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Optimization of teacher volunteer transferring problems using greedy genetic algorithms

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ABSTRACT

In this paper, an evolutionary approach based on a greedy genetic algorithm (GA) is studied to serve as an efficient solver for real world teacher volunteer transferring problems (TVTPs). In the proposed approach, the transferring problems are first mathematically formulated into constrained combinational optimization problems and then, an improved neighborhood-search based on greedy search rules is embedded into the mutation operator of the proposed GA method to explore optimal solutions. For verifying the correctness and efficiency of the proposed methods, several real-world transferring cases are studied, and the results show the benefits while adopting the proposed approach in the practical application which can greatly increase the successful transferring numbers comparing to the official TVTP results.

1. Introduction

Due to personal factors, such as career planning, educational promotion and inconveniences of living environments in transportation, many teachers have the needs to change their current employments (Castetter & Phillip Young, 2000). In particular, the kernel flow of the transferring activities involves a specific rostering operation which belongs to a NP-hard personnel scheduling family with many variants such as nurse scheduling (Inoue, Furuhashi, Maeda, & Takaba, 2003; Tsai & Li, 2009), airline crew scheduling (Chen, Liu, & Chou, 2013; Yan & Tu, 2002) and short-term work scheduling (Peters, de Matta, & Boe, 2007). In the literature, there are several tutorial surveys concerning the related researches and applications (see, Burke, De Causmaecker, Vanden Berghe, & Van Landeghem, 2004; Ernst, Jiang, Krishnamoorthy, & Sier, 2007; Gopalakrishnan & Johnson, 2005).

However, as pointed out in the work of Ernst et al. (2007), although there were a large number of software packages available to assist with personnel planning, they most only provided larger optimization capabilities at a specific application area and could not be easily transferred to another practices (Gordon & Erkut, 2004). Hence, many rostering practices were developed according to specific requirements from either human culture or management consideration. The same condition happened in the development of official teacher volunteer transferring programs (TVTPs) in Taiwan (Guo, 2002) which should obey a series of specific laws and rules, and a project-oriented organism (see http://nces.ed.gov/timss/) was thus built up to develop a specific transferring program.

1.1. Transferring operations in Taiwan TVTPs

Since 1996, Taiwan government has developed a centralized teacher volunteer transferring program (TVTP) to give consideration to both the willing of teachers and the government policy, and some historical background for the program can refer our previous work (Chen, Liu, Chou, & Wang, 2010). For the teachers serving in Taiwan public kindergarten and elementary schools, they can have the aid of TVTPs to be transferred to the expected employments according to their willing without additional interviews, but both the teachers and their schools also have to fully accept the results issued from TVTPs.

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Due to the impossibility of exhaust search in large-size NP-hard problems (Desaulniers et al., 1997), TVTPs in Taiwan have been designed and administrated with two deterministic operations (http://exc.ks.edu.tw/): *single posting* and *multiple transferring*. Fig. 1 shows the flow to execute the two kinds of operations.

Single posting is a monotonous job, and its prerequisite is directly related to the vacancies coming from the staffing requirements of the schools. If there is no vacancies matching the volunteers of all participating teachers, *single posting* cannot come into effect. This operation gives vacancies to teachers in the order from the highest to the lowest scores. It first filters teachers by their capabilities and transferring voluntariness, and then a procedure is held to transfer teachers with higher scores until all vacancies are filled. For the teachers who are successfully transferred, their schools will release new vacancies in the next round. This operation will be repeatedly held until all vacancies are filled.

On the other hand, *multiple transferring* is also an iterative operation for pairing the teachers who fail in *single posting*. Its goal is to maximize the possible transferring instances by mutually exchanging teachers' employments. Its intrinsic NP-hard complexity requires some heuristics rules to be used to obtain an optimal or near-optimal solution. The current official operation adopts four exchange rules to search the transferring results containing *mutual*, *triangular*, *rectangular* or *pentagonal transferring*. The processes of these transferring rules are explained as follows: if teachers A and B both join the transferring program, teacher A can meet the needs of teacher B's school, and teacher B also can meet the needs of the A's school, this case can make a successful *mutual transferring* between teachers A and B; after validating all the *mutual transferring* cases, the teachers without any transferring chance in the *mutual transferring* process will join next round by sequentially checking the following transferring rules: "*triangular*", "*rectangular transferring*" and "*pentagonal transferring*"; that is, these rules adopt the similar steps to explore successful transferring instances between any three, four or five teachers in each round separately.

