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A Binary Model on the Basis of Cuckoo Search Algorithm in Order to Solve the Problem of Knapsack 1-0

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Abstract. Cuckoo Search Algorithm is one of the newest and strongest methods of evolutional optimization, and no Binary model is introduced for it up until now. Obtained experimental results presented that the convergence rate and quality of obtained solution via this algorithm is much better than other algorithms such as Genetic Algorithm, Particles Swarm Optimization, Ant Colony System, Simulated Annealing, Tabu Search. Binary Cuckoo search algorithm makes giving the optimum answer possible 40 percents more than other algorithms.

Keywords: Cuckoo search, Discrete Problems, Knapsack Problem, Genetic Algorithm, Particles Swarm Optimization, Ant Colony System, Simulated Annealing, Tabu Search

1. Introduction

Some algorithms like GA, ACO, and ICA can be mentioned as usual meta-heuristic algorithms on the basis of population. Some other algorithms like SA and TS also can be mentioned as usual meta-heuristic algorithms on the basis of one response. Cuckoo search algorithm (short of "COA") is one of the newest introduced algorithms on the basis of population. It was introduced by Yang et al. in 2009 [1]. This algorithm was inspired by life style of a bird, called cuckoo. Interesting life style and egg-laying of this bird was the harbinger of a proper optimum algorithm in wild nature. It was a method to survive in the battle with other animals for existence by the least struggle. Then a more complete method was offered by Ramin Rajabioun [2] on the same basis in order to solve the continuous nonlinear optimization problems. But its Binary discrete algorithm has not been evaluated up to now. The Binary model of it is offered in this study.

Lots of problems have discrete nature. Furthermore discrete processes are utilized to solve most of connected problems as well. Therefore a discrete cuckoo search algorithm (short of "BCOA") is needed, because both discrete and connected problems are solvable at the same discrete atmosphere. The main version of cuckoo search has been utilized in order to solve different problems up until now, but this model can be changed to a discrete model better by making some changes in the cuckoos' movements toward the habitats.

An extensive definition of the knapsack problem is presented in the second part of the article. Explaining the COA is offered in third, suggested discrete binary 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. Cuckoo search algorithm

COA begins with an initial population, exactly the same as other evolutional algorithms. The population consists of cuckoos [1]. The population possesses some eggs that will lay them on the nest of some other host birds. Those legs that look like the host bird eggs have a chance to survive and be changed into a grown-up cuckoo. The rest of the eggs are identified by the host bird and will be wiped out. The number of grown-up eggs represents the suitability of nests in that region. Whatever the number of surviving and existing eggs is higher; more interests (trends) are allotted to that region. Thus a condition, in which the most number of eggs are surviving, will be a parameter that COA intends optimization [2].

All cuckoos will be at the same point of optimization with maximum similarities between their eggs and the host birds' eggs after some repetition. Also more food sources will be available there. This place possesses the most total interests and the least wiping out in eggs. Ultimate end of cuckoo search optimization algorithm (COA) is more than 95% convergence of all cuckoos toward a special point.

4. Discrete Binary Cuckoo search algorithm

Lots of problems have discrete nature. Furthermore discrete processes are utilized to solve most of connected problems as well. Therefore a discrete cuckoo search algorithm is needed, because both discrete and connected problems are solvable at the same discrete atmosphere. The main version of cuckoo search has been utilized in order to solve different problems up until now, but this model can be changed to a discrete model better by making some changes in the cuckoos' movements toward the habitats.

Changing the level in cuckoos' movements:

Considering this point that all cuckoos do their best to arrive in a better habitat during each algorithm repetition, so part of their habitats would be the best habitat. Hence the usual cuckoo search model can change to its discrete model by defining the structure of each habitat, exactly the same as chromosomes structures in genetic algorithm, and cuckoos emigration to habitats can be exerted by implementing the operation "crossover".

After defining the habits structures as a chromosome, the proper crossover operator should be defined as well. 0 and 1 represent the lack of existence or existence of eggs respectively in each nest of different habits in Graph Bisection problem. Zero means lack of egg existence, and one means the existence of it in nest (i).

The half uniform crossover is used for (cuckoos' movement toward the best habitat) emigration. First of all 50 percent of nests (genes) are randomly chosen from each habitat in half uniform crossover (Short of "HUC"), then the amount of the best habitat is replaces by it at the same place.

