SHORT TERM SCIENTIFIC MISSION (STSM) – SCIENTIFIC REPORT

The STSM applicant submits this report for approval to the STSM coordinator

Action number: CA15140
STSM title: Characterizing the Runtime Distribution and Anytime Behavior of Multi-objective Search Algorithms
STSM start and end date: 07/01/2018 to 13/01/2018
Grantee name: Alexandre Jesus

PURPOSE OF THE STSM

One of the main challenges from multi-objective combinatorial optimization is to identify (or approximate) the set of Pareto optimal solutions, known as the Pareto set. In contrast to the single-objective case, a multi-objective optimization problem does not have a single optimum, but rather several optima representing the set of optimal trade-offs between the objectives. As a consequence, measuring the performance of multi-objective nature-inspired heuristics and other multi-objective search algorithms is a difficult task.

Recently, many approaches have been using the hypervolume indicator in order to guide the search process towards the Pareto set. The hypervolume indicator corresponds to the measure of the multi-dimensional area dominated by a set of points, bounded by a reference point.

The aim of this STSM was to characterize the solution quality obtained by multi-objective algorithms, measured in terms of the hypervolume indicator, during the run-time. In particular, prior to the STSM a theoretical model had been developed on the value of the hypervolume indicator during run-time under simple assumptions on the shape of Pareto optimal set in the objective space and on the guiding rule to collect the optimal points.

Therefore, during the time of this STSM, the main objective was to empirically validate the theoretical model on a benchmark set of instances of a multi-objective knapsack problem, and if necessary adjust the model according to the results.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

The work was carried out at one of the Bonus research group rooms, in the Inria facilities adjacent to the University of Lille, where it was supervised by Prof. Dr. Arnaud Liefooghe. The work mostly consisted in developing an algorithm for the bi-objective unbounded knapsack problem based on the ideas of the theoretical model, and comparing the run-time performance of this algorithm with the results of the theoretical model. In more detail the work was distributed as:

Day 1 (07/01/2018):

- Arrival to Lille and to the International Residence;
- Get to know the university campus;
- Preparation of the theoretical results for the first meeting on Monday.

Day 2 (08/01/2018):

- Meeting with Prof. Dr. Arnaud Liefooghe to discuss week planning and the theoretical model;
- Analyze the theoretical model and create a script to view its run-time performance;
- Start developing an ε-constraint algorithm for the bi-objective unbounded knapsack problem.

Day 3 (09/01/2018):

- Meeting with Prof. Dr. Bilel Derbel, member of the research group, about the work being carried out;
- Finish development of the ε-constraint algorithm.

Day 4 (10/01/2018):

- Development of a script to analyze the ε-constraint algorithm results against those of the theoretical model;
- Use the script above to generate results on various benchmark instances.

Day 5 (11/01/2018):

- Meeting with Prof. Dr. Arnaud Liefooghe, and Prof. Dr. Luís Paquete (my PhD supervisor at the University of Coimbra) to discuss the results obtained. In this meeting we noticed that our model wasn't performing very well for some instances, and thus decided to alter the model a little. We also discussed ways to relate the model parameter to the instances;
- Alteration of the model, and the ε-constraint algorithm following the meeting above;
- Relate different problem instances to the model parameter. In particular, we ended up using a dichotomic search to find an initial supported point of the Pareto set, and from this point derive the parameter for our model;

Day 6 (12/01/2018):

- Finish alteration of the model and algorithm;
- Generate and analyze new results.

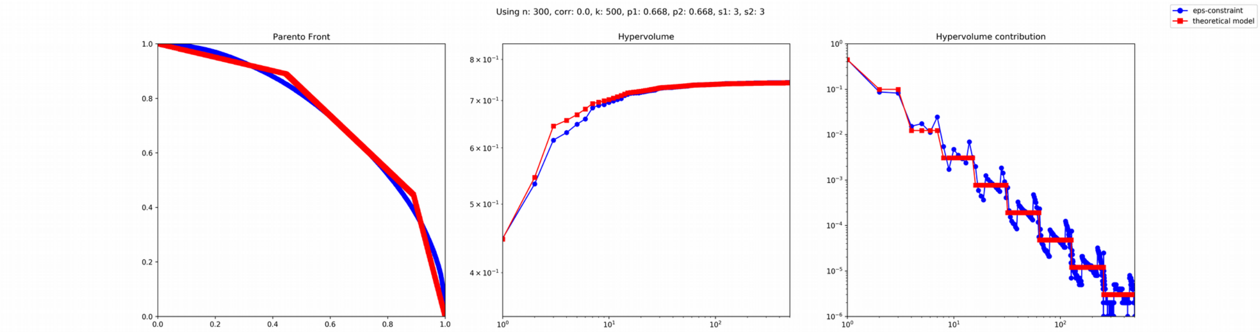
Day 7 (13/01/2018):

- Departure from Lille.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

During my stay in Lille I was able to develop an ε-constraint algorithm for the unbounded knapsack problem based on our theoretical model. Furthermore, we were able to define a way to get the model parameter from a given instance by performing a single step of a dichotomic search and finding the initial supported point.

By analyzing the results of algorithm against those of the model, we found some shortcomings in the model, and had to slightly change it and the algorithm. Our final results, in the figure below, show that the run-time performance of the model and the algorithm are quite similar.



We can see that a simple analytical theoretical model (in red) with a single parameter can predict quite well the shape of the Pareto front, total hypervolume and hypervolume contribution at each point of our algorithm (in blue). We performed several tests with different instance parameters (size and correlation).

FUTURE COLLABORATIONS (if applicable)

Following the results of this STSM, we will be writing a conference paper in the near future. Also a co-tutelle for my PhD is now being prepared with the University of Lille, which will allow for more collaboration opportunities in the future between the two research groups.