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Linkage based deferred acceptance optimization

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ABSTRACT

In general, heuristic optimization techniques lose some of the optimal solution of the objective function in the optimization process. This paper proposes a concept to retain those variables that might help in accelerating the complete optimization process. The motivation is to derive linkages between variables in a population set that will be used in crossover strategy. This crossover strategy is dependent on a deferred acceptance algorithm (DAA). Also, the property of linkages or interrelation is implemented to derive the relation between variables among dimensions. This paper proposes a linkage based deferred acceptance optimization (LDAO) technique. It is observed that the proposed algorithm has proved its efficacy on the set of unconstrained and constrained objective functions. Also, the proposed algorithm is tested on challenging real world problems (CEC 2011) and the functions present in CEC 2014 competition.

1. Introduction

The standards of human race are increasing at an enormous speed, so do their technology. Daily few new problems are created and resolved in the field of computer science, operations research and engineering. The solution to these problems is not straight forward due to the presence of significant number of factors that are involved such as economics, quality and quantity. Not only this, there can be various parameters impacting each of these factors. These parameters can have dependencies on these factors on the basis of linearity/non-linearity, continuous/discrete and uni/multi-modal. Moreover, the problem can be constrained or unconstrained where constrained means the problem is subjected to satisfy some equality and inequality equations. These parameters can be bounded or free to move in search space. The optimal solution may lie on the boundary or inside the feasible search space. The problem complexity increases with the increase in the number of variables on which optimization of function depends.

These types of problems can be solved based on the evolutionary algorithms such as differential evolution (DE) algorithm by Storn and Price [23], particle swarm optimization (PSO) technique by Kennedy and Eberhart [13], genetic algorithm by Goldberg [8], artificial bee colony (ABC) by Karaboga and Basturk [12] etc. There is a long history of various techniques on their successful solution providing capabilities, discussed by many researchers for over a decade now. Each of these algorithms is based on classical strategy to reach optimal fitness that is initialization, function evaluation, update strategy and selection. These steps have been adopted by every heuristic optimization technique. Initially, a random population set is generated within a feasible search space and fitness is evaluated for each set. The best fitness and corresponding variable set

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is stored. An update strategy is executed that is followed by selection to get the new population set for the next iteration. Practically, population set is pushed towards a new set point based on any criteria that varies from method to method. Gradually, pushing each variable towards a new set point will eventually optimize the fitness function. Although, due to the randomness involved in the heuristic algorithms, it is not guaranteed that the solver will reproduce an optimal solution.

In [22], authors have used the term *metaphor* stating that the various metaheuristic techniques are based on behavior of virtually any species of insects, the flow of water, musicians playing together etc. Authors have recommended to improvise the already state-of-the-art techniques rather than launching another metaheuristic algorithm. Keeping this in mind, this paper proposes a crossover strategy based on a deferred acceptance algorithm by Roth [19]. In general, crossovers between variables occur randomly. Also, occurrence of crossover is dependent on a probability that will ascertain to restrict the crossover for certain number of variables in each population. In our algorithm, crossover occurs between each variable according to each variables preference list. Also, each variable is asked for their preferentially matched variable to come together in the new population. Each variable has also got the right to reject or accept the other variables proposal of being together in the new population.

This idea is adopted from a well-known, accredited by noble prize, stable matching algorithm presented by Gale and Shapley [6]. This algorithm was established in 1960s and till now it has been implemented in various real time problems such as hospital-resident allotment, school–student admission, bride–groom marriage decision and assignment problems as present literature. Here, each entity is divided into two sectors: proposer and acceptor. Proposer is the one who proposes the acceptor according to its preference list. Acceptor has also prepared its own preference list that will help in deciding on acceptance or rejection of the offer given by proposer. This game is made such that proposer is always having an upper edge as he approaches the acceptor whereas acceptor has no other option to accept or reject. Acceptor cannot approach its own preferred proposer for the matching. With these points jotted down, there can be two cases possible: (a) one-to-one matching: where each of the proposer will propose only one acceptor and proposer will move to next acceptor only if he gets rejected from the first acceptor. Also, acceptor cannot accept two proposals. Acceptor has to reject one before accepting any other proposal. Examples are bride–groom matching, doctor–patient allotment. (b) Many-to-one matching: where acceptor can accept more than one proposal according to its capacity. For example, school-student admission problem where schools can accommodate more than one student but students cannot be allocated to more than one school at an instant.

In the context of heuristic optimization, proposers and acceptors are the variables itself. It is crucial to identify and make a preference list among each variable within a population set. This is done based on the concept of linkage by Devicharan and Mohan [3] and Singh et al. [21]. Linkage is the concept adopted from “epistasis.” Epistasis is a phenomenon that consists of the effect of one gene being dependent on the presence of one or more modifier genes (genetic background) by Miko [17]. Its effect on evolutionary algorithms especially on genetic algorithm is presented by Jong et al. [11] where authors have stated its subtleness in execution of crossover and mutation. Also, the effect of epistasis is more clearly observed for balanced exploration/exploitation constants. Linkage means the connection of parameters among each other based on the deviation in fitness value. This connection is created by perturbing each parameter in a lexicographical order and the deviation in the fitness is retrieved. Each parameter is ranked based on this fitness deviation. A similar strategy is proposed in [1] which uses the state-of-the-art cultural algorithms for problem solving. It is facilitated by the exchange of knowledge between a network of active knowledge sources in the belief space and networks of individuals in the population space. Restructuring of the social fabric interconnections that facilitate flexible communication among the problem solvers in the population space that enhance its performance.

There is a need to push each population towards an optimal solution. This push can be given by any conventional heuristic optimization technique. Therefore, the proposed method of crossover is a generic one that can be implemented on top of any of the heuristic, meta-heuristic or stochastic optimization technique. This freedom can be over-exhausted and utilized its benefit on any random optimization technique. However, there are many hybrid algorithms have evolved by altering the steps of various metaheuristic algorithms to tackle the issues of *premature convergence* and *slow convergence* as stated by Ting et al. [25]. Some of the recent algorithms that has been used to improvise PSO are as follows: Wu et al. [27] has proposed a superior solution guided PSO (SSG-PSO) framework integrated with an individual level based mutation operator and different local search techniques that maintains a collection of superior solutions and updated with the evolutionary process, such that each particle can comprehensively learn from the recorded superior solutions. Shin and Kita [20] has proposed that the information of the global and personal best particles with the use of the information of the second global best and second personal best particles improves the search performance of the original PSO. In [29], authors have proposed a comprehensive learning particle swarm optimization (CLPSO) that is able to locate the global optimum region for many complex multimodal problems as it is excellent in preserving the particles diversity and thus preventing premature convergence. Some of the recent algorithms that has been used to improvise DE are as follows: Islam et al. [10] has proposed a new mutation strategy, a fitness induced parent selection scheme for the binomial crossover of DE, and a simple but effective scheme of adapting two of its most important control parameters with an objective of achieving improved performance. Yang et al. [28] has proposed the population adaptation regarding population diversity at the dimensional level and a mechanism named auto-enhanced population diversity (AEPD) to automatically enhance population diversity by identifying the moments when a population becomes converging or stagnating by measuring the distribution of the population in each dimension. Gua and Yang [9] has proposed an eigenvector-based crossover operator that utilizes eigenvectors of covariance matrix of individual solutions, which makes the crossover rotationally invariant. Fan and Yan [4] has proposed