Chapter 7

Conclusions and Future scope

This is the concluding Chapter of this Thesis. In section 7.1 the overall conclusions of this study are summarized. In section 7.2 some future scopes are highlighted for future research.

7.1 CONCLUDING OBSERVATIONS

The objective of this thesis is to study the hybridization of Genetic Algorithm (GA) with the Chemo-tactic step of Bacterial Foraging Optimization (BFO). GA is popular evolutionary algorithm and BFO is a recent popular Bio-inspired evolutionary computing technique. The Chemo tactic step of BFO is the key mechanism in BFO. So, an attempt has been made in this regard to hybridize only the Chemo tactic step of BFO in GA cycle. The newly designed algorithm is named as Chemo inspired GA (CGA).

Initially, the hybridization of CGA is compared with the hybridization of GA with entire BFO (i.e. GA-BF) over a set of 4 benchmark functions of various dimensions. Then it is concluded that CGA is more efficient over GA-BF in terms of better objective function value, less CPU time and less number of function of function evaluations. Again from the convergence graph it is observed that CGA converges faster than GA-BF. Further CGA is also compared with the simple GA, over 5 typical benchmark functions. CGA confirms its better performance over GA too.

Reconsidering the earlier recommendation of parameters, the test bed of unconstrained problems is then extended to a set of 22 benchmarking functions. The aim is to testify the stability of the proposed CGA on a wide range of problems. The comparison of CGA is also made with a popular hybridized techniques called Quadratic Approximation based Hybridized Genetic Algorithm (QGA) and simple GA. It has been observed that CGA gives challenging result as compared to QGA and simple GA too in terms of all parameters under consideration.

Then CGA is to be applied on unconstrained real life problems. Firstly, three real life problems have been picked up. They are (i) Optimal capacities of Gas production Facilities, (ii) Solving system of linear equations and (iii) Frequency modulation sounds parameter identification problems. The first real life problem has been solved considering three different search spaces under three different cases. The CGA is compared with GA over those three cases. In remaining two real life problems, CGA has been compared with LXPM and HLXPM. It is concluded that CGA gives similar/better result as compared to GA, LXPM and HLXPM. Secondly, a successful application of CGA is done in the field of Electrical Engineering problem. The considered problem is 'Model Order Reduction (MOR) problem of linear time invariant Single Input and Single Output (SISO) system'. Three case studies of MOR problem have been picked up and solved by CGA, where the reduced models are obtained by minimizing the Impulse Response Energy (IRE) and Integral Square Error (ISE). The results obtained by CGA are being compared with Linearly Increasing Cognitive Differential Evolution (LICLDE), Fitness Based Differential Evolution (FBDE) and other state-of-the-art algorithms. It is shown that CGA outperforms LICLDE, FBDE and few other recent algorithms. Finally, the better performance of CGA is recommended with respect to different measure. Therefore, it is worth to note that CGA is a better candidate over the state-of-the-art algorithms in solving not only benchmark problems but also real life problems, wherever unconstrained optimization is concerned.

Next, the code is developed to make CGA capable of handling constrained optimization problems. The newly generated algorithm is named as Chemo inspired GA for constrained optimization problem (CGAC), where the last 'C' in the abbreviation stands for 'constrained optimization'. The bracket operator penalty method has been used to handle the constraints.

In order to measure the efficiency of the proposed CGAC, a typical set of 15 constrained benchmark problems have been considered. The results of CGAC are compared with LXPMC and HLXPMC, which is the real coded GA (that uses Laplace crossover (LX) and power mutation (PM)) and its hybrid version respectively. The last 'C' stands for constrained optimization. Further, a set of 11 benchmark functions taken for consideration for the comparison of time and function evaluations with some other popular and recent bio-inspired algorithms. The time comparison of CGAC has been done with Improved Genetic Algorithm (IGA), Pareto Strength Evolutionary Algorithm (ZW), Stochastic Ranking Algorithm (RY) and Homomorphous Mapping Method (KM). The function evaluations have been compared with Teaching Learning Based Optimization (TLBO), Multi membered Evolutionary Strategy (M-ES), Particle Evolutionary Swarm Optimization (PESO), Cultural Differential Evolution (CDE), Co-Evolutionary Differential Evolution (Co-DE) and Artificial Bee Colony (ABC) algorithms. It is observed that CGAC provides more success rate, yields better objective function values and Standard Deviation (S.D) are better in most of the cases as compared to LXPMC and HLXPMC. But, it is observed that CGAC takes more number of function evaluations, but in return it takes less computational time in comparison to LXPMC and HLXPMC. It is also observed that CGAC takes less time and less number of function evaluations as compared to Improved Genetic Algorithm (IGA), Teaching-Learning Based Optimization (TLBO) and most of other popular algorithms mentioned above.

