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A Novel Memetic Algorithm with Imperialist Competition as Local Search

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Abstract. A special position has been allocated to combinatory strategy among several solutions which are offered to solve the meta-heuristic problems. This strategy is obtained by applying different techniques in the process of problem solving. Memetic algorithms are the most famous member of this family, which are made by combining the genetic algorithms with heuristic local searches. Imperialistic competitive algorithm is used in this research as local search and its efficiency level is evaluated in solving the knapsack 1-0 problem. Obtained results revealed more efficiency of this method comparing with usual genetic algorithm; also the simulations show that it does not have any better glowing results in comparison to imperialistic competitive algorithm.

Keywords: knapsack problem, imperialist competitive algorithm, genetic algorithm, mimetic algorithm.

1. Introduction

Genetic algorithms– relying on Darwin evolutional theory– are one of the most popular and applicable meta-heuristics which are utilized in optimization [1]. As it has depicted in fig. 1, genetic algorithms, like other meta-heuristics– such as particles swarm optimization– identify local and global optimizations properly during the first steps of executing the local algorithms, but they perform too slowly in the rest of their way toward global optimal.

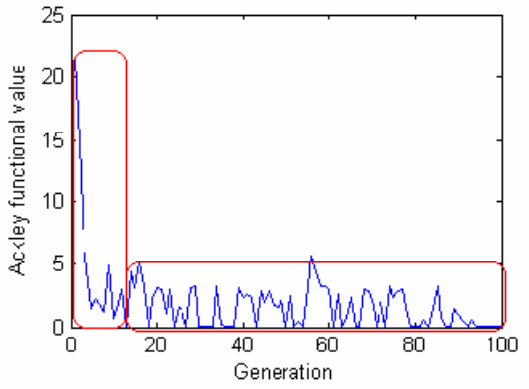

Fig. 1: Minimization trend in Ackley function via genetic algorithm.

Instability of algorithm is the second important problem in meta-heuristics, like genetic algorithm. It means that the quality of answers, obtained by different algorithms applying may vary a lot, or may not be trustable.

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Combinatory strategy is one of the most reliable solutions among offered methods to solve the meta-heuristic problems.

This strategy consists of applying different techniques in the process of problem solving. Memetic algorithms (short of "MA") are the most famous member of this family, which are made by combining the genetic algorithms with a heuristic local search [2].

Imperialistic competitive algorithm is used in this research as local search and its efficiency level is evaluated in solving the knapsack 1-0 problem, comparing with usual genetic algorithms and imperialistic competitive algorithm by itself.

Like other evolutionary optimization methods, Imperialist Competitive Algorithm (short of "ICA") begins with some initial population. Every element of the population is called a country in this algorithm. Countries are classified in two different groups: Colony and Imperialist. Every colonialist brings some colonies under its dominion and controls them according to its power [3]. Assimilation policy and imperialist competition is the core of this algorithm. This policy is accomplished by moving the colonies towards empires on the basis of a determined connection which is defined completely in [4].

Generally, imperialist competitive algorithm is unlimitedly used to solve every continues optimization problem. Therefore this algorithm is used easily in different fields, such as electrical engineering, mechanics, industries, management, civic developments, artificial intelligence, etc.

An extensive definition of the knapsack problem is presented in the second part of the article. Explaining the MA is offered in third, suggested memetic model is offered in fourth, tests and comparing the algorithms to solve the mentioned problem is offered in fifth part of this article. Finally, some results and suggestions for future works are added to section six.

2. An Explanatory Definition of the Problem

Problem of Knapsack 1-0:

A knapsack and some packs are supposed to be in this problem. Every pack possesses a specific weight and value. On the other hand the knapsack has a specific volume, too. It means that definite number of packs can be put in it. We want to put the packs into the knapsack in a special way to have the maximum value of them [17].

Mathematical Formulation of the Problem:

Maximize:

$$\sum_{i=1}^{n} v_i x_i \quad , \quad x_i \in \{0,1\} \tag{1}$$

In order to:

$$\sum_{i=1}^{n} w_i x_i \leq W \quad , \quad x_i \in \{0,1\} \tag{2}$$

It should be mentioned that the problem of knapsack 1-0 is an NP-Complete Problem [18]. According to the algorithm which is used to find an exact solution for this problem, its time consequence is expressed as follow:

$$T(n) = \theta(2^n) \tag{3}$$

Solving this problem would be hard(and even impossible) at the polynomial time, when the number of (n)s is getting big.

3. Memetic Algorithm

Exactly the same as biologists who recognize the gene as a unit of transferring the physiological characteristics – such as eye color, hair color, etc – from parents to children, psychologists recognize the Meme as a unit of transferring the behavioral characteristics – such as irascibility, traditionalism, etc – from parents to children.

