Numerical Optimization Using the Heart Algorithm

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ABSTRACT

In this article the authors investigate the application of the heart algorithm for solving unconstraint numerical optimization problems. Heart algorithms are a novel optimization algorithm which mimics the heart function and circulatory system procedure in the human beings. It starts with a number of candidate solutions for the given problem and utilizes the contraction and expansion actions to move the candidates in the search space for finding optimal solution. The applicability and performance of the heart algorithm for solving unconstrained optimization problems has been tested using several benchmark functions. Experimental results show its potential and superiority.

KEYWORDS

Heart Algorithm, Numerical Optimization, Optimization Algorithms, Unconstrained

1. INTRODUCTION

Optimization problems play an important role in different scientific fields. There are many optimization problems that are very complicated and cannot be solved using traditional methods. Meanwhile, optimization algorithms based on meta-heuristics are suitable and robust alternatives to solve complex optimization problems.

Due to the computational shortcomings of the traditional algorithms, researchers have relied on optimization algorithms which are based on simulations of entities such as ants, birds, fish, and natural phenomena for solving some complex optimization problems. These algorithms include the genetic algorithm (GA) (Haupt & Haupt, 2004), gravitational search algorithm (GSA) (Rashedi, Nezamabadi-pour, & Saryazdi, 2009), particle swarm optimization algorithm (PSO) (Kennedy & Eberhart, 1995), ant colony optimization algorithm (ACO) (Dorigo & Blum, 2005), artificial bee colony algorithm (ABC) (Karaboga & Ozturk, 2011), firefly algorithm (FA) (Watanabe, Zeugmann, & Yang, 2009), black hole algorithm (Hatamlou, 2013), etc. Over the last decades, optimization algorithms have been used to solve various engineering problems (Fox, Xiang, & Lee, 2007; Hatamlou, Abdullah, & Hatamlou, 2011; Hatamlou, Abdullah, & Nezamabadi-pour, 2012; Hatamlou & Hatamlou, 2013; Hatamlou & Hatamlou, 2013; Geem & Cisty, 2010; Hosseini, 2007; Manoj & Elias, 2012; Cuevas, 2012). They have outperformed traditional numerical algorithms on finding better solutions for difficult and complex problems. All these algorithms can solve different optimization problems. However, there is no unique algorithm to find the best solution for all kind of problems and applications. Some algorithms achieve better solutions for some specific problems than others. Hence, designing novel algorithms for solving optimization problems is an open research area. Applying existing algorithms to find high quality solutions than other algorithms is also another problem.

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2. HEART ALGORITHM

Heart algorithm is an optimization algorithm which mimics the heart action and circulatory system in the human beings (Hatamlou, 2014). Similar to other evolutionary algorithms, the heart algorithm starts with a population of candidate solutions for the given problem. The initial population is generated and spread randomly over the search space. Then the objective function is calculated for population and the best candidate among population is chosen to be the heart and other candidates are considered as blood molecules.

After initialization of the population as heart and blood molecules, the population starts moving in the search space by simulating contraction and expansion actions of the biological heart. In this way, the heart attracts all other candidates and enforces them to move in the problem space and search for better solutions. The movement of candidates toward the heart is formulated using following equation:

\[ x_{i}^{\text{new}} = x_{i}^{\text{current}} + \text{rand} \cdot (x_{\text{heart}} - x_{i}^{\text{current}}) \quad i = 1, 2, ..., N \]  

(1)

Where \( x_{i}^{\text{current}} \) and \( x_{i}^{\text{new}} \) are the current and new locations of the \( i \)-th candidate in the search space, respectively. \( x_{\text{heart}} \) is the location position of the heart in the current iteration. \( \text{rand} \) is a random number in the interval \([0, 1] \). \( N \) is the population size or the number of candidate solutions.

After moving candidates to the new locations in the search space, the fitness value of candidates is calculated again in the new positions. If there is a candidate which has a better fitness value than the current heart, that candidate becomes the new heart and the current heart becomes a normal candidate. In other words, in each iteration the best fit candidate is chosen as the heart and it may change during iterations.

When the candidates are moved toward the heart, some of candidates may enter to the heart (become very close to the heart position). In such a case, the heart starts contraction and pumps these candidates to the new positions in the search space in a random way. The contraction action enforces the candidate solutions to search the problem space efficiently. It helps the population to keep its diversity and prevents premature convergence of the candidates. Without the contraction of the heart, after a few number of iterations all candidates in the same place in the search space and they lose their capability to move in the search space and finding better solutions. But the contraction action enforces candidates to go away from the heart position and start a new search. This causes the candidates to meet new positions and increases the chance of finding better solutions. The contraction of the heart is simulated using the following equation:

\[ x_{i}^{\text{new}} = x_{\text{heart}} + \text{rand} \cdot p \cdot x_{\text{heart}} \]  

(2)

where \( x_{i}^{\text{new}} \) is the new location of the stagnated candidate after contraction operation. \( x_{\text{heart}} \) is the location of the heart in the current iteration. \( \text{rand} \) is a random number between 0 and 1. \( p \) is used to control the power of the heart during iterations. It is a decreasing function of time, which is initialized to 1 at the first iteration and is linearly decreased to 0 at the last iterations. The \( p \) variable causes the heart to pump and to spread the candidates over a much wider area in the search space at the early iterations, which assures the global convergence or the exploration of the algorithm and prevents the algorithm to stick on a local optima solution. At the later iterations by decreasing the value of \( p \), the heart becomes week and pumps the candidate to a small area of search space near the heart and increases the intensification and exploitation of the algorithm.

These expansion and contraction procedures are carried out repeatedly and enforce the candidates to move in the search space toward/away the heart until a termination criterion is met. In this research the termination criterion is a predefined number of iterations.
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