

Robust optimization algorithms for problems with uncertain data

Description for the general public

Optimization problems are omnipresent in engineering, industry, economics, as well as provide a fundamental tool for analysis of physical systems. Many problems of this kind emerge spontaneously in nature: for example, molecules of a chemical system may undergo a reaction that leads to the minimization of its total energy. Properties of different physical phenomena may be determined or predicted through finding extremal points of appropriately defined functions – mathematical models. Such problems are also considered in almost all branches of engineering: electrical, mechanical, civil or material. They appear in automatic control, transportation, supply chain management, facility location, as well as in specialized medical applications (such as the image reconstruction from noisy observations in positron emission tomography), or in load planning and distribution of energy in national electric grid.

Due to the development of efficient computing devices in recent years, as well as a result of advancements in the research on optimization algorithms, it became possible to realize a great potential of many new technological inventions. However, in some applications the efficiency of these methods is still largely constrained, because of the simplifications and limitations of the available models. One of the main issues is the uncertainty in problems' data, which may result from the applied technology, or may be an inherent property of the considered phenomena.

In order to prevent negative effects of data uncertainty it is required to apply appropriate methods for mathematical modeling of the considered processes. One of the main theoretical frameworks used for this purpose is the *stochastic* approach, which in case of complex objects typically requires a very large number of observations, in order to faithfully reproduce the actual properties of the problem. This approach may be, however, not adequate for such applications, in which the solution accuracy is of a critical importance (e.g., design of nuclear power plant or design of large-scale suspension bridge, etc.). Moreover, for problems of great scale, there may be not enough historical data available for estimating parameters reliably. Consequently, it is proposed to use the *robust* framework, in which the construction of mathematical model is aimed at the analysis of the worst-case scenarios. In other words, such approach allows to determine solutions that are immunized to the unfavorable realizations of the problems' data.

During the course of the project, models of this kind will be analyzed and new numerical solution methods will be developed. Considered problems belong to typical areas of optimization under uncertainty, including operations research, scheduling, process engineering, design and analysis of transportation networks, as well as bioinformatics, and automated processing of spectral images in particular. Efficient methods and algorithms for solving these classes of problems will be developed under appropriate assumptions regarding data uncertainty. Conditions will be determined, which must be satisfied by the problem to be tractable in a suitably short time. For large scale problems and that of a high degree of complexity, approximate solution methods will be developed with provably good properties. Finally, numerical experiments will be carried out with the use of cluster computing hardware, allowing for statistical verification of the developed methods.