

Optimization Research Activities

The main focus of the research activity of the group is on mathematical theory and methods applicable to managerial decision-making, particularly non-linear, discrete, and multi-criteria optimization. Research is typically a mixture of theoretical investigation and practical application or industrial collaboration.

The research interests of the members of the group are given below.

Professor M Kočvara

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Professor in Applied Mathematics

Algorithms for large-scale nonlinear and semidefinite optimization

We are interested in the development of algorithms and software for large-scale optimization problems. We aim at combining efficient algorithms of mathematical optimization with powerful tools of numerical linear algebra. Particular interest is given to linear and nonlinear semidefinite programming problems, and problems with special data structures. Professor Kocvara is a co-author of a computer program PENNON which is the first known code that can solve optimization problems with a combination of standard non-linear and matrix inequality constraints. Possibilities for PhD work include, among others, development of novel algorithms using special structure of the underlying models, special data structure of the problems, and strong links to modern techniques of numerical linear algebra, like multigrid and domain decomposition.

Optimization of elastic structures

Our goal is to design optimal material properties and distribution within an elastic body. Emphasis is given to so-called Free Material Design which deals with the question of finding the lightest structure subject to one or more given loads when both the distribution of material and the material itself can be freely varied. The techniques and tools of material and topology optimization accelerated rapidly in the last ten years and recently found a way to many industrial companies, in particular in the automotive and aircraft industry. Prof. Kocvara is a member of the team that developed a computer code MOPED used, among others, in the design of components of the new Airbus A380. Possibilities for PhD work include, among others, development of new mathematical models for topology and material optimization based, in particular, on (nonlinear) semidefinite programming.

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Dr Peter Butkovič

Reader in Optimization

Max-algebra (tropical algebra) and its applications to the control of industrial processes

Max-algebra is a rapidly evolving branch of mathematics that provides mathematical theory and techniques for solving nonlinear problems that can be given the form of linear problems, when arithmetical addition is replaced by the operation of maximum and arithmetical multiplication is replaced by addition. Problems of this kind are sometimes of a managerial nature, arising in areas such as manufacturing, transportation, allocation of resources and information processing technology. After 2000 we have seen a considerable expansion of this area in a number of research centres worldwide (such as Paris, Berkeley, Moscow and Delft). Tropical linear algebra is part of tropical mathematics which overlaps with a wide range of fields from algebraic geometry and topology, functional analysis, linear algebra and geometry, combinatorics and algebraic statistics to non-linear and stochastic optimisation. Some of the results achieved at Birmingham have been used in the modelling of multi-machine interactive production processes. Attention has also been paid to the max-algebraic discrete-event dynamic systems theory where results of fundamental importance have been achieved. Dr P Butkovic has been awarded three EPSRC grants in support of this research and an LMS grant to organise an international workshop on max-algebra. He is also the Chair of the LMS Joint Research Group on Tropical Mathematics and Its applications.

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Dr Sandor Nemeth

Lecturer

Cones and ordering

The Cone is an important mathematical object which occurs in many application oriented investigations. The order structure of a linear space is determined by its positive cone. Several new results were obtained in this topic. Some of the results were used for complementarity problems and finding the projection onto cones of special structure, but many results have not been applied yet. S. Z. Németh has introduced the notion of isotone retraction cones which gives a nice connection between the geometry, topology and ordering structure of the space.

Projection onto polyhedral cones and applications

Projecting efficiently onto high dimensional polyhedral cones is an open problem with many practical and theoretical applications. Possible applications are regression, image reconstruction, pattern recognition, complementarity problems, non-negative solutions of linear systems of equations etc. The particular problem of projecting efficiently onto simplicial cones is also open and important. Recently A. Ekárt, A. B. Németh & S. Z. Németh have developed a seemingly efficient heuristic method for projecting onto simplicial cones. At the moment the method is empirical only and there is need to develop a theoretical foundation for it. For isotone projection cones (simplicial cones with a special ordering structure) A. B. Németh & S. Z. Németh have developed an efficient method of projection. Any new result in this topic is very important and can open new opportunities for applications. A. B. Németh & S. Z. Németh are preparing a book about Euclidean Vector Lattices which deals with the problem of projecting onto simplicial cones too.

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Dr Yunbin Zhao

Lecturer

Cardinality and Matrix Rank Minimization

Cardinality and matrix rank minimization problems have wide applications in science and engineering. Dr Yunbin Zhao's recent research interest is to develop theory and efficient mathematical optimization methods for solving these problems (either exactly or approximately). This research is aiming at developing some new computationally tractable approximation to the cardinality and rank minimization problems. Combined with the modern convex analysis (especially the semi-definite programming) and linear algebra tools, Dr Y.B. Zhao is developing a unified iterative algorithm for locating the sparse or the sparsest solution of the problems. The applications can be in such fields as system control, statistics, image processing, wireless communication, and other fields.

