# 27. AN EXTRACTION TRAIL GENERATOR USING LIDAR DATA AND TABU SEARCH

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The transport of timber from stump to mill relies on a range of machines and equipment for primary (forwarders) and secondary transport (road trucks). This makes optimization of timber transport a complex task, which also should consider road planning and construction. Given the complexity of optimizing timber transportation, exact methods are limited by problem size. In this case, metaheuristics is a method proven to give good solutions in reasonable time. Forest operations can be divided in several tasks. For a cut to length system, the tasks are felling and delimbing/bucking/sorting by a harvester and transportation and sorting by a forwarder. For other systems, the order of the tasks can be different.

This work describes a computer implementation of tabu search (TS) for generating good trails for wheel based forest machines using the cut to length system. The implementation uses a digital terrain model (dtm) from remotely sensed Lidar (light detection and ranging) data as well as raster interpretations of conventional road and soil data.

We use a dtm from high resolution Lidar, with an average of 10 measurements per m². Some of the measurements will be reflections from the forest canopy, used to survey the forest stand. However, depending on the density of the forest, some measurements are reflections from the ground, and from these measurements we can generate an accurate dtm at reasonable cost.

Tabu search is one of the most frequently used metaheuristics, and is proven to give good results. TS is a local search, we have a current solution and evaluate a neighbourhood. This neighbourhood is a set of solutions resulting from (small) changes in a (small) part of the current solution. Local search will accept a new solution if it has a better objective value, whereas TS also accepts a solution with worse objective value. To stop TS from going back, the old solution, or parts of it, is labelled tabu for some iterations. Hopefully, this will stop TS from getting trapped in a local minimum/maximum. The neighbourhood implemented is adding of a part of a trail. In addition, we will use a neighbourhood of deleting whole or parts of a trails, a neighbourhood of moving whole or parts of a trail and a routine for merging of trails.

In addition to the dtm and road and soil data, we will use environmental data from registrations of key species. The environmental impact will be implemented either as a penalty to the objective function or as multi objective tabu search.

We use a high resolution grid of 1m x 1m, and the digital terrain model from Lidar combined with soil data is used to evaluate both where the machines can operate and identify trails representing the lowest cost of terrain transport. The problem is to find the best subset of vertices representing the trails, while every vertice has a minimum distance to the subset. This minimum distance is given by the reach of the machines. This is a Steiner Tree Problem, and is NP-hard.

The method will be tested at a full scale level in a forest in Norway. Firstly, we will compare the estimated cost of harvesting with actually incurred cost at a stand. If the model gives good estimates, it will be useful to the forest owner, who can acquire a better estimate of the cost of harvesting. (Macro economics - better decisions from accurate pricing?)

Secondly, an interesting question is whether we can use Lidar to identify where a forest machine can operate. We will compare the suggested trails to terrain trails actually created by machine operators, and if the accuracy of the dtm is good enough, the method can be used for generating more efficient trails and reduce harvesting cost. Also, the method will be the basis in further research. An estimation of the trade-off between primary and secondary transport costs could provide the basis for the planning of new forest roads, and the method could also be used in matching harvesting systems to sites.

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