on a given subject *resource*, allowing all of the members of a given group to have a similar knowledge (skill) of the resource.

Recently, several researchers have dealt with the problem of team formation without leaders in different scenarios, such as multi-functional skill requirements of the teams. In these situations, the makeup of the teams must take into account the personal or technical skills of the staff. In situations with very different staff skill categories, the problem may be difficult, and there is not a unified definition of the model to be used. In [14], a novel approach to this multi-functional version of team formation is presented, and fuzzy planning to match customer's requirements and engineers' characteristics (skills or knowledge) is proposed. Different works have also used this fuzzy model, such as [15,13]. In [12], the authors use fuzzy modeling to take into account the different skills of the staff in different tasks and propose a fuzzy decision-support system based on evolutionary programming. In fact, the authors proposed an island model to improve the performance of their approach in the team formation problem.

The purpose of the present paper is to introduce an alternative model to deal to the multi-functional team formation problem, based on *group technology* problems which arise in manufacturing. Group technology has been defined as "an approach to the organization of work in which organizational units are relatively independent groups, each responsible for the production of a given family of products" [25]. One of the key problems of group technology is the Machine-Part Cell Formation (MPCF) problem [19,17,21,22] in which *parts* and *machines* in a given manufacturing process are assigned to different *cells*, maximizing the machine

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utilization within a cell and minimizing the between-cell movement of parts. This allows manufacturers to group together products with similar processing needs and characteristics, identifying the set of machines needed to process these product families. In this paper, we extend the MPCF to model the multi-functional team formation problem in teaching or similar institutions (Team Formation Problem based on Group Technology (TFPGT), hereafter). We state the TFPGT and propose a hybrid grouping genetic algorithm (HGGA) to solve it. The grouping genetic algorithm was introduced by Falkenauer in [26]. Since then, this approach has been successfully applied to numerous problems [26–31] in very different fields, including the MPCF [18,17]. In this case, the hybrid-grouping genetic algorithm employed is modified to consider the peculiarities of the TFPGT. First, we introduce a novel encoding of the problem into the grouping genetic algorithm. Using this new encoding, each individual is composed of three parts: the first one is called the *assignment* part; the second one is called the *resource* part; and the third one the *groups* part. The objective function of the TFPGT has been adapted from the MPCF model to consider the peculiarities of the TFPGT. Also, a local search is introduced in the grouping genetic algorithm to improve its performance. A final implementation of the algorithm, including an island model (similar to the one used in [12]), is also included in the paper. In the experimental part of the paper we show the good performance of this approach on the TFPGT, specifically in several synthetic instances and in a real problem in a Spanish University.

The structure of the rest of the paper is as follows: Section 2 introduces the TFPGT problem. Section 3 describes and analyzes the proposed hybrid-grouping genetic algorithm, including a local search procedure to improve the algorithm's performance. A first study of the proposed algorithm using simulations in several randomly generated TFPGT instances is conducted in the experimental section (Section 4). Also in this section, a real application in the organization of the teaching at the Department of Signal Theory and Communications, Universidad de Alcalá, Madrid, Spain, is carried out as a final test for the model and algorithm proposed in this paper. Section 5 closes the paper, giving some final conclusions on the work presented.

P(i)/M(j)	1	2	3	4	5	6	7	8	9	10
1	0	0	1	1	0	1	0	0	0	0
2	1	0	0	0	0	0	1	0	0	1
3	0	1	0	0	1	0	0	1	0	0
4	0	0	0	1	0	1	0	0	1	0
5	0	1	0	0	1	0	0	1	0	0
6	0	0	1	0	0	1	0	0	1	0
7	0	0	0	0	0	0	1	0	0	1
8	0	1	0	0	1	0	0	1	0	0
9	0	0	1	1	0	1	0	0	1	0
10	1	0	0	0	0	0	1	0	0	1
11	1	0	0	0	0	0	1	0	0	1
12	1	0	0	0	0	0	1	0	0	1
13	0	1	0	0	1	0	0	1	0	0
14	0	0	1	1	0	1	0	0	1	0
15	0	1	0	0	1	0	0	1	0	0

Fig. 1. Example of initial matrix for the MPCF problem.

