Obituary

Peter L. Hammer (1936-2006)

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Peter Ladislaw Hammer was born in Timisoara, Romania, on December 23, 1936. He earned his Ph.D. in mathematics under Academician Grigore C. Moisil at the University of Bucharest in 1966. He defected to Israel in 1967 where he became a professor at the Technion in Haifa. After moving to Canada, he taught from 1969 to 1972 at the University of Montréal, and from 1972 to 1983 at the University of Waterloo. In 1983, he moved to the USA and became a professor at Rutgers University, where he founded RUTCOR - the Rutgers Center for Operations Research. He remained the director of RUTCOR until his untimely death in a tragic car accident, on December 27, 2006.

For more than 40 years, Peter Hammer has ranked among the most influential researchers in the fields of operations research and discrete mathematics. He has made numerous major contributions to these fields, launching several new research directions. His results have influenced hundreds of colleagues and have made a lasting impact on many areas of mathematics, computer science, and statistics.

Most of Peter Hammer's scientific production has its roots in the work of George Boole on propositional logic. More than anyone else, Peter Hammer has used and extended Boole's *machina universalis* to handle questions relating to decision making, analysis and synthesis as they arise in natural, economic and social sciences. Over the span of his scientific career, he has conducted eclectic forays into the interactions between Boolean methods, optimization, and combinatorial analysis, while adapting his investigations to the most recent advances of mathematical knowledge and of various fields of application. Among the main research topics which have received his attention, one finds an impressive array of methodological studies dealing

with combinatorial optimization, some excursions into logistics and game theory, numerous contributions to graph theory, to the algorithmic aspects of propositional logic, to artificial intelligence and, more recently, to the development of innovative data mining techniques. His publications include 19 books and over 240 scientific papers. (See the Web site `rutcor.rutgers.edu` for a complete bibliography.)

At the very onset of his career, as a researcher at the Institute of Mathematics of the Academia of Romania, Peter Hammer wrote several important articles on transportation problems, jointly with Egon Balas. At the same time his advisor, Grigore Moisil, directed him to the study of Boolean algebra. In this field, a central role is played by functions depending on binary variables, and taking either binary values (i.e., Boolean functions) or real values (i.e., pseudo-Boolean functions). In a series of papers, Peter Hammer demonstrated that a large variety of relevant problems of operations research, combinatorics and computer science can be reduced to the optimization of a pseudo-Boolean function under constraints described by a system of pseudo-Boolean inequalities. A further main conceptual step in his work was the characterization of the set of feasible solutions of the above system as solutions of a single Boolean equation (or, equivalently, of a satisfiability problem). This led him, in joint work with Ivo Rosenberg and Sergiu Rudeanu, to the development of an original approach inspired from classical Boolean methods for the solution of a large variety of discrete optimization problems.

This research project culminated in 1968 with the publication of the book *Boolean Methods in Operations Research and Related Areas* (Springer-Verlag, 1968), co-authored by Sergiu Rudeanu. This landmark monograph, which founded the field of pseudo-Boolean optimization, has influenced several generations of students and researchers, and is now considered a "classic" in operations research.

In a sense, Peter Hammer's early work can be viewed as a forerunner of subsequent developments in the theory of computational complexity, since it was in effect demonstrating that a large class of combinatorial optimization problems is reducible to the solution of Boolean equations. However, this purely "reductionist" view of his work would be quite narrow. In fact, Peter Hammer has systematically used the "canonical" representation of various problems in terms of Boolean functions or Boolean equations to investigate the underlying structure, the "essence" of the problems themselves. More than often, this goal is met through a simplifying process based, once again, on the tools of Boolean algebra. This approach provides, for instance, a simple way to demonstrate that every system of linear inequalities in binary variables is equivalent to a set of inequalities involving only $0, 1, -1$ coefficients, as observed in a joint paper by Frieda Granot and Peter Hammer (1972). It also led Peter Hammer, Ellis Johnson and Uri Peled (1975) to early investigations into the facial structure of knapsack polyhedra.

In a related stream of research, Peter Hammer has established numerous fruitful links between graph theory and Boolean functions. In a fa-

mous joint paper with Vašek Chvátal on the aggregation of inequalities in integer programming (1977), he introduced and characterized the class of threshold graphs, inspired by threshold Boolean functions. Threshold graphs have subsequently been the subject of scores of articles and of a book by N.V.R. Mahadev and Uri Peled, two of Peter Hammer's former doctoral students. Other links between graphs and Boolean or pseudo-Boolean functions have been explored in joint work with Claude Benzaken, Dominique de Werra, Stephan Foldes, Toshihide Ibaraki, Alex Kelmans, Vadim Lozin, Frédéric Maffray, Bruno Simeone, etc.

