Babeş-Bolyai University

Faculty of Mathematics and Computer Science

Computational intelligence models in solving game theoretic and complex network problems

Habilitation Thesis

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Outline of the thesis

This habilitation thesis is focused on computational models for solving problems in two main research areas: non-cooperative game theory and complex networks. Problems arising in these areas are difficult to handle; therefore, the use of evolutionary algorithms is essential, these being powerful solving models for complex problems.

The main activity of the author lies in designing algorithms to solve continuous and combinatorial optimization problems, and their use in different real-world applications: for example, the community structure for the functional connectivity networks of the brain, environment- based testing in industrial settings, co-authorship network analysis, and distributed computing.

Results described in the habilitation thesis are an extension of the research activity of the author who obtained a PhD degree in the field of computer science in 2011. The results of the author have been presented in more than 45 publications, including 23 ISI proceeding conference papers, four book chapters and eight articles indexed in the ISI Web of Knowledge. Research activity has also been completed in five national young research team projects, three of which as a principal investigator.

The thesis is organized into two main parts. The first part describes the scientific contributions of the author; it is organized into two chapters.

The first chapter concerns the evolutionary methods of non-cooperative game equilibria detection in static and dynamic environments. Non-cooperative games share similarities with multi-objective optimization problems; therefore, some domination relations (like Pareto domination) for certain equilibria are proposed. For the studied equilibrium concepts - ((k,t)-robust, t-immune, Berge-Zhukovskii optimal Nash equilibria) - no computational method to obtain them exists. Therefore, this study, in which an algorithm is designed, could open new application possibilities. In the case of the generalized Nash equilibrium, existing methods have limitations regarding the constraint types. The proposed equilibrium detection method is also useful in tracking different equilibria (e.g., Nash and Berge-Zhukovskii) in a dynamic environment. In this chapter, we adopt different evolutionary algorithms for equilibrium detection, illustrating the robustness of the equilibria domination relations. In the second chapter, complex network problems and the approach of evolutionary algorithms are presented. The mainly studied NP-hard problems, namely the community detection problem, the maximum influence node detection problem, and the bi-objective critical node detection problem, are of general interest.

In the case of the community detection problem, we study different types of networks. A game theory-based approach is described and used to detect communities in synthetic and real-world networks. For multi-partite networks, a new fitness measure is introduced and analyzed, and new synthetic benchmarks are proposed. We also design a new fitness measure for community detection in multiplex networks, considering synthetic and real datasets. In the case of the maximum influence node detection problem, an Extreme Optimization algorithm is adapted and we approach it with a cooperative game theory-based notion, the Shapley value. For the bi-objective critical node detection problem, new memetic algorithms are investigated and compared. This chapter also presents a section on network models of co-authorship data. These new network types - the proposed paper network, the hypergraph paper network, and the multi-layered network - give new useful insights into scientometric research.

In the second part of the thesis, the research overview and future directions are presented. A didactic and academic development plan is outlined, accentuating the former didactic activities, presenting the new proposed courses, the connection between the didactic and academic activities, and the main future research directions. This part also describes the planned activities in the Centre for the Study of Complexity, and collaboration plans with academic and industrial environments. There is a summary of the author's main research activities since obtaining her PhD.