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Chapter XIII. Summary. (p 167-172)

XIII

Summary

The main purpose of this thesis is to adapt the Markov decision programming techniques to be able to cope with the animal replacement problem in a satisfactory way. The problems to be solved are the dimensionality problem (i.e. that the size of the state space tends to be so large that optimization is prohibitive), the uniformity problem (i.e. that the traits of animals are difficult to define and measure) and problems caused by herd restraints, as for instance a milk quota or a limited supply of heifers or gilts. A secondary purpose is to illustrate and discuss the applicational perspectives of the techniques.

In Chapter II a systematic survey of the developed techniques is given in the framework of traditional Markov decision programming. The notion of a hierarchic Markov process is mentioned as a way of dealing with the dimensionality problem. The uniformity problem is handled by a technique based on Bayesian updating and the herd restraints are partly solved by the introduction of a new criterion of optimality (the milk quota) and partly by a method called parameter iteration (the limited supply of heifers).

In Chapter III the notion of a hierarchic Markov process is explained. It is a series of Markov decision processes, called subprocesses, built together in one Markov decision process called the main process. The hierarchic structure is specially designed to fit replacement models, which in the traditional formulation as ordinary Markov decision processes, are usually very large. The basic theory of hierarchic Markov processes is described and examples are given of applications in replacement models. The theory can be extended to fit a situation where the replacement decision depends on the quality of the new asset available for replacement.

In Chapter IV a dairy cow replacement model based on a hierarchic Markov process is presented. In the model a cow is described in terms of lactation number, stage of lactation, the level of milk yield during the previous and present lactation, the length of the calving interval and the genetic class defined from the breeding value of the father. The criterion of optimality is the maximization of the present value under an infinite planning horizon. Revenues from milk, calves and replaced cows, feed costs and costs of replacement heifers are considered. The future profitability calculated from the optimal solution is used for ranking of the cows in the herd. The genetic class makes it possible to include the heifers available for replacement and to let the replacement decision depend on the genetic class of the heifers.

In Chapter V a new criterion of optimality in Markov decision processes is discussed. The objective is to maximize the average net revenue per unit of physical output (or input). The criterion is relevant in some production models, where a restraint is imposed on the physical output (production quota) or on an input factor (scarce resources). An obvious application is in dairy cow replacement models under milk quotas. Iteration cycles are presented for ordinary completely ergodic Markov decision processes and for hierarchic Markov processes. The consequences of the new criterion is illustrated by a numerical example.

In Chapter VI the new criterion is applied to a dairy cow replacement model under a milk quota, and the results are compared to those under the usual discounted net revenue criterion. Optimal replacement policies, future profitabilities and rankings under the two criteria are compared. It turns out that culling should be less intensive under milk quotas because of a smaller variation in future profitability. Considerable differences in future profitability and ranking are found, and it is concluded that it is important that the correct criterion is used when milk quotas are in effect.

In Chapter VII the nature of the variation in the traits of an animal is discussed. It is argued that the variation may be described as a sum of a permanent effect which is constant over time, only varying among animals, and a temporary effect varying over time for the same animal. Only the sums of the permanent and temporary effects are observable, but we have a prior knowledge described by a probability distribution of the permanent

effect. As observations of the sums are taken, the knowledge on the true value of the permanent effect increases (i.e. the probability distribution changes). Also a more general model, involving several random traits each being influenced by several unobservable effects, is described. If the permanent effects had been directly observable, an optimal replacement policy might be determined by a hierarchic Markov process (or an ordinary Markov decision process in small models). On the other hand, the updating of knowledge on the permanent effects may be handled in a causal probabilistic net (Bayes belief net), but that method does not provide an optimization technique. Therefore, the Bayesian updating technique used in causal probabilistic nets has been combined with the optimization technique of a hierarchic Markov process in order to solve the animal replacement problem with variation in traits. The method is illustrated by a numerical example which shows that the benefits from updating of knowledge may be considerable. Furthermore, the method is compared to approaches in the literature, and it is argued that in some cases it may reduce the size of the state space in animal replacement models.

In Chapter VIII, the dairy herd is described as a multi-component system, where the components are the cows and heifers. The problem of finding an optimal replacement policy to the multi-component system is considered. The complication of the multi-component model is that if the supply of heifers is limited (i.e. the dairy farmer uses only home-grown heifers), the replacement decision concerning a cow does not only depend on the state of that particular cow, but also on the states of the other cows and heifers in the herd. Initially it is demonstrated that the multi-component replacement problem may be formulated as an ordinary Markov decision process. Unfortunately, the model is far too large to be solved by any known methods. Therefore, an approximate method combining dynamic programming and stochastic simulation in the determination of a set of descriptive parameters is suggested. The parameters are used in the calculation of the multi-component replacement criterion for cows as well as for heifers. The method has been tested by extensive simulations under 100 different conditions concerning prices and average milk yield of the herd. It is concluded that when the replacement costs (price of a heifer minus the price of a calf and the carcass value of a cow) are small, the method improves the economic results considerably compared to the usual models, assuming unlimited supply of heifers. The information concerning heifers, which is provided by the method, makes it relevant even in cases where the replacement costs are large. The basic idea of the study may be relevant in a more general range of problems involving replacement under some constraint.

In Chapter IX, the applicational perspectives of the techniques are discussed. It is argued that they may be applied as tools in the study of the traits and conditions that influence the optimal policies and as tools in comparative studies of operational methods for application in commercial herds. The following chapters (X and XI) are examples of such applications. Direct application in commercial herds is not realistic at present.

In Chapter X, the economic value of culling information is studied. The net returns to housing, labour and management are calculated analytically using three different replacement policies in the presence and absence of a milk quota. The conclusions are that in the absence of a milk quota there are considerable benefits from using a decision support system, but under a quota the benefits are negligible if compared to the very simple policy of only replacing cows which fail to conceive within 238 days. If a system based on calculations assuming no quota is used under a quota, the dairy farmer will be directly misinformed. Decision support systems for culling should be specifically designed for the quota situation where reductions of costs are the most important means for improving herd net returns.

In Chapter XI, operational methods for direct application in commercial herds is studied. In order to develop a ranking criterion, two criteria are tested by means of stochastic simulation based on random number generation. Under the first criterion, the ranking is provided by a dynamic programming model, but instead of herd individual conditions a set of standard conditions is used. Under the second criterion the cows are ranked according to their expected net returns to housing, labour and management during the next 12 months. Both criteria are tested in the presence and absence of a milk quota. The simulation results show that both criteria are suitable for practical implementation in both situations. Thus the final choice depends on other considerations including implementation and operation costs as well as comprehensibility. A third criterion called expected maximum net returns, which has been suggested in literature, was considered, but rejected for theoretical and empiriral reasons.

In Chapter XII, it is concluded that the hierarchic Markov process, as an exact and fast method, has raised the upper limit of the size of the state space to be dealt with. In that way it contributes to the solution of the dimensionality problem, but still, the upper limit has not been eliminated. The Bayesian updating technique is considered to be an important contribution to the solution of the uniformity problem. It is expected to be useful if diseases are included in the state space. Furthermore, the method may in some cases reduce the size of the state space without loss of information. As concerns herd restraints, two methods have been proposed. A new criterion of optimality has been introduced in order to study the effect of a milk quota, and the approximate parameter iteration method has been successfully applied in a situation with shortage of heifers. As a future research area methods for state space reduction are requested.