International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Memetic Algorithm: Hybridization of Hill Climbing with Replacement Operator

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Abstract: ***Genetic Algorithms are the population based search and optimization technique that mimic the process of natural evolution. Premature Convergence and genetic drift are the inherent characteristics of genetic algorithms that make them incapable of finding global optimal solution. A memetic algorithm is an extension of genetic algorithm that incorporates the local search techniques within genetic operations so as to prevent the premature convergence and improve performance in case of NP-hard problems. This paper proposes a new memetic algorithm where hill climbing local search is applied to each individual mutation operation. The experiments have been conducted using three different benchmark instances of tsp and implementation is carried out using MATLAB. The problems result shows that the proposed memetic algorithm performs better than the genetic algorithm in terms of producing more optimal results and maintains balance between exploitation and exploration within the search space.***

Keywords: TSP, hybrid genetic algorithms, hill climbing, memetic algorithms.

1. Introduction

Genetic algorithms are the search technique based on the evolutionary ideas of natural selection and genetics [1]. Genetic algorithms use the principles inspired by natural population genetics to evolve solutions to problems. They follow the principle of survival of fittest [2], for better adaptation of species to their environment. For more than four decades, they have been applied on wide range of optimization problems.

The performance of genetic algorithms depends on the balancing between the exploitation and exploration techniques. Exploitation means to use the already available knowledge to find out the better solution and Exploration is to investigate new and unknown area in search space. The power of genetic algorithms comes from their ability to combine both exploration and exploitation in an optimal way [3]. Genetic algorithms are inspired from biological genetics model and most of its terminology has been borrowed from genetics.

Each allele has a unique position on chromosome called locus. Genetic algorithm uses an iterative process to create a population. The algorithm stops, when the population converges towards the optimal solution. It consists of following steps:-

- INITIALIZATION: Randomly generate a population of N chromosomes.
- SELECTION: Individuals are selected to create mate pool for reproduction according to selection methods.
- REPRODUCTION: Crossover and mutation operators applied on the mate pool individuals.
- REPLACEMENT: Individuals from old population are replaced by new ones according to replacement strategies.

In practice, the population size is finite that influences the performance of genetic algorithm and leads to the problem of genetic drift that occurs mostly in case of multimodal search space. Incorporating a local search method within the genetic operators can introduce new genes than can overcome the problem of genetic drift and accelerate the search towards global optima [4]. A combination of genetic algorithm and a local search method is called as hybrid genetic algorithm or memetic algorithm. In hybrid genetic algorithms, knowledge and local search can be incorporated at any stage like initialization, selection, crossover and mutation. This paper incorporates hill climbing based local search after mutation step, the new algorithm is proposed called as hybrid genetic and hill climbing algorithm (HGHCA).The proposed HGHCA is compared with Genetic algorithm(GA) on standard benchmark multimodal functions.

The paper is organized in the following sections. In section 2, literature review is given on different researches related to hybrid genetic algorithms. In section 3, memetic algorithm approach and hill climbing search along with their pseudo codes are discussed. In section 4, benchmark test functions considered for implementation are described. Implementation details and computational results are specified in section 5 and conclusion and future work are given in section 6.

2. Related Work

Holland [3] and David Goldberg [1] by using k armed bandit analogy showed that both exploration and exploitation are used by genetic algorithm at the same time. Due to certain parameters, it has been observed that, stochastic errors occur in genetic algorithm that leads to genetic drift [5,6]. Rakesh Kumar et al. proposed a novel crossover operator that uses the principle of Tabu search. They compared the proposed crossover with PMX and found that the proposed crossover yielded better results than PMX [7].

H.A. Sanusi et al. investigated the performance of genetic algorithm and memetic algorithm for constrained optimization knapsack problem. The analysis results showed that memetic algorithm converges faster than genetic algorithm and produces more optimal result [8]. A comparative analysis of memetic algorithm based on hill climbing search and genetic algorithm has been performed for the cryptanalysis on simplified data encryption standard problem by Poonam Garg [9].She concluded that memetic algorithm is superior for finding number of keys than genetic algorithms.

