Summer School on Operational Research and Applications

May 10 – 14, 2017

National Research University Higher School of Economics,

Nizhny Novgorod

Faculty of Informatics, Mathematics and Computer Science

Laboratory of Algorithms and technologies for network analysis

Wednesday, May 10

Arrival of participants

Thursday, May 11

Room 402 HSE, 136 Rodionova Str.

9:30-10:00 Registration of participants

10:00 -10:50 Panos Pardalos

Opening lecture: On Objective Function Representation Methods in Optimization

10:50 -11:10 Coffee break

11:10 -12:00 Mikhail Khachay

Lecture 1: Deterministic approximation algorithms and PTAS for the Traveling Salesman Problem and its generalizations

12:10 -13:00 Mikhail Khachay

Lecture 2: Randomized approximation algorithms for TSP and its generalization

13:00 -14:30 Lunch

14:30 -15:20 Mikhail Khachay

Lecture 3: Polynomial time approximation schemes for Vehicle Routing Problems

15:30 -16:20 Ilias Kotsireas

Lecture 1: Introduction to high-performance computing (HPC) and Parallel Programming

16:20 -16:30 Coffee break

16:30 -17:20 Ilias Kotsireas

Lecture 2: Meta-programming with Maple

Friday, May 12

Room 402 HSE, 136 Rodionova Str.

10:00-10:50 Stefan Pickl

Lecture 1: Introduction to Data Science: Data Mining and Data Farming

10:50 -11:10 Coffee break

11:10-12:00 Stefan Pickl

Lecture 2: From Data Science to Predictive Analytics

12:10-13:00 Alexander Lazarev

Lecture 1: Scheduling Theory and Applications

13:00-14:30 Lunch

14:30-15:20 Alexander Lazarev

Lecture 2: Scheduling Theory and Applications

15:30-16:20 Alexander Lazarev

Lecture 3: Scheduling Theory and Applications

16:20 -16:40 Coffee break

16:40 -17:30 Ilias Kotsireas

Seminar: Low Autocorrelation Binary Sequences (LABS)

Saturday, May 13

Room 402 HSE, 136 Rodionova Str.

10:00-10:50 Jun Pei

Lecture 1: Study of coordinated scheduling and transportation based on serial-batching

10:50 -11:10 Coffee break

11:10-12:00 Jun Pei

Lecture 2: Serial batching scheduling of deteriorating jobs to minimize the makespan

12:10-13:00 Stefan Pickl

Seminar: Risk Assessment and Optimal Behavior

13:00-14:30 Lunch

14:30-15:20 Jun Pei

Seminar: Data-driven scheduling in manufacturing

15:30-16:20 Oleg Prokopyev

Lecture 1: Fractional 0–1 Programming: Applications, Complexity and Algorithms

16:20 -16:40 Coffee break

16:40 -17:30 Oleg Prokopyev

Lecture 2: Fractional 0–1 Programming: Applications, Complexity and Algorithms

17:30 -17:50 Closing

Sunday, May 14

Departure of participants

On Objective Function Representation Methods in Optimization

Panos M. Pardalos

[1] Center for Applied Optimization (CAO),
University of Florida, USA
[2] Laboratory of Algorithms and Technologies for Network Analysis (LATNA),
National Research University Higher School of Economics, Russia

Abstract. The problem of representation (or decomposition) of a continuous function and its use in optimization has been well studied. The most well known and used methods include the representation of functions as the difference of two convex functions (DC optimization) or difference of two monotonically increasing functions (Monotonic Optimization). Other techniques include reduction to separability (total or partial), and methods based on Kolomogorov's superposition theorem.

After a summary of existing work, we will focus on DC discrete optimization. In particular, we are going to discuss details for the solution of degree-constrained fault-tolerant spanning subgraph problem by DC optimization.

Deterministic approximation algorithms and PTAS for the Traveling Salesman Problem and its generalizations

Mikhail Khachay

Institute of Mathematics and Mechanics of Russian Academy of Science, Ural Branch, Ekaterinburg

Abstract. We consider the classic Traveling Salesman Problem (TSP) and its generalization Cycle Cover Problem (CCP) also known as Multiple TSP. The both problems are strongly NP-hard even being formulated in the Euclidean plane. Also, it is known that their general settings can not be approximated in polynomial time with accuracy O(2^n). Meanwhile, metric and Euclidean cases of the problems are approximable much better. The lecture deals both classic and very recent approximation results.

Randomized approximation algorithms for TSP and its generalization

Mikhail Khachay

Institute of Mathematics and Mechanics of Russian Academy of Science, Ural Branch, Ekaterinburg

Abstract. In this lecture, we continue the discussion of approximation algorithms for the Traveling Salesman Problem and some of its generalizations. Unless the previous one, this lecture aims to introduce the randomized approximation and asymptotically optimal algorithms for these problems. The asymptotically optimal algorithms seem to be very surprising especially in the context of the well known 'curse of dimensionality' conjecture and bridge a promising connection between two fast growing fields of theoretical computer science, combinatorial optimization and statistical learning theory.

Polynomial time approximation schemes for Vehicle Routing Problems

Mikhail Khachay

Institute of Mathematics and Mechanics of Russian Academy of Science, Ural Branch, Ekaterinburg

Abstract. The Vehicle Routing Problem (VRP) is a famous combinatorial optimization problem having a variety operations research applications and adopting many efforts and publications in the field of algorithm design. Although, moderate-size instances of the problem can be solved to optimal using well known Branch-and-Price algorithms, contemporary applications produce a challenge of tackling instances of much bigger size, for which only approximate solutions can be found efficiently. Although, the main stream in this field is presented by several kinds of heuristics and meta-heuristics, polynomial time algorithms with theoretically proved approximation guarantees and PTASs are actively developed as well. In this lecture, we give a short overview of these results.

Introduction to high-performance computing (HPC) and Parallel Programming

Ilias Kotsireas

Wilfrid Laurier University, Ontario, Canada

Abstract. We will present a thorough introduction to MPI (Message Passing Interface), the most popular parallel programming paradigm. This will include MPI basics, collective communication and load balancing. MPI will be illustrated with fully worked-out code examples on an actual parallel cluster. A tutorial introduction to Linux tools (bash shell, sed, awk) will be provided, if needed, depending on the audience.

Meta-programming with Maple

Ilias Kotsireas

Wilfrid Laurier University, Ontario, Canada

Abstract. We will explain how to use meta-programming techniques to produce bug-free and provably correct code. Another advantage of using meta-programming techniques is that they allow one to produce fast and reliably several millions of lines of MPI code that can then be compiled and executed on parallel clusters. We will focus on solving hard combinatorial problems on supercomputers, using the meta-programming approach.

Introduction to Data Science: Data Mining and Data Farming

Stefan Pickl

Universität der Bundeswehr München, Germany

Abstract. In the first part we give a general introduction and overview on modern data science (text mining, web mining, data analysis). The relationships between datamining and datafarming is characterized. Furthermore, we motivate actual problems from a certain Operations Research perspective.

From Data Science to Predictive Analytics

Stefan Pickl

Universität der Bundeswehr München, Germany

Abstract. After having introduced central optimization problems to model and analyze (big) data like cluster analysis, machine learning and pattern recognition, we refer to predictive analytics. Is it possible to estimate an optimal behavior or treatment? Can we identify and characterize certain trends? The underlying theory is introduced.

Scheduling Theory and Applications

Alexander Lazarev

V.A. Trapeznikov Institute of Control Sciences of RAS,
Lomonosov Moscow State University,
National Research University Higher School of Economics,
Moscow Institute of Physics and Technology, Moscow, Russia.

Lecture 1

Abstract. The first lecture is devoted to the fundamentals of scheduling theory. The basic concepts of scheduling theory will be presented. We will discuss the results of pioneers in this field of research: J. R. Jackson., W. E. Smith., S. M. Johnson. Classification of problems will be presented. Also, we will talk about modern problems related to the scheduling theory. In particular, new projects of the laboratory of "Discrete Optimization and Scheduling Theory" will be described (www.orsot.ru). One of this projects is the Cosmonauts Training Scheduling Problem. We will debate in detail the basic rules for scheduling the training of cosmonauts, their mathematical formalization and methods for solving the problem.

Scheduling Theory and Applications

Alexander Lazarev

V.A. Trapeznikov Institute of Control Sciences of RAS,
Lomonosov Moscow State University,
National Research University Higher School of Economics,
Moscow Institute of Physics and Technology, Moscow, Russia.

Lecture 2

Abstract. The second lecture is devoted to the NP-hard in strong sense Resource Constrained Project Scheduling Problem (RCPSP). RCPSP belongs to the most popular exploration areas in the sphere of operational research. The RCPSP setting is as follows. Given:
- a set of incoming orders;
- durations of each operation involved to execute the order;
- a set of resources;
- the timetable of availability of every resource for each moment of time;
- the amount of each resource required to execute every operation of every order;
- precedence relationship for every pair of operations of all orders.
It is required to define the start time of every operation for every input order in such a way that minimizes some objective function. RCPSP is NP-hard problem and exact methods are not effective for its solving. We will discuss a new method to detect a lower bound of total execution time of the project.

Scheduling Theory and Applications

Alexander Lazarev

V.A. Trapeznikov Institute of Control Sciences of RAS,
Lomonosov Moscow State University,
National Research University Higher School of Economics,
Moscow Institute of Physics and Technology, Moscow, Russia.

