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A Novel Approach to Solve TSP Using Hybrid Genetic Algorithms

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Abstract— Travelling Salesman Problem (TSP) is a NP – Hard problem which is difficult to solve using deterministic algorithms. This paper proposes an improved hybrid Genetic Algorithm, where a new variation of Partially Matched Crossover operator and a variation of inversion Mutation operator are used. Hill Climbing based local search is applied after selection to prevent stuck at local optima. Implementation is carried out in MATLAB and tested using different problems of symmetric TSP taken from TSPLIB. The results are compared with pure Genetic Algorithm (GA) which is promising in terms of convergence towards the optimal solution.

Keywords-Genetic Algorithm, Hill climbing, Hybridization, Tournament Selection, Travelling Salesman Problem (TSP)

I. INTRODUCTION

Genetic Algorithms belong to the class of evolutionary algorithms, which are used to find the approximate solutions to optimization and search problems. In brief GA mimics the principle of natural selection - the concept of survival of fittest [1]. Performance of Genetic Algorithms is mainly affected by the genetic operators viz. selection, crossover and mutation. Individuals are selected from population using some selection technique like roulette wheel selection, rank selection and tournament selection. The main criteria of selection scheme is "the better is an individual, the higher its chances of being selected" [10] .The selected individuals then exchange genetic information among them by applying some crossover technique .Finally mutation operator is applied to the individuals in order to maintain diversity of population and prevent premature convergence.TSP is one of the most widely studied NP –hard combinatorial optimization problem in GA. Its Search space increases exponentially with the increase in number of cities which is $(n-1)!/2$ for n city symmetric TSP problem.

Hybrid Genetic Algorithm (HGA) combines some local search technique like Hill climbing to search in the neighborhood of already obtained optimal solution. It is required to have good balance of exploration and exploitation in order to find global optimum solution. Exploitation means to use the problem specific knowledge with the hope to find better solutions and Exploration means to probe new and unknown portion of search space. In this paper hill climbing based local search is applied after selection operator to the 50% of the most optimal solution based on the fitness function value.

This paper also tries to put forth the idea of generating 6 different offspring chromosomes from randomly selected 2 parent chromosomes in partially matched crossover operator. Then the two best chromosomes are selected from generated 6 offspring chromosomes and sent for mutation. Mutation operator is useful to recover genetic material lost due to crossover and reproduction [1].This paper proposes a variation of inversion mutation operator which generates 3 different mutated chromosomes from one chromosome.

The remainder of this paper is organized as follows: Section II presents a concise summary of previous works carried on hybrid genetic algorithm. Section III explains the proposed work in hybrid GA along with the variation of PMX crossover and variation of inversion mutation. Section IV compares the proposed approach with pure GA. Section V discusses the conclusion and possible future work.

II. BACKGROUND WORK

Many different approaches have been suggested by researchers across the world for the improvement of genetic algorithms to solve TSP. The authors Olga Yugay, Insoon Kim, Beomjune Kim and Franz I.S. Ko in their research paper [4] proposed a new hybrid genetic algorithm for solving Travelling Salesman Problem with sorted population. Size of very large initial population is reduced so that only those with the higher fitness value are retained. They concluded that their proposed hybrid GA shows better results. Similarly the authors D. Kaur and M.M. Murugappan in their research paper [3] presented a hybrid GA based on nearest neighbor heuristics for the initialization of population. Results are

compared with pure GA and the convergence rate is improved by more than 200% for 90 city problem. The authors Luo Delin, Zhang Lixiao and Xu Zhihui presented a heuristic simulated annealing genetic algorithm (HSAGA). Simulated Annealing is applied to 20% of the most optimal solutions at each iteration [5]. They tested their proposed algorithm on problem instances taken from TSPLIB and concluded that algorithm is effective to solve TSP problems. The authors Kusum Deep and Hadush Mebrahtu in their research paper [8] proposed three new variations of order crossover based on the cut point analysis. They concluded that new variations perform better over existing variants of order crossover when the number of cities are less than or equal to 100. The authors Devasenathipathi N. Mudaliar and Dr. Nilesh K. Modi in their research paper [6] proposed m-crossover operator which is able to produce 18 different offspring chromosomes from 2 selected parent chromosomes. They compared it with already existing crossover operators and found that proposed new crossover operator is faster in searching the better solutions.