Antariksha [10], proposed a hybrid genetic algorithm based on GA and Artificial Immune network Algorithm (GAIN) for finding optimal collision free path in case of mobile robot moving in static environment filled with obstacles. She concluded that GAIN is better for solving such kind of problems. E .Burke et al. proposed a memetic algorithm that based on Tabu search technique to solve the maintenance scheduling problem. The proposed MA performs better and can be usefully applied to real problems [11]. Malin et al [12] proposed a memetic algorithm for feature selection in volumetric data containing spatially distributed clusters of informative features in neuroscience application. They concluded that the proposed MA identified a majority of relevant features as compared to genetic algorithm.

3. Hill Climbing

An optimization problem can usually also be modelled as a search problem, since searching for the optimum solution from among the solution space [7]. Without any loss of generality, assuming that our optimization problems are of the maximization category. So, here is the hill climbing technique of search:

1. Start with an initial solution, also called the starting point. Set current point as the starting point
2. Make a move to a next solution, called the move operation
3. If the move is a good move, then set the new point as the current point and repeat (2). If the move is a bad move, terminate. The last current solution is the possible optimum solution.

The move operation is problem dependent. In a discrete optimization problem, such as the Travelling Salesman Problem, a move operation would probably shuffle a couple of positions in the original solution [7].To avoid getting stuck in local minima we adopt a random-restart hill-climbing. Random initial states are generated, running each until it halts or makes no discernible progress. The best result is then chosen. Hill climbing is used widely in artificial intelligence fields, for reaching a goal state from a starting node. Hill climbing is often used when a good heuristic function is available for evaluating states but when no other useful knowledge is available. Hill climbing can often produce a better result than other algorithms when the amount of time available to perform a search is limited, such as with real-time systems

3.1 Description of the GA with Hill Climbing Method:

Iteratively, GA produces better solutions using HC as an 'accelerator' mechanism thanks to the exploitative properties of HC [9]. When evaluating the fitness of each individual, GA use the results of HC working with an initial guess corresponding to this individual, there are thus as many HC running in parallel as individuals in the population [10]. During reproduction and genetic transformation (crossover, mutation) for the production of the individuals of the next generation, GA work on the new solution.

It must be noted that, when evaluating the individuals with HC, it is not necessary to reach complete convergence. Individual optimization (life) can be performed ova a limited number of steps for two reasons, one because the main part of the information given by the search with HC is acquired during the first few steps, and two the search is pursued and refined over the next generations anyway. In practice, the hybrid terminates with an 'extended-life' in which the best individual of the last GA generation is exploited by HC using the normal termination criteria (nearly complete convergence). Optimization problem of De Jong's function (finding the minimal value approaching zero) solved using simple genetic algorithm with Replace All scheme. In memetic algorithm, in spite of using the basic generational update, hill climbing helps in finding the better individuals for replacement. These improvements accumulate over all the generations, resulting in a larger improvement in the total performance. Genetic algorithm and local search have complementary properties, which helps in optimization of objective function with fast convergence.

4. Methodology

Procedure for memetic algorithm is same as simple genetic algorithm except that a local search method is implemented in one of the operator (crossover, selection, replacement) to exploit the search space. Applying Hill climbing in replacement operator work efficiently to find the optimal solution.

Simple GA represents an intelligent exploration, having a random search confined within a defined search space for solving a problem optimally. Simple GA starts with random initialization of population. After this fitness function is used to calculate the fitness of each individual and then reproduction is applied. In order to incorporate the offspring into original population replacement is used. Various replacement schemes are used for maintaining the useful diversity of population [11]. Elitist replacement schemes improve the performance of genetic algorithm. Using different replacement and selection schemes in steady state, genetics converge quickly and have a useful diversity. Diversity helps in finding the optimal solution. The time needed to reach the global optimum can be reduced if local search methods and local knowledge are used to accelerate locating the most promising region in addition to locating the global optimum starting within basin of attraction [12]. Meta heuristic search mechanism in the memetic algorithm offers the speed and quality of convergence. Reducing the population size can lead to an increase in the algorithm convergence speed.

