

GENETIC ALGORITHM TO INCLUDE HERD LEVEL EFFECTS IN OPTIMISING INDIVIDUAL ANIMAL DECISIONS

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Les systèmes d'aide à la décision utilisés par les vétérinaires et les éleveurs ne concernent actuellement que les cas où la décision à prendre est au niveau de l'animal. La décision prise pour un animal a certainement des répercussions sur le reste de l'élevage. L'exemple présenté dans cet article concerne les décisions sur le remplacement des animaux dans un élevage de 16 vaches avec un quota réduit en utilisant un algorithme génétique. Avec un quota réduit, on peut avoir un conflit entre les décisions individuelles et les répercussions sur l'ensemble du troupeau. Remplacer par exemple une vache avec un potentiel génétique élevé est profitable puisqu'on évite les pénalités liées à une surproduction. Pour les 16 vaches, on a simulé une période de deux ans en utilisant le modèle de gestion des vaches laitières (TACT) en comparant deux différentes fonctions object pour l'algorithme génétique. La fonction object A qui optimise le niveau troupeau pour l'année en cours entraîne des remplacements élevés et réduit la capacité de production l'année suivante. Pour éviter ce problème, la fonction object B est définie pour tenir compte également de la production de l'année suivante. Cette dernière fonction est moins radicale et permet de gérer le conflit entre les intérêts individuels et ceux de l'élevage. L'algorithme génétique peut être également utilisé par les vétérinaires où les décisions ont des répercussions sur l'état sanitaire du troupeau. Par exemple, dans un élevage laitier, la réforme d'une vache atteinte de mammites réduit les cas supplémentaires de mammites dans l'élevage.

INTRODUCTION

Decