Hybrid Polygamous Selection: An Improvement in Genetic Algorithm

Manju Sharma, Sanjay Tyagi

Abstract— Genetic algorithms are the adaptive heuristic search algorithms that have been used in a number of optimization problems successfully. Performance and convergence speed of a genetic algorithm depends on the operators used for selection, crossover and mutation. Selection operator is used to select individuals from a population, so as to create a mate pool for reproduction process Polygamy is a special case of elitism in which the best individual from each generation is selected and participated in the crossover with all other individuals in the mating pool selected by any other selection technique.Polygamous selection mainly leads to the premature convergence. In this paper a hybrid polygamous selection is proposed, in which the individual selected by polygamy technique undergoes refinement through the local search technique before crossover. The experiment has been conducted using benchmark TSP problems and the implementation has been carried out using MATLAB. Result shows that the proposed hybrid polygamous selection performs better than the existing selection used in genetic algorithm in terms of producing more optimal solution and better convergence speed.

Index Terms— Genetic algorithm, Hybrid genetic algorithm, Memetic algorithm, Polygamy, Roulette wheel, Selection

1 Introduction

Evolutionary algorithms are the ones that follow the Darwin concept of "Survival of the fittest" mainly used for optimization problems for more than four decades [1]. Evolutionary algorithms are heuristic search algorithms which do not always guarantee to provide the exact optimal solutions, but they will definitely find better optimal solutions within less amount of time. Some of them are Genetic algorithms, Genetic programming, Evolutionary programming Evolutionary Strategies etc. Genetic algorithms are adaptive optimization algorithms that mimic the process of natural selection and genetics [2].

GA works on the population of fixed length strings. The strings are analogous to chromosomes in genetics. Chromosomes are made up of genes and the values of genes are called alleles. There is a fitness value associated with each chromosome. A generic genetic algorithm consists of following operations namely: Initialization, Selection, Reproduction and Replacement. Initialization refers to the generation of initial population by using some suitable encoding scheme. Selection operator selects the individuals randomly or according to their fitness. Crossover and mutation are used to maintain balance between exploitation and exploration. During replacement the old individuals are replaced by some new offspring. The cycle stops when the optimal result is achieved.

Genetic Algorithms are based on Darwin theory of evolution. So, according to the principle of survival of fittest [2], the better individuals have more chances to survive and passed to new generation than the worst individuals.Elitism prevents the best individual to undergo the reproduction process, so as to preserve them until next best one is not discovered. Elitism mainly speeds up the search process, but the main drawback of elitism is the decrease in diversity of the population that leads to the premature convergence.

Polygamy is a special case of elitism where the best individual is selected as one parent for mating with other indiviuals selected through normal selection technique.But the selection of best individual in each case also leads to the loss of diversity that causes premature convergence. Good balance between exploitation and exploration has to be maintained while implementing polygamy and elitism. In this paper a novel hybrid polygamous selection is proposed, in which the individual selected by polygamy technique undergoes refinement through the local search technique before crossover. 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.

The paper is organized in the following sections. In section 2, literature review is given on different researches related to polygamy, elitism, selection and hybrid genetic algorithm. Different selection methods used in addition to polygamy along with hybrid genetic algorithm are described in section 3. Algorithms related to simple genetic algorithm, genetic algorithms implementing polygamy and proposed hybrid polygamous selection based genetic algorithm are presented in section 4. Implementation and computational results are given in section 5 and concluding & Future work is given in section 6.

2 Literature Review

In 1975, De Jong proposed the concept of Elitism in which the best quality individuals passes from one generation to another, so as to reduce the problem of genetic drift. Elitism preserves the individuals to lose their best quality due to crosso-

- *Manju Sharma is currently pursuing M.Tech in Computer Science and Applications in Department of Computer Science and Applications, Kurukshetra University, Kurukshetra, Haryana, India. E_mail: manjusharmaknl@gmail.com*
- *Sanjay Tyagi is currently working as an Assistant professor in Department of Computer Science and Applications, Kurukshetra University, Kurukshetra, Haryana, India. E_mail: tyagikuk@yahoo.com*

ver and mutation De Jong introduced several elitist models to copy the best individual from one generation to another generation. The elitist model (R2) improved the offline as well as online performance. R2 model combined with R3 model (expected value model) to form elitist expected value model (R4) [3]. Sharmishtha et al. proposed an elitist generational genetic algorithm based iterative procedure for computing the non linear least squares estimates [4]. Results from simulation and real life examples indicated the better performance of proposed technique.

