STOCHASTIC OPTIMIZATION LIMITED

EFFECTIVE MANAGEMENT OF UNCERTAINTY

DOASA

DOASA (Dynamic Outer Approximation Sampling Algorithm) is a sampling-based optimization package for solving multi-stage stochastic linear programming problems. DOASA can be applied to any multi-stage stochastic linear program with the following specific features:

1) All problems exhibit relatively complete recourse;
2) All the uncertain parameters appear in the right-hand side of the constraints;
3) Uncertain parameters are stagewise independent.

These properties appear restrictive but can be relaxed with some loss in computational efficiency. For example the objective function coefficients can also be random and stagewise independent. The mathematics underlying DOASA is described in more depth in the papers by Philpott and Guan (2008), and Girardeau et al (2015) that can be downloaded from www.epoc.org.nz/publications. In these paper, DOASA is shown to converge almost surely to an optimal solution.

DOASA follows a similar solution approach to methods using SDDP. The main difference is its use of a single sample path (forward pass), and its termination criterion. Unlike SDDP, DOASA does not test the candidate policy for optimality while iterating. It runs for a fixed number of iterations (chosen by the user). The policy is stored and can be tested by simulation at the completion of the iterations.

DOASA was developed by researchers at the Electric Power Optimization Centre at the University of Auckland and is available for licensing from Stochastic Optimization Limited (SOL) who hold exclusive sublicensing rights. SOL's prototyping code DOASA 1.0 is written in AMPL/CPLEX and is very flexible. DOASA 1.0 can very quickly be configured to solve problems from many different industrial settings. AMPL and CPLEX are not included as part of a license for DOASA 1.0 and must be licensed separately from AMPL Inc and IBM/ILOG.

The use of AMPL makes DOASA 1.0 quite slow, and so for situations that require repeated applications, SOL has developed a faster version DOASA 2.0. DOASA 2.0 is written using a C++ library that can be configured to solve particular instances of multi-stage stochastic linear programs. DOASA 2.0 can be configured to call CPLEX or CLP, the open source COIN-OR solver. When using CPLEX, DOASA 2.0 is about 20 times faster than DOASA 1.0.

DOASA is available for license from Stochastic Optimization Limited (SOL). Interested parties should contact software@sol.co.nz for more details.

References:
Philpott, A.B. and Guan, Z., On the convergence of stochastic dual dynamic programming and related methods, *Operations Research Letters*, 36, 450-455, 2008.

De Matos, V., Philpott, A.B. and Finardi, E.C., Improving the performance of Stochastic Dual Dynamic Programming, *Journal of Computational and Applied Mathematics*, 290, 196-208, 2015.

Girardeau, P., Leclere, V. and Philpott, A.B., On the convergence of decomposition methods for multi-stage stochastic convex programs, *Mathematics of Operations Research*, 40(1):130-145, 2015.

Settings where DOASA has been successfully applied

1. Benchmarking the New Zealand electricity market.

DOASA 1.0 was used to build a centrally planned counterfactual electricity generation policy that was then simulated over historical data. The results were compared with the actual generation observed in the electricity market. The number of state variables in this application was 8 and the number of stages was 52. Work has continued in the application of DOASA to models with risk aversion. The largest models here have 32 states (accounting for stage-wise dependence in inflows) and run for 5000 iterations.

References:
Philpott, A.B., Zakeri, G., Khazaei, J. and Guan, Z., Productive inefficiency of electricity markets with hydro generation, *Utilities Policy*, 18, 4, 174-185, 2010.

Philpott, A.B. and de Matos, V.L., Dynamic sampling algorithms for multi-stage stochastic programs with risk aversion, *European Journal of Operational Research*, 218, 470-483, 2012.

Philpott, A. B., Matos, V. L. D., and Finardi, E. C., On Solving Multistage Stochastic Programs with Coherent Risk Measures. *Operations Research*, *61*, 957-970, 2013.

Philpott, A.B. and Guan, Z., Models for estimating the performance of electricity markets with hydro-electric reservoir storage, May 12, 2013, http://www.epoc.org.nz/papers/EMBERPaperv32b.pdf.

2. Hydro-electric river valley scheduling

DOASA 1.0 was used to build policies for releasing water from hydro reservoirs in a river chain to maximize revenue over a 52 week horizon. Two river chains with different structures from Electricite de France's system were tested. The number of state variables in this application was 3 and 4 respectively, and the number of stages was 52. DOASA 1.0 gave near optimal policies after 100 iterations (about 2 hours computation).

Reference:

Philpott, A.B., Dallagi, A. and Gallet, E., On cutting-plane algorithms and dynamic programming for hydro-electricity generation, in *Risk Management and Energy Trading*, R.M. Kovacevic., G.Ch. Pflug, and M.T. Vespucci (ed.) Springer, 105-127, 2013.

3. Inventory management of dairy products under uncertain supply

DOASA 1.0 was used to build policies for selling dairy products for a multinational producer of dairy products over a 12 month season. Inventory policies were constructed that accounted for contract and spot sales of dairy products and linear demand curves, as well as uncertain milk supply. To account for contracts, the number of state variables in this application was 41, and there were 12 monthly stages.

Reference:

Guan, Z. and Philpott, A.B., A multistage stochastic programming model for the New Zealand dairy industry, to appear in *International Journal of Production Economics* Special Issue on Robust Supply Chains under Uncertainty, 2011.