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A tabu search approach for solving a difficult forest harvesting machine location problem

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Abstract

This paper deals with two main problems in forest harvesting. The first is that of selecting the locations for the machinery to haul logs from the points where they are felled to the roadside. The second consists in designing the access road network connecting the existing road network with the points where machinery is installed. Their combination induces a very important and difficult problem to solve in forest harvesting. It can be formulated as a combination of two difficult optimization problems: a plant location problem and a fixed charge network flow problem. In this paper, we propose a solution approach based on tabu search. The proposed heuristic includes several enhancements of the basic tabu search framework. The main difficulty lies in evaluating neighboring solutions, which involves decisions related to location of machinery and to road network arcs. Hence, the neighborhood is more complex than in typical applications of metaheuristics. Minimum spanning tree algorithms and Steiner tree heuristics are used to deal with this problem. Numerical results indicate that the heuristic approach is very attractive and leads to better solutions than those provided by state-of-the-art integer programming codes in limited computation times, with solution times significantly smaller. The numerical results do not vary too much when typical parameters such as the tabu tenure are modified, except for the dimension of neighborhood.

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1. Introduction

The problem of how to use machinery when harvesting an area is an important one in forest industries. Machines are needed to haul logs from the point where they are felled to the roadside, where they are loaded into trucks for further transportation. The use of machinery depends on the slope of the ground. High slopes require the use of cable logging (towers), while flat grounds are handled using skidders (tractors). Access roads (usually quite short) are needed to connect the existing road network with the points where machinery is installed.

A computational system, PLANEX [4], has been used during the last decade by Chilean forest enterprises as a decision support system for locating the harvesting machineries and the access roads to build. The system is based on a graphic interactive interface linked to a geographical information system (GIS) storing information on topography, timber availability and geographical barriers like rivers and ravines. The GIS information is available for each 10 by 10 m cell. The decision process of PLANEX is based on a greedy heuristic. The system has been used very successfully, leading to important cost savings as well as better preservation of the environment [4,5].

Exact formulations have been proposed to improve the solution process. In [16], a model representing this problem was formulated. It is a difficult combinatorial problem and commercial mixed integer programming software is able to solve only small or medium size instances. A moderately better approach was proposed in [16] using Lagrangian relaxation to decompose the problem into its two basic components. The first sub-problem is a plant location problem: the machinery locations act as plants and timber cells represent customers. The second sub-problem is a fixed charge network flow problem. Both sub-problems are difficult to solve, in particular the fixed charge network flow problem. Strengthening the formulation of each sub-problem and using other enhancements made it possible to obtain better solutions, but still only for moderate size problems of up to 40 ha, 4000 cells, and 60 potential machine locations.

In this paper, we propose an alternate solution approach based on tabu search. The basic principles of this heuristic are the following. Evaluating neighbor solutions is difficult. Indeed, when we consider just the location problem, a typical neighbor solution is obtained either by modifying the status of one location (opening or closing it) or by exchanging the status of two locations (opening the one currently closed and closing the one currently opened). These modifications are easy to execute but, in our case, given any modification of locations, the corresponding access road network must be modified accordingly. This operation is very time consuming if done exactly. Thus, we approximate the cost of the new access road network by referring to a spanning tree of all relevant nodes, defined a priori. Hence, we obtain rapidly a suboptimal value of the neighbor solution. Once a set of locations is identified with this approach, we use a Steiner tree heuristic to determine the associated access road network. Other typical enhancements of the basic tabu search approach are also implemented and tested: (a) reduction of the neighborhood size [2], carried out by evaluating sequentially only a fraction of the neighboring solutions at each iteration, (b) variable tabu tenure [14], (c) intensification and diversification strategies, (d) GRASP [6,12] and other randomized selection processes to select the modifications generating the neighbor solutions, and (e) path relinking [8,11].

The numerical results indicate that reducing the neighborhood size has an important impact on CPU time, without significantly deteriorating the quality of the solutions. The impact of the other enhancements is less significant. The approach is tested using real life size problems with up to 500 ha, 50,000 cells, and 520 potential machine locations. As noted above, the approach proves to be very stable. When compared