Ramakrishna and Ahn [5] proposed two elitism based algorithms namely persistent elitist compact genetic algorithm (peCGA) and non persistent elitist compact genetic algorithm (neCGA) to solve the problem associated with inadequate memory in CGA. Simple genetic algorithm & compact genetic algorithm were compared and was observed that the elitism improved the convergence speed and quality of solution. It was found that the two proposed algorithms could search the search space speedily and efficiently without any memory requirement.

Gu Min and Yang Feng proposed a genetic algorithm based on polygymy – one father, many mothers and some bachelors. Crossover occurs between father and mothers. Mutation occurs among bachelors. The function optimization results show that the proposed algorithm has higher convergence speed and alleviates the problem of premature convergence [6].Rakesh Kumar and Jyotishree proposed three variants of polygamous selection i.e. polygamy, $\mu + \lambda$ polygamy and extended $\mu + \lambda$ polygamy. Implementation results showed the improvement of proposed variant of polygamy over traditional selection operators [7].

Antariksha [8] 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 based on Tabu search technique to solve the maintenance scheduling problem. The proposed MA performs better and can be usefully applied to real problems [9]. Malin et al [10] 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.

Manju Sharma and Sanjay Tyagi proposed a selective initialization based hybrid algorithm that supplies more fit individuals in the beginning phase itself. The experiment has been conducted using TSP problem. The Implementation result shows that the proposed memetic algorithm performs better than the existing initialization scheme in terms of better solution [11].

3 Selection, Polygamy & Memetic Algorithm

Selection is the process of selecting the individuals from the population that will create the offspring. Selection is done with a hope that the individual with high fitness value will reproduce to generate fitter offspring. But, there is a need to balance the selection pressure. High selection pressure sometimes leads to premature convergence and low selection pressure will results in slow convergence. In literature different selection methods are given namely- roulette wheel selection, rank selection, tournament selection etc.

3.1 Roulette Wheel Selection

In Roulette wheel selection [12], all the individuals are placed on the roulette wheel having a marker according to their fitness. A portion of wheel is assigned to each individual according to its fitness proportion. The individual with high fitness value occupies more portion of wheel. Then the wheel is spinned. The individual, where marker stops, is selected. The Roulette wheel selection focuses only on exploitation, so it leads to premature convergence and loss of diversity.
Probability of selecting the i^{th} individual is

$$P_i = F_i / \sum_{j=1}^{n} F_j$$

F_i = fitness of i^{th} individual
n = number of individuals.

3.2 Polygamy

Polygamy is a mating system in which a single individual of one gender mates with several individuals of opposite gender to produce offsprings. Polygamy is found to be beneficial genetically in various species [13]. Polygyny is a form of polygamy in which one male individual of a species mates with several females of same species. Polygyny is commonly seen in different species like lion, dog, elk, fur seals, some baboons and many more. Polyandry is another form of polygamy in which female individual mates with more than one male individual during a breeding season, resulting in offsprings of more than one father. Honey bees polyandrous because a queen bee typically mates with more than one male that maintains diversity in the colony.

Similar concept is used in genetic algorithm, where polygamy is a special case of elitism that selects the best individual from each generation and participated in the crossover with all other individuals present in the mating pool selected by any other selection technique.

3.3 Memetic Algorithm

Incorporating problem specific information in a genetic algorithm at any level of genetic operation forms a hybrid genetic algorithm [14]. The technique of hybridization of local search and global genetic algorithm is memetic algorithm (MA). MA is motivated by Dawkins notation of a meme. A meme is a unit of information that reproduces itself as people exchange ideas [15]. MA binds the functionality of GA with several heuristic's search techniques like hill climbing, simulated anneal-

ing, Tabu search etc. A number of issues should be carefully addressed when an effective hybrid genetic algorithm is constructed. Two popular ways of hybridization depends on the concepts of "Baldwin effect" [16] and "Lamarckism" [17].
According to Baldwinian search strategy, the local optimization can interact and allow the local search to change the fitness of individual, but genotype itself remains unchanged. Baldwinian search also have the effect of obscuring genetic differences and hindering the evolution process. This is known as Hindering effect [18]. This occurs as a result of different genotype mapping to the same phenotype. According to Lamarckism, the characteristics acquired by individual during its lifetime may become heritable traits. According to this approach, both the fitness and genotype of individuals are changed during local optimization phase. Most of the memetic algorithms are based on Lamarckism approach of hybridization.