P(i)/M(j)	1	7	10	2	5	8	3	4	6	9
2	1	1	1	0	0	0	0	0	0	0
7	0	1	1	0	0	0	0	0	0	0
10	1	1	1	0	0	0	0	0	0	0
11	1	1	1	0	0	0	0	0	0	0
12	1	1	1	0	0	0	0	0	0	0
3	0	0	0	1	1	1	0	0	0	0
5	0	0	0	1	1	1	0	0	0	0
8	0	0	0	1	1	1	0	0	0	0
13	0	0	0	1	1	1	0	0	0	0
15	0	0	0	1	1	1	0	0	0	0
1	0	0	0	0	0	0	1	1	1	0
4	0	0	0	0	0	0	0	1	1	1
6	0	0	0	0	0	0	1	0	1	1
9	0	0	0	0	0	0	1	1	1	1
14	0	0	0	0	0	0	1	1	1	1

Fig. 2. Example of the diagonalized matrix for the MPCF problem.

2. Team formation based on group technology: definition of the problem

2.1. Background: the MPCF problem

The MPCF is a classical problem in Group Technology. It is formulated as a block diagonalization problem of a 0–1 machine-part (MP) matrix [17]. Specifically, given A (binary machine-part incidence matrix), an element $a_{ij}=1$ stands for a machine j is needed by part i, whereas $a_{ij}=0$ otherwise. The objective of the problem is to obtain a different matrix A', with columns and rows rearranged in an order corresponding to the groups identified by the MPCF solution. To clarify the problem Fig. 1 shows an example of MP incidence matrix A, with 10 machines and 15 parts. Fig. 2 shows the resulting block diagonal matrix A', containing three cells, the first cell contains machines {1, 7, 10} and parts {2, 7, 10, 11, 12}, the second cell contains machines {2, 5, 8} and parts {3, 5, 8, 13, 15} and finally, the third cell contains machines {3, 4, 6, 9} and parts {1, 4, 6, 9, 14}.

The block structure of the MPCF solution must be evaluated in terms of a quality measure. Several measures to this end have been defined in the literature [3,4,6,7]. The original measure is due to Chandrasekharan and Rajagopolan [3]. It was called *grouping efficiency*, and is defined as follows:

$$\eta = q\eta_1 + (1-q)\eta_2 \tag{1}$$

where q is a weighting factor, η_1 is the ratio of the number of 1s in the diagonal blocks to the total number of 0s in these diagonal blocks, and η_2 is the ratio of the number of 0s in the off-diagonal blocks to the total number of 0s and 1s in the off-diagonal blocks. An improved measure called *grouping efficacy* was proposed soon later by Kumar and Chandrasekharan in [4], defined as

$$\tau = \frac{e-e_0}{e+e_v} \tag{2}$$

where e is the total number of 1s in a given MP matrix A, e_v is the number of voids (0s within diagonal blocks) and e_0 is the number of exceptions (1s off-diagonal blocks). Other measures have been proposed for the MPCF, such as the *grouping index* [5], the *group capability index* [6] or the doubly weighted grouping efficiency [7].

2.2. Definition of the TFPGT

The definition of the TFPGT tackled in this paper can be stated based on the MPCF. The TFPGT is also a problem of matrix rearrangement, but in this case the matrix represents the knowledge that a given staff member has on the different *resources* available in the institution.[1] This means that the TFPGT starts from a *knowledge* (skill) matrix K, in which each component k_{ij} stands for the knowledge that the i-th staff member, $i=1,\ldots,E$ (E staff members) has on the j-th resource, $j=1,\ldots,R$ (R resources). Note that, in this case, matrix K is not a binary matrix, but a matrix of integer numbers, each encoding a level of knowledge (or skill) about a given resource. The objective of the TFPGT is to obtain the

[1] Here the word *resource* is used with a general meaning: it can refer for example to a given subject in a University degree, or to the management of a certain type of machinery in a manufacturing company, etc.