ImAppNIO STSM Report

Research visit between Vilnius Gediminas Technical University (Lithuania) and University of Almeria (Spain)

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STSM topic: High-performance implementations of evolutionary multiobjective optimization algorithms

Host: Prof. Dr. Gracia Ester Martín Garzón, University of Almeria, Almeria, Spain, gmartin@ual.es

Period of STSM: 31/03/2018 – 15/04/2018

Dr. Ernestas Filatovas visited Almeria university from March 31st to April 15th. The goal of the STSM visit was to develop, investigate and apply parallel versions of the preference-based evolutionary multiobjective optimization algorithms with controllable approximation accuracy. Moreover, one of the main objectives of this STSM was to strengthen the collaboration between Vilnius Gediminas Technical University and the University of Almeria.

During the STSM visit, I have spent more than two weeks under the supervision of professor Gracia Ester Martín Garzón – the head of the research group "High-Performance Computing – Algorithms". The main research lines of this group are High-Performance Computing, Global, and Multi-objective optimization, Systems Modelling and Resolution, Energy Efficient Computing.

Background

Many real-world problems are multiobjective, where several conflicting objective functions must be optimized. Usually, there is no solution which would be the best for all objectives, however, a set of optimal solutions in a multiobjective sense exists. These solutions are defined as the solutions where none of the objective values can be improved without deteriorating other(s). Such a set of solutions is called the Pareto set and the corresponding set of objective vectors, the Pareto front. Determination of the Pareto front is the main goal of multiobjective optimization, however, often it is impossible to identify the exact Pareto front due to the reasons as continuity of the front or complexity of the problem being solved. Therefore, algorithms that approximate the Pareto front are widely-used. Evolutionary Multiobjective Optimization (EMO) approaches are commonly employed for this task [1, 2]. The set of obtained solutions approximating the entire Pareto front is presented to the Decision Maker (DM). However, EMO algorithms are computationally expensive and time-consuming. Additionally, only a reasonable number of solutions should be given to the DM so that he/she can make an adequate decision avoiding the usually complex analysis of a large amount of information and reducing cognitive burden. Moreover, the DM is commonly interested only in a certain part of the Pareto front and prefers to explore that part deeper. Thus, incorporation of DM's preferences into EMO algorithms has become a relevant trend during the last decade [3-6] and Preference-based Evolutionary Multiobjective Optimization (PEMO) algorithms have obtained big popularity.

Preparatory works before the STSM visit

Before the STSM visit in collaboration with Prof. I. Kaliszewski and Dr. J. Miroforidis from Polish Academy of Sciences, Systems Research Institute (Warsaw, Poland) STSM applicant Dr. Ernestas Filatovas has developed a PEMO algorithm. The core idea of the algorithm is that it approximates part of the Pareto front by two-sided approximations – one from inside and another from outside of the feasible objective set, called, respectively, lower shell and upper shell [7, 8]. During the run of the algorithm, two groups of solutions (approximations) are obtained. The first group is iteratively obtained by performing crossover, mutation and selection operators and preserving only those non-dominated solutions to the next generation that are feasible. The second group is obtained by mutating solutions from the first group and preserving only those non-dominated solutions that are outside the feasible set. In such a way, two-sided approximations are generated (lower shell and upper shell), true Pareto front lies, in a certain sense, in-between these approximations. Accuracies of Pareto front approximations by such pairs can be measured and controlled with respect to the distance between such approximations. The biggest advantage of the approach is that it allows to get us approximation with the controllable accuracy that satisfies the DM. Moreover, the algorithm is suitable for solving large-scale problems, however, requires high computational resources.

Works during the STSM visit

During this STSM it was focused on the improvement of the PEMO algorithm, parallelization as well as its application.

At the beginning of my mission together with “High-Performance Computing – Algorithms” group members Prof. Dr. Gracia Ester Martín Garzón and Dr. Gloria Ortega Lopez we have discussed the currents state of our common researchers, as well as, lines of our further collaboration, and we also composed a detailed work plan of the pre-experimental and experimental investigations to be carry out during and after the STSM.

The most of the time we have spent on developing parallel CPU and GPU versions of the PEMO algorithm with controllable accuracy. These versions are adopted to homogeneous and heterogeneous platforms. We were testing parallel algorithms versions by solving different sets of benchmark problems ZDT and DTLZ [9] with different number of objectives and different sizes of population. Various types of HPC platforms available at Almeria university were used [10]. The developed parallel implementations were evaluated in terms of runtime and energy efficiency. The obtained results are promising and showed potential for the further development and application of the algorithm.

Next, during the STSM the works on the application of the developed parallel versions of the algorithm to the large-scale multiobjective cancer radiotherapy planning problem have been started. The problem is of high complexity – some cases it has up to 50000 variables. The real data of the problem was provided by Department of Medicine Physics, Cancer Center and Institute of Oncology (Warsaw, Poland). Currently, we are on the experimental stage, and our common investigation continues.

At the end of the STSM visit, the archived results were presented and discussed with the members of the “High-Performance Computing – Algorithms” group.

Work after the STSM visit

The results that are the outcome from the STSM will be presented at the EURO 2018 conference in the talk “A preference-based multiobjective evolutionary algorithm with controllable approximation accuracy” (the abstract was accepted to the talk on the conference). Moreover, during my STSM we started drafting a research paper in which we will publish our results in periodic scientific publication, having an impact factor, in the Clarivate Analytics Web of Science database.

This research of the STSM is enclosed into the Working Groups WG1: "WG Theory-Driven Applications" and WG2: "WG Practice-Driven Theory" of the COST Action ImAppNIO CA15140. A goal of the proposed STSM action corresponds to the ImAppNIO focus on improvement of the applicability of nature-inspired optimization methods.

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