A Teaching-Learning-Based Optimization Algorithm for Solving Set Covering Problems

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Abstract. The Set Covering Problem (SCP) is a representation of a kind of combinatorial optimization problem which has been applied in several problems in the real world. In this work we used a binary version of Teaching-Learning-Based Optimization (TLBO) algorithm to solve SCP, works with two phases known: teacher and learner; emulating the behavior into a classroom. The proposed algorithm has been tested on 65 benchmark instances. The results show that it has the ability to produce solutions competitively.

Keywords: Set Covering Problem · Teaching-Learning-Based Optimization algorithm · Combinatorial optimization · Metaheuristics

1 Introduction

The Set Covering Problem (SCP) is a popular $\mathcal{NP}$-*hard* problem [15] that has been used to a wide range of airlines and buses crew scheduling [27], location of emergency facilities [29], railway crew management [8], steel production [30], vehicle scheduling [14] and ship scheduling [13] between others.

The formulation of SCP is as follows: Let $A = (a_{ij})$, a zero-one $m \times n$ matrix, and nonnegative n-dimensional integer vector C, and $I = \{1, \ldots, n\}$ and $J = \{1, \ldots, m\}$ be the row and column set respectively. Given $c_j > 0$ for $(c_j \in C,\ j \in J)$ the cost of selecting the column j of matrix A. If $a_{ij} \in A$ is equal to 1, we say that row i is covered by column j, otherwise it is not. In SCP, the objective is to find a minimum cost subset of columns of A such that

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each row is covered by at least one column in the subset S. We can formulated mathematically as:

$$\text{minimize} \quad Z = \sum_{j=1}^{n} c_j x_j \tag{1}$$

Subject to:

$$\sum_{j=1}^{n} a_{ij} x_j \geq 1 \quad \forall i \in I \tag{2}$$

$$x_j \in \{0, 1\} \quad \forall j \in J \tag{3}$$

The SCP was also successfully solved with meta-heuristics such as taboo search [9], simulated annealing [7,28], genetic algorithm [16–18], ant colony optimization [1,18], swarm optimization particles [11], artificial bee colony [10,31] and firefly algorithms [12].

2 Binary Teaching-Learning-Based Optimization Algorithm

Teaching learning based optimization (TLBO) was originally proposed by Rao et al. (2011). The main idea of TLBO is that the teacher is considered as the most knowledgeable person in a class who shares his/her knowledge with the students to improve the output (i.e., grades or marks) of the class. The quality of the learners is evaluated by the mean value of the student's grade in class. In addition learners also can learn from interaction between themselves, which also helps in their results [2].

TLBO is population based method. In this optimization algorithm a group of learners is considered as population and different design variables are considered as different subjects offered to the learners and the results obtained by learners are analogous to the solutions fitness values of the optimization problem. In the entire population the best solution is considered as the teacher.

TLBO is used to solve problems like: global optimization problems [26], unconstrained optimization problems [21].

The working of TLBO is divided into two parts: Teacher phase and Learner phase.

2.1 Teacher Phase

The teacher phase produces a random and ordered state of points called learners within the search space. Then a point is considered as the teacher, who is highly learned person and shares his or her knowledge with the learners, and others learn significant group information from the teacher. It is the first part of the algorithm where the mean of a class increases from M_A to M_B depending upon a good teacher. At this point, assumed a good teacher is one who brings his/her learners up to his/her level in terms of knowledge [20]. However, in practice this