2000年度日本オペレーションズ・リサーチ学会
秋季研究発表会

Solving Large Scale Open Pit Mine Scheduling Problems

Louis Caccetta and Stephen P. Hill

School of Mathematics and Statistics
Curtin University of Technology
GPO Box U 1987
Perth WA 6845
AUSTRALIA
caccetta@cs.curtin.edu.au
hillsp@cs.curtin.edu.au

ABSTRACT The economic viability of the modern day mine is highly dependent upon careful planning and management. Declining trends in average ore grades, increasing mining costs and environmental considerations will ensure that this situation will remain in the foreseeable future. The operation and management of a large open pit mine having a life of several years is an enormous and difficult task. Though a number of optimisation techniques have been successfully applied to resolve some important problems, the problem of determining an optimal production schedule over the life of the deposit is still very much unresolved. Due to the size and complexity of the problems involved, the most popular commercial package for finding a production schedule involves repeatedly solving the "ultimate pit limit" problem using different cost sets. This problem is most commonly defined as finding that pit which, if all ore and waste could be extracted today, would yield the highest possible profit. Note realistic constraints such as blending, capacity bounds and mill throughput rates are not considered in the above optimisation process. Thus production schedules are typically determined by taking output from the above process and refining it by hand.

In this paper we discuss some of the techniques that are being used in the mining industry for production scheduling indicating their limitations. We also present a mixed integer linear programming (MILP) model for the scheduling problems which incorporates the many different types of constraints. In addition, a detailed algorithm based on Branch and Cut is developed. Branch and Cut is a state of the art large-scale optimisation technique introduced for solving large scale travelling salesman problems. Over the past decade it has emerged as an extremely powerful technique for solving

large MILP problems. These include applications of the technique to many real life scheduling problems such as those in the airline and transportation industries. We highlight key features of our method including the cutting planes used, our search strategies, the use of a linear programming (LP) based heuristic and methods for reducing the LP subproblems. We also comment on the structure of the MILP and its use in solving the problem. In addition, we show how the model may be extended to include realistic constraints not considered in the mining literature or by current commercial packages. These include the processing of different ore types, mining to a maximum vertical depth and ensuring the pit has a minimum pit bottom width.

Lastly we provide computational results for practical sized problems. Applying our method to a producing gold mine, we generate an acceptable schedule that increases profits by 15% compared to one generated by mining engineers using a commercial package. Based on these results our implementation is currently being commercialised.