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Introducing Researchers

Featured in this issue is Assistant Professor Akiko Takeda who challenges complex problems of our society, taking advantage of Operations Research (OR) techniques.

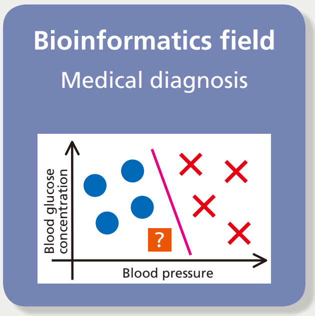
Using OR to Derive Optimal Solutions

Mathematics takes up the challenge of the actual world

Suppose you intend to reach your destination in a metropolitan area using different modes of public transportation such as JR, private and subway lines, you may be familiar with several different routes but may be at a loss which route to choose. In this type of case, the "train transfer guide" site accessible from your cellular phone or PC is very useful. Capable of instantly receiving the shortest and cheapest route from among the various routes, this convenient tool is the result of a field of applied mathematics known as Operations Research. What type of study is this OR that is inseparable from daily and vital needs of our modern society and Ms. Akiko Takeda's specialty OR field?

What is Operations Research?

Ms. Akiko Takeda, Assistant Professor, Department of Administration Engineering, Keio University Faculty of Science and Technology, remarks: "Operations Research is a scientific method to find solutions to various problems of our world, taking advantage of mathematical and statistical modeling, statistics, algorithms and the like. I especially specialize in studies on what is known as "optimization" – a method of computation for problem solving. In this method, you model a targeted actual problem in the form of an optimization problem and seek a solution for the model. And the concept of "optimization" is concerned with diverse fields of applied studies, such as business management, finance, bioinformatics and control."

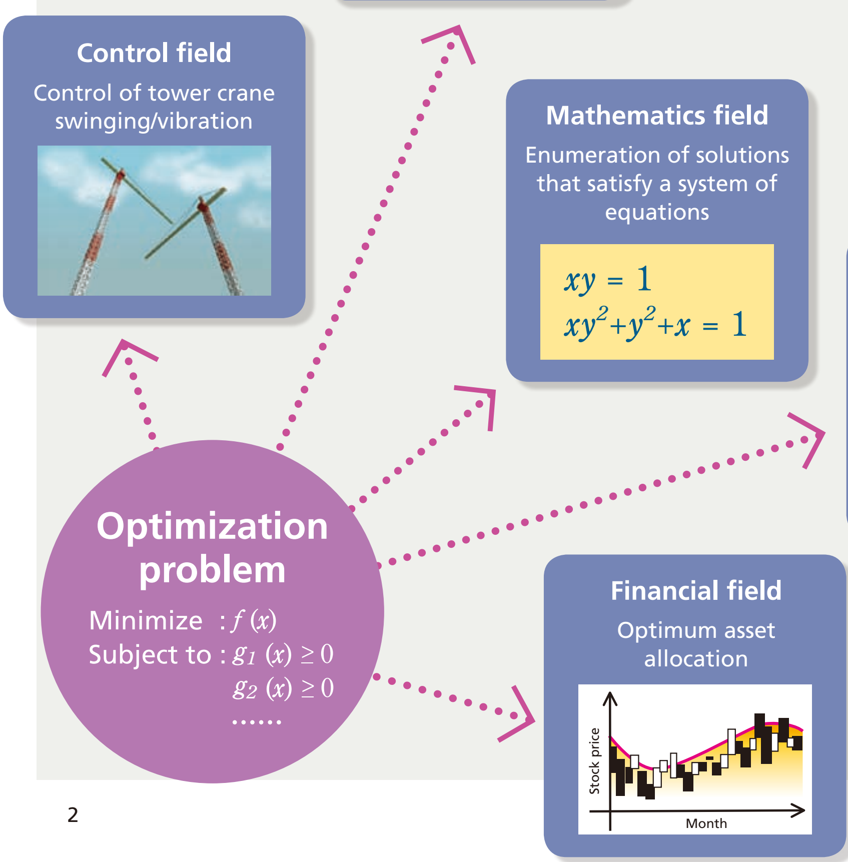


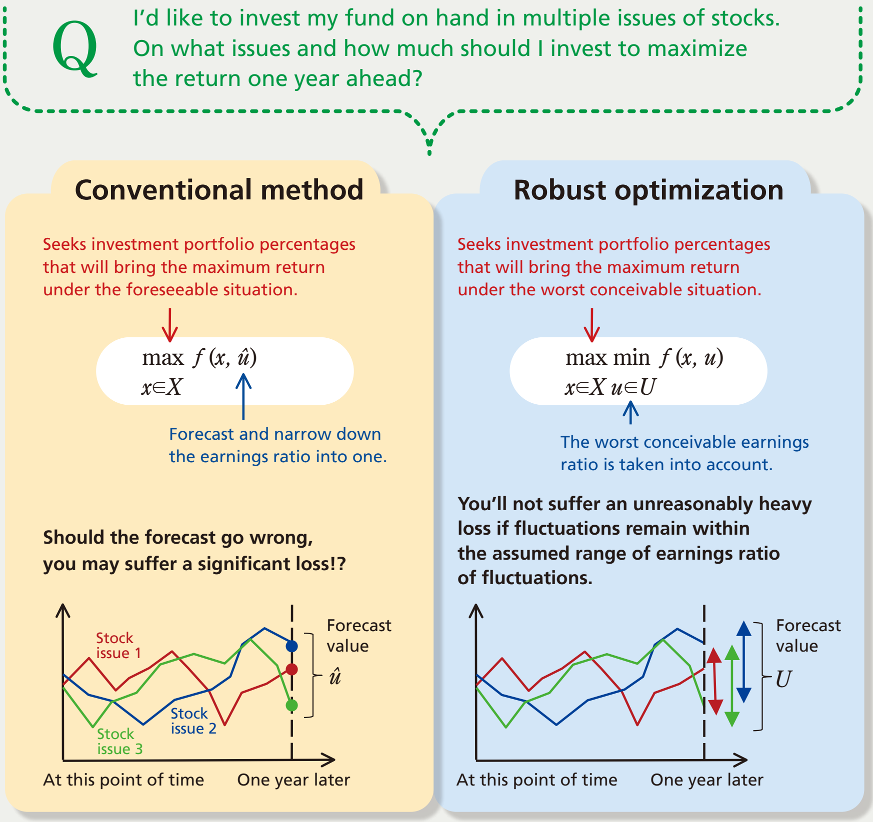
Operations Research is a field of study initiated during the Second World War (see the column on page 8). After the war ended, OR has made phenomenal progress in pace with the development of computers, and is now quantitatively utilized as an effective tool for solving complex and difficult problems of our society.

"For example, OR is used to compute solutions to questions such as "How many windows should a hospital or bank provide?" and "How long will an average waiting time be if the number of windows is pre-fixed?" Aside from the main issue, it may interest you to know that the current Prime Minister Yukio Hatoyama's specialty was also OR when he was young and the theme of his doctoral thesis was 'Machinery maintenance model based on the queuing theory.' In other words, he studied the computing method as to at what point of time should machinery maintenance and repair be conducted.

Optimization being applied to diverse fields

Upon completion of her doctor's course, Ms. Takeda joined an electrical machinery manufacturer where she was assigned to a post tasked with power generation planning for an electric power company. The power company would utilize coal, oil, and natural gas-fueled generators and Ms. Takeda's task was to determine power output for each of these generators so that the company could generate electricity at the lowest possible costs. It was a highly demanding task especially as it involved future fuel price changes due to foreign exchange rate fluctuations. She added: "Satisfying electricity needs was imperative as power failure was out





of the question. At the same time I had to hold down costs while taking future fuel price fluctuations into account. However, solving the problem would become impossible if unforeseeable rapid price fluctuations had to be assumed. So it was required to set conditions within a solvable range."