Quick convergence toward the global optimum response, low possibility of difficulty in local optimum points, and general movement of population toward the better points via destroying the improper responses are some advantages of mentioned algorithm. You can see an example of binary movement of the cuckoos in Table.1 and Table.2.

Tab.1 A sample on random selection of the nests for HUC

Best habitat	1	0	1	1	1	1
Habitat1	0	1	0	1	0	0
Habitat2	0	0	0	1	0	0
…						
Habitat n	1	1	0	0	1	0

Tab.2 Movement of cuckoos toward best environment according to HUC

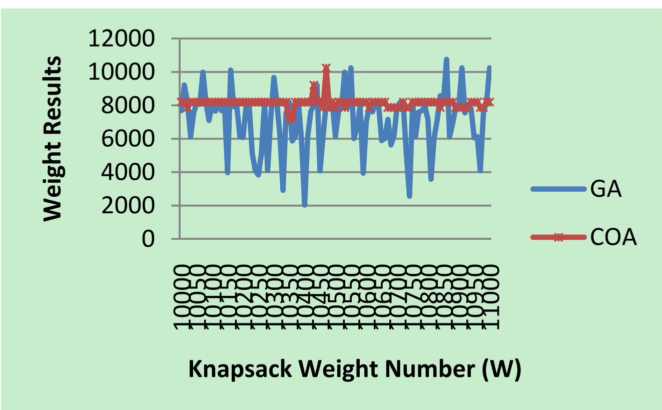
Best habitat	1	0	1	1	1	1
Habitat1	1	1	1	1	0	0
Habitat2	1	0	0	1	1	0
…						
Habitat n	1	0	0	0	1	1

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 [20]. 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. All algorithms are executed at the same condition in 50 generations, and the best created amounts by them are compared with different optimization algorithms in discrete binary cuckoo search algorithm, the results are depicted in figures 1 to 5.

Superiority of cuckoo search and its stability comparing with other optimization algorithms can be seen in all figures.

The average of optimals for each algorithm in 50 repetition cycles is depicted in figure 6. As you can see, COA possesses has the nearest average in approaching to optimal response.



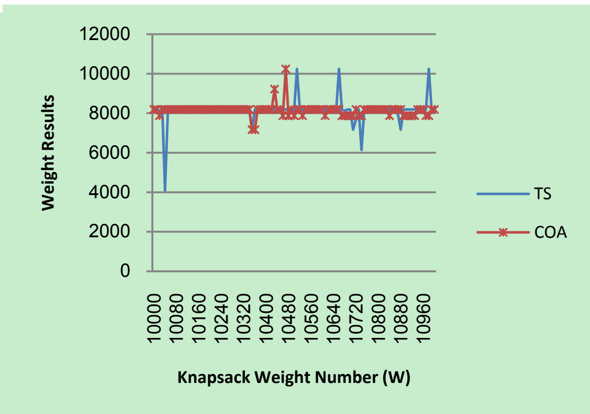


Fig. 1: Results of solving the knapsack 1-0 problem with GA and COA after 50 generations. GA is fluctuating; however COA is stable relatively.

Fig. 2: Results of solving the knapsack 1-0 problem with TS algorithm and COA after 50 generations. Though TS is relatively stable, like COA, this stability is on a specific response near the global optimum, But COA is stable on the main response.

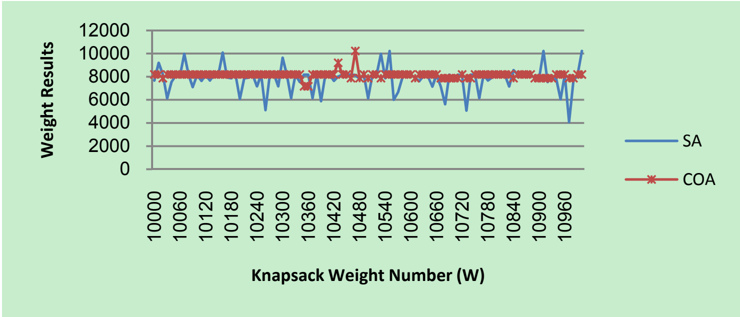


Fig. 3: Results of solving knapsack 1-0 problem with SA and COA after 50 generations. SA is extremely fluctuating; however COA is stable relatively.

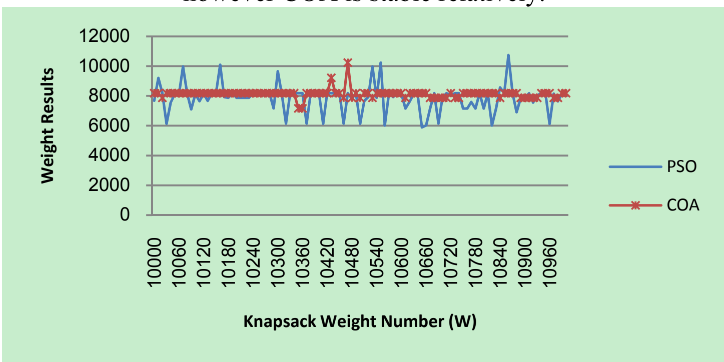


Fig. 4: Results of solving the knapsack 1-0 problem with PSO and COA after 50 generations. PSO is extremely fluctuating; however COA is stable relatively.

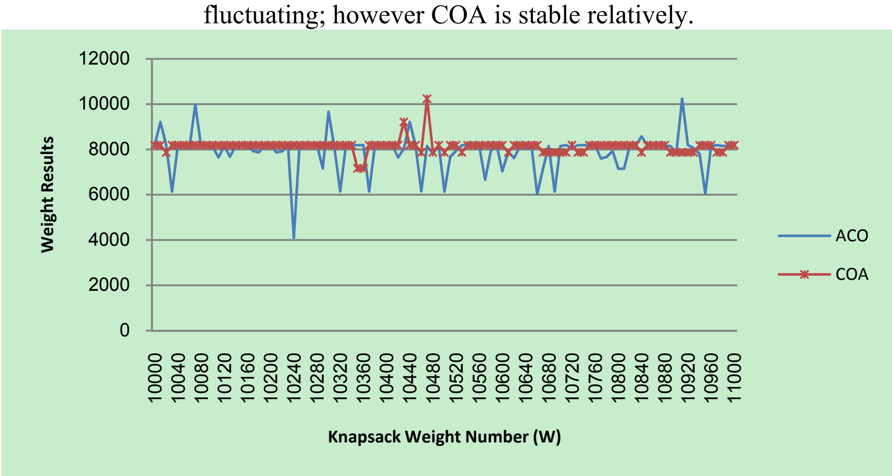


Fig. 5: Results of solving the knapsack 1-0 problem with ACO and COA after 50 generations. ACO is extremely fluctuating; however COA is stable relatively.

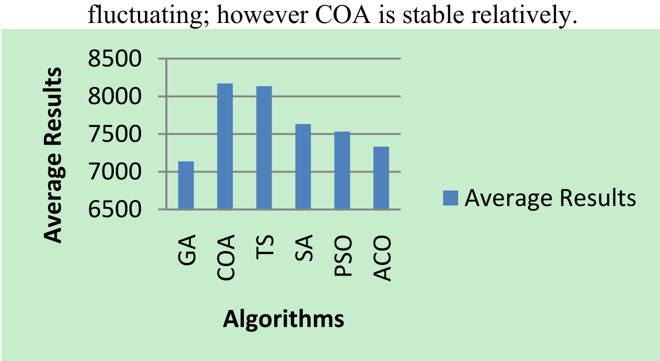


Fig. 6: Average of the best optimal results after 50 repetition cycles in all algorithms. COA got the highest average.

A scale is introduced in [3] to evaluate the level of efficiency in optimization algorithms 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. COA possesses the nearest level to 1, as it can be seen in figure 7. Therefore this algorithm is certainly able to approach the optimal response.

Fig. 7: The level of Hit Rate in all tested algorithms. DB-ICA got the highest Hit Rate.

6. Results and future works

In this article cuckoo search was explained to solve the discrete problem of knapsack 1-0. Quick convergence toward the global optimum response, low possibility of difficulty in local optimum points, and general movement of population toward the better points via destroying the improper responses are some advantages of mentioned algorithm.

Regarding the accomplished executions, it can be deduced that this algorithm performs better than some other well-known heuristic algorithms. Regarding the proper results of this algorithm in Knapsack 1-0 problem, cuckoo search can be utilized in future studies for more general problems like cutting stock problem.

7. References

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