Effective methods for automated design of complex technical objects and systems

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In almost any field of human activity, people choose optimal options from a great variety of possible alternatives. When designing new devices, products and systems, researchers and engineers always strive to ensure that their systems have the best characteristics and are economically viable. Thus, for example, a new car being developed must be fast, consume a minimum amount of fuel, be reliable and, in addition, it should not be too expensive.

So it comes as no surprise that researchers at the Lobachevsky University are actively involved in the research of models and methods for making optimal decisions when solving complex problems. A team of scientists under Professor Roman Strongin has proposed a large number of approaches to solving global (multi-extremal) optimization problems, including linear programming of the problems of unconditional optimization, problems of nonlinear programming, and many others.

With these approaches, it is possible to solve many problems of optimal decision-making by using some key properties. For example, it is assumed in linear programming problems that all the existing dependencies in the optimization problem are linear. However, existing approaches do not fully cover all possible tasks for making optimal decisions.

According to Professor Victor Gergel, a leading member of the research team at the Lobachevsky University, the distinguishing feature of this class of problems is the assumption of multi-extremality of optimized efficiency criteria, for which the optimality among close variants does not necessarily mean the optimality among all possible alternatives.

"This determines the complexity of global optimization problems: in order to prove the optimality of the chosen option, one must show that this particular option is the best in the whole range of possible solutions," says Victor Gergel.

At an additional level of complexity, it becomes possible to have several simultaneous performance criteria, which is important in practical applications. In fact, how can engineers choose one quality criterion when developing a new car? Most likely, it is possible to specify several individual partial indicators, such as weight, cost, maximum speed, etc. However, the partial efficiency criteria are, as a rule, contradictory, and no available options would be the best in all respects (the fastest car will not be the cheapest).

Therefore, the solution of multicriteria problems is reduced to finding effective compromise options that cannot be improved simultaneously with respect to all the partial criteria. At the same time, it may be necessary in the course of calculations to find several effective solutions. In the extreme case, this may be an entire set of undominated options.

When solving multicriteria optimization problems, the complexity of computations substantially increases when it is necessary to find several (or the entire set of) effective options. Finding even one compromise option requires a significant amount of computations, while the definition of several (or the entire set of) effective options becomes a problem of exceptional computational complexity.

To overcome the computational complexity of multicriteria problems, Professor Strongin's research team proposed a two-fold approach. First, effective global search algorithms developed within the framework of the information-statistical theory of multi-extremal optimization will be used for solving optimization problems. Second, when performing calculations, all the search information received during the calculation will be used to the greatest possible extent. On the whole, the re-use of search information will result in a continuously decreasing amount of calculation when searching for the next effective options.

Computational experiments performed by Lobachevsky University scientists show that the proposed approach makes it possible to reduce more than a hundredfold the amount of required computations when searching for the next effective solution.

A good example of practical application of this approach is the optimized profile of railway wheels. This result was obtained jointly with the colleagues from the Technical University of Delft (the Netherlands).

"Our calculations show that the proposed optimized profile of train wheels provides an increase in the wheel life to 120 thousand km (more than five times compared with the wheel of the original profile), while increasing the maximum permissible speed from 40 m/sec to 60 m/sec," notes Professor Strongin.

More information: Victor Gergel et al. Efficient multicriterial optimization based on intensive reuse of search information, *Journal of Global Optimization* (2018). DOI: 10.1007/s10898-018-0624-3

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