4.1 Pseudo Code for Memetic Algorithm:

Encode solution space
1) Encode solution space
2) Set pop_size, chrom_size, max_gen, Gen=0
3) Initialize population P randomly
4) For each individual i € P: calculate fitness (i);
5) While(Gen<Gensize)
   Apply generic GA *selection * cross-over *mutation
   ** For each individual i € P: do local_search(i);
   *replacement
6) Test: Test whether the termination condition is Satisfied. If so, stop. If not, return the best solution in current population and go to Step 5

Hill climbing is applied in replacement for hybridization. A chromosome is chosen randomly and its random gene value is replaced by a random value. If the newly generated chromosome have better fitness than it replace the old chromosome else check the loop condition. To analyse the optimization ability of the algorithm on different De jong's functions, work is applied on it. Algorithms that are not able to discover good directions underperform in some problems.

4.2 Pseudo Code for Memetic Local Search:

1. Loop: if i < no_of_run
2. Select random chromosome
3. Select random gene position and Replaces its value by a randomly generated valid value
4. Calculate the fitness of new chromosome
5. If (fitness_new < fitness_old) Replace the old chromosome if better

The simplest test function is De Jong's F1. It is continuous, convex and unimodal. The performance on Sphere is a measure of the general efficiency of the algorithm Generalized Rastrigin Function is a typical example of non-linear multimodal function. This function is a fairly difficult problem due to its large search space and its large number of local minima. The Ackley Problem is a minimization problem. Originally this problem was defined for two dimensions, but the problem has been generalized to N dimensions. Number of local minima: several local minima. The global minimum: $\mathbf{x}^* = (0\ldots, 0), f(\mathbf{x}^*) = 0$.Schwefel's function is deceptive in that the global minimum is geometrically distant, over the parameter space, from the next best local minima. Therefore, the search algorithms are potentially prone to convergence in the wrong direction. The schwefel's function is symmetric, separable and multimodal (left). Rotating this function creates a non-separable surface with similar features [13].

5. Experimental Results

Using the method described in the previous section we tried to determine the effect on the performance of GA. Using low probability for mutation removes an additional variable of consideration. The general parameters used for all experiments, unless otherwise stated were:
- Random initialization
- Permutation encoding
- PMX crossover
- Inversion mutation
- 0.8 crossover probability
- Breeding pool at 100% of population size
- mutation probability .01
- For 500 Generations.
- Population size of 50 and 100.

Next section of this chapter includes graph of proposed hybrid and simple genetic algorithm applied on chosen TSP instances as well as result table. Graphs are plotted for minimum tour cost found in every generation. Implemented code is attached here with this report in the appendix.

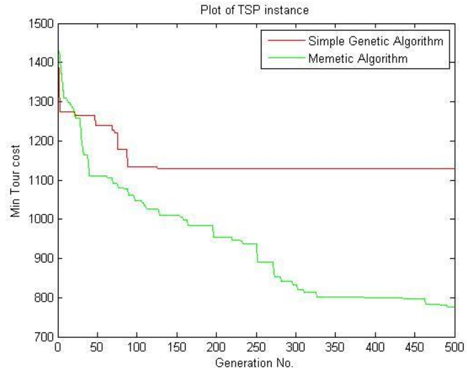

Figure 1: EIL51 Results with population size 50

Figure 1 shows the performance of Genetic algorithm and Memetic algorithms on eil51 with 50 population size and 500 generations and shows more closeness to optimum with memetic algorithm in comparison to simple genetic algorithm.

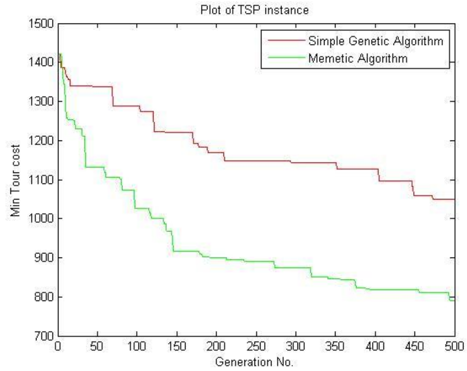

Figure 2: Eil51 Results with population size 100

Figure 2 shows the performance of Genetic algorithm and Memetic algorithms on eil51 with 100 population size and 500 generations and shows more closeness to optimum with memetic algorithm in comparison to simple genetic algorithm.