3.4 Proposed Hybrid Polygamous Selection

In the proposed hybrid polygamous selection, individual selected by polygamy technique undergoes refinement through the local search technique before crossover. Polygamous selection mainly leads to the loss of diversity. In proposed algorithm, hill climbing local search is applied to each chromosome selected through polygamy so as to replace the worst building blocks with better building blocks (genes). The algorithm uses the Lamarckism approach of hybridization in which both the genotype and fitness of individual are changed.

4 ALGORITHMS

This section discussed the different algorithms used for implementation.

4.1 Roulette wheel Selection

Procedure RW (P, num)
// num = number of individual in population
// matepool = matepool size
// Cum_k = cumulative fitness

```
i=1, j=1, k=1
While (i <= num)
        {
                sum = sum + Fi
        }
While (j <= matepool)
        {
                r=rand( 0, sum);
        k=1;
        While (k <= num )
        {
        Cumk = Cumk-1 + Fk
        If (r <= cumk)
        {
        Select kth individual
        }
        j=j+1
        }
        End procedure
```

4.2 Simple Genetic Algorithm

Procedure SGA (fitfxn, n, Pc, Pm)
// fitfxn – fitness function to evaluate chromosome
// n – size of population in each generation
// Pc – crossover probability
// Pm – mutation probability

```
Encode the solution space
P = Initialize population
gen=1
while gen <= mxgen
{
 // Call roulette wheel selection to create mating pool of
 size
        L= RW (P, n)
 // Apply PMX crossover n/2 times
        C = Crossover (L, n, Pc)
 //Apply Inversion Mutation
         M= Mutation (C, Pm)
 //Apply generational replacement
        Replace(P, M, n)
//Find best individual in generation
        z(gen):=min(P)
gen = gen+1
}
best =min(z)
// Optimal solution
End procedure
```

4.3 Genetic Algorithm with polygamy

Procedure PGA (fitfxn, n, Pc, Pm)
// fitfxn – fitness function to evaluate chromosome
// n – size of population in each generation
// Pc – crossover probability
// Pm – mutation probability

```
Encode the solution space
P = Initialize population
gen=1
while gen <= mxgen
{
 // Best individual to be a parent in polygamy
        king:=min(fitfxn(P))
 // Call roulette wheel selection to select other individuals
        L= RW (P, n)
 // Apply PMX crossover n/2 times
        C = Crossover (L, king, n, Pc)
 //Apply Inversion Mutation
         M= Mutation(C, Pm)
 //Apply generational replacement
        Replace (P, M, n)
//Find best individual in generation
        z(gen):=min(P)
gen=gen+1
}
```

best=min(z)
// Optimal solution
End procedure

4.4 Hybrid Polygamous Selection

Procedure HPGA (fitfxn, n, Pc, Pm)
// fitfxn – fitness function to evaluate chromosome
// n – size of population in each generation
// Pc – crossover probability
// Pm – mutation probability

Encode the solution space
P = Initialize population
gen=1
while gen <= mxgen
{
// Best individual to be a parent in polygamy
king:=min(fitfxn(P))
// Apply local search to above selected parent
hybrid:=localsearch(king)
// Call roulette wheel selection to select other individuals
L= RW (P, n)
// Apply PMX crossover n/2 times
C = Crossover (L, hybrid, n, Pc)
//Apply Inversion Mutation
M= Mutation (C, Pm)
//Apply generational replacement
Replace(P, M, n)
//Find best individual in generation
z(gen):=min(P)
gen=gen+1
}
best=min(z)
// Optimal solution
End procedure

5 Implementation & Observations

In this paper, MATLAB code is developed for genetic algorithm. The problem considers is the Travelling salesman problem. Travelling salesman problem (TSP) is one of the important NP hard problems often used as a benchmark for optimization techniques. TSP has several applications like planning, logistics, manufacture of microchips and DNA sequencing. TSP problem is to find the Hamiltonian Path or shortest distance through a set of vertices, such that each vertex is visited exactly once. Code considers the benchmark TSP problems namely Oliver30, EIL51 & EIL76 as the test problem. Parameters used for implementation are-

- Population size (n) : 10
- Encoding: Permutation Encoding
- Maximum Generation: 500
- Crossover: PMX crossover
- Crossover probability (Pc=0.7)
- Mutation probability (Pm=0.01)

Average and minimum Tour length is computed in each generation to check the performance in 3 selection stratregies namely: Simple genetic algorithm using roulette wheel selection (SGA), Genetic algorithm using polygamous selection (PGA) and hybrid polygamous genetic algorithm (HPGA).

