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COAP 2008 best paper award: Paper of P.M. Hahn, B.-J. Kim, M. Guignard, J.M. Smith and Y.-R. Zhu

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Since 2004, the Computational Optimization and Applications (COAP) editorial board has selected a paper from the preceding year's COAP publications for the "Best Paper Award." The award competition among papers published in 2008 culminated in a tie between two papers. This article concerns the award winning work of Peter Hahn, Bum-Jin Kim, Monique Guignard-Spielberg and Yi-Rong Zhu at the University of Pennsylvania and J. MacGregor Smith at the University of Massachusetts, Amherst, and their paper "An algorithm for the generalized quadratic assignment problem," published in Volume 40, Issue 3, pages 351–372.

The authors' interest in the subject of the award paper began in December 2003, when they came across the website of Sourour Elloumi [4], which showed her work and that of her colleagues on various quadratic 0-1 assignment problems. What intrigued the authors was the similarity of these problems to the Quadratic Assignment Problem (QAP), on which they had been working for years. They had learned two important facts about the QAP. First, dual ascent algorithms based on making subtractions in the objective function cost matrices make very fast lower bound calculations [1, 6]. Second, researchers have over the years ignored the advantages afforded by combining complementary variables (i.e., variables that are equal to each other) in quadratic problems. So, the authors set about to work on these new problems as a challenge. Months later they came across the work by Lee and Ma [11], who coined the term Generalized Quadratic Assignment Problem (GQAP) and had been the first to provide an exact solution algorithm.

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The authors' instincts proved to be right. The bounds they achieved by making subtractions in the cost matrices and combining complementary variables were good and furthermore these bounds were fast. The bounds were improved by adding special treatments to take into account the knapsack constraints. Finally, the authors devised a branch-and-bound algorithm, similar to the one they had been using for solving QAP instances. After this award paper, Artur Pessoa at the Universidade Federal Fluminense, Brazil [12] proposed a new improved method using a transformational approach based on a new Lagrangean relaxation procedure, which resulted in significant progress for solving the GQAP exactly. Three of the authors collaborated with Pessoa in this work.

Peter Hahn and his Ph.D. students have devoted many years to research on quadratic assignment problems. This includes heuristic, cutting plane, and Lagrangean relaxation approaches. Hahn's exact solution methods for the Quadratic Assignment Problem (QAP) [1], the Quadratic 3-dimensional Assignment Problem (Q3AP) [7] and the Generalized Q3AP (GQ3AP) [8] are arguably the best available. His and his colleague's experience with the QAP reformulation linearization technique (RLT) methods and dual ascent approaches are referenced in a survey article invited by the International Transactions on Operations Research [9].

For nearly three decades, J. MacGregor Smith and his Ph.D. students have studied topological network design problems, including quadratic assignment, quadratic set packing, Steiner tree, and related network design problems. In particular, they are doing research on Steiner minimal trees in 3 dimensions, applications of Steiner Trees to Minimum Energy Configurations (MEC's) and protein modeling. They are also working on state dependent queuing network analysis and finite buffer queuing network models, quadratic assignment and set packing problems. Applications include the design and layout of manufacturing plants, health care facilities, and many other production and service oriented systems. One of the unique modeling tools developed in their research is concerned with dynamic traffic flow models using queuing theory and queuing networks. Their approach to integrating quadratic assignment and stochastic network flow algorithms, as evidenced in the Stochastic Quadratic Assignment Problem (SQAP), is unique [13]. They continue to seek creative and effective problem formulations and efficient algorithms for the solution of this class of problems, including tighter lower bound calculations for the exact solution of SQAP problems.

Monique Guignard-Spielberg and her Ph.D. students have made significant advances in applying integer programming and duality. Their work over the last twenty years has concentrated on the theory and applications of relaxations, particularly Lagrangean relaxation (including decomposition and substitution), and associated dual ascent and Lagrangean heuristic methods. These techniques have been used to solve very difficult linear combinatorial optimization problems in planning, scheduling, distribution and management of natural resources. Recently, their work has turned towards solving stochastic 0-1 programming problems and a new relaxation for nonlinear integer programming, called the primal relaxation. This relaxation is computationally feasible, while Lagrangean relaxation usually is not. Its extreme case, the convex hull relaxation, promises to have a huge impact in solving convex nonlinear integer problems with linear constraints, as well as a heuristic approach for nonlinear non-convex integer problems.

In 2004, Monique Guignard-Spielberg, Peter Hahn at the University of Pennsylvania and Zhi Ding at the University of California, Davis received a five year grant to study the Q3AP for the purpose of optimizing the design of wireless communications systems. Hahn et al. [7] are the first to have solved Q3AP instances. They developed a branch-and-bound algorithm based upon one of the best techniques available for solving the QAP exactly, as well as four different heuristic solution methods whose genesis came from previous work applied to solving the QAP. Although the computational results are encouraging, they also illustrate the level of difficulty associated with the Q3AP. Recently, Galea et al. [5] developed a parallel version of the exact solution algorithm of Hahn et al. [7]. This parallel code is not only an instrument for solving exactly large instances, but will also enable experimentation for improving the runtime of Q3AP exact solution algorithms.

