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# Solving Optimization Problem by Hybrid Genetic Algorithm using Hill Climbing in Replacement Operator

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**Abstract—***Genetic algorithm is a population-based search and exploiting objective function. Every basic genetic operators used in a simple GA utilizes "random choice" to an extent or another. Optimization ability can be improved when problem specific knowledge is incorporated and goal oriented operators are used. The population based local refinement mechanism, searches the local area for minima. GA and neighborhood search technique will result in early findings of the optima. In this paper implementation of hill climbing in replacement operator and empirically analyze the convergence rate of hybrid algorithm with simple genetic algorithm. Both algorithms use the complementary property of exploitation to find optimal solution. Memetic algorithm performs good to find optimal result of complex problems. Performance of memetic algorithm is affected by population size and number of generated children. Proposed work also tries to analyze the convergence rate of memetic algorithm on TSP Eil 51 and Eil 76 problems.*

## 1. INTRODUCTION

Genetic algorithms are the search technique based on the evolutionary ideas of natural selection and genetics . Genetic algorithms use the principles inspired by natural population genetics to evolve solutions to problems. They follow the principle of survival of fittest, 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. 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 this paper Memetic algorithm can be defined as genetic algorithm that include non-genetic local search to improve genotypes. Review of local search techniques as Hill climbing with replacement operator is presented and its pseudo code given.

### 1. 1 Related Work

Holland and David Goldberg 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 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. 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. 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. She concluded that memetic algorithm is superior for finding number of keys than genetic algorithms. Antariksha, 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. Malin et al 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.

## 2. HYBRID GENETIC ALGORITHM

Moscato & Norman (1992) have introduced the term memetic algorithm to describe evolutionary algorithms in which local search plays a significant part. Heuristic optimization algorithms such as Simulated Annealing or Genetic Algorithms often can locate near optimal solutions but can require many function evaluations. Local search algorithms, including both gradient and non-gradient based methods, are quite efficient at finding the optimal within convex areas of the design space but often fail to find the global optimal in multimodal design spaces. It is possible to combine GAs with a secondary method to create a hybrid GA (also referred to as a Memetic algorithm). Hybrid GAs usually consist of a GA combined with either a local search (for a general problem solver) or a heuristic (for a more problem dependant solution).

Hybrid GAs can provide a number of advantages over a standard GA.

**Speed:** Quicker convergence to the optimum once the GA has located a promising area in search space.

**Repair:** Replacing invalid individuals with similar valid individuals. This is very useful if the crossover operator used does not guarantee to produce a valid individual.

**GA functional enhancement:** The genetic operators used by a genetic algorithm may be enhanced or replaced with a secondary method.

Hybrid design issue

### 2. 1 Local Search and Learning

Local search methods use local knowledge to improve a solution's chances to propagate its characteristics into the next generations. Due to the similarities in the role of the local search within the genetic search and the role of learning within the evolution process, the local search is usually viewed as a learning process. Lamarckian evolution and Baldwin effect: One of the important issues of hybrid genetic algorithms is how the information gained during local search is used by the global algorithm. Either the Lamarckian or the Baldwin approach can be used. In the Lamarckian approach the traits acquired during the learning process are passed from parents to their offspring. This means that both the genetic structure of an individual and its associated fitness value are modified to reflect the changes in phenotype structure as a result of performing local search. The Baldwin Effect is somewhat Lamarckian in its results but using different mechanisms. In the Baldwin approach the learning process can help the individual to adapt to its environment and as a result to survive and gain more chance to pass on its traits to the next generation. In this case, only the improved fitness value is modified to reflect the effect of performing local search, thereby allowing individuals with the ability to learn to proliferate in the population.

## 2.1. Balance between Global and Local Search:-

The hybrid algorithm should strike a balance between exploration and exploitation, in order to be able to solve global optimization problems. According to the hybrid theory, solving an optimization problem and reaching a solution of desired quality can be attained in one of two ways. Either the global search method alone reaches the solution or the global search method guides the search to the basin of attraction from where the local search method can continue to lead to the desired solution. In the genetic-local hybrid, the main role of the genetic algorithm is to explore the search space in order to either isolate the most promising regions of the search space, or, to hit the global optimum. However, the main role of the local search method is to exploit the information gathered by the global genetic algorithm. The division of the hybrid's time between the two methods influences the efficiency and the effectiveness of the search process. The optimal division of the algorithm's time is an important issue that is faced the designers of hybrid genetic algorithms.