According to psychological opinions, a person who was born in an illiterate family, should not stay illiterate necessarily in the whole life, he/she can develop by learning some skills in his/her environment. But according to biologists' opinion, chromosomes genes are stable and unchangeable from birth to death.

This principle is the base of MA s. Despite of genetic algorithms, which recognize the people as unchangeable and fixed creatures from the birth moment to reproduction process for next generation and to the end of life, in a MA a person can promote his/her competence in one generation via an operator, called mimicry.

A local research with a predetermined neighborhood domain will be carried out around related chromosome in recognition of each produced person in the society in order to accomplish this goal [5].

Chromosome genes are saved according to the initial amounts in the obtained result by mimicry that is calculated via local research in MA on the basis of Lamark theory; but the saving place of Meme separates from the genes in MA on the basis of Baldwin theory. Above point is depicted in fig. 2.

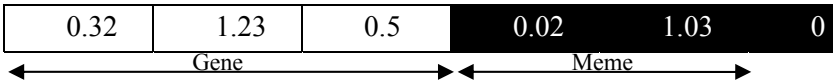

Fig. 2: Chromosome structures in Baldwin MA s.

In Baldwin MAs, genes are used in reproduction process and Memes are used in choosing the chromosomes for attending in reproduction process. Mentioned strategy leads to this point that among people with the same competence, the probability of choosing the chromosomes with better answers in their neighborhood is higher than other chromosomes in reproduction process.

4. Memetic Algorithm on the Basis of Imperial Competition

Memetic algorithm is similar to genetic algorithm. Their main difference is the optimization of each generation after accomplishing the operators – like crossover, mutation, elitism – in genetic algorithm. During the optimization of each generation, we look for a local optimum for each chromosome, on the basis of the neighborhood domain size and mimicry level. After finding the local optimization, we replace it by the initial chromosome [5]. A local search algorithm, like fig. 2, is begun from the initial state (S_0) – that can be produced randomly or via some other techniques – and is entered a circle to pass the search atmosphere, or neighborhood domain "$N(S_0)$". Each time of search is the repetition of circle from one state (S_i) to its neighbor state (S_{i+1}).

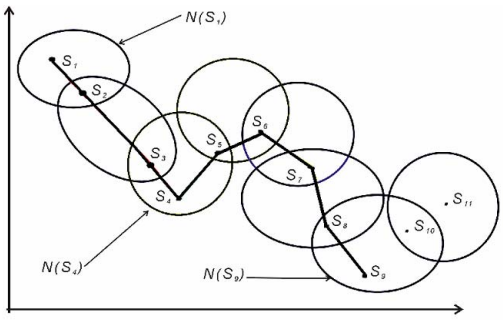

Fig. 3: A sample of points' neighborhood on the graph of a function.

The search estimates the quality of each state by the competence function in each level. This process will be continued in order to find the best chromosome on the neighborhood of entrance chromosome. Hill climbing, simulated annealing, and steady-stable movement are three usual local searches that are applied. These three methods or a combination of them have been used in several Memetic algorithms about different optimization problems. The ability of Memetic algorithm is increased in finding the global optimum in this article by imperial competitive algorithm as a local search.

5. Simulation Results

Results of the tests are offered in this part. Mentioned algorithms are executed in a system with 1.67 GHz processor and 1G of RAM memory, in MATLAB programming software. Utilized data in the problem are in concordance with the same data in [6]. The number of objects equals 16 in these data (n = 16), weight of each object(i = 0, 1, …, 15): as $w_i = 2^i$. The value of all objects equals 1 ($v_i = 1$). The optimum number

(W) in this problem was arranged between 10000 and 11000. The optimal response in this problem is: W = 8191. It should be mentioned that changing the weight of the knapsack in the determined period of time does not change the optimum response. It only makes the condition more complicated for its finding.

Applying local search is the priority of Memetic to genetic algorithm. Furthermore comparing the results of applying the Memetic algorithm clears that the solution of knapsack problem via local search of imperialist competitive can influence the process of executing the algorithm and minimize the time of convergence toward optimal answer.

