VALUE OF INFORMATION IN THE PLANNING OF COST-EFFECTIVE OPERATIONAL FOREST INVENTORIES

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Abstract

Pre-harvest inventories are used to estimate the volume of timber in a forest stand before the stand is scheduled for harvesting. In the inventory, the volume of timber is measured in randomly selected sample plots and the accuracy of the volume estimates essentially depends on the size and number of these plots. We consider a planning problem with two nested stages. In the inner stage, the posterior volumes are available and the task to schedule the stands for harvesting so that the monthly demand targets for timber can be fulfilled as closely as possible. In the outer stage, the decision on the inventory method is made for each stand. More accurate inventory methods lead to lower variance of the volume estimates but also cost more than less accurate methods. Value of information (Eidsvik et al., 2015) measures the gain from the lower variance. The problem is to assign an inventory method for each stand while making sure that the total cost of inventories is below the given budget limit.

We formulate the problem as a two-stage Bayesian decision problem (Raiffa & Schlaiffer, 1967) where the uncertain timber volumes and their observations are modelled using probability models. We cast the decision problem as a maximisation problem that seeks to maximise the value of information subject to a forest inventory budget constraint. Computing the value of information in our context is analytically intractable, since it requires the solution of an NP-hard binary optimisation problem within a high-dimensional integral. In particular, the binary optimisation problem is a special case of a generalised quadratic assignment problem (cf. Lee and Ma., 2004; Hahn et al., 2008). We present a practical method that solves the problem with an approximation to the value of information which combines Monte Carlo sampling with a greedy, randomised method for the binary optimisation problem.

We apply the developed method with realistic data obtained from Skogforsk, The Forestry Research Institute of Sweden. The data contain 100 forest stands for which some prior knowledge on the timber volume is available . For each stand, the choice of inventory method is made between three alternatives with different costs. We derive optimal inventory decisions for these stands across a range of inventory budgets.

Keywords: Bayesian model, Data collection, Decision making, Forestry

References

Eidsvik J., Mukerji T., Bhattacharjya D. (2015) *Value of information in the earth sciences: Integrating spatial modeling and decision analysis.* Cambridge University Press.

Raiffa H., Schlaiffer R. (1967) *Applied statistical decision theory.* Wiley, New York.

Lee, C.-G. and Ma, Z. (2004) *The generalized quadratic assignment problem.* Technical report, Department of Mechanical and Industrial Engineering, University of Toronto, Canada.

Hahn, P. M. and Kim, B.-J. and Guignard, M. and Smith, J. M. and Zhu, Y.-R. (2008) An algorithm for the generalized quadratic assignment problem. *Computational Optimization and Applications*, (40):351–372.