Parallel Genetic Algorithm Based Crowding Scheme Using Neighbouring Net Topology

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***Abstract*— In this article, the notion of crowding is employed to maintain stable subpopulations at niches of a multi modal nonlinear function. In this work, we have attempted to parallelize the crowding scheme and hence, propose new concepts of net topology while devising the parallel scheme based on coarse grained parallelization. Besides, we have also proposed a new interconnection model which takes care of the intra deme migration. The use of Generalized Crossover (GC) operator is found to be superior to that of the scheme using two point crossover operators. The effect of different net topology, based on the neighbourhood structure, upon the solution is investigated. It was found that the net topology with second order neighbourhood structure is good enough to yield satisfactory results.**

Key words:*Parallel Genetic Algorithm, Crowding, Clustering*

I. INTRODUCTION

Genetic Algorithms (GAs) and Evolutionary Computation have been extensively used in different fields for solving complex optimization problems[1], [2]. GA based class models have been developed to maintain stable subpopulations at the niches of a multi modal function[3] . Usually these class models are developed based on the notion of crowding and sharing. Although satisfactory results have been obtained by using GA, the major bottleneck is the high computational burden. Hence, the objective of designing parallel GA is two fold: (i)reducing the computational burden and, and (ii) improving the quality of the solutions. The design of parallel GAs (PGAs)involves choices of multiple populations where the size of the population must be decided judiciously. These populations may remain isolated or they may communicate exchanging individuals. This process of dividing the entire population into subpopulations and then providing the mechanism of interaction between them is known as coarse grained parallelism [4], [5]. The takeover times in case of coarse grained Parallel genetic Algorithms have been investigated in [6].

In this article, attempts have been made to parallelize the crowding scheme with a view to accelerate the rate of convergence and the quality of the solution as well. Towards this end, we introduce a notion of neighbouring net topology based on the neighbourhood structure. The parallelization is based on the coarse grain approach. Migration is allowed only among the neighbouring demes as opposed to all the demes of the network. In each deme of the neighbourhood structure , intra deme migration is allowed along with the inter deme migration. This helps the algorithm to converge faster than that of the net using only the inter deme migration. *Generalized Crossover operator (GC)* as proposed by Nanda et al[7] is introduced to explore the diversity and the quality of the solution. The effect of the net structure with different neighbourhood is investigated and compared with that of the fully connected network. It is observed that the network with the second order neighbourhood produces satisfactory results. Since, the migration is allowed among the demes in the selected neighbourhood structure, the computational burden is substantially reduced as compared to a fully connected net. Although, effect of migration policies, rate of migration, number of demes and size of the demes on the quality of the solution has been investigated, for the sake of illustration simulation results are presented only for the migration policy where the Good migrants of a demes replaces the bad migrants of other demes.

II. CROWDING METHOD

In case of nonlinear multi modal function optimization, the problem of determining the global optimal solution as well as the local optimal solution reduces to determining the niches in the multi modal function. Thus the problem boils down to clustering the population elements around the given niches. Some effort has been directed in this direction for last couple of years where new strategies and algorithms are proposed[3], [8], [6].

In the deterministic crowding, sampling occurs without replacement [3]. We will assume that an element in a given class is closer to an element of its own class than to elements of other classes. A crossover operation between two elements of same class yield two elements of that class, and the crossover operation between two elements of of different class will yield either ; (i) one element from both the classes, (ii) one element from two hybrid classes. For example, for a four class problem, the crossover operation between two elements of class AA and BB may result in elements either belonging to the set of classes AA, BB or AB, BA. Hence, the class AB offspring will compete against the class AB parents, the class BA offspring will compete with class BA parents. Analogously for a two class problem, if two elements of class A get randomly paired, the offspring will also be of class A, and the resulting tournament will advance two class A elements to the next generation. The random pairing of two class B elements will similarly result in no net change to the distribution in the next generation. If an element of class A gets paired with an element of class B, one offspring will be from class A, and the other from class B. The class A

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offspring will complete against the class A parent, the class B offspring against the class B parent. The end result will be that one element of the both classes advances to the next generation no net change.

III. NET TOPOLOGY

Our parallelization of crowding scheme is based on the coarse grain approach, where the migration is allowed among all the demes. In other words communication is allowed between a deme and every other deme of the net work. This yields appreciable results but the computational burden is horrendous. Hence, we introduce the notion of neighbourhood and thus various network structure evolves. Population elements of a deme need not migrate to all other demes rather migration is allowed among only the neighbouring demes. Towards this end, we define the order of the neighbourhood. The closest ones of a deme belong to the first order neighbourhood. Similarly, the second order neighbourhood structure with intra deme migration is shown in Figure 1. More and more number of demes are incorporated for the migration with the increase in the order of the neighbourhood. Thus, we evolve different network structure.If we increase the neighbourhood further, eventually we obtain a fully connected network. Thus, the fully connected network can be viewed as a network of special neighbourhood structure. We have studied all the three neigbourhood network together with the fully connected network.

The new model is fully interconnected in the sense that intra deme and inter deme exchanges are allowed. The intra deme migration accelerates the convergence because it allows the proportion of the good individuals to grow rapidly. In a model consisting of more than four demes, each deme is connected to every other deme in the interconnection topology. Thus the proposed model is a fully connected hybrid model based on the notion of Island model with the exception that the neighboring demes take part in migration.

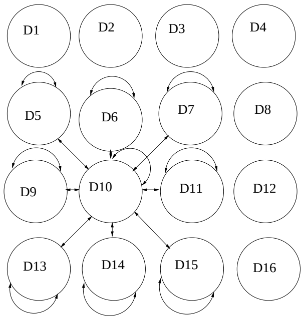

Fig.1: Second order neighbourhood structure

IV. ALGORITHM

The steps are the parallelized Crowding scheme are the following.

