Artificial Intelligence Design Challenge

THE remarkable growth in capability for microprocessor systems in recent years has greatly expanded the opportunities and challenges for guidance and control applications. Low cost, light-weight microprocessors now offer computational power that rivals that of mainframe systems of a decade ago. Hence, embedded processor applications with "nearly intelligent" functionality are now feasible for planning, decision support, and complex control systems in autonomous vehicles, brilliant munitions, battle managers, and network controllers, as well as in piloted vehicle, sensor, and communications systems. One of the characteristics of many of these applications is the combinatorial complexity of the decision or search space of all possible solutions. Another characteristic is the requirement to deal with uncertainty in the external environment, oftentimes expressed by a stochastic objective function. Finally, there is the requirement to execute within "real-time" constraints that may range from seconds to minutes on processors of approximately one million instructions per second capability.

This issue contains a special section devoted to the design challenge that culminated in a session at the 1987 Guidance, Navigation, and Control Conference in Monterey, California. The design objective was an algorithm implemented in executable computer code, which would optimally and robustly solve variations on a stochastic traveling salesman problem. Teams from industry and academic institutions participated, with solutions documented and executed in several languages across several desktop microcomputer types. The methodologies employed included heuristics, expert systems, and linear programming. A relative evaluation of all entries was performed with specific problem variations that were not known a priori to the participants. The evaluation basis was optimality of solutions obtained and normalized computation time within an overall time constraint.

The design challenge overview, rules, and comparative results are presented in a paper by the session organizer, Dr. Owen L. Deutsch (without whom this special issue and the design challenge would not have been possible). The papers are grouped by the design methodology. The first set employs heuristically-based algorithms and includes the paper by Press and Callan. Their method includes the use of an incremental value-to-cost ratio heuristic, the Gaussian approximation to the stochastic cost function, and a high-temperature simulated annealing control structure. The paper by Doty illustrates the use of a multialgorithm approach and an efficient bounding procedure to evaluate the stochastic constraint. The tradeoff between solution speed and optimality and the requirement for robustness is very deliberately addressed. The paper by DeJong shows a different adaptation of the cost-to-value heuristic for tour construction and modification. The paper by Sung, Sheu, and Naddef shows the use of a knapsack problem solver coupled to tour improvement heuristics and heuristics to address specific problem constraints.

The next set of papers focuses on enumeration techniques, usually in combination with heuristics for pruning of the search space. The paper by Dahl, Keating, Levy, Salamone, Nag, and Sanborn combines partial enumeration to create a starting tour with a heuristic insertion procedure to expand the tour. The paper by Shaw, James, and Grunberg uses a full enumeration technique that is made feasible for this problem size by the extensive use of bounding and pruning techniques. The paper by Schaechter illustrates some of the programming development techniques that have enabled the solution of this problem by a brute force enumeration modified with pruning heuristics.

The final set of papers includes the expert system and linear programming approaches. The paper by Lirov includes an implementation with heuristics and search algorithms structured as an expert system. The paper by Huang and Lane uses a number of heuristics to identify particular situations and control the use of tour construction and modification heuristics. The paper by Padberg and Rinaldi shows how this problem can be formulated as a linear program and develops approximations to enable efficient and timely solutions to be obtained.

The performance of all of the contest entries showed orders of magnitude improvement over classical techniques such as dynamic programming. This suggests that the ability to solve complex problems in this new domain of guidance and control will be determined in larger measure by the ingenuity of algorithmic approaches rather than in evolutionary improvement in processor hardware.

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