Table 1: Results for Eil51 with 51 cities and 426 Known optimum

Sr. No.	*Best tour cost with Simple GA*	*Best tour cost with Memetic Algorithm*
1	1153	746
2	1034	712
3	1035	635

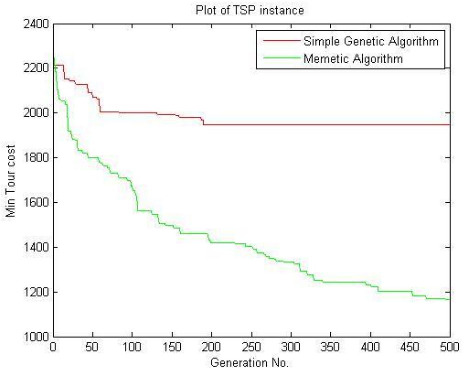

Figure 3: Experiment Results with population size 50

Figure 3 shows the performance of Genetic algorithm and Memetic algorithms on eil76 with 50 population size and 500 generations and shows more closeness to optimum with memetic algorithm in comparison to simple genetic algorithm.

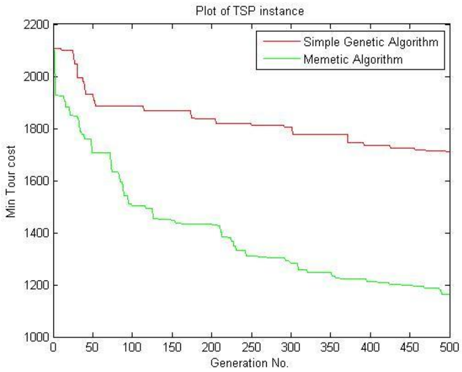

Figure 4: Experiment Results with population size 100

Figure 4 shows the performance of Genetic algorithm and Memetic algorithms on eil76 with 100 population size and 500 generations and shows more closeness to optimum with memetic algorithm in comparison to simple genetic algorithm.

Table 2: Results for Eil76 with 76 cities and 538 known optimum

Sr. No.	Best tour cost with Simple GA	Best tour cost with Memetic Algorithm
1	1884	1118
2	1787	1101
3	1765	1076

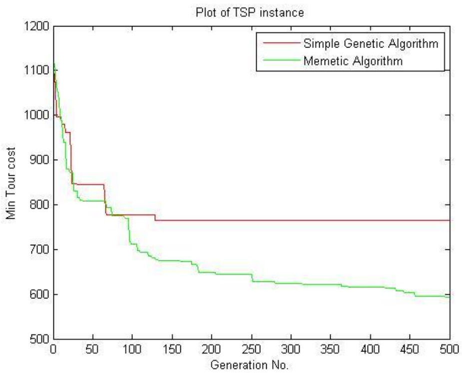

Figure 5: Experiment Results with population size 50

Figure 5 shows the performance of Genetic algorithm and Memetic algorithms on oliva30 with 50 population size and 500 generations and shows more closeness to optimum with memetic algorithm in comparison to simple genetic algorithm.

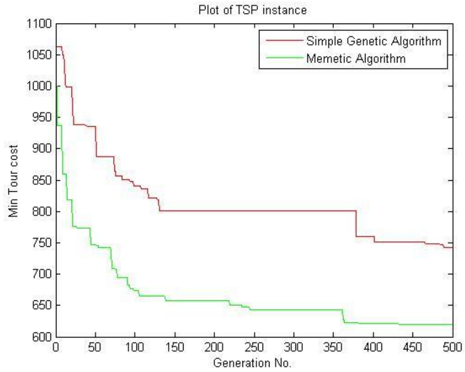

Figure 6: Experiment Results with population size 100

Figure 6 shows the performance of Genetic algorithm and Memetic algorithms on oliva30 with 100 population size and 500 generations and shows more closeness to optimum with memetic algorithm in comparison to simple genetic algorithm.

Table 3: Results for Oliva30 with 30 cities and 426 known optimum

Sr. No.	Best tour cost with Simple GA	Best tour cost with Memetic Algorithm
1	758	565
2	725	578
3	712	501

6. Conclusion

This paper proposes a hybrid genetic algorithm and analyze the optimization ability of Hill climbing in replacement (by implementing the proposed algorithm in matlab). The memetic algorithm ability depends on the way of utilizing the information from both the searching mechanism i.e. genetic algorithm and local search. The optimization of different tsp instances is implemented to evaluate the general computational behavior of Genetic and memetic algorithm. At the initial stage, the genetic algorithm is implemented as the basic architecture on this algorithm. Further, the analysis is performed on the different replacement operators.

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