"Not limited to this problem, but after actually having solved problems, in most cases you find that the answers derived via OR are close or similar to what you have been practicing by rule of thumb at your workplace. However, you can use optimization as an effective means for obtaining a consensus within your company or persuading your client because it allows you to derive answers quantitatively instead of relying on intuition or experience. In recent times the optimization method is being increasingly used as a quantitative method to justify managerial choices."

Furthermore, optimization is useful when examining and building up an investment portfolio based on an ideal combination of various financial products such as stocks, bonds, etc. It helps you to determine optimal asset allocation percentages to realize an expected level of return while minimizing risks as it allows you to combine issues prone to move according to market price fluctuations with those which are significantly less impacted by business trends.

Worthy of mention in this connection is Dr. Harry M. Markowitz who advocated a modern portfolio selection theory. He was awarded the Nobel Prize in Economic Sciences for his contribution of proposing a portfolio optimization problem known as the "Mean-Variance Model."

Much is expected of Robust Optimization

Meanwhile, optimization has its own problem. In the event of rapid stock price and/or foreign exchange fluctuations as seen in the recent economic turbulence triggered by the so-called "Lehman's Shock," investment portfolios, which were initially designed for low risk and high return by anticipating price/foreign exchange earnings ratios beforehand, often fail to match the market reality, making investors suffer significant losses. Although an optimization problem is created with the aim of building up a low-risk/high-return portfolio, it becomes extremely difficult to apply the model to market reality if one single optimization problem is to be chosen by forecasting data such as earnings ratios.

As in the previous case of the generators at the electric power company, for example, answers will vary largely depending on how you forecast fuel price fluctuations. In traditional methodologies, we defined an optimization problem by forecasting only one fuel price and derived the answer (which fuel-type generator to choose) despite the fact that fuel price is an uncertain factor. Should the forecast go wrong, reliability of the answer is lost. Against such a background, in 1998 two American research scientists, Aharon Ben-Tal and Arkadi Nemirovski, proposed what is known as the "Robust Optimization." Instead of limiting data to only one since the data may be uncertain, this method offers a permissible range that allows you to derive the best possible answer to choose from while assuming the worst situation within the given range.

"While the term 'robust' means 'strong' or 'tough,' the robust optimization may be considered a method to derive a solution resistant to fluctuations. Back to the above-mentioned power generators, robust optimization enables the worst case to be anticipated as it makes computation by allowing some latitude for values concerning fuel price and electricity demand. This helps you when you make the actual decision."

Robust optimization is also useful for optimization for tower crane operation to haul up an object. It optimizes the operation while allowing latitude for the object's weight, the length of the crane's rope and the arm's boom's angle as well as wind velocity which is an uncertain external force. Expectations are high for robust optimization as a tool that can maximize efficiency while satisfying the absolute requirement, safety.

"With robust optimization it is necessary to solve optimization problems of complex structure, but it is often the case that these problems are too difficult to obtain answers. This has given rise to a new wave of studies: "If yours is a robust optimization problem that satisfies a condition like this, then there is a way to transform it into an easier-to-handle problem". This approach aims to answer how you can transform your problem into an easier one by satisfying such-and-such conditions, or, if it's impossible, what computation method should be employed to seek a relatively better answer instead of the 'best possible' answer."

There are many themes of study for me to address. While theoretically solving these themes one by one, I would like to use the results of my work for the benefit of our society by expanding the scope of application through collaboration with research scientists from other diverse fields. Right now I'm writing a finance-related thesis, citing the robust optimization, along with one on machine learning related to bioinformatics."

While in pursuit of mathematical theories, Ms. Takeda always pays attention to the real world. From Ms. Takeda's work, I could recognize that Operations Research has unlimited potentialities and is indispensable as something that supports our modern society from behind the scenes.

(Report and text: Madoka Tainaka)