Figure 1, Figure 3 and Figure 5 depicts the comparison of minimum tour length for Oliva30, EIL51 and EIL76 respectively,whereas Figure 2, Figure 4 and Figure 6 depicts the comparison of average tour length for Oliva30, EIL51 and EIL76 respectively in three different selection approaches for 500 generations.

Table 1 list the detailed data for six different problem generations and analyse the performance of the three approachs for Oliver30. Table 2 and Table 3 list the detailed data for for EIL51 and EIL76.

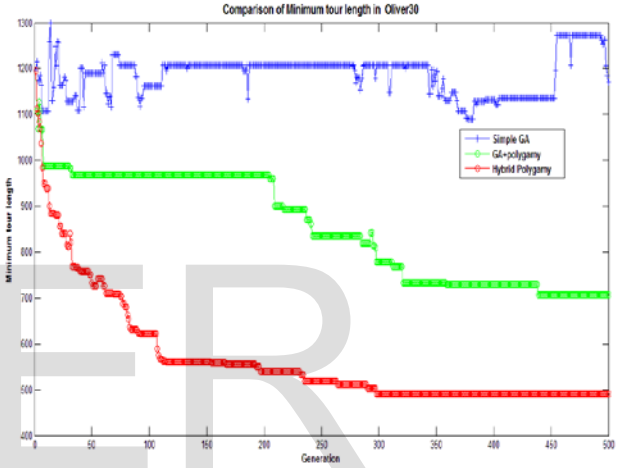

Fig. 1. Comparison of minimum tour length in Oliver30

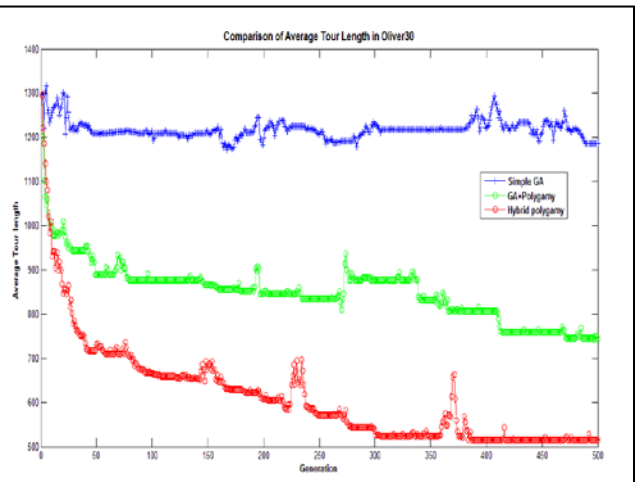

Fig. 2. Comparison of average tour length in Oliver30

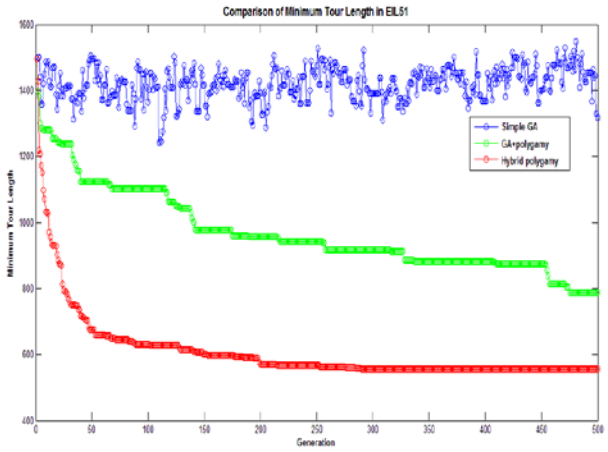

Fig. 3. Comparison of minimum tour length in EIL51

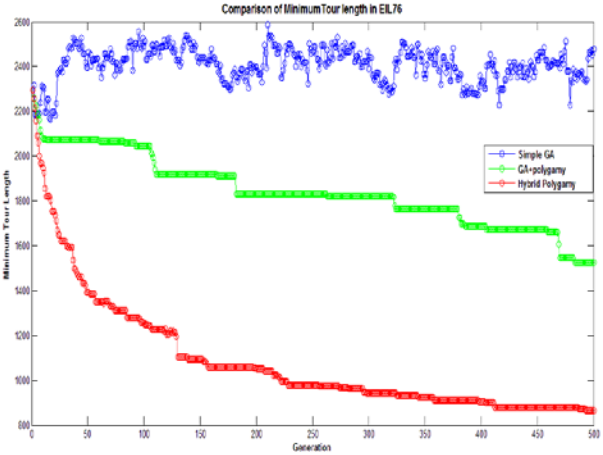

Fig. 5. Comparison of minimum tour length in EIL76

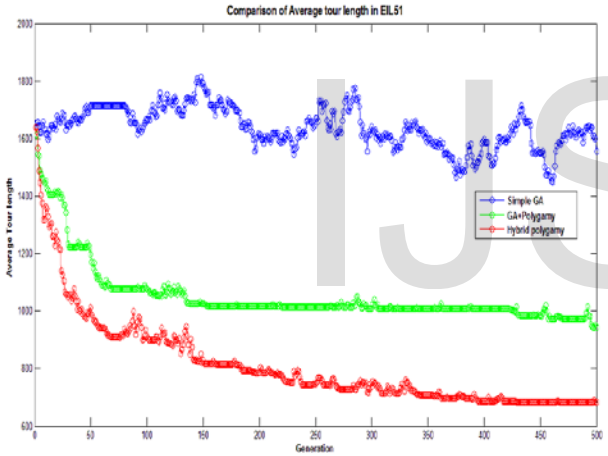

Fig. 4. Comparison of average tour length in EIL51

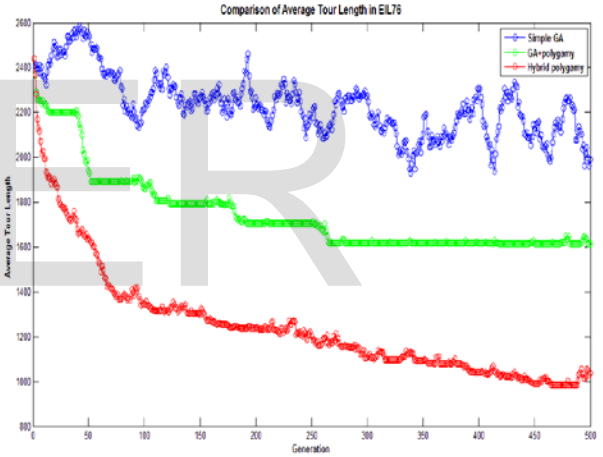

Fig. 6. Comparison of average tour length in EIL76

TABLE 1
COMPARISON OF MINIMUM TOUR IN DIFFERENT APPROACH FOR OLIVER30

Gen	SGA	PGA	HPGA
50	1209	956.7	750.4
100	1187	905.6	569.1
200	1125	868.1	563.5