## 3. HILL CLIMBING

Hill Climbing algorithm searches for a better solution in the neighborhood. If it finds a better solution, it changes the current solution with this new one. If the new solution is not the better one then the algorithm stops and keeps the current local optimum solution. The simplex method of linear programming is also a hill climbing procedure that moves from one extreme point solution to another, using an exact neighborhood.

**Algorithm** Hill Climbing (Iterative improvement) **begin**

*i*:=initial solution

**repeat**

generate an *s* ϵ *Neighbour(i);*

**if** fitness(*s*) > fitness(*i*) **then** *i*:=*s*;

**until** f(*s*) ≤ f(*i*) for all s ϵ *Neighbour(i);*

**end**

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.

**Move operation:** 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.

**Good/Bad Move:** A move is said to be good, if a point obtained by the move operation improves the quality of the solution, as compared to the previous solution. A bad move is defined similarly.

Hill climbing has three well-known drawbacks:

1. **Local Maxima**: a local maximum as opposed to global maximum.

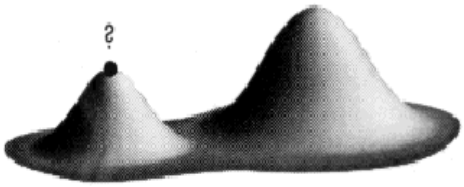

**Fig. 1: local maxima in hill climbing**

2. **Plateaus**: An area of the search space where evaluation function is flat, thus requiring random walk.

**Fig. 2: Plateaus in hill climbing**

**Ridge**: Where there are steep slopes and the search direction is not towards the top but towards the side.

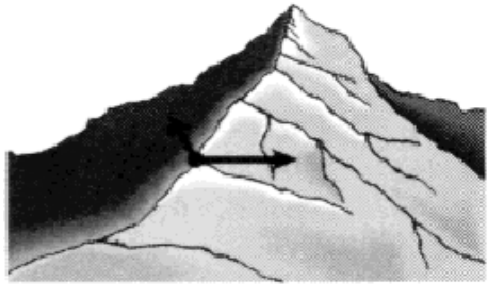

**Fig. 3: Ridge in hill climbing**

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.

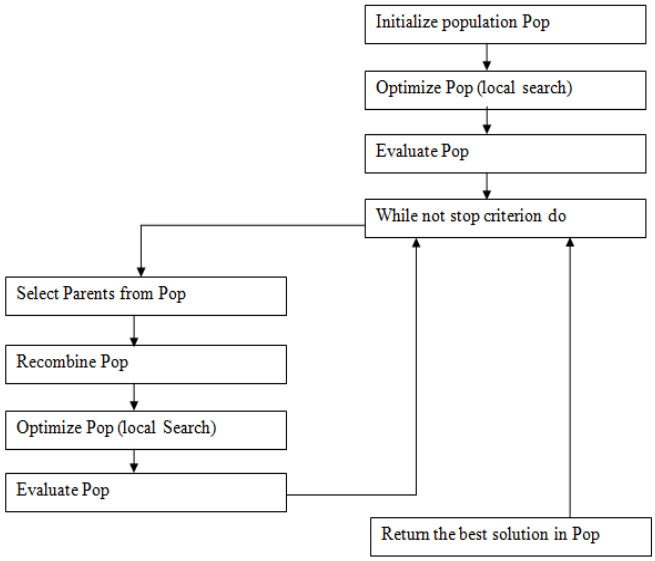


**Fig. 4: Two possible ways of combining local search with SGA**

## 4. DESCRIPTION OF GA WITH HILL CLIMBING METHOD

Iteratively, GA produces better solutions using HC as an 'accelerator' mechanism thanks to the exploitative properties of HC. 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. 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 over 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). 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

## 5. 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. 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. 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.

**Pseudo code for memetic algorithm**

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.

