Scientific Report of the Short Term Scientific Mission

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Purpose of the Short Term Scientific Mission:

The purpose of this STSM was to continue working in my PhD topic, whose objective is to construct optimization models in the context of the analysis of complex networks where appear some uncertainty or randomness in the parameters that define the model. The objective in this period was to work in it but with special emphasis in Mixed-Integer Nonlinear Programming Problems (MINLP) and in one of its most attractive applications: the management of different aspects of the energy systems.

Description of the work carried out during the STSM:

- During the STSM I attended to some seminars and talks where several leading researchers in different areas of Optimization were invited to provide a wide view of the current challenges in their areas.
- Furthermore I attended to some courses in Nonlinear Optimization and Optimization applied to energy planning.
- But especially, during the STSM I have been carrying out a research activity focused on the Minmax Regret Criterion: exploring the existing literature about this criterion, summarizing some existing general results about its complexity on classical combinatorial problems, summarizing also some general results about approximation, and trying to develop some new applications of min-max regret for problems where there are some dependent relationships between the unknown parameters, due to the fact that most of the results in the literature assume independence in these unknown parameters.

  We can introduce the minmax regret criterion as follows:

  We consider a general optimization problem of the form

$$\begin{array}{ll} \text{minimize} & f(x) \\ \text{subject to} & x \in X \end{array}$$

  where $f : \mathbb{R}^n \rightarrow \mathbb{R}$ is the objective function that we want to minimize, and the decisions vectors $x = (x_1, x_2, ..., x_n)$ belong to the nonempty feasible region $X \subset \mathbb{R}$, and assuming standard conditions for the existence of the minimum. Whereas deterministic optimization problems are formulated with known parameters, in practical applications the exact values of input data like costs, times, legths, etc., are often not known in advance. It is caused by a lack of knowledge about a considered system or by the varying nature of the world. One of the frameworks for modelling optimization problems that involve uncertainty is robust optimization, and one of the criteria that we can find in robust optimization is the minmax regret criterion.

If we consider particularly the class $\mathscr{C}$ of $0-1$ problems with a linear objective function, and model the uncertain parameters using discrete or interval scenarios ξ in a set S, the min-max regret problem corresponding to a problem $\mathscr{P}$ in $\mathscr{C}$ can be stated as

$$\min_{x \in X} \max_{\xi \in S} (val(x, \xi) - val^*_\xi)$$

where $val(x, \xi)$ is the value of x in the objective function considering the coefficients in the corresponding scenario ξ, x^*_ξ denotes an optimal solution under scenario ξ, and val^*_ξ the corresponding optimal value val^*_ξ.

This criterion is suitable in situations where the decision maker may feel regret if he makes a wrong decision. He thus takes this anticipated regret into account when deciding. Particularly, we can apply this criterion in some energy system problems.

Description of the main results obtained:

The complexity of minmax regret criterion has been studied extensively and it is known that most of the classical combinatorial problems are strongly NP-hard. Due to the complexity of this minmax regret problems there exist in the literature some approximation results for this criterion. Particularly Kaperski and Zielinski gave in 2006 an approximation of constant factor 2 for the minmax regret problem in the interval scenario case.
But as mentioned before, most of the results in the literature consider independence among the unknown parameters, but sometimes this independence is not possible. During this STSM we obtained two new applications of min-max regret in the Set Covering and Set Packing Problems, and in the Most Reliable Path Problem when there are some dependent relationships between the unknown parameters. This two new applications can be used in the management of different aspects of the energy systems.

- The first of the applications, which is in the Set Covering Problem (SCP) and we can extend to the Set Packing Problem, define a possible relation of dependence between the parameters and a transformation of the problem that allows us to obtain an approximate solution of constant factor 2, applying the existing results for independent parameters.

- In the second application we consider the Most Reliable Path Problem (MRPP), where we have a graph with an origin and a destination node, and we associate to each arc the probability of not having accident in that arc. We want to find the most reliable path.

  We can assume that the probabilities are uncertain parameters, but we can compare them 2 by 2, and obtain what is known in the literature as *assurance regions*: $\alpha_{ijkl} \leq \dfrac{p_{ij}}{p_{kl}} \leq \beta_{ijkl}$.

  Doing some transformations, and assuming that the matrix associated to the dependence admits inverse, we can again transform the problem in one with independence between the unknown parameters, and get, in this way, a 2-approximate solution of the Most Reliable Path Problem with the dependence described.

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To Whom it may concern:

Bologna, June 9, 2015

Reference: COST-STSM-TD1207-26546

This letter is to confirm that

Marina Leal Palázon

has successfully completed the STSM regarding her visit to the University of Bologna in the period March 20 - May 31, 2015.

Sincerely,

Andrea Lodi