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Hybrid chaos optimization and affine scaling search algorithm for solving linear programming problems

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ABSTRACT

In this study, we addressed Single Objective Linear Programming (SOLP). This article proposed a new combination of Chaos Optimization Algorithm (COA) with Affine Scaling Search (AFS) to be used as a Hybrid COA and AFS algorithm (Chaos AFS) for solving SOLP. The potential of COA as an emerging optimization algorithm to improve efficiency and effectiveness of AFS is investigated. Chaos AFS method is so-called numerical search algorithm that searches through the domain of decision variables of SOLP to obtain final feasible solution. An initial solution point, obtained from COA, will be used as starting solution point in AFS algorithm to improve the performance of AFS algorithm. The result shows that Hybrid COA and AFS for solving SOLP problems significantly improves the results of objective value compared to pure AFS and reduces the number of iteration steps compared to simplex and pure AFS.

1. Introduction

Linear Programming (LP) has been proven to be useful in numerous field of application in operation research and engineering fields, such as telecommunication, electrical, and structural engineering as well as computer science since the invention of Simplex Algorithm by George Dantzig in 1947. Single Objective Linear Programming (SOLP) is an LP consists of one objective function subject to one or more linear constraints [1]. The general notation for LP is min/max $\{c^T x : Ax = b, x \geq 0\}$, where $c \in \Re^n$, $b \in \Re^m$, $x \in \Re^n$ and $A \in \Re^{m \times n}$. Simplex algorithm searches through extreme point in boundary of feasible region to find optimal solution of LP problem. Simplex algorithm was a predominant method to solve LP until 1984 when Karmarkar published new method of solving LP. Since Karmarker's breakthrough with his polynomial time algorithm to solve linear programming, Interior Point Methods (IPM) grow significantly and become one of the most efficient method in optimization of linear convex problems. The ability of IPM to efficiently solve structured, sparse and large-scale LP problem becomes the reason of choice and one of researcher's main agenda in LP research [2–3]. The basic idea of Karmarkar's algorithm, which is so-called IPM, is to search freely in the domain of feasible region instead of search through the extreme point in the boundary of feasible region. IPM has two main approaches which are normal equation approach and augmented system approach [4].

In IPM, an initial feasible solution point has to be determined as a starting point for searching iteration in the domain of decision variables. This starting point determination as initial feasible solution will significantly affect the whole results of the searching process [5–6]. Subsequently, a good starting point will lead to near optimal solution. Shengsong et al. [7] has used chaos algorithm with primal-dual search to optimize non-linear optimal power flow problem. The chaos can improve the results and accelerate the process. Chuanwen and Bompard [8] combine chaos with particle swarn optimization for reactive power optimization. In their results, the combination can effectively and practically optimize the shunt capacitor and tap position of load-ratio voltage transformer. In this study, we present a novel combination of Chaos Optimization Algorithm (COA) and Affine Scaling Search (AFS), which is one of IPM methods, to solve SOLP problem. The potential of COA as an emerging optimization algorithm, which moves among feasible points based on ergodicity, stochastic, and regularity of the chaos properties, is investigated to improve efficiency and effectiveness of AFS. Predetermined feasible initial point was improved by implementing COA before being used as a starting point in AFS searching procedure. The results of this new combination of algorithm will be compared to thus from simplex and AFS method.

The structure of the article is as follows: in Section 2, chaos optimization algorithm will be discussed and the chaos optimization algorithm will be presented. The basic theory of interior point method and affine scaling search will be presented in Section

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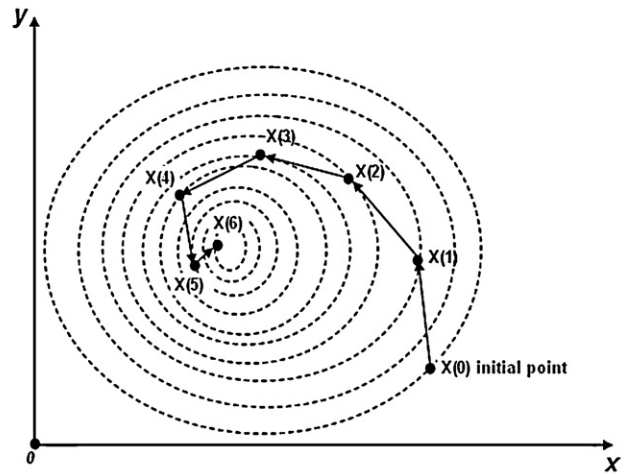

Fig. 1. An illustration of improvement search.