**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

Following parameters will be used in TSP problems:-

1. Encoding:- Permutation Encoding
2. Selection:- Roulette Wheel Selection
3. Crossover:- Partially Matched Crossover(PMX)
4. Mutation:- Inversion
5. Hill Climbing
6. Replacement:- Derived $( \lambda,\mu)$ update

In TSP there are cities and given distances between them. Traveling salesman has to visit all of them, but he does not want to travel more than necessary. We will find a sequence of cities with a minimum traveled distance. We are considering symmetrical distance that is distance from A to B is same as distance from B to A. Path is two way that is we can move from A to B as well as B to A.

**Permutation Encoding**

Here the encoded chromosome describes the order of cities the salesman visits.

For example:- Chromosome A 153264798

**Roulette Wheel Selection**

It is also known as fitness proportionate selection. In fitness proportionate selection the chance of an individual being selected is proportional to its fitness,greater or less than competitor's fitness. Conceptually,this can be thought as a game of Roulette. The wheel is spun n times where n is the no of chromosomes in the population,each time selecting a chromosome,choosen by the wheel pointer.

**PMX**

In Partially Matched Crossover, two strings are aligned, and two crossover points are selected uniformly at random along the length of the strings. The two crossover

points give a matching selection, which is used to affect a cross through positionby-position exchange operations.

Consider two strings:

Parent A 4 8 7 3 6 5 1 10 9 2

Parent B 3 1 4 2 7 9 10 8 6 5

Two crossover points were selected at random, and PMX proceeds by position wise exchanges. In-between the crossover points the genes get exchanged i. e., the 3 and the 2, the 6 and the 7, the 5 and the 9 exchange places. This is by mapping parent B to parent A. Now mapping parent A to parent B, the 7 and the 6, the 9 and the 5, the

2 and the 3 exchange places. Thus after PMX, the offspring produced as follows:

Child A 4 8 6 2 7 9 1 10 5 3

Child B 2 1 4 3 6 5 10 8 7 9

where each offspring contains ordering information partially determined by each of its parents. PMX can be applied to problems with permutation representation.

**Inversion**

Two points are selected along the length of the chromosome,the chromosome is cut at those points and the end points of the section cut,gets reversed(switched,swapped).

**Derived ( $\lambda$,μ) update**

Here parent population of size μ produces children of size $\lambda$. The μ best individuals from offspring population produce new generation.

TSP Eil 51 and Eil 76 consist of 51 and 76 cities respectively and the distance between those cities are given. Chromosome represent the sequence in which cities are visited that means a particular tour. For calculating the distance of a particular tour we will add the distance between it's cities. The tour whose distance will be less,it's fitness will be more. The tour with minimum distance will have highest fitness. Hill Climbing is a local search technique. In this changes in chromosome are less. Convergence rate is faster and it finds better optimal solution. It is simple to implement. GA requires many function evaluations when used alone. Because of complementary properties of GA and Hill Climbing,they can be used together. GA will find out the most promising area of attraction. Hill climbing will find optimum in that area. Hill Climbing in TSP will shuffle couple of position of original chromosome and calculate its fitness. If the fitness of new choromosome is more than the old chromosome than new chromosome will replace the old one. The result of GA is fed into Hill Climbing and the result of Hill Climbing is fed into GA. Hill Climbing is applied until the chromosome with minimum distance is obtained to produce new generation. It is easy to find a solution that visits all the cities but will be very poor compared to the optimal solution. The algorithm starts with such a solution and makes small improvements to it, such as switching the order in which two cities are visited. Eventually,a much better route is obtained.


**Fig. 5: Flow chart of method for solving TSP**

## 6. CONCLUSION

Genetic-local hybrid techniques are quite useful in particular scenarios. It quickly depends on the way of utilizing the information from both the searching mechanisms in both of them. It is good enough to control some parameters when mixing both strategies like duration of local search, frequency of local search etc. Uncontrollable parameters will lead to resource wastage. Genetic algorithms and neighborhood search techniques will result in early findings of the optima. They both are good alone, but if one will combine them somehow in controllable environment, things can be done quite easily.

Although GA's are effective complete search algorithms with crossover and mutation operators, genetic algorithms can be improved using local search methods and they can be made competitive with others when the search space is too large to explore.

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