Novel Approach to Polygamous Selection in Genetic Algorithms

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Abstract. Genetic algorithms are adaptive heuristic search algorithms which have been successfully used in a number of applications and their performance are mainly influenced by selection operator. In this paper three variants of polygamous selection, a special case of elitism where the best individual of the population act as one parent for mating with other chromosomes in all crossover operations, are proposed, their performances are compared along with other selection approaches such as roulette wheel, rank, annealed etc.

Keywords: Elitism, Genetic Algorithms, Polygamy, Selection.

1 Introduction

Genetic algorithms are random search algorithms that were invented by John Holland in 1975 [1]. They follow the genetic process of biological evolution. They were defined as adaptive heuristic search algorithms based on the evolutionary ideas of natural selection and natural genetics by David Goldberg [2]. A typical genetic algorithm is composed of three main operators – Selection, Crossover and Mutation. A genetic algorithm is an iterative procedure which operates on population of constant size where each individual has a specific fitness value depending on the objective function. Individuals from current generation are selected according to their fitness value and produce offsprings using crossover to form the next generation of individuals. Mutation operator maintains diversity in population. Genetic algorithms are based on Darwin's principle of "Survival of Fittest", so better fit individuals are carried forward to next generation leaving behind the less fit ones [2]. The process of forming next generation of individuals by replacing or removing some offsprings or parent individuals is done by replacement operator. Genetic algorithms iterates till maximum number of generations is reached or until the optimal solution is achieved.

<u>Basic Genetic Algorithm:</u>

```
Procedure GA(tourlength, θ, n, r, m, ngen)
//tourlength function evaluates individuals in population
//θ is the fitness threshold to determine when to halt
//In TSP, best fitness is minimum value of tourlength
// n is the population size in each generation (say 100)
```

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```
// r is crossover probability(0.7)& m is mutation rate (0.01)
// ngen is total number of generations
   P := generate n individuals at random
// h represents the chromosome in the population P
   i:=1
   while (min(tourlength(hi)) < θ or i <= ngen do
   {  //Reproduction step:
      //Select n/2 individuals of P as per any selection method
      Call Select(P,n,r) and store in L
      Probabilistically select (1-r) n individuals from L
      and store in k1 and k2   //mating pool for crossover
      foreach pair selected (k1,k2), produce two offspring
      by applying PMX crossover operator and add to S
      //mutation step
      Choose m% of S and Mutate chromosomes by inversion
      P := S   //next generation depending on replacement
      i:=i+1
   }
   Find b such that tourlength(b) = min(tourlength(hi))
   return(b)
end proc.
```

In this paper, a different selection approach – polygamy is considered. Polygamy refers to special case of elitism where the best individual of the population is treated as one parent for mating with other chromosomes in all crossover operations. The paper proposes three different approaches of polygamy with an aim to choose the best chromosome so as to retain good characteristics in the new generation and compares the performance of genetic algorithm in different cases proposed. The paper is organized in the following sections. Research work related to polygamy and replacement strategies have been reviewed in section 2. Different notations used throughout the paper are given in section 3. Algorithms of different approaches for selection and polygamy are described in section 4. These approaches are implemented on Travelling Salesman Problem to test. Implementation procedure and computational results are provided in section 5 and concluding remarks are given in section 6.

2 Related Work

Polygamy is a mating system in which a single individual of one gender mates with several individuals of opposite gender. Polygamy has two forms – Polygyny and Polyandry. In Polygyny, one male individual mates with several females of the respective species as in elk, fur seals etc. In Polyandry, one female mates with more than one male during a breeding season like Honey bees [3]. An improved genetic algorithm based on polygymy was proposed by Gu Min and Yang Feng wherein the population had one father , many mothers and some bachelors. Father and mothers mated with each other using crossover and bachelors participated only in mutation operation [4]. Al jaddan et al. applied different selection operators on eight test function and compared the performance of genetic algorithm in terms of various criteria like convergence, time, and reliability [5]. Generational and Steady state are two forms of replacement. In generational replacement, entire population of genomes is replaced at each generation. In this case, generations are non-overlapping. In steady state replacement, new individuals are inserted in the population as soon as they are created [6,7]. The (μ+1) approach was the first steady state replacement strategy introduced by Rechenberg in 1973 and had parent population greater than one (μ > 1) [8]. De Jong introduced the generation gap G as a parameter to genetic algorithm where a percentage of population is chosen via fitness proportionate selection to undergo crossover and mutation[9]. Schwefel proposed (μ+λ) and (μ,λ) models that correspond to overlapping and non-overlapping populations [10].

3 Notations and Definitions

Some of the symbols and notations used in the paper are listed below:

Symbol	Meaning	Symbol	Meaning
ngen	Total number of generations	F_{best}	Best fitness value
nogen	Current number of generation	F_{avg}	Average fitness value
N	Total population size		
RWS	Roulette Wheel selection with generational replacement	RS	Rank selection with generational replacement
AS	Annealed selection with generational replacement	$F_{i,j}$	Fitness of jth individual in ith generation
mpool	Number of chromosomes in mating pool	$FX_{i,j}$	Fitness of individual in Annealed selection

4 Various Approaches for Selection, Polygamy and Replacement

Selection operation is used to choose the best fit individuals from the population for crossover operation. Selection of individuals in the population is fitness dependent and is done using different algorithms [11]. Selection chooses more fit individuals in analogy to Darwin's theory of evolution – survival of fittest [12]. There are many methods in selecting the best chromosomes such as roulette wheel selection, rank selection etc. Replacement operator chooses the offsprings that will stay in the population and the individuals that would be replaced to form the next generation. Polygamy is special case of selection and has biological evidences in natural evolution. In this case, the best fit individual in the current generation would act as one parent in all the crossover operations to create the next generation. The paper analyses the comparison of roulette wheel selection, rank selection and annealed selection [13] and effect of these selection operators in combination with polygamy, μ+λ polygamy and extended μ+λ polygamy.

4.1 Roulette Wheel Selection

Roulette wheel selection technique places all the individuals in the population on virtual roulette wheel according to their fitness value [2,9,11]. Roulette wheel selection uses exploitation technique and individuals with higher fitness have more probability of selection.

4.2 Rank Selection

Rank Selection sorts the population first according to fitness value and ranks them. Then every individual is allocated selection probability with respect to its rank [14]. Individuals are selected as per their selection probability. It is exploratory in nature.

4.3 Annealed Selection

The annealed selection approach is to blend the exploratory and exploitive nature of rank selection and roulette wheel selection respectively. The perfect blend of the two approaches is achieved by computing fitness value of each individual as per the current generation number as under:

$$FX_{i,j} = F_{i,j} / ((ngen+1) - nogen) \quad (4)$$

Selection pressure is changed with changing generation number [13].
Algorithm for annealed selection is:

```
Annealed selection
       Set l=1, j=1, i=nogen
       While j<=N
       {    FXi,j = Fi,j / ((ngen+1)-nogen)    }
       Set j=1, S=0
       While j<=N
       {     S=S+FXi,j  }
       While l <= mpool
       {    Generate random number r from interval (0,S)
            Set j=1, S=0
            While j<=N
            {      cj=cj-1+FXi,j
                   If r<=cj, Select the individual j
            }
            l=l+1
      }
```

4.4 Polygamy

Polygamy is special kind of selection which has biological evidences in nature as in the case of honey bee, lion, leech etc. This approach is based on the biological fact that selecting the most fit parent would lead to fitter offsprings for the next generation [3]. Salient Features of Polygamous selection are:

- The best fit individual of the population is selected as one parent and will participate in all crossover operations.
- Second parent is selected using any of the three selections discussed earlier.
- The best parent selected for polygamy participates in crossover in its respective generation only.

- Next generation of population is generated using generational replacement.

Module selecting the best parent is as follows:

```
Polygamy(P,n)
    Select hi having min(tourlength) and store in k1
    Call Select(P,n,r) and store in L
End.
```

Outline of Genetic algorithm implementing polygamy is given below:

```
Procedure GA(tourlength, θ, n, r, m,ngen)
      :
      //Reproduction step:
      Call Polygamy(P,n)
      :
end proc.
```

4.5 μ+λ Polygamy

μ+λ polygamy is combination of polygamy and competitive elitism. Salient features of μ+λ polygamy are:

- The best individual from the pool of current and the previous generation is selected as one parent that will participate in all crossover operations.
- The second parent is selected depending on earlier discussed selection methods.
- The best parent selected can participate in crossover in successive generations.
- Offsprings generated follow μ+λ replacement strategy to form the next generation.

Genetic algorithm implementing μ+λ polygamy is given below:

```
Procedure GA(tourlength, θ, n, r, m,ngen)
      :
      //Reproduction step:
      Call Polygamy(P,n)
      :
      pb:=min(tourlength(hi))
end proc.
```

4.6 Extended μ+λ Polygamy

Polygamous selection leads to premature convergence in certain cases. This may be due to loss of diversity by repeated selection of same best parent in each generation. Extended μ+λ polygamy suggests a novel idea of polygamy by limiting the best parent to participate in crossover in consecutive generations. Its salient features are:

- The best individual from the pool of consecutive generations is selected as one parent that will participate in all crossover operations.
- If the best parent selected is same as that of last crossover, then it is replaced by second best individual in the respective generation.

- Second parent for crossover is selected using any of the above selection methods.
- Best parent selected cannot participate in crossover in consecutive generations.
- Offsprings that form the next generation follow μ+λ replacement strategy.

Genetic algorithm implementing extended μ+λ polygamy is given below:

```
Procedure GA(tourlength, θ, n, r, m,ngen)
      :
      Call Polygamy(P,n)
      If pb=k1,replace k1 by next hi having min(tourlength)
      :
      pb:=min(tourlength(hi))
end proc.
```

5 Implementation and Observation

In this paper, code for genetic algorithm is developed using MATLAB for benchmark TSP using Eil51 population as test problem. The code was run for 100 generations using same parameters in different cases of selection and performance was compared in terms of minimum tour length (F_{best}) and average tour length (F_{avg}). Table 1 lists the data for F_{best} and F_{avg} for Eil 51 population in different approaches of selection. Fig. 1 depicts the comparison of average tour length F_{avg} and Fig. 2 depicts the comparison of minimum tour length F_{best} in twelve different cases.

Table 1. Comparison of Different Approaches for Eil 51 population

Method	**Favg**	**Fbest**
RWS	1720.973	1371.3383
RS	1667.4847	1387.9336
AS	1515.5429	1315.1413
Polygamy +RWS	1230.7096	1214.776
Polygamy +RS	1106.0641	1073.5741
Polygamy +AS	1190.3857	1171.1816
μ+λ Polygamy +RWS	1201.0688	1183.7948
μ+λ Polygamy +RS	1128.3626	1094.5386
μ+λ Polygamy +AS	1300.7513	1288.4802
Extended μ+λ Polygamy +RWS	1198.0254	1138.488
Extended μ+λ Polygamy +RS	1442.51	1284.19
Extended μ+λ Polygamy +AS	1154.1404	1132.5966

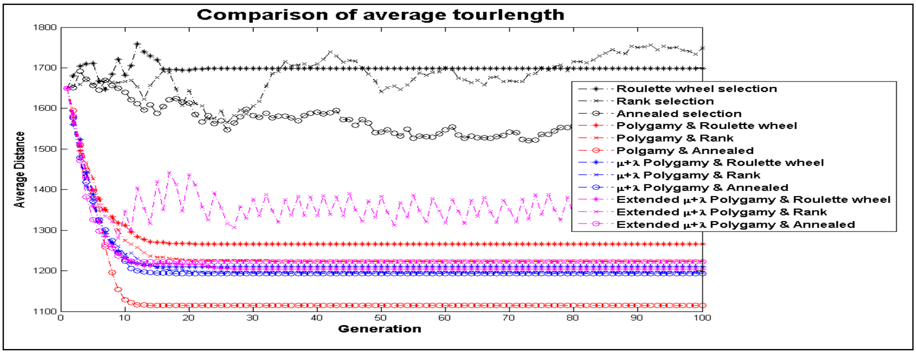
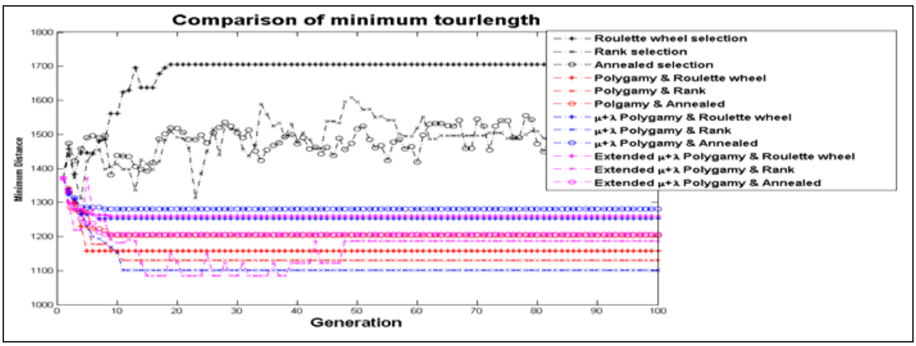


Fig. 1. Average Tour Length vs. Generation



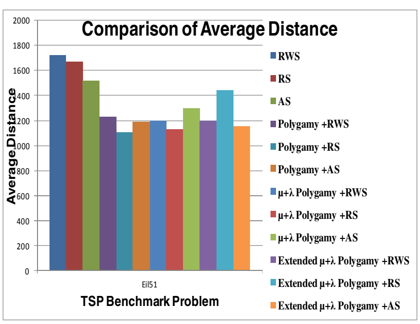


Fig. 3. Comparison of Average tour length

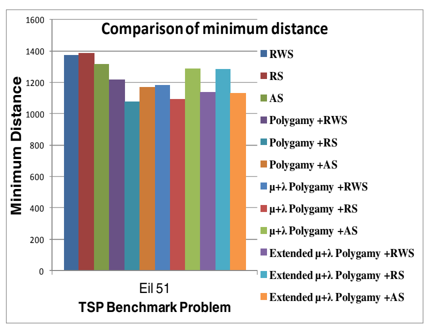


Fig. 4. Comparison of Minimum tour length

It was observed that among the three selection approaches considered, the annealed selection is more promising. The results improved drastically on introduction of polygamy. It is very much clear from the graphs Polygamy is better than simple selection. On further experimentation with μ+λ and Extended μ+λ polygamy, it was observed that the results improved and were even better than or at par with polygamy.

6 Conclusion

The paper compared three different approaches for polygamy using different replacement strategies. It was found that polygamy resulted in better results and detailed analysis suggested that polygamy with generational update led to early convergence due to lack of diversity. Further, the two modified polygamy techniques were compared using μ+λ replacement and resulted in better performance than generational update. μ+λ replacement with polygamy has its biological evidence in case of lions. Extended μ+λ polygamy maintained diversity in population and gave better results. Seeing this result, it can be thought of to have varying dying periods for the best parent in polygamy. This may lead to introduction of diversity in population and would delay or avoid premature convergence.

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