Theoretical and Computational Foundations of Management Class Simulation

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Abstract: Investigations on complicated, complex, and not well-ordered systems are possible only with the aid of mathematical methods and electronic data processing. Simulation as a method of operations research is particularly suitable for this purpose. Theoretical and computational foundations of management class simulation must be integrated into the planning systems of forest management and must provide a large number of alternatives for action. A model already in wide use is described.

INTRODUCTION

Research on complicated, complex, and not well-ordered systems is possible only with the aid of mathematical methods and electronic data processing equipment. With analytical model analysis (e.g. optimization models), the solution algorithm yields a specifically defined result, but computational experiments are more or less systematic test procedures for which there is no logically certain procedure for optimal solution. The purpose of the computational experiment is to search for the optimal solution or the best corresponding decision. Complete and partial searches are differentiated according to the scope of search processes within the framework of a given decision model. In complete searches all possible constellations of variables are calculated, and the optimum with respect to the objective concepts exists with certainty among the variants. The partial search is limited to a sample of all possible searches. It must be guaranteed that partial search procedures are directed toward the research goal. Partial searches differentiate between pure simulation and "design game plan." In simulation one specifically formulates definitions for actual decisions through decision rules at the beginning of a series of searches. In the design game plan, the strategies for a search series are not fixed at the beginning of the game, but develop in the course of the game as the result of chains of decisions.

Simulation is suitable as a method for operations research because of its adaptability for analysis of systems with numerous input and output quantities and complicated structures. It is distinguished by the following essential crite

1. A system can be simulated if it can be subdivided into a variety of elements for which the behavioral rules can be assigned.

2. The simulation encompasses a mathematical model which "runs" but is not solved; i.e., time is very important in the simulation.

3. The process of system optimization is not directly contained in the simulation.

4. The output of the modeled system is weighted in the simulation with respect to deterministic or stochastic modifications of the input.
   A number of steps must be considered in the development of a simulation model:
   (a) Formulation of goals
   (b) Formulation, weighting and comparison of possible alternatives
   (c) Selection of the best alternative with respect to the objective function (decision)
   (d) Control of the elaboration of decisions and eventual corrective measures.

The principle of the mathematical simulation is presented in figure 1.