Lecture 3

Abstract. The third lecture is devoted to the Railway Scheduling Problems. Due to their practical significance and challenging mathematical nature, the scheduling problems, where it is necessary to specify the departure times and the order of trains in some railway network, remains the object of intensive research from the middle of twentieth century. In some models it is also necessary to define the way for each train, or to form the train from the set of railway cars. In the first part of the lecture the pioneers in railway scheduling research and the correspondence between railway timetabling and classical scheduling theory will be presented. Secondly, a set of most commonly used solution approaches will be discussed. Then attention will be focused on the several railway scheduling problems, considered by the laboratory team.

Low Autocorrelation Binary Sequences (LABS)

Ilias Kotsireas

Wilfrid Laurier University, Ontario, Canada

Abstract. We will describe the LABS problem, a challenging optimization problem that arises in mathematics, communications engineering and statistical physics. We will discuss the state-of-the-art algorithmic techniques to solve this problem as well as some complexity estimates derived from experimental work by various authors. The algorithmic techniques used in the LABS problem include branch and bound methods, group theory and high-performance (parallel) computing. We will also mention the open problems in the realm of LABS, as well as some recent ideas in joint work with Prof. Panos M. Pardalos.

Risk Assessment and Optimal Behavior

Stefan Pickl

Universität der Bundeswehr München, Germany

Abstract. Both introductory parts can be used as a basis for an holistic risk assessment and crisis management. We concentrate on a practical problem (complex threat analysis on graphs, interdiction games, strategic planning, system dynamics under uncertainty, complex network analysis). Within an interactive seminar atmosphere we develop together a success story in the context of simulation based optimization. An outlook to modern Business Intelligence (BI) systems in the context of modern Decision Science Intelligence (DSI) will be presented.

Study of coordinated scheduling and transportation based on serial-batching

Jun Pei

School of Management, Hefei University of Technology,
Hefei City, China

Abstract. We systematically analyze the multi-period production and transportation collaborative scheduling problems under several circumstances, which are abstracted from the processing procedures on the serial-batching machine of extrusion factory. These different circumstances are including the cases of limited vehicles, dynamically jobs arrival, machine breakdown, and collaborative scheduling of multiple manufacturers distributed in different locations. Since that all these problems are NP-Hard, we analyze the properties of optimal scheduling plans, based on which efficient heuristics and intelligent algorithms can be developed. On the other hand, the lower bounds of these problems are also derived, which can be used to assess the accuracy of the developed algorithms.

Serial batching scheduling of deteriorating jobs to minimize the makespan

Jun Pei

School of Management, Hefei University of Technology,
Hefei City, China

Abstract. The production and transportation collaborative scheduling problem is studied when the jobs processing time is deteriorating. Several single machine scheduling problems under the circumstances of deteriorating jobs processing time are analyzed, of which the objectives are respectively minimizing the makespan, minimizing the number of tardy jobs, minimizing the total jobs completion time, and the accordingly optimization algorithms are designed. Based on the research results of the single ma-chine scheduling problem, the production and transportation collaborative scheduling problem with buffer area is considered, and corresponding mathematical model is established, of which the objective function is to minimize the makespan. Besides, the production and transportation collaborative scheduling problem without buffer area is also studied, and the mathematical model is established based on the constraint condition of no buffer area, of which the objective function is to minimize the makespan. The properties of optimal solution are analyzed, new lower bound is derived, and a heuristic for the problem is constructed. The results of simulation experiments show that when the number of jobs are larger than 260, the average and maximum relative gaps of the heuristic are both less than 0.01%.

Data-driven scheduling in manufacturing

Jun Pei

School of Management, Hefei University of Technology,
Hefei City, China

Abstract. With the continuous development of network technology and global economic integration, the competition in manufacturing becomes more and more fierce. There is increasing awareness of the supply chain participants that they have to reinforce the cooperation between each other to improve the competitiveness of supply chain so as to decrease each operation cost. The development of Internet of Things technology provides an information basis of the cooperation between the participants of supply chain. It can not only return the production information to the management center, but also share the information to other participants. The Internet of Things technology pushes the cooperation between supply chain participants to a new level that by using the information effectively can decrease the production cost, increase the profit, improve the satisfaction of customers, and in the end enhance the competitiveness of the whole supply chain. Besides, introducing the technology of the Internet of Things also broadens the theoretical area of the research on scheduling problems. Therefore, how to transform the information value into economic and social value, and use the information acquired by the Internet of Things to obtain efficient production plans becomes the key issues. Based on the background of Aluminum production manufacturing chain in China, we focus on the data-driven scheduling in manufacturing.

Fractional 0–1 Programming: Applications, Complexity and Algorithms

Oleg Prokopyev

University of Pittsburgh, USA

Abstract. In this lecture we overview a class of nonlinear integer optimization problems commonly known as fractional 0–1 programming problems (also, often referred to as hyperbolic 0–1 programming problems), where the objective is to optimize the sum of ratios of affine functions subject to a set of linear constraints. Such problems arise in diverse applications across different fields, and have been the subject of study in a number of papers during the past few decades. We overview the literature on fractional 0–1 programs including their applications, related computational complexity issues and solution methods including exact, approximation and heuristic algorithms.