Quadratic 0-1 optimization has been one of Peter Hammer's main fields of investigation. The theory of roof-duality (1984), jointly developed with Pierre Hansen and Bruno Simeone, builds on concepts from linear programming (linear relaxations), Boolean theory (quadratic Boolean equations) and networks (maximum network flow problems) to compute best linear approximations of quadratic pseudo-Boolean functions and tight bounds on their maximum value. Further research along similar lines has been conducted by Peter Hammer in collaboration with Endre Boros, Jean-Marie Bourjolly, Yves Crama, David Rader, Gabriel Tavares, Xiaorong Sun, etc.

Peter Hammer has also shown interest for the application of Boolean models in artificial intelligence and related fields, as witnessed by numerous joint papers with Gabriela and Sorin Alexe, Martin Anthony, Tiberius Bonates, Endre Boros, Yves Crama, Oya Ekin, Toshihide Ibaraki, Alex Kogan, Miguel Lejeune, Irina Lozina, and other coworkers. His contributions bear on automatic theorem proving, compression of knowledge bases, algorithms for special classes of satisfiability problems, etc. About 20 years ago, he launched an innovative approach to data mining based on a blend of Boolean techniques and combinatorial optimization. The basic tenets of this approach were presented in a joint paper with Yves Crama and Toshihide Ibaraki (1988) and were subsequently developed by Peter Hammer and his coworkers into a new broad area of research, which he dubbed *Logical Analysis of Data*, or LAD for short. The effectiveness of the LAD methodology has been validated by many successful applications to data analysis problems. In particular, some front-of-the-line medical centers are increasingly using LAD in the practice of medical diagnosis for a variety of syndromes.

Many aspects of Peter Hammer's contribution to the study of Boolean functions and their combinatorial structure are to be found in a forthcoming monograph entitled *Boolean Functions: Theory, Algorithms, and Applications*, co-authored by Yves Crama and several other close collaborators of Peter Hammer, to be published by Cambridge University Press in 2007.

Beside his scientific production, Peter Hammer will undoubtedly be remembered for his vigorous contribution to and promotion of discrete mathematics and operations research. He was the founder and editor-in-chief of several highly-rated professional journals, including *Discrete Mathematics*, *Discrete Applied Mathematics*, *Discrete Optimization*, *Annals of Discrete Mathematics*, *Annals of Operations Research* and the *SIAM Monographs on Discrete Mathematics and Applications*. At Rutgers University, Peter Ham-

mer was the founding Director of the operations research programme, and he was largely responsible for developing RUTCOR into an internationally recognized center of excellence and an open institute, where seminars, workshops, graduate courses, and a constant flow of visitors create a stimulating research environment. He was also a tireless organizer of professional conferences and workshops, where he always made sure to provide opportunities for interactions between experienced scientists and younger researchers.

The importance of Peter Hammer's scientific contribution was acknowledged by the award of numerous international distinctions, including the "George Tzitzeica" prize of the Romanian Academy of Science (1966), the Euler Medal of the Institute of Combinatorics and its Applications (1999), and honorary degrees from the Swiss Federal Institute of Technology in Lausanne (1986), the University of Rome "La Sapienza" (1998), and the University of Liège (1999). He was a Fellow of the American Association for the Advancement of Science since 1974, and a Founding Fellow of the Institute of Combinatorics and its Applications. Several conferences were organized in his honor, including the First International Colloquium on Pseudo-Boolean Optimization (Chexbres, Switzerland, 1987), the Workshop and Symposia Honoring Peter L. Hammer (Caesarea Rothchild Institute, University of Haifa, 2003), and the International Conference on Graphs and Optimization (GO V, Leukerbad, Switzerland, 2006).

Peter Hammer was not only an outstanding scholar and a tireless organizer, but also a kind, generous and humorous human being. He relished the interaction with students and colleagues, and made everybody feel comfortable to work with him, be it on a mathematical question (which he was always keen to formulate) or on planning a conference. He supervised numerous graduate students with respect and fatherly understanding, considering each one of them as his "best student". He was also a true "citizen of the world": born in Romania from a Hungarian family, he subsequently took the Canadian citizenship, then the US one, wrote joint papers with co-authors of 28 different countries, fluently spoke 6 languages (or more), traveled the world extensively, spent extended periods of time in Belgium, France, Israel, Italy, Russia, Switzerland and many other countries, and developed an extended network of friends and coworkers on all continents.

Finally, last but certainly not least, Peter Hammer was a loving husband, father and grandfather. He is survived by his wife, Anca Ivanescu, whom he married in 1961 and whose family name he assumed for a few years, by his two sons Alexander and Maxim, and by four beloved grandchildren, Isabelle, Madeline, Annelise, and Oliver.

He will be missed by everyone who knew him, always and forever.

Endre Boros[1] , *Yves Crama*[2] and *Bruno Simeone*[3]

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