New computational intelligence models applied to complex optimization problems

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Abstract

The current thesis presents the results obtained by a research focused both on the development of competitive intelligent computational techniques and on the application of such methods to complex optimization problems. The research results therefore concern new search strategies for evolutionary algorithms, new recombination schemes for evolutionary algorithms applied to combinatorial optimization problems and new approaches to community detection in complex networks and rules detection in cellular automata.

The first chapter of the thesis contains a short introduction and a short presentation of the scientific results that are to be described in this thesis.

The second chapter of the thesis contains the results obtained by the investigation of connections between multi-agent systems, distributed networks and evolutionary models, aiming at develping new search models able to efficiently address complex real-world problems. The search models presented in this chapter relie on a spatial distribution of individuals, coevolution and agent-based interactions within a population structured in societies with different strategies. An asynchronous search process is facilitated through a gradual propagation of genetic material into the population. Recombination and mutation processes are guided by the population geometrical structure. The proposed model specifies three strategies for recombination corresponding to three subpopulations (societies of agents). Each individual (agent) in the population has the goal of optimizing its fitness and is able to communicate and select a mate for recombination. Both an empirical and theoretical analysis of the proposed search strategy is performed and presented in this chapter.

The third chapter of the thesis relates to permutation-based encoding, which stays at the heart of many evolutionary algorithms dealing with combinatorial optimization problems. An important aspect of the evolutionary search refers to the recombination process of existing individuals in order to generate new potentially better fit offspring leading to more promising areas of the search space. In this chapter we present a new recombination operator for permutation-based encoding. The proposed operator makes use of genetic information from the two parents as well as from the best individual obtained up to the current generation. These two sources of information are integrated to determine the best order of values

in the new permutation. In order to evaluate the performance of the best-order crossover, we address three well-known NP-hard optimization problems i.e. Traveling Salesman Problem, Vehicle Routing Problem and Resource-Constrained Project Scheduling Problem. Numerical results emphasize a good performance of the proposed crossover scheme which is able to lead to overall better quality solutions.

The study of complex networks preoccupied the scientific community in the last years, as they exhibit interesting non-trivial features that are not easy to approach by means of classical techniques. One important aspect in the analysis of complex networks is given by community detection, due to its multiple real-world applications (recommender systems, epidemiology, cloud computing etc). The focus of the forth chapter is the proposal of new intelligent computational techniques which are able to deal with the difficult problem of community detection in complex networks. Both overlapping and non-overlapping community structure detection is approached, as well as the case of dynamic communities. The results previously obtained on the subject of search and recombination strategies have been applied and further improved in order to be able to approach these problems. A very interesting new game theory approach is also presented in this chapter, describing a game whose equilibrium coincides with the community structure of a network. Performed experiments on both synthetic data and real-world networks show the potential of the proposed techniques.

Cellular Automata represent important tools in the study of complex interactions, emergent behaviour and computational complexity of a system. They are characterized by local interactions that are able to trigger a certain global behaviour, and the detection of such local interaction rules represent a very difficult problem. In the fifth chapter we approach this problem by means of new competitive techniques based on intelligent computation, in the context of the well known Density Classification Task. Several techniques are therefore proposed: a collaborative approach, a geometric approach and a signal detection approach. Several CA topologies are also investigated in order to improve the performance of the CA for Density Classification Task. Network topologies are therefore investigated, a new hybrid topology and induced neighborhood, as well as node weighted network topologies. Obtained results are an indicator both of the proposed techniques efficiency and of the proposed cellular automata topologies.

Chapter 6 concludes the presentation of the proposed models and their applications and is followed by a chapter containing both future research directions and a career development plan.