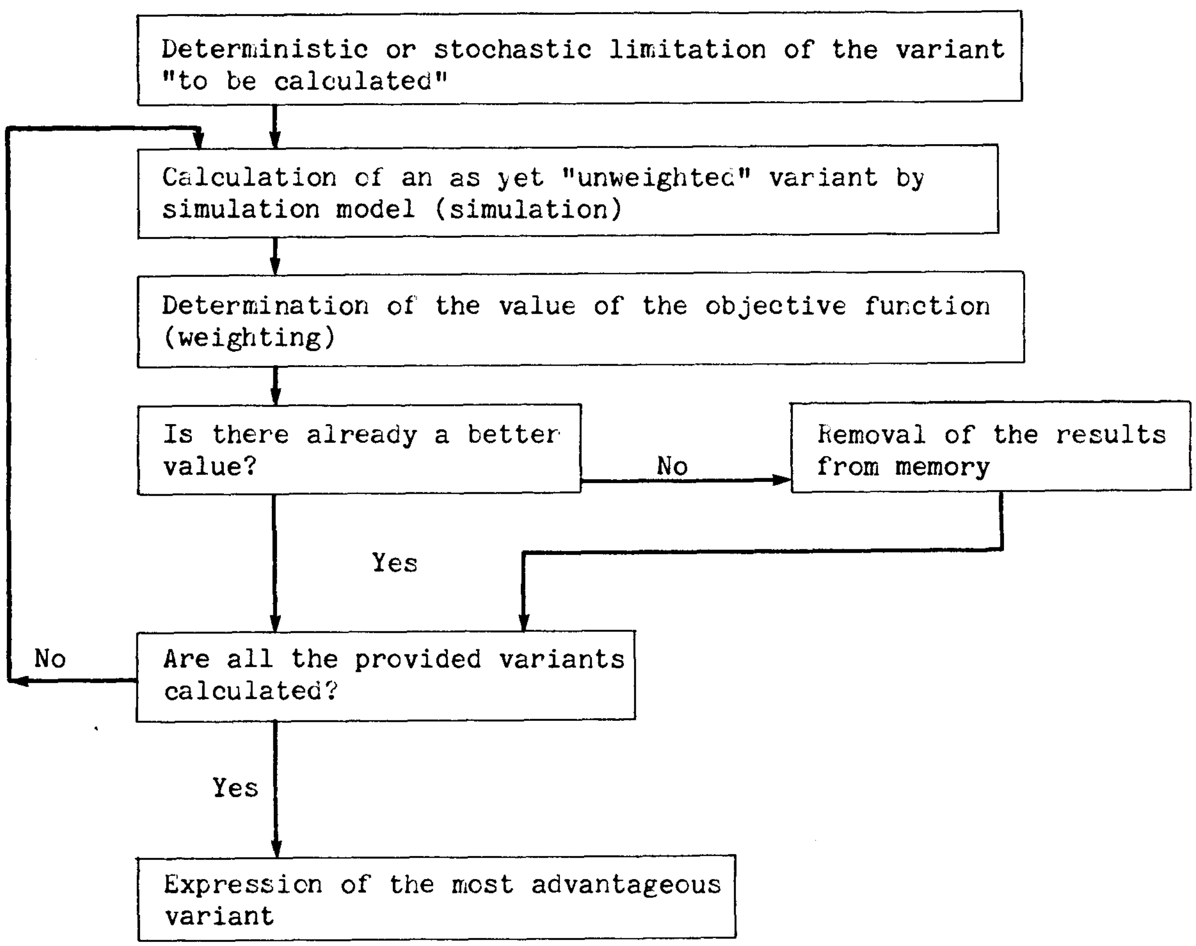

Figure 1--Principle of mathematical simulation in the form of a flow diagram.

FOUNDAIIONS OF THE MANAGENENT CLASS SIMULATION

The significance of simulation for forestry problems is conditioned primarily by the long duration of the production process. The extensive time differences between managerial measures and their effects on the forest necessitates the inclusion of future developments in present decisions. The value of a measure can be interpreted only in view of its effect on long-term goals.

The management class as a system within a sustained unit is decidedly significant for the complex planning of a forest evaluation. Its stratified structure is only ascertainable through simulation of multiple alternatives in its combined time and space-related development. A management class simulator (Gerold 1976) is a model based on the specific state of a tree species management class, which includes all stands of a tree species cultivated for similar production goals and found within a sustained unit. With this model, the effects of different variants of production and yield regulation on the development of this management class over long periods of time (the prognosis) can be analyzed. Also, the mutual correlation of the component problems of the sustained unit can be demonstrated. The formulation of this type of model has the following foundations and requirements:

(a) The model must be integrated into the total planning system of the forest evaluation. It must have numerous alternatives and include, therefore, many component problems of sustained yield regulation. The time interval over which simulation takes place should be determined by the user.

(b) The stand is the active element in a management class. The complex sustained yield regulation requires that the input information of the simulator refer to this conditional unit. All management class data are derived from the aggregation of stand information during simulation. The accuracy of stand information should be known, to correctly classify the results of the simulation model with respect to certainty within the framework of the decision aids.

(c) Component models, weighted and easily integrated into the planning system of forest evaluation, are to be used for the generation of many alternatives (e.g., intermediate and final yield strategies), i.e., a large scope, in the formulation of a model. The scope of the alternatives is determined by the flexibility and quality of the management class simulator.

(d) An efficient, updating algorithm, which guarantees certain extrapolation, is necessary for the simulation of stand information.

(e) The model must make possible the processing of management classes of any stand, i.e., of any age, quality, and growing stand density structure. If the memory capacity of the electronic data processing unit is not sufficient for calculation of larger conditional units, because stands are numerous, then the stands are aggregates into "computation units of a higher order." In this case, the criteria must be as follows:
    Age (e.g., 2-year intervals)
    Quality (e.g., have quality grades)
    Density stand volume (units of 10)

This facilitates the use of the simulator for sustained units of any given size.

(f) On the basis of goals formulated for the stands, and of management class information, the actual conditions obtained in the individual stages of the prognostic time span, and the planning magnitude are to be weighted according to valuation criteria for the age structure and the stand density. From the weighting, the deviation from the norm is to be estimated. This weighting facilitates the selection of certain planning alternatives by the planner in the context of the overall goals.

(g) The following prerequisites apply for the preparation of the computed information:
   (1) An electronic data processing unit with a large memory capacity and high calculation speed must be available.

   (2) The simulation program is based on the block principle to provide flexible subroutine exchange, thereby making possible simple consideration of new alternatives.

   (3) The presentation of results using a high speed printer must be in the form of` clear and easily visible tables. Automatic symbol equipment to represent the development of specific key numbers of the management class are to be used as much as possible.

   (4) The preparation of stand information is rationally possible only through electronics. An additional prerequisite is a functionally efficient, permanently actualized data memory containing information which can be recalled at any time using available sorting identifiers.

Figure 2 presents the general program design of a management class simulator to calculate a planning variant. Any of the available variants (alternatives) can be simulated using this sequential scheme.

DESCRIPTION OF A MANAGEMENT CLASS SIMULATION MODEL

A management class simulator was developed on the basis of the fundamentals presented in Figure 2. It is submitted as the program flow chart and calculation program using the program language ALGOL for the electronic data processing unit BESM:-6. The Soviet large-capacity computer is suitable due to its high calculation speed of an average of 10^6 operations/second for the generation of the simulation model. The memory capacity of BESM-6 permits direct processing of management classes with a maximum of 3800 stands. On the average, this corresponds to an information scope of approximately 5000 hectares. For larger conditional units, an aggregation (see figure 2) should be used. The stand data used (age, land, mature crop, quality) are available in handbooks of forest management in the data bank of the forest fund. Extensive information for various planning strategies is derived from these data during simulation for, each 10-year period of the prognostic time span. It is printed in the form of the following tables:

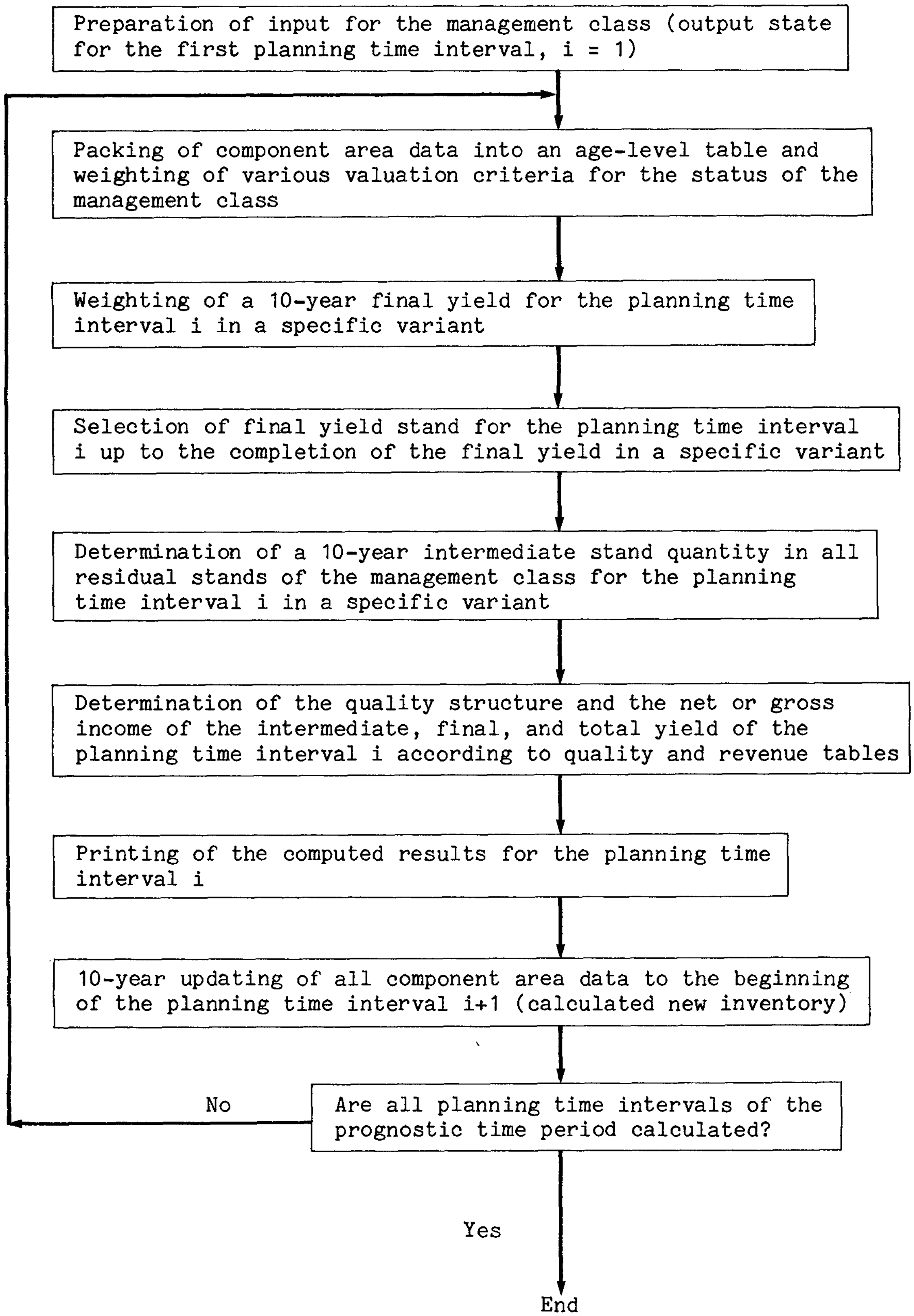

Figure 2--Representation of a general program design in the form of a program flow chart for a specific planning variant.

Age distribution table

Table for final cutting stands

Table for intermediate yields of stands

Summary of harvest and growth

Table of the range of harvest.

The simulation model is constructed in a deterministic manner; i.e., alternatives do not have any random features. Its functional efficiency was tested in a series of real management classes (Gercld 1976; Gerold and Kurth 1977; Kurth and Gerold 1977; Gerold 1978).

LITERATURE CITED

Gerold, D. 1978. Effect of age structure on the growth increment capacity of management classes. Wiss. Ztschr. der Tech. Univ. Dresden, 27:(2).

Gerold, D. 1976. Untersuchungen zu Problemen der Verknupfung einzelner Nachhaltbegingungen mit Simulationsmodellen fur die Baumart Fichte [Investigations on the problem of decisions for individual sustained conditions using simulation models for spruce species]. Dissertation A, Tharandt.

Gerold, D., and H. Kurth. 1977. Proposals for further development of a normal forest model. Wiss. Ztschr. der Tech. Univ. Dresden, 26:(2)497-501.

Kurth, H. and L. Gercld. 1977. Simulation model for sustained yield regulation. Paper presented at the IUFRO Symposium, Subject Group S.04, Session Zvolen. Sept. 12-15, 1977.