III. METHODOLOGY

A. Variation of Partially Matched Crossover (PMX) Operator

PMX is a crossover operator which tends to respect absolute city position [1]. Under proposed variation of PMX, chromosome is divided into 3 parts by randomly selecting two cut positions. For example crossover takes place for chromosome P and Q denoted by ABC and A'B'C' respectively. First, position by position exchange takes place by replacing the substring A of parent P with the substring A' of parent Q. Then, the inverse replacement is carried outside the first cut position in order to remove duplicates. This will produce 2 offspring. Similarly, 4 more offspring chromosomes are generated by considering B (second part of chromosome) and C (third part of chromosome) as matching section one by one.

Example indicating the proposed crossover operator:

Suppose the two parent chromosomes are 'P' and 'Q' with their path representation given below.

Parent P= 1 4 6 7 9 5 8 3 10 2
Parent Q= 1 3 5 8 2 4 6 7 10 9
Let the cut points are chosen as 4 and 7.With these each chromosome can be divided into three parts
Parent P= [1 4 6 7] [9 5 8] [3 10 2]
Parent Q= [1 3 5 8] [2 4 6] [7 10 9]
Proposed crossover produces following 6 offspring after performing variation of PMX operator
Child 1=1 3 5 8 9 6 7 4 10 2
Child 2=1 4 6 7 2 3 5 8 10 9
Child 3=1 5 8 7 2 4 6 3 10 9
Child 4=1 3 4 6 9 5 8 7 10 2
Child 5=1 4 6 3 2 5 8 7 10 9
Child 6=1 7 5 8 9 4 6 3 10 2

Then the two best chromosomes based on the value of fitness function are selected from the generated 6 offspring chromosomes.

B. Variation of inversion Mutation

Mutation operator is performed with small probability by randomly altering the genes of the chromosome [1]. Under the proposed mutation operator 2 positions are chosen randomly so that the chromosome is divided into 3 parts. For example, a chromosome is represented as ABC. Let A', B' and C' are the reverse order of genes of A, B and C respectively. Then the 3 chromosomes after the mutation are A'BC, AB'C and ABC'

Example depicting the proposed mutation operator:

Chromosome C1= [1 4 6 3] [2 5 8] [7 10 9]
Let cut points are chosen as 4 and 7. Proposed mutation will produce the following 3 chromosomes.
Chromosome C2=3 6 4 1 2 5 8 7 10 9
Chromosome C3=1 4 6 3 8 5 2 7 10 9
Chromosome C4=1 4 6 3 2 5 8 9 10 7
Then the one best chromosome based on value of fitness function is selected.

C. Local Search Strategy with Hill Climbing

Genetic Algorithms are hybridized with the local search technique to speed up the search to find global optimum solution. While designing a hybrid Genetic Algorithm, several issues must be taken into consideration of utilizing local search information [7].Hill Climbing is an optimization algorithm that performs search in the neighborhood of already obtained optimal solution. It is variation of generate and test approach with added heuristic function to guide the search towards the optimal solution. Here, Hill Climbing is applied after selection operation to 50% of most optimal solutions based on the value of fitness function. This also reduces the cost of applying unnecessary hill climbing on solutions that fall outside the promising regions of search space [7].

The procedure of proposed hybrid GA is illustrated below:

```
begin TSP
        Create initial population randomly
        While generation number < n do
                / / n =max number of generations
                begin
                        Tournament Selection with elitism
                        Hill climbing to top 50 % population
                        Variation of PMX crossover
                        Variation of inversion Mutation
                        Replacement
                end
                Output the best individuals found
end TSP
```

Figure 1: Proposed Hybrid GA

Elitism has been applied in the proposed approach with the tournament selection. Elitism is the method which copies the first best chromosome or the few best chromosomes to the next generation directly [9]. It ensures that quality of solution does not degrade from one generation to next generation. In this paper, one best fitted chromosome is copied directly to next generation and the rest is done in classical way.
The procedure for Hill Climbing is as follows:

```
Procedure Hill Climbing (current)
// Current – Currently known optimal solution
While (termination criteria is not met) do
        New ← neighbor (current)
        If (fitness (New) > fitness (current))
                Current ← New
        End if
End while
```

Figure 2: Pseudo Code of Hill Climbing\

IV. COMPUTATIONAL EXPERIMENTS & RESULTS

A. Parameters Setup

In order to test the performance of the proposed hybrid genetic algorithm, four problems are taken from TSPLIB [2] including eli76, eli101, kroa150 and rat195. Simulation parameters are used as follows:
Population Size: 20
Probability of crossover: 0.9
Probability of mutation: 0.05
Encoding: Permutation encoding
Selection Method: Tournament selection with tournament size is equal to 2
Number of generations: 150 and 300
Fitness Function: 1/Tour Length

B. Experimental Results

Following table and figures record the results:

GA Approach		SGA PMX Tour Length	SGA Order Tour Length	SGA Cyclic Tour Length	Propose HGA Tour Length	Figure Number
Gen=150	eli76	1120	1038	965	617	Fig. 3
	eli101	1409	1546	1406	790	Fig. 4
	kroA150	114938	105695	108930	46418	Fig. 5

	rat195	11014	10825	11028	4925	Fig. 6
Gen=300	eli76	878	828	777	584	Fig. 7
	eli101	1173	1260	1104	723	Fig. 8
	kroA150	90186	89343	79390	35282	Fig. 9
	rat195	8462	9129	8159	3883	Fig. 10

Table I: Comparison of tour length between Pure GA and proposed Hybrid GA

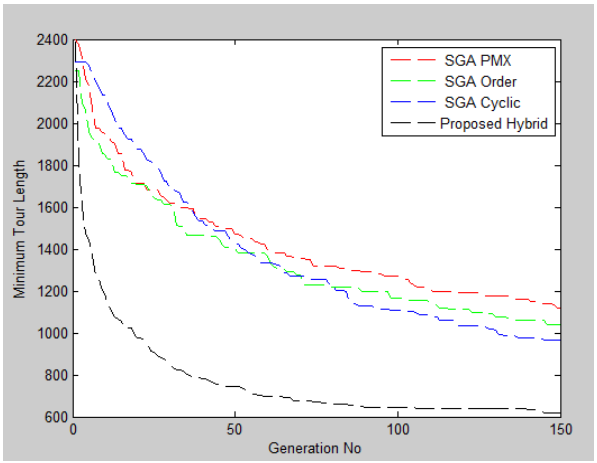

Figure 3 Comparative convergence of eli76

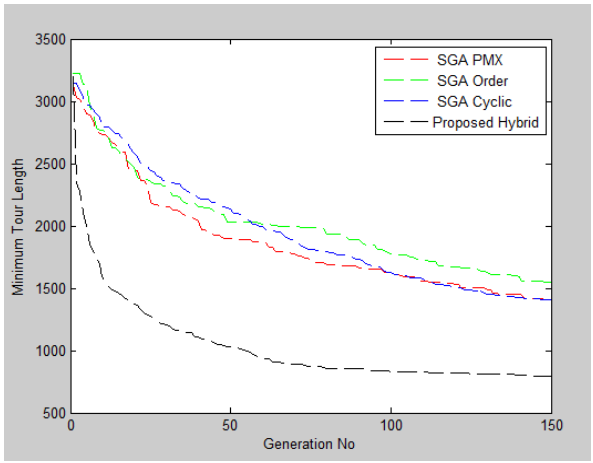

Figure 4 Comparative convergence of eli101

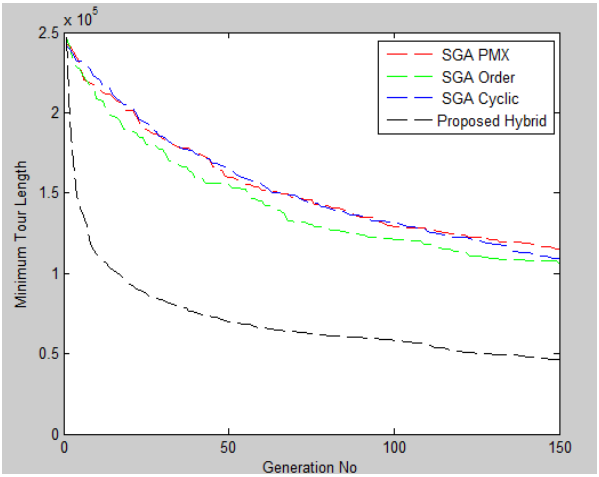

Figure 5 Comparative convergence of kroa150

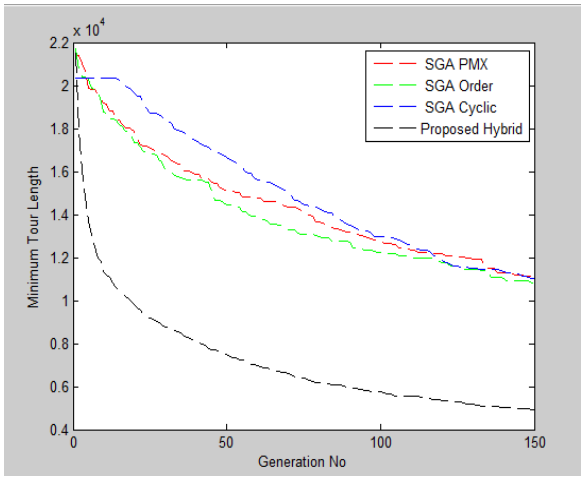

Figure 6 Comparative convergence of rat195

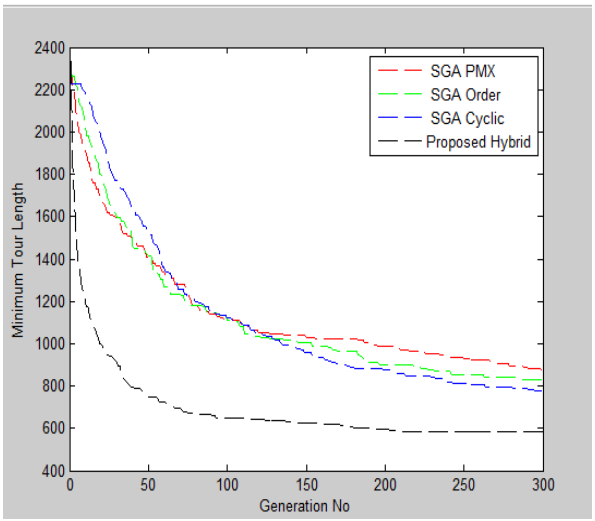

Figure 7 Comparative convergence of eli76

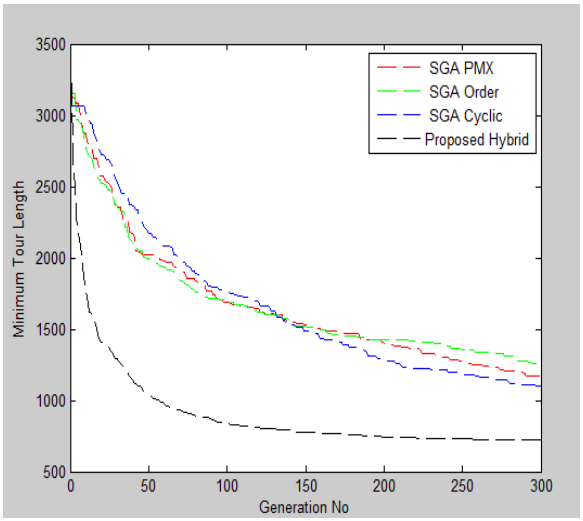

Figure 8 Comparative convergence of eli101