300	1087	735.8	546.5
400	1075	725.4	532.0
500	1090	706.2	491.1

TABLE 2
COMPARISON OF MINIMUM TOUR IN DIFFERENT APPROACH FOR EIL51

Gen	SGA	PGA	HPGA
50	1410	1275	1065
100	1380	1176	840.3
200	1339	986	734
300	1241	871	708.3
400	1243	806	619
500	1240	788.3	555.3

TABLE 3
COMPARISON OF MINIMUM TOUR IN DIFFERENT APPROACH FOR EIL76

Gen	SGA	PGA	HPGA
50	2416	1850	1498
100	2376	1808	1354
200	2250	1767	1193
300	2204	1628	1188
400	2187	1577	939.8
500	2105	1528	865.1

It has been observed from the Figures and Tables that the proposed Hybrid Polygamous Selection has outperformed genetic algorithm as well as Polygamy in terms of convergence and optimal solution. The proposed Hybrid selection maintains more diversity in population and prevent algorithm to stick in local optima and genetic drift problem. The genetic algorithm usually results in premature convergence due to finite population size. But in proposed hybrid algorithm, the individual selected by polygamy as one of the parent undergoes refinement through hill climbing local search. This results in the incorporation of better building blocks in the chromosome. Hybrid polygamous selection maintains the balance between the exploration and exploitation.

