A Simplified Approach to Forest Decision Support Systems

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Abstract

Forest management decisions, because of the many conflicting issues involved, require many iterations to arrive at a feasible plan. Various optimization methods have been attempted to automate this process, but none have been widely accepted. A flight simulator'prototype has been developed, based on the exchange of 'scenarios ', the current or proposed state of the forest. This simple approach produces a good feedback loop: the manager proposes a plan, and this is evaluatedfor various criteria. He may then modify his plan to improve various indices and re-submit it.

Instead of having a single scenario generated as input, we will often need to generate a sequence of interventions that conform as far as possible to our economic criteria. An example of this is the evaluation of varying road construction schedules, where a particular annual budget must be assigned to the most appropriate road segment.
However; it is not feasible to develop automatic systems for such plans, as there are too many other factors, such as terrain traficability, that are not yet capable of being removed from the realm of human judgement. Thus any such tools must then allow manual modification, followed by a furtlzer evaluation step.

Introduction

Forest harvest modelling is a particularly difficult problem when approached from the traditional direction of optimization. There are several reasons. One is that in a real-world situation there is only a limited variety of data (wood volume, species etc.) available in the detailed data base. Another is that in practice the forest manager must take into account a wide variety of more imprecise data and rules-of-thumb that can not normally be handled in such a system. This includes a great deal of information about the terrain. and trafficability, which is based on experience rather than formal rules. This is part of the whole problem of handling space: we have relatively limited tools to talk about adjacency, distance, etc.

This means that the results of such a process are frequently of little use to the forest manager. who must manually edit. or completely re-do, the maps produced. Simulation models have some of the same problems. In particular, if a particular 'run' is unsatisfactory then a variety of non-intuitive parameters need to be adjusted in order to attempt to produce something more intuitively reasonable in terms of the spatial distribution of the harvesting schedule on the output map. Respected simulation models are described in Baskent and Jordan (1991) and in Moore and Lockwood (1990). It appeared that it would be beneficial to allow the user to interact with the forest map, rather than with abstract parameters, in order to develop more reasonable results.

The 'Flight Simulator' Approach

Gold (1993) developed the "flight simulator" concept to describe a system based on scenario evaluation rather than optimization.

It was based on a simple concept of “bandwidth”: the capacity of the channel of communication between the computer (good at calculations) and the manager (good at judgements made with imprecise data). The computer data largely consisted of simple properties for large numbers of forest stands (e.g. wood volume, species. area) and simple rules (maximum allowable cut). The human data consisted of large quantities of imprecise information of a general nature (political and social consequences, terrain trafficability. practical rules for the management of men and machines). The problem was to take advantage of the strengths of each. and transfer information between the two in the most appropriate form. The conclusion for data transfer was the scenario, which could be understood by the manager in its global form. and evaluated by the computer in its details. (A scenario may be defined as some current state, or else an action plan on that state. that is to be submitted for evaluation. A state is the condition of the forest at some point in time, visualized as a forest map with the depiction of existing stands, cutting areas. and regenerating areas.) Thus at the simplest, the manager would edit the map, labelling the stands to be cut, and the computer evaluates the costs. benefits and various desired indices for that scenario. At a somewhat more elaborate level, the manager may suggest a sequence of scenarios at sequential time intervals, and the evaluation may show the change in wood volume. costs. wildlife habitat. etc., over this time sequence.

The key question is the iterative sequence of scenario generation and evaluation, These could be modified as necessary for the particular context. For example, a manager could prepare a plan, involving a particular harvesting sequence for a portion of the forest, and the computer could evaluate it for a variety of ecological. economic, social and wildlife criteria - whatever items were of interest. and for which reasonable models existed. (A good deal of wildlife modelling is devoted to providing habitat indices for a variety of indicator species. Thus a particular forest state at a particular time may be rated for habitat suitability for some species. This species is chosen as being either representative of a group of species - a guild - or as being particularly sensitive to change.)

This simple approach produces a good feedback loop: the manager proposes a plan. and this is evaluated for various criteria. He may then modify his plan to improve various indices, and re-submit it. The various criteria may be imagined as being shown on a set of gauges or dials on the screen. and the manager’s objective is to keep all the needles out of the ‘red’ zones. We call this the Flight Simulator paradigm, as there are two objectives: to go from some original state to some final state as efficiently as possible (but above all without any catastrophic error!), and to train the operator by practical experience as to what actions are generally positive. and which are not.

The main purpose of forest management, however, is to minimize man’s impact while maximizing the economic value of the forest. Thus the main objective of decision support systems is to help the forest manager to plan his interventions in the forest (harvesting. road building, silviculture, etc.) to maximize the economic return (value minus cost) while minimizing the adverse long-term impact. Thus. in our scenario evaluation, the initial input is the current forest state plus the proposed harvesting plan, (These plans themselves are subject to a large number of regulatory constraints. such as not cutting too close to a river, restricting the size of the cut block, and not allowing adjacent blocks to be cut within some specified ‘green-up’ time period.) The economic considerations are not merely to grab the best wood first. but to make the best use of the economic resources available (men and machines) over the long term, which often means attempting to equalize the volume of wood, of each desirable species, going into the mill each year, and to extract this while using the same number of men. heavy equipment, logging trucks and road-building crews each year as well. Not an easy task! Our flight simulator thus has a series of dials for economic criteria. as well as environmental parameters, for each of the time periods being simulated.