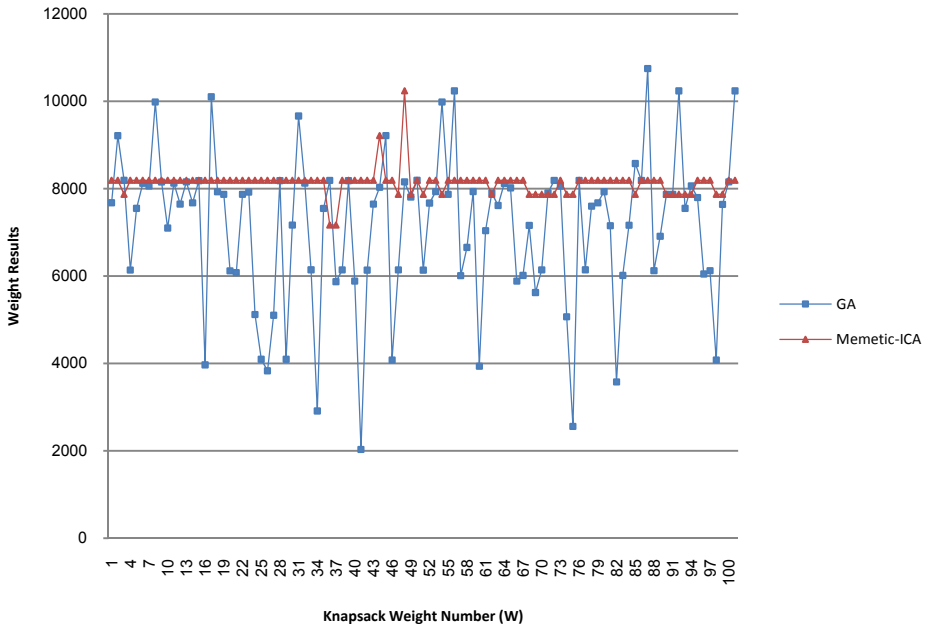

Fig. 4: Results of solving the knapsack 1-0 problem with GA and Memetic-ICA after 50 generations. GA is fluctuating; however Memetic-ICA is stable relatively.

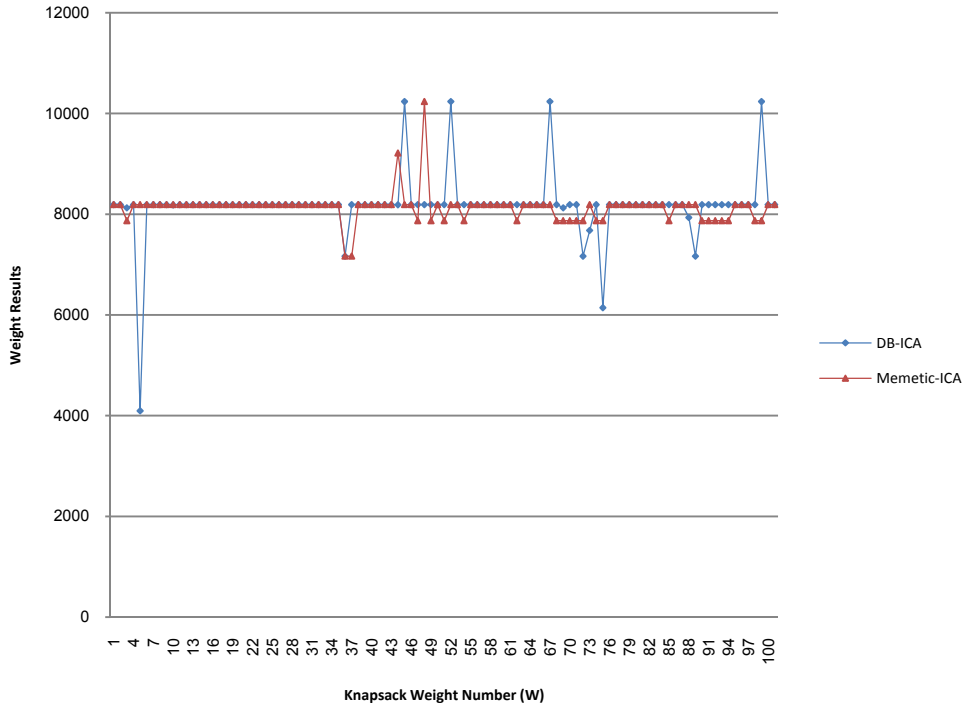

Fig. 5: Results of solving the knapsack 1-0 problem with DB-ICA and Memetic-ICA after 50 generations. Both Memetic-ICA, and DB-ICA are stable on the main response.

The average of optimals for each algorithm in 50 repetition cycles is depicted in figure 3. As you can see, ICA based algorithms both possess the nearest average in approaching to optimal response.