Bum-Jin Kim worked under the supervision of Peter Hahn as a candidate for the Ph.D. in Systems Engineering at the University of Pennsylvania from January 2003 to June 2006. His Ph.D. research focused on the development of exact and heuristic solution methods for the Q3AP and the GQAP. Kim successfully developed the new lower bounds for the axial 3-dimensional assignment problem [10] required in the branch-and-bound scheme of solving the Q3AP and designed three heuristic solvers for the Q3AP by adapting stochastic local search techniques [7]. His work on the Q3AP contributed to winning the above mentioned NSF Grant.

Yi-Rong Zhu worked under the supervision of Peter Hahn as a candidate for the Ph.D. in Systems Engineering at the University of Pennsylvania from January 2004 to August 2007. Her research focused on theoretical and practical applications of quadratic assignment and its related problems. Her main achievements were addressing the inherent relationship between assignment problems, modeling new applications in facility evacuation and cross-dock facility design as GQ3AP; establishing theoretical outlines for its algorithmic implementation and developing exact solution methods. She also introduced the level-3 RLT formulation of the QAP for the first time and illustrated its promise to provide superior lower bounds, and established a hierarchy of zero-one assignment problems, parallel to the RLT hierarchy of the QAP, in order to provide new theoretical connections among them.

The GQ3AP is a generalization of the Q3AP and the GQAP. This problem arises in the assignment of spaces within multi-story buildings or within multi-deck naval vessels, so that the movement of people and materials between spaces is efficient and that the time to escape from the structure is simultaneously minimized. This problem is known as the Multi-story Space Assignment Problem or MSAP [8]. J.M. Smith posed the MSAP and devised the MSAP test instances, which are currently available on: http://www.seas.upenn.edu/"msaplib. Bum-Jin Kim developed a GQ3AP heuristic solver, which performs well on MSAP instances.

Another application of the GQ3AP is in the design of cross-dock facilities in the less-than full load (LTL) trucking business. In [14], Zhu, et al. explain how the GQ3AP is used to assign incoming trucks to unloading docks (strip doors) and simultaneously assigning outgoing trucks to shipping docks (stack doors), so that the cost of moving goods from strip doors to stack doors is minimized. This problem is known as the Cross-dock Door Assignment Problem (CDAP). Ying Liu, a Masters student at the University of Pennsylvania, prepared CDAP test instances and has experimented with several CDAP solution algorithms to determine the best procedure for optimizing cross-dock layouts. Monique Guignard-Spielberg and her student Aykut Ahlatçıoğlu [2, 3] developed a Convex Hull Relaxation (CHR) that provides optimal or close-to-optimal solutions extremely fast for GQAP, MSAP and CDAP instances.

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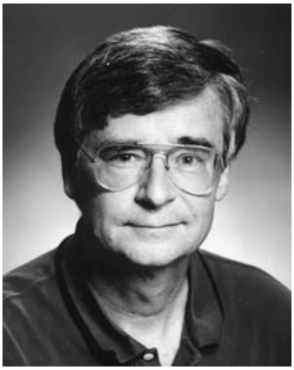
Peter Hahn graduated with a B.E.E. from the City College of New York. He received the M.S.E.E and Ph.D. in Electrical Engineering from the University of Pennsylvania. He worked as a systems engineer and manager for Ford Aerospace, RCA Corporation and General Electric and taught systems engineering courses part-time at Drexel University and the University of Pennsylvania. As a consultant for Sci-Tech Services, Inc., Philadelphia, PA, he worked for Alcatel Postal Systems in Paris, France. Hahn now supervises QAP research and advises graduate students at the University of Pennsylvania.

Bum-Jin Kim graduated with a B.S. from the Temple University. He received two master's degrees in Computer Information Science and Systems Engineering and Ph.D. in Electrical and Systems Engineering from the University of Pennsylvania. He worked as a research associate at the Catholic University of America. Bum-Jin Kim is currently working as a consultant in Samsung SDS Co., Ltd, Seoul, Korea.

Monique Guignard-Spielberg graduated with a Ph.D. and a Doctorat-es-Sciences Mathematiques from the University of Lille, France. She was a Maitre de Conference at the University of Lille, and has been Professor in the Statistics and OR Department, then in the OPIM Department, of the Wharton School, University of Pennsylvania. She was a consultant at IBM New York and Philadelphia Scientific Centers, and at IBM Scientific Computing in White Plains, New York. She has advised eighteen Ph.D. students.



James MacGregor Smith graduated with a B.Arch and M.Arch from the University of California at Berkeley and a Ph.D. in Operations Research from the University of Illinois in Champaign-Urbana. He has been a Professor in the Department of Mechanical and Industrial Engineering at the University of Massachusetts, Amherst campus since 1978. Recently, Smith spent a sabbatical in Greece after receiving a Fulbright Fellowship to spend a semester at the University of Piraeus in Piraeus, Greece.

Yi-Rong Zhu graduated with B.S. and M.S. in Operations Research from Fudan University, China. She received M.S. and Ph.D. in Systems Engineering from the University of Pennsylvania. Now she is a research scientist with the data mining consulting company Elder Research, Inc. in Virginia.