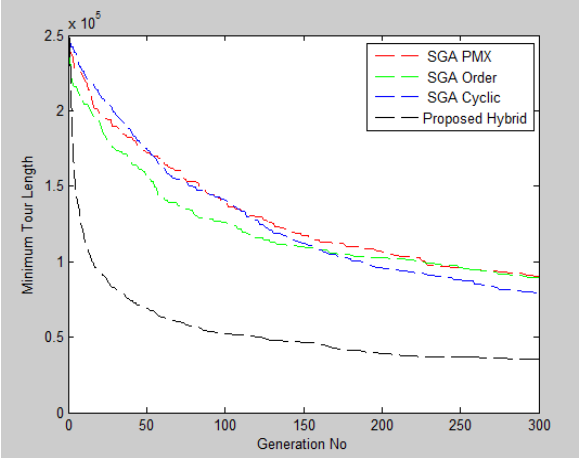

Figure 9 Comparative convergence of kroa150

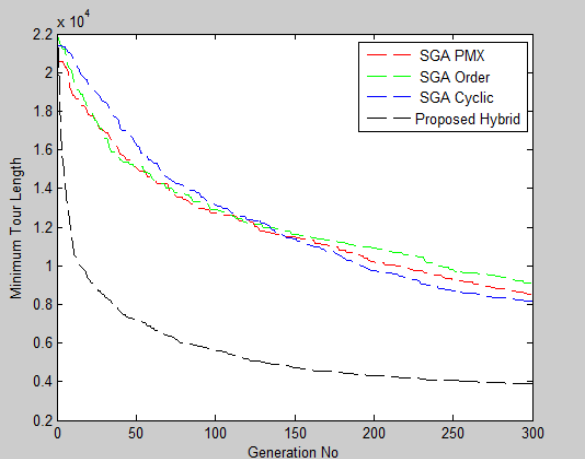

Figure 10 Comparative convergence of rat195

V. CONCLUSION AND FUTURE WORK

This paper compares the proposed hybrid GA with pure GA. Three crossover operators are considered in pure GA for comparison namely PMX, Order and cycle crossover. It was found that proposed hybrid GA is effective in terms of convergence towards the optimal result. The proposed variation of crossover and mutation has the benefit of retaining the good solutions by using the value of fitness function. In future proposed approach can be tested and implemented on different NP Hard problems like vehicle routing problem, Job Shop Scheduling problem and knapsack problem. Study can also be conducted to analyze the performance of algorithm with hill climbing is applied to different percentage of population.

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