3. In Section 4, problems used in this article will be presented. Proposed method which combines chaos optimization and affine scaling search will be presented in Section 5. All experiment results and comparison between result of simplex method, AFS and combination of COA and AFS will be discussed in Section 6. Finally, conclusion of this study will be in Section 7.

2. Interior-point method and affine scaling search

2.1. Interior-point method

In linear programming (LP), simplex algorithm is the most widely used algorithm to solve this optimization problem since its first use by Dantzig. After publication of Karmarkar polynomial time algorithm to solve LP problem in 1984, different search strategies occur, following improvement search paradigm. These new search techniques implement different methods. Instead of searching extreme point on the boundary of feasible region which is a method of Simplex algorithm that move from one extreme point to another extreme point, these new techniques, called interior point methods (IPM), search start from feasible initial solution point in the feasible region and keep searching through the interior region of feasible region (Fig. 1).

For solving optimization problem, there are different types of solution methods, which are exact algorithm, such as Branch and Bound, Approximation/Numerical search algorithm, and heuristic search algorithm, such as simulated annealing, evolutionary algorithm, genetic algorithm, etc. as shown in Fig. 2. These solution types are different class of methods that have their own way to generate feasible solutions. IPM is a type of numerical searches algorithm that repeatedly look for different values combination of decision variable in a systematic mathematical approach, to find near optimal solution of the problem. This method is an efficient procedure to solve LP and convex optimization problems since it has a polynomial-time numbers of steps in the worst-case [9–11]. Then, IPM is faster than simplex method that has exponential-time numbers of steps in the worst-case. If the new solution is better than the previous solution, then the searching process advances to this new solution, and repeat the searching process until satisfying certain stopping criteria. Otherwise, the searching process stops on current solution [6]. Many efforts needed in each step to search better solution due to its mathematical complexity. However, numbers of steps are significantly reduced. Subsequently, these methods are best used for large scale and sparse LP and convex optimization problems that are extremely difficult to be solved analytically. Many leading software in optimization system use IPMs implementation [9]. All these IPMs method use Newton step iteration as the basic concept.

The nature of numerical search is to find better solution by searching inside the solution space domain to find near optimal solution. This technique uses mathematical formulation as a guide in the searching process. In fact, in each iteration, this formulation is used to determine search direction (Δx), search step size (λ) > 0 and solution index t. The general formula of Newton step for determining new feasible solution point within the solution space is:

$$x^{(t+1)} = x^t + \lambda_{(t+1)} \Delta x^{(t+1)} \tag{1}$$

2.1.1. Gradient condition of improvement direction

Suppose that searching process of objective function f has arrived at current solution point x, subsequently the change in

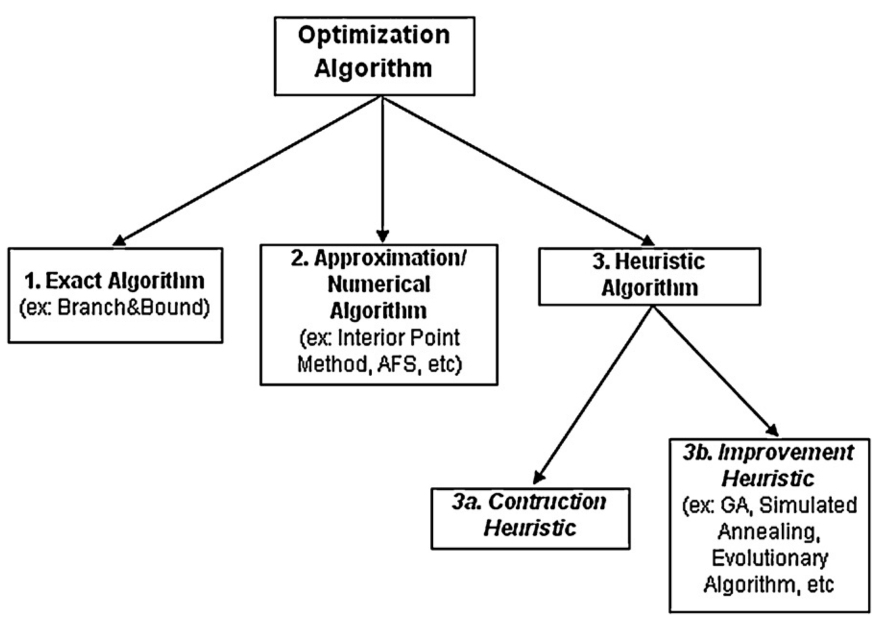

Fig. 2. Types of solutions for optimization problems.