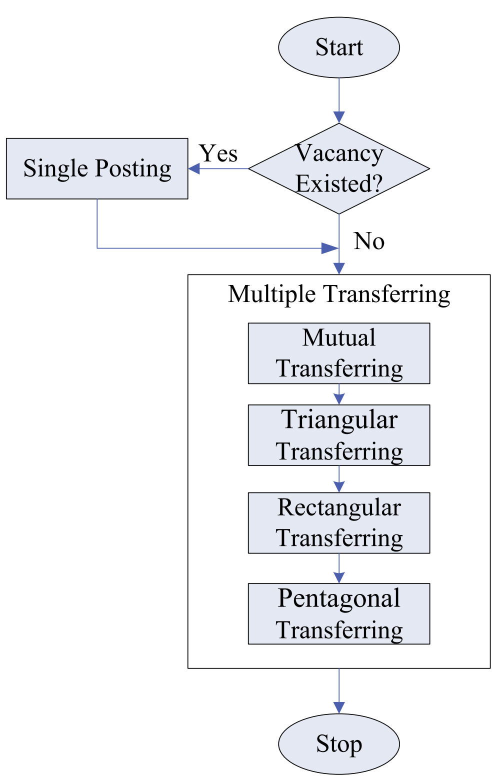

Fig. 1. Flow chat of the official TVTP contains two main operations: single posting and multiple transferring.

1.2. Motivation and contribution

However, the practical results based on the official transferring rules are quite limited. Fig. 2 uses two transferring examples to demonstrate this critical issue. In the examples, the result adopting the current *multiple transferring* operation is much poorer comparing to the one adopting different transferring sequences. It also explains the main reason for the low successful rate in the current official results.

In the literature, several evolutionary approaches have ever been adopted to solve practical NP-hard problems (Bayir, Toroslu, & Cosar, 2007; Hwang, Lin Bertrand, Tseng, & Lin, 2005), and their studies demonstrate that high quality solutions can be successfully obtained by the evolutionary approaches within a limited time period. Therefore, in this paper, we propose an evolutionary approach which first formulates the *multiple transferring* problems as combinational optimization problems containing various constraints, and uses genetic algorithms (Holland, 1975) integrating a local search mechanism as global solvers. In the local searching schema, we adopt a greedy search to improve permutation-based neighborhood search (PNS) mutation (Cheng, Gen, & Tsujimura, 1999). The PNS mutation searches the neighborhood area of a chromosome and requires a large amount of fitness calls to evaluate all the enumerated individuals. The proposed greedy-search-based mutation improves the search behavior. It only searches a single good individual according to the designed greedy rules and performs more efficiently.

For verifying the correctness and efficiency of the proposed approach, various real-world TVTP cases are studied to clarify the advantage of the proposed approach. In our experiments, the proposed approach obtains much better results than those explored by both a simple GA and the PNSGA, and compared to the officially published data, all the transferring cases have a large improvement.

The rest of this article is organized as follows. Section 2 describes the mathematical optimization models containing various practical constraints of TVTP. Section 3 introduces permutation neighborhood search mutation and proposes an improved greedy version to cooperate with other genetic operators. Section 4 uses real-world transferring cases to build up study cases and shows the positive results of applications adopting the proposed methods. Finally, conclusions are drawn in the last section.

2. Problem definition and formulation

The essential goal of TVTPs is to generate the most successful transferring instances under two kinds of practical constraints.

2.1. Practical constraints

The first constraint originates from the matching criteria between schools' staffing requirements and teachers' qualifications, and it is called "*essential constraint*" in this paper.

Essential constraints mainly come from the capability verification requirements for teachers. For example, while identifying whether teacher A can be transferred to teacher B's school, teacher B's school should be present in A's volunteer transferring list (VTL) first, and then two additional factors should be considered also: the first is teacher A should be able to handle the subject taught by teacher B; the other is teacher A should meet the area type limitation of B's school. Table 1 shows the area type qualification table with some related limitations. In general, both factors can be checked