The thesis, in its last parts attempts to solve some constrained real life problems by using CGAC. At first, 6 engineering design problems namely (i) Welded Beam Design case 1, (ii) Welded Beam Design case 2, (iii) Pressure Vessel Design problem, (iv) The Tension/ Compression spring problem, (v) Three bar truss design problem and (vi) Speed reducer design optimization problem have been solved by CGAC. The obtained results have been compared with Differential Evolution with Level Comparison (DELC), Differential Evolution with Dynamic Stochastic Selection (DEDS), Hybrid Evolutionary Algorithm (HEAA), Genetic Algorithm (GA), Social Behavior Inspired Optimization Technique (SBO), Hybrid PSO with a feasibility based rule for constrained optimization (HPSO) and other state-of-the-art algorithm. It is clearly concluded that the proposed algorithm is more reliable, more efficient and more accurate as compared to other stated above, in solving constrained optimization problems.

Finally, CGAC is applied to solve another electrical engineering real life problem called Economic Load Dispatch (ELD) problems. Four test cases of ELD problems have been considered which consists of 3, 13, 40 and 15 generators. The first three test cases are solved considering the valve point loading effect, Power balance constraints and Generator capacity constraints. The last test case i.e. 15 generator problem is solved considering all the generational constraints i.e.(i) Quadratic cost function, (ii) Generator Capacity constraint, (iii) Power balance constraint, (iv) Ramp rate limits and Prohibited Operating Zones(POZ) constraints. The CGAC is being compared with Chaotic PSO and Sequential Quadratic Programming (CPSO-SQP), Evolutionary Programming (EP), PSO, PSO and Sequential Quadratic Programming (PSO-SQP), Chaotic PSO (CPSO), Fire Fly Algorithm and many other popular and continuous methods, where CGAC outperforms the rest.

In case of 3, 13 and 40 generator problem with valve point loading effect, CGAC is further compared with GA-BFO (Hybridization of GA and BFO) in terms of objective function value, total number of function evaluations, mean time and standard deviation. CGAC beats GA-BFO in terms of numerical comparison. The convergence graphs for CGAC and GA-BFO further confirms the supremacy of CGAC over GA-BFO.

For the 15 generator problem including all the generational constraints, the algorithm is being compared with Iteration PSO (IPSO), GA, PSO, different versions of Chaotic PSO (CPSO) i.e. CPSO 1, CPSO 2, Self-organizing Hierarchical PSO (SOH_PSO) etc. It is observed that mean cost ($/h) and minimum cost ($/h) are better in comparison to all mentioned algorithms.

All in all, the final recommended conclusion that the Chemo-inspired

GA is a better candidate to solve unconstrained optimization problems. Similarly, the further designed constrained version of Chemo-inspired GA is really works very efficiently in solving all most all sorts of constrained optimization problems, better than its competitors. Especially, it can be worth mentioning here 'not to hybrid the entire BOF with GA', rather better 'to hybrid only the chemo tactic step of BFO with GA', in order to reduce the computational burden and to achieve results with a high improved precision.

7.2 SCOPE FOR FUTURE RESEARCH

The thesis has also come to an end. But, since the research is a never ending process, the research in this direction may continue further.

Some of the scopes / suggestions for future research are briefed below.

i. The proposed algorithms of this thesis may be applied to multi-objective optimization problems.

ii. The algorithm may apply to some more typical real life problems like solving Time tabling problem, Travelling salesman problem, Networking problem, Sudoku puzzle and many other engineering optimization problems.

iii. The algorithm will be applied to Integer and Mixed integer programming problems too.

iv. The developed algorithm in this thesis may be designed for parallel computing in order to reduce the computation time complexity.

v. Best suit operators may also be investigated further for the proposed algorithms.

vi. The hybridization of other evolutionary techniques with Chemo-GA (CGA) may be analysed for handling unconstrained as well as constrained optimization problems.