6 CONCLUSION

In nature as well as in genetic algorithm, the key of evolution is the selection of individuals on the basis of some fitness function to create the mating pool. A number of selection mechanisms have been observed in nature and in genetic algorithm. Polygamy, a special case of elitism selection mainly leads to the problem of premature convergence. In this paper a new hybrid polygamous selection mechanism is proposed that incorporates a local search with polygamous selection. Results are promising and show the improvement of hybrid polygamous selection over other two selection operators in terms of optimal solution and prevent premature convergence. The Proposed algorithm can prove to be better for different NP Hard problems also. It can be tested and implemented with different combination of selection, mutation to substantiate its performance.

REFERENCES

[1] J. Holland, *Adaptation in natural and artificial systems*, University of Michigan Press, Ann Arbor, 1975.

[2] D.E. Goldberg, *Genetic algorithms in search, optimisation, and machine learning*, Addison Wesley Longman, Inc., ISBN 0-201-15767-5, 1989.

[3] K.A. De Jong, "An Analysis of the behavior of a class of genetic adaptive system", Phd dissertation, University of Michigan, University Microfilms No. 76/9381, 1975.

[4] S. Mitra and A. Mitra, "A genetic Algorithms based technique for computing the nonlinear least square estimates of the parameters of sum of exponential model", *Expert systems with Applications*, Vol. 39, ISSN 6370-6379, 2012.

[5] C.W. Ahn and R. S. Ramakrishna, "Elitism-based compact genetic algorithms", *IEEE transactions on Evolutionary Computation*, Vol 7, no 4, pp 367-385, , August 2003.

[6] Gu Min and Yang Feng, "An improved genetic algorithm based on polygymy", *Proc. Third International Symposium on Intelligent Information Technology and Security Informatics*, pp 371-373, 2010.

[7] Rakesh Kumar and Jyotishree, "Novel Approach to Polygamous Selection in Genetic Algorithms", *Proc. Springer. International Conference of Information System Designs and Intelligent Applications 2012* , Vol 132 , pp 39-46, , January 2012, doi:10.1007/SCIS 978-3-642-27443-5_5

[8] Antariksha Bhaduri, "A mobile robot path planning using genetic artificial immune network algorithm", *Proc. IEEE. World Congress on Nature and biologically Inspired Computing (NaBIC)*, pp 1536-1539, 2009.

[9] E. K. Burke and A. J. Smith, "A memetic algorithm for the maintenance scheduling problem", *Proc. Springer. International Conf on Neural Information Processing and Intelligent Information*, pp 469-473, 2010.

[10] Malin Bjornsdotter and Johan Wessberg, "A memetic algorithm for selection of 3D clustered featured with applications in neuroscience", *Proc. IEEE. International Conference on Pattern Recognition*, pp 1076-1079, 2010.

[11] Manju Sharma and Sanjay Tyagi, "Selective Initialization: A Novel Genetic-Local Hybrid Approach towards Boosting the Performance of Genetic Algorithm", *Proc. Elsevier.2nd National conference on Advancements in the era of Multidisciplinary systems AEMDS-2013, 6-7* April 2013.

[12] D. E. Goldberg and K. Deb, "A comparative analysis of selection schemes used in genetic algorithms", *Foundations of Genetic Algorithms*, San Mateo, CA, Morgan Kaufmann, pp 69-93, 1991.

[13] Robert John Paxton, "Male mating behaviour and mating systems of bees: an overview", Article published by EDP Sciences, vol 36, pp 145–156, June 2005.

[14] P. Mascato and P. C. Cotta, "A gentle introduction to memetic algorithms", *Handbook of Metaheuristics*, pp 105-144, 2003.

[15] R. Dawkins, "The selfish gene", *Oxford University Press*, Oxford, 1976.

[16] K Ku., M. Mak, "Empherical analysis of the factors that affect the Baldwin effect, Parallel problem solving from nature", *Proc. Berlin, Heidelberg: Springer 5th International Conference, lecture notes in computer science*, pp 481-90, 1998.

[17] G. M. Morris, G. M. Goodsell. , R. S. Halleday et al., "Automated docking using a Lamarckian genetic algorithm and an empherical bending free energy function", *Journal of Computational Chemistry*, vol 19, pp 1639-62, 1998.

[18] G. Mayley, "Landscapes, learning costs and genetic assimilation," *Evolutionary Computation*, vol. 4, pp. 213 - 234, 1996.