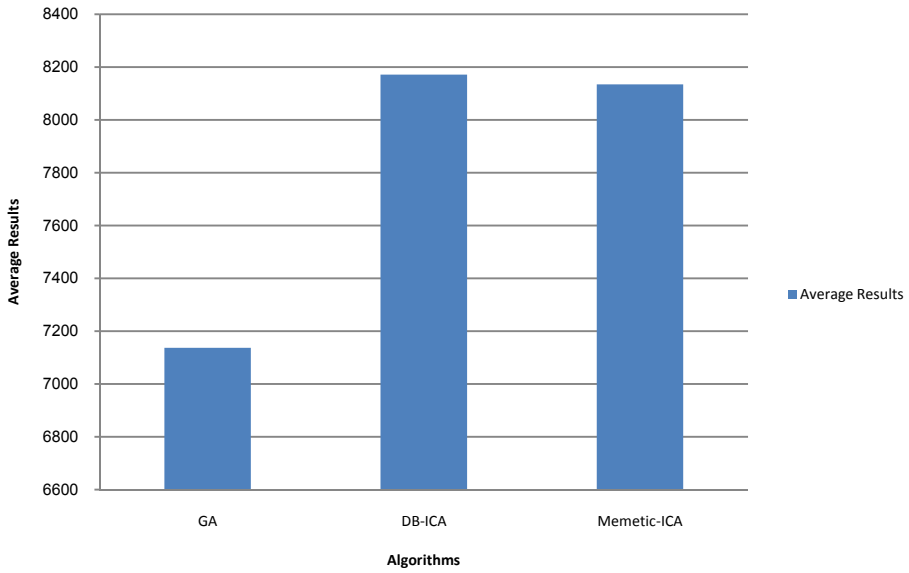

Fig. 6: Average of the best optimal results after 50 repetition cycles in all algorithms.

A scale is introduced in [6] to evaluate the level of efficiency in order to solve the problem of knapsack 1-0, called Hit Rate. This scale calculates the level of ability in approaching the pattern to the optimal response, regarding the domain at the size of a Hit Scale. For example, if global optimization equals 100, and Hit Scale equals 0.3, then if the algorithm response equals a number between 70 to 130, it will be claimed that the response is "hit", it means the Hit Rate equals 1. Consider the Hit Scale equals a number between 0.002 and 0.03, so the level of algorithms ability in approaching to global optimum is being compared

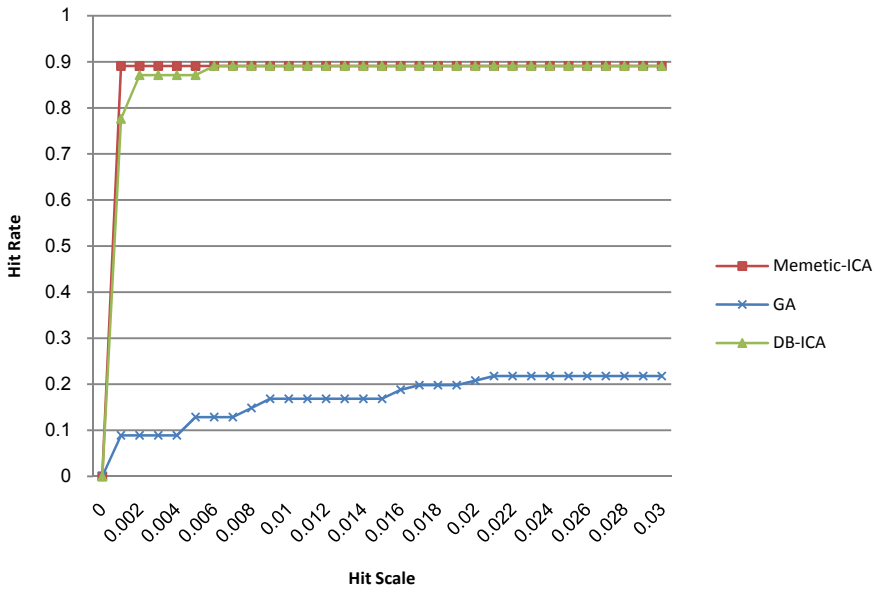

Fig. 7: The level of Hit Rate in tested algorithms. Memetic got the highest Hit Rate and it has hit the optimal, Therefore these algorithms are certainly able to approach the optimal response.

6. Results and Future Works

In this article, a new method of Memetic algorithm model was offered. It can be deduced that the introduced model of Memetic algorithm performs well in different conditions for knapsack problems with high possibility of other heuristic methods in local optimization.

Defining the optimization of neighborhood domain is the most important problem in designing the Memetic algorithms. It should be considered as an important factor during the execution. In this article the search domain was obtained via a trial. We considered the evaluation of a proper domain in order to solve various discrete problems by the Memetic algorithm on the basis of imperialist competitive algorithm as a topic for our next works.

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