OPERATIONS RESEARCH AND THEORY OF COMPUTING

IBM Research is known for its groundbreaking work in Operations Research (OR) and in the Theory of Computing. Pioneering contributions to the field of OR include integer programming (Ralph Gomory and Ellis Johnson), decomposition methods (Phil Wolfe), graph theory (Alan Hoffman), and linear programming (Alan Hoffman).The foundations of many types of complexity have been laid or built upon at Research. Among these are polynomial-time complexity (Alan Cobham), algebraic complexity (Shmuel Winograd), Fast Fourier Transform (Jim Cooley), fast matrix multiplication (Shmuel Winograd and Don Coppersmith), information-theoretic complexity (Greg Chaitin), descriptive complexity (Ron Fagin), alternating complexity (Ashok Chandra, Dexter Kozen, and Larry Stockmeyer), parallel complexity (Nick Pippenger), and computational complexity on the reals (Michael Shub).

Our dual objective is to pursue basic research on a broad range of theoretical topics and to impact real-world issues by applying our expertise to solving problems for IBM and its clients. Through IBM's On Demand Innovation Services (ODIS) organization, a partnership between IBM Research and IBM Business Consulting Services, and through IBM's Center for Business Optimization, researchers have access to an extensive array of challenging problems that motivate innovative solutions and, at the same time, constantly push the theoretical state-of-the-art with the development of new algorithms and new optimization techniques.

FUNDAMENTAL RESEARCH

The scope of our basic research encompasses advances in techniques for integer programming, combinatorial optimization, nonlinear integer optimization, network optimization, stochastic programming, and randomized algorithms, as well as the creation of such new areas as algorithmic game theory and quantum complexity. Much of this research is directed toward advancing the fundamental theoretical issues underlying many business problems, such as scheduling, approximate solutions to large-scale optimization problems, and approximation algorithms. One of our widely recognized recent results is in the theory of lattices, i.e., integer combinations of basis vectors. The problem of finding the shortest non-zero vector in a lattice has been open for 150 years. IBM researchers showed how to generate a lattice at random in such a way that the average-case hardness of finding a short vector is as bad as the worst case. On this foundation, a public-key cryptosystem was built, which, provably, is as hard to break on average as in the worst case.

ADVANCED MATHEMATICAL SOFTWARE

To spur development of high-quality, secure open-source software tools for the OR community, IBM researchers founded the COmputational INfrastructure for Operations Research (COIN-OR), and now lead many of its innovative projects, including state-of-the-art algorithms for linear, nonlinear, mixed-integer, and derivative-free optimization. IBM Research's high-performance computational kernels, such as the Engineering and Scientific Subroutine Library (ESSL) and the Watson Sparse Matrix Package (WSMP), are used extensively by companies, laboratories, and universities worldwide. Moreover, the design of every custom microprocessor developed by IBM uses ESSL and WSMP, together with nonlinear optimization software available on COIN-OR.

SOLUTIONS

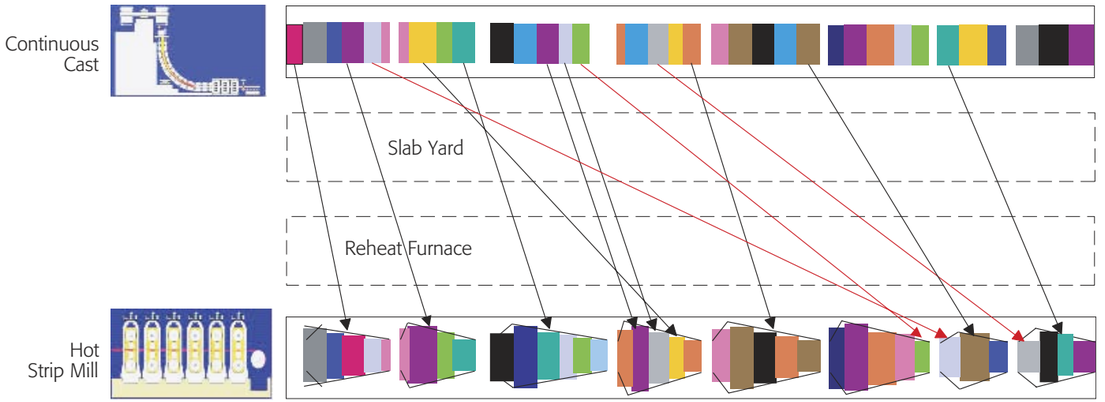
With their deep knowledge of theory and algorithmics, IBM researchers provide innovative, custom solutions to business and industrial problems that are at the boundaries of what can be solved today. Here are a few recent examples:

The United States Postal Service (USPS) moves forty percent of the world's mail volume, operating one of the world's largest transportation networks. USPS has undertaken an ambitious initiative to redesign its multi-modal logistic network. Through ODIS, IBM researchers are helping USPS to minimize transportation costs by developing tools that optimize nationwide transportation schedules and mail routings. Large-scale optimization techniques have been developed to address the multi-commodity flow and network design problems.

A major steel manufacturer needed to improve its production capabilities to remain competitive. By customizing a library of algorithms (combination of traveling salesperson problem, outlier-detection algorithms, and local search methods), researchers optimized the company's production processes, resulting in significant reductions in costs and in inefficiencies, especially in scheduling and order fulfillment. For example, the number of stock slab types was decreased by up to 40 percent, unused weight in each slab was cut by as much as 50 percent, and the number of scheduling experts needed was reduced by 10 percent.

The "punch" process was a gating factor in IBM's manufacture of multilayer ceramic modules for chip mounting. Electrical connections between the 10-100 ceramic layers, made with over 10,000 metal-filled "via" holes per layer, are mechanically punched in each layer. By applying computational geometry techniques together with algorithms for the traveling salesperson, set cover, and other, less standard, problems, throughput for the punch and die process was increased by 20-50 percent, production volume rose, and millions of dollars were saved.

Integration of Caster and Hot Strip Mill



Objectives:
- Maximize Hot Charge Rate (HCR) (red arrows lower HCR rate)
- Maximize tundish/roll size
- Minimize requested surplus
- . . .