1) Initialize randomly population elements of size N.
2) Divide the population space into fixed number of sub-populations and determine the class of individual in each sub-population.
3) i) In the given sub-population, choose two elements at random for Generalized Crossover (GC) and mutation operation.
   ii) Evaluate fitness of each parents and offspring.
   iii) The tournament selection mechanism is a *binary tournament* selection. Among the two parents and offsprings, the set which contains the individual having highest fitness among the four cements is selected to be the set of parents for the next generation.
   iv) Repeat steps (i), (ii), and (iii) for all the elements in the sub-population.
   v) Repeat step (i), (ii), (iii) and (iv) for a fixed number of generation.
4) Step (3) is repeated for each sub-population.
5) Migration is allowed from each deme to every other deme. The individuals are migrated based on the selected migration policy. Numbers of elements to migrate are determined from the selected rate of migration. The elements migrate with migration probability P_{mig}. At last some percentage of individuals of one deme replace the same percentage of individuals of the same deme, this self migration is valid for all demes with a probability of migration P_{smig}. The individuals migrated in self-loop are based on the selected migration policy.
6) Repeat steps 3, 4, and 5 till convergence is achieved. The algorithm stops when the average fitness of the total population is above preselected threshold.

V. RESULTS AND DISCUSSION

In our simulation, We have considered the four class problem given by the following functions; $f(x) = \mid Sin 4\pi x \mid$ $0 \leq x \leq 1$. Simulation is carried out for two cases of net topologies; one consisting of 16 number of demes and the other 25 number of demes. We have investigated the performance of the network with fully connected structure and with $1st, 2nd$ and $3rd$ order neighbourhood structure. The parameters used are: Number of population elements in each deme N=100, Probability of Crossover=0.8, Probability of mutation=0.001, Probability of migration $p_{mig} = 0.9$, probability of self migration $P_{smg} = 0.9$, rate of migration=8$\%$, and the threshold of fitness for the stopping criterion=0.98. In our simulation we have employed only Good-Bad migration policy. Simulation was carried out 40 times with different initial sampling and the average of the 40 experiments is presented. The population of elements converged to their respective peaks as shown in Figure 5. In all the cases we have employed the GC operator. Figure 5 shows the distribution of population for 1st order net topology after convergence. As seen from the figure 2, it is clear that stable subpopulations are maintained at the respective niches and hence proper classification of the four classes. The performance of the net with and without intra deme migration is shown in figure 3. With the intra deme migration the algorithm converges faster than that of net without intra deme migration. Although the initial rate of growth of average fitness is same for both the cases, after few generations the fitness of net with intra deme migration grows faster than that of the net without intrademe migration. This effect is evident from figure 3. Similar effect is also observed in case of 2nd and 3rd order network structure as shown in Figure 7 and 8. Besides, the performance of all the network topologies are compared as shown in figure 4. As observed from figure 4, though the initial rate of growth of fitness is same for all the network but after few generations the fitness grows faster with the increase in neighbourhood structure of the net. In figure 4, NET0 corresponds to the fully connected network. It is clear from figure 4, that the 2nd order net converges after 20 generations and hence in many cases the rate of convergence may be acceptable. The 2nd order Network yields the same solution after 20 generation as opposed to 10 generations for the fully connected network. Hence, the 2nd order network may be acceptable and thus the computational burden is reduced because migration is allowed among the neighbouring demes.

VI. **Conclusions**

In this work, we also have introduced the notion of intra deme migration with a GC operator. The performance of the net topology is investigated while parallelizing the crowding scheme. From our study, it is observed that migration need not be allowed with every deme of the network. Satisfactory results are also obtained with 2nd order neighbourhood structure. Thus the migration will only take place among the neighbouring demes. This reduces the computation burden and thus makes the parallelization more suitable from a practical standpoint.

VII. ACKNOWLEDGMENTS

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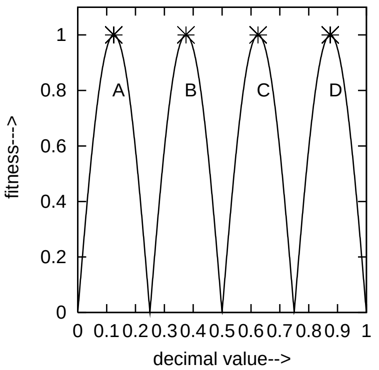

Fig.2: Good-Bad migration policy, A=372,B=372,C=424,D=432,

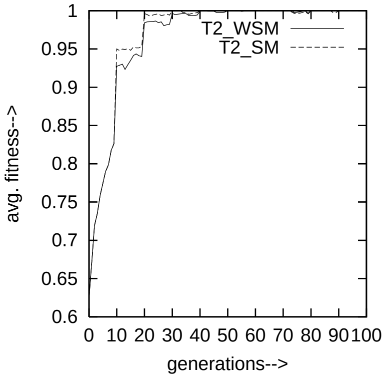

Fig.3: Good-Bad Migration policy, $T1\_SM$ for net topology with second order neighbourhood without self migration and $T2_$SM with self migration .

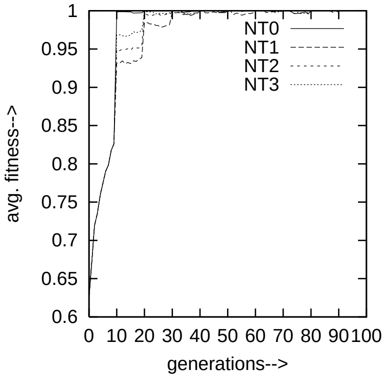

Fig.4: Net topology with 3rd order neighbourhood with and without self migration.

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