Generating Multiple Scenarios

At this stage. instead of having a single scenario generated as input, we will need to generate a sequence of interventions that conform as far as possible to our economic criteria. The forest manager will thus specify a general plan, and the scenario generator will put together a sequence of scenarios, with varying economic or other parameters, that may be run through the computer-based evaluation system. An example of this is the evaluation of varying road construction schedules. where a particular annual budget must be assigned to the most appropriate road segment. (Appropriate here means that it makes accessible an appropriate portion of the forest, for current or future exploitation.) Algorithms may be developed to suggest plans based on varying budget levels. However, it is not feasible to develop automatic systems for such plans, as there are too many other factors. such as terrain trafficability. that are not yet capable of being removed from the realm of human judgement. Thus any such tools must then allow manual modification, followed by a further evaluation step.

Harvesting and Road Construction Modelling

One of the difficulties with traditional harvest planning systems is that there is no real model of space inside the system. For this reason they are aspatial, and only provide lists of forest stands to be cut in a particular time period. without any spatial grouping. The spatial planning was then done by hand. The next generation of such systems included the spatial knowledge of a standard GIS, where each forest stand or polygon is coded with information about its neighbours. GIS-Forman (see Baskent and Jordan, 1991) falls in this category. Here the adjacency information is used to grow harvesting blocks around selected central stands. On this basis it is possible to navigate throughout the map, and to use the standard GIS functions to cut out unavailable regions, etc. The approach used in this project was to extend this adjacency information, by constructing the dual graph of the polygon map, and working within this framework.

For any set of contiguous stands, if one takes some centroid of each stand, and connects each pair of centroids whose stands share a common boundary. the result is in general a triangulation. This triangulation may be thought of as a crude transportation network, where all the possible paths from one stand to the next are displayed. The centroids represent the stand as a whole. While only approximate. some kind of distance measure may be given to each edge of the triangulation, representing the ‘distance’ from any stand to its neighbour. This gives a graph structure, for which a variety of well-known algorithms are available.

Modelling of this kind-may be used to plan a harvesting schedule on the basis of spatial adjacency first - the way someone in the field would think. First look around from your currently accessible locations, and then select the next stand of the appropriate type. Continue in this fashion until you have achieved some form of quota. "Accessible" could mean that one starts from the mill location and cuts the closest good stand, or it could mean that a primary road network is defined in advance (following triangle edges, as an adequate approximation). and then the best stand selected. This would start to extend the secondary transportation network. adding new stands to the accessible list, and the selection operation would be repeated. This would certainly not produce an optimal solution. but at least it would be spatially feasible. In any case, the reality of forest management is that conditions change yearly, due to regulations. fires. etc.. and so a reasonable approximation is quite sufficient for most parts of the planning process. Basic graph traversal algorithms are described in Sedgewick. 1988.

While this is a very crude mechanism, as in our current prototype, the selection process could be made more sophisticated in terms of the stand attributes, corresponding more closely in this respect to the traditional aspatial method. As an addition step, the road construction schedule - a significant overall cost - could be modelled by simple optimization heuristics. In this case the potential primary road network would be entered by the forest manager, and the value of adding each additional segment would be based on the wood volume that it would make accessible, given some maximum haulage distance along the secondary structure. This would give a sequence of 'scenarios' or forest maps, for which a variety of indicators could be calculated by the computer and submitted to the manager for evaluation. These indicators could include wood volume and species mix, change in wildlife habitat. haulage and road construction costs, and many others. Manual intervention could modify the potential road network or exclude certain areas as desired, and the 'scenario stack' could be regenerated. evaluating the scenario at each time period.

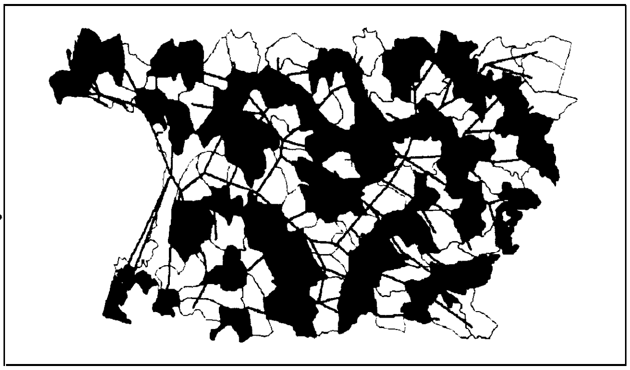

Figure 1. Selectton of stands based on proximity to principal roads

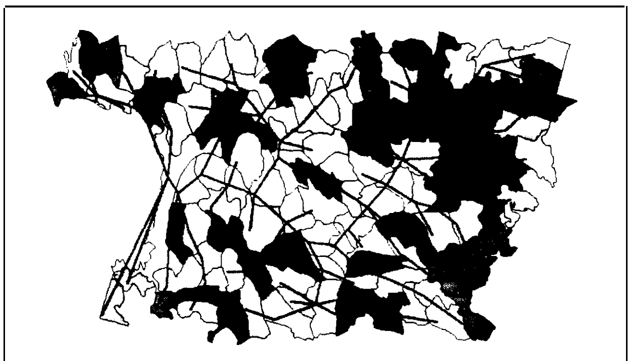

Figure 2. Selection of stands based on optimizing road construction.

Results and Conclusions

Our current prototype does not yet use stand attributes in its calculations, although simple graph algorithms may be of use in spatial planning. Figure 1 shows a forest map with the original primary road network shown in black. and the secondary routes shown so as to minimize the distance to the primary road. Stands are coloured so that the closest are cut first, etc. Figure 2 shows the results when up to 50 km of secondary routes may be built in each time period, each additional road segment being priorized by the volume per km of road in its hinterland. Colours again represent stands reached during each time step.

We feel that a simple, interactive approach of this type, where the first level of analysis was based on the spatial structure, followed by the stand attributes. could form a viable PC-based toolkit for the forest manager.

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Biography and Acknowledgements

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