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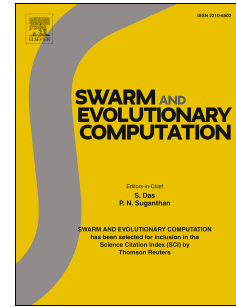
Population Topologies for Particle Swarm Optimization and Differential Evolution

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Abstract- Over the last few decades, many population-based swarm and evolutionary algorithms were introduced in the literature. It is well known that population topology or sociometry plays an important role in improving the performance of population-based optimization algorithms by enhancing population diversity when solving multiobjective and multimodal problems. Many population structures and population topologies were developed for particle swarm optimization and differential evolutionary algorithms. Therefore, a comprehensive review of population topologies developed for PSO and DE is carried out in this paper. We anticipate that this survey will inspire researchers to integrate the population topologies into other nature inspired algorithms and to develop novel population topologies for improving the performances of population-based optimization algorithms for solving single objective optimization, multiobjective optimization and other classes of optimization problems.

Keywords - particle swarm optimization, differential evolution, optimization, population topology, social network, cellular, distributed, static, dynamic, ring, wheels, random, von Neumann, star, hierarchical, niching, multiswarm, subswarm, subpopulation, heterogeneous;

I. Introduction

Evolutionary algorithms (EAs) are population-based metaheuristic optimization algorithms inspired by Darwin's theory of evolution [1-3]. The individuals in the population represent the potential solutions to an optimization problem. The individuals collaborate with and compete against each other to find the optimal solution in the search space. Survival in the population is based on the quality of the solutions which is determined by the fitness function. The better candidate solutions are selected to breed offspring for the next generation by applying stochastic variation operators to them. The mutation operator is applied to one selected candidate solution to generate to a new candidate solution. The recombination operator is applied to two or more selected candidate solutions to produce one or more new candidate solutions. In this way, evolution of the population takes place via the processes of selection, mutation and recombination and the population moves toward better solutions in the search space.

Darwin described the importance of a population structure on evolution in [4] as well as it is well-known in the literature that the performance of an evolutionary algorithm is significantly influenced by the organization of the individuals in the population [5-9]. The simple and standard population structure used in Evolutionary Algorithms (EAs) is the *panmictic* structure. In the panmictic population structure, mating selection is random and all the individuals can interact with any other individual in the population during the evolutionary process. Therefore, this structure promotes rapid information flow and consequently the population loses its diversity potentially leading to premature convergence. In order to address this problem, researchers suggested that like natural biological populations, it is possible to define a population structure with neighborhood or topological properties [5, 8]. In the structured populations, mating selection depends on fitness as well as topological relationships and mating is more common between the individuals that are close [10, 11]. Thus, spreading of good solutions throughout the population is slowed down thereby discouraging stagnation and premature convergence. The structured population models can be divided into two main groups: cellular/fine-grained model [12, 13] and distributed/coarse-grained model [7, 8]. The population topologies of cellular and distributed models are presented in Figure.1.

The cellular/fine-grained model is also known as the *diffusion* model [14]. In cellular models, the population is distributed in a grid and each individual has a unique coordinate in the grid. The individuals are allowed to interact only within their neighborhood. Thus, due to the slow diffusion of information through the grid from neighborhood to neighborhood, the risk of premature convergence is lowered [5].