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Soccer league competition algorithm for solving knapsack problems

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ABSTRACT

Soccer league competition (SLC) algorithm, is a new meta-heuristic optimization technique and has been successfully used to tackle the optimization problems in discrete or continuous space. Fundamental ideas of SLC are inspired by a professional soccer leagues and based on the competitions among teams and players. Population individuals or players are in two types: fixed players and substitutes that all together form some teams. The competition among teams to take the possession of the top ranked positions in the league table and the internal competitions between players in each team for personal improvements are used for simulation purpose and convergence of the population individuals to the global optimum. In this study, an enhanced SLC algorithm is proposed to solve knapsack problems effectively. This new version is free and independent from adjusting the parameters. The experimental results on the some benchmark knapsack problems demonstrate that the proposed SLC is efficient and effective, which outperforms the other algorithms, in terms of the search accuracy, reliability and convergence speed.

1. Introduction

The knapsack problem which, is one of the classical NP-hard problems, has been thoroughly studied in the last few years. It offers many practical applications in many areas, such as project selection and investment decision-making [1]. In recent years, many evolutionary algorithms have been employed to solve knapsack problems: Shi improved the ant colony optimization (ACO) algorithm [2], Liu and Liu presented a schema-guiding meta-heuristic algorithm (SGEA) [3], Lin applied genetic algorithm [4] and Li presented a binary particle swarm optimization based on multi-mutation strategy (MMBPSO) for solving the knapsack problems [5]. Although many of these techniques could solve knapsack problems successfully, the research on them is still significant, because some new and more difficult and large knapsack problems hidden in the real world have not been analyzed. For instance, some methods proposed recently only solve knapsack problems with very low dimension, but they may be unavailable or unable to solve knapsack problems with high dimension sizes [6]. Zou et al. proposed a novel global harmony search algorithm (NGHS) to solve high dimension knapsack problems [6]. Soccer league competition (SLC) algorithm is a new meta-heuristic algorithm, which has been recently used to find optimal design of water distribution systems [7]. The basic idea of SLC is inspired by professional soccer league and search process is based on the competitions among teams and players [8]. Population is divided into two levels: 1-teams; 2-players, which each of them helps to find global optimum effectively. In a real soccer league, during the course of a season, which usually lasts from September to June, each team plays every other team twice, once at home and once away, for a total of $Mx(M-1)$ (M=number of teams). Teams receive three points for a win, one point for a draw, and no points for a loss. Teams are ranked by total points, with the highest-ranked club at the end of the season crowned champion. In SLC algorithm, each player is a solution vector and during the course of a season, each team plays every other team once and teams receive points by updating their players. Players that are more powerful constitute more powerful team which stands on the top rank in the league table. Moreover, powerful teams have a higher chance of winning their matches. However, it is not possible to predict the exact winner of a specified match before the game ends.

As well as the league competitions among teams, there is an internal competition in each team. Players compete with each other to attract the head coach's attention by improving their performance. This internal competition leads to a growth in the quality and power of a team.

In each team, there is a key player which is called Star Player (SP). SP has the best performance among other players in the team. Moreover, there is a unique player in each league which is called the Super Star Player (SSP). SSP is defined as the most powerful player in the league [7,8]. For example, in Spain Liga (La-Liga) Cristiano Ronaldo is SSP of the league and SP of real Madrid on the other hand Lionel Messi is SP of Barcelona.

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After every match, players in winner team adopt different strategies for improving their future performance. When a team wins a match, players try to imitate the team's SP, and the SSP of the league. Imitation and Provocation operators in SLC algorithm simulate this strategy. In this study, an enhanced imitation operator is introduced which is according to harmony search (HS) algorithm and can improve the performance of SLC to find global optimum. We apply enhanced SLC to find optimal design of 18 knapsack problems and results show that the proposed algorithm converges to the answer more reliable and rapidly in comparison with other popular meta-heuristic methods.

The structure of this work is as follows. First, a brief description of SLC modeling is given, and knapsack problem is formulated in a single modeling framework. Second, a detailed numerical study is presented on 18 knapsack problems where dimensional sizes of the problems are from small to very large in order to evaluate robustness and effectiveness of SLC algorithm and finally, a discussion of results is provided.

2. Soccer league competition (SLC) algorithm for solving knapsack problems

Competitions between teams in a soccer league for reaching success, and among players for being a SP or SSP can be simulated for solving optimization problems. Similar to a soccer league in which every player desires to be the best (SSP), in an optimization problem each solution vector seeks for the global optimum position. Therefore, each player in a league, Star Player (SP) in each team, and the Super Star Player (SSP) can be assumed as a solution vector, a local optimum, and the global optimum, respectively. A schematic view of a league is shown in Fig. 1. There are M teams in this league which each team has two forms of players: (1) fixed players (2) substitutes.

Each player is a solution vector in SLC algorithm.

For each player, an objective function is calculated which stands for the power of its corresponding player and can be calculated by following formula:

$$PP\,(i,j) = C(i,j)\ i \in team, j \in player, C = objective\ function \quad (1)$$

The total power of a team is defined as the average power value of its fixed players.

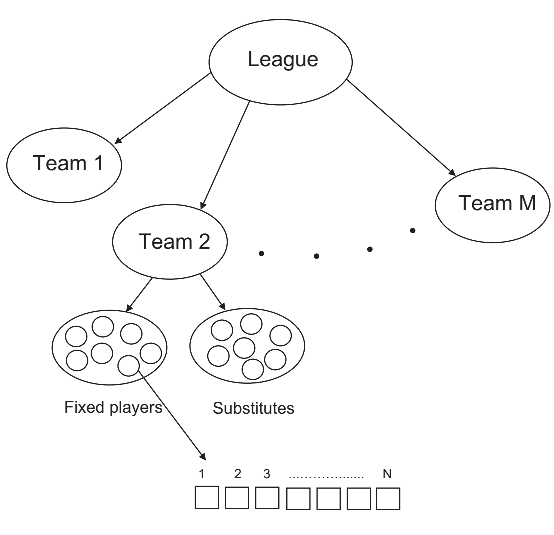

Fig. 1. Schematic view of a league.

In a knapsack problem, larger values of objective functions illustrate powerful players (*PP*). The total power of a team is defined as the average power value of its fixed players. The following formula shows how a Team's Power (*TP*) is calculated.

$$TP(i) = \left(\frac{1}{nF}\right) \sum_{j=1}^{nF} PP(i,j) \quad (2)$$

where nF is the total number of fixed players in the ith team. In each match, the team with more power has a higher chance of winning. The probability of victory for each team in a match is given by:

$$Pv(k) = \frac{TP(k)}{(TP(i)+TP(k))} \quad (3)$$

$$Pv(i) = \frac{TP(i)}{(TP(i)+TP(k))} \quad (4)$$

in which, Pv stands for the probability of victory. It should be noted that the sum of $Pv(k)$ and $Pv(i)$ equals 1. After each match, the winner and the loser are noticed and some players (solution vectors), including fixed and substitute, experience changes. These changes, which are aimed to improve performance of both players and teams, are simulated with the following operators:

Imitation operator, provocation operator.

The steps in the procedure of SLC are as follows:

- Step1. Initialize problem and algorithm parameters.
- Step2. Samples generation.
- Step3. Teams assessment.
- Step4. League start.
- Step5. League update.
- Step6. Check the stopping criterion.

2.1. Step 1. Initialize the problem and algorithm parameters

In Step 1, the knapsack problem is described as follows:

$$Max\ C = \sum_{k=1}^{N} v_k x_k$$

$$subject\ to\ \sum_{i=1}^{N} w_k x_k \le W$$

$$x_k = 0 \text{ or } 1 \quad k = 1, 2, \ldots, N \quad (5)$$

where x_k indicates whether item k is included in the knapsack or not; N is the number of items; v_k is the profit of item k; w_k is the weight of item k, and W is the knapsack capacity.

In knapsack problem, the objective function is the profit function; the presence or absence of one item are the decision variables; the number of decision variables N is the number of items in the problem; the set of decision variable values is the range of {0,1}.Then, the number of seasons (*nSeason*), the number of teams included in the league (nT), the number of fixed players (nF), and the number of substitutes (nS) are determined.

2.2. Step 2. Samples generation

The total number of players in a league is calculated by the following formula:

$$n\ Players = nT \times (nF + nS)$$

In most problems, it is suggested that

$$4 \le nT \le 10,$$

$$nF = 10,$$