Scientific Report of the Short Term Scientific Mission: "COMBINATORIAL OPTIMIZATION AT WORK".

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Purpose of the Short Term Scientific Mission:

The purpose of this STSM was to attend to the workshop "Combinatorial Optimization at Work" in Zuse Institute Berlin in order to increase my expertise and knowledge on the use of combinatorial optimization and mathematical programming techniques (Linear Programming, Mixed Integer Programming and Mixed Integer Non Linear Programming) in concrete real-world industrial applications from practice, and use some of this knowledge to continue working in my PhD topic, because one of the main objectives of it is to construct optimization models in the context of the analysis of complex networks in those who join random and/ or uncertain aspects in the parameters that define the model.

Description of the work carried out during the STSM:

During the STSM I attended to the activities and talks organised by the Institute for the Workshop. For the talks several leading researchers in different areas of Combinatorial Optimization and Mathematical Programming Techniques were invited. And the activities included solving exercises and a excursion to automatized production facilities in the area.

Below I summarize some of the topics and the activities covered each day:

Day 1: Introduction to Linear and Mixed Integer Optimization: first approach to the algorithms to solve Linear Problems (Fourier-Motzkin Elimination, The Primal Simplex Method, The Dual Simplex Method, The Ellipsoid Method, Interior-Point/Barrier Methods and Lagrangian Relaxation, Subgradient/Bundle Methods) and Mixed Integer Problems (Branch and Bound, Cutting Planes, Column Generation, Primal and Dual Heuristics, Constraint Programming Ideas).

Introduction to SCIP: toolbox for generating and solving constraint integer programs.

Day 2: Description of the modelling process, introduction to some modelling languages, with special emphasis in ZIMPL, and introduction to the importance of a "good" formulation, and how to compare different ones.

Exercises using ZIMPL and SCIP in the "Equitable Coach Problem".

An introduction to Polymake: software for polytope constructions in linear and integer optimization.

Day 3: Some methodologies in optimization for solving Mixed Constraint Integer Problems and how to do it in SCIP. Some exercise in SCIP to implement Constraint Handlers in it.

Applications in Telecommunications: Optimization in Telecommunication Networks, particularly in Network Layout Planning and Network Dimensioning and Routing.

Day 4: Gas Network Optimization. Some applications in Gas Network Optimization taking into account the following components for the model: Flow conservation constraints at nodes and all kinds of arcs: pipes (non linear), resistorns (non lineral), shortcut, valves, control valves, compressors; which derives in a Mixed Integer Non Linear Program.

Introduction to Mixed Integer Non Linear Programming: LP-relaxation, Polyhedral relaxation, solving methods: branch and bound, nonconvex MINLP, how SCIP handles nonconvex MINLPs.

Methods for Gas Network Optimization: Gas Network Expansion via Loops, Convex Relaxations for Loop Expansions, a discrete model for Gas Network Topology Optimization and Solution Frameworks.

Some exercises related with the topic of the day.

Day 5: Advanced Mathematics, how useful they are: the role of mathematics in this century, modern industry problems, modelling of real-world problems, the solution cycle of modern mathematics, software advances and some examples (Matheon, Traffic, Telecom).

Introduction and exercise in GAMS: the Genearl Algebraic Modeling System, a high-level modeling system for mathematical programming and optimization. It consists of a language compiler and a stable of integrated high-performance solvers.

How to win the Graph 500 competition.

Day 6: All day was dedicated to Traffic Optimization: combinatorial optimization problems, running times and study of some traffic optimization problems (Travelling Salesman Problem, Shortest Path Tree, Knapsack Problem, Military Logistics, Min Cost Flows, Assignment Problem, etc).

Day 7: Linear Programming: historical perspective, computational progress and the Dual Simplex Algorithm.

Mixed Integer Programming: historical perspective, computational progress and solving MIP (presolve, solve continuous relaxations, cutting planes, branching variable selection and primal heuristics).

Day 8: Presentation of some commercial solvers: Gurobi Optimizer, CPLEX and Xpress.

Gourobi: introduction, history, algorithms, performance, etc.

CPLEX: introduction, recent advances in MILP (parallel cut loop, local implied bound cuts, lift-and-project cuts) and using computing resources.

Xpress: introduction, robust optimization, robust optimization in Xpress, some exercises.

Day 9: Excursion to automatized production facilities: Bosch-Siemens and DHL end of runway.

Bosch-Siemens: guided tour in the production chain, visit to the museum, talk about the business.

DHL end of runway: guided tour to the store and explanation of the storing system.

Day 10: Algorithms for MINLP: basic algorithms for the Convex Case, and some steps into Non-Convexity.

MINLP, Global Solvers: ANTIGONE, BARON, Couenne, LindoAPI, SCIP, CO-CONUT, MINOTAUR. Differences among them.

Introducton on SemiDefinit Program: formulations and strong duality on SDP, algorithms on SDP, computation on SDP.

Semidefinite Optimization Using MOSEK: Conic Optimization, Conic Quadratic Modeling, Semidefinite Modeling.

Mixed Integer Nonlinear Optimization: modeling in MINLP and algorithms for MINLP.

Day 11: Lifecycle Optimization in Civil Engineering: study of some problems, some properties, etc.

Introduction to LITIC software: a brand-new fully browser-based analytics platform with a strong emphasis on User Experience Design to support the developers and users of analytic apps and services. Overview, development of two models and competitive element for the participants.

Description of the main results obtained:

As mentioned at the beginning I am working with problems under uncertainty. On the basis of these problems and its applications are classical problems of combinatorial optimization and its many applications . In fact , many times , these problems under uncertainty can be reduced to classic combinatorial optimization problems and/or be solved using mathematical programming techniques.

After this course I have a lot of new theoretical and algorithmical tools in the area of Combinatorial Optimization and Mathematical Programming (algorithms, solvers, modeling languages, applications, etc.) to expand the vision in the field of applications of combinatorial optimization problems, and to serve as a starting point or guide for the study and creation of new applications in the area of problems under uncertainty.

Confirmation by the host institution of the successful execution of the STSM:

CERTIFICATE of PARTICIPATION

This is to certify that

Marina Leal

has participated in the workshop

Combinatorial Optimization at Work 2015

on the use of combinatorial optimization and mathematical programming techniques (LP/MIP/MINLP) in concrete real-world industrial applications from practice,

held at Zuse Institute Berlin (Takustr. 7, 14195 Berlin, Germany),

September 28th - October 10th, 2015.

Berlin, 10.10.2015

Prof. Dr. Thorsten Koch

Berlin Mathematical School

TRR 154

Mathematische Modellierung, Simulation und Optimierung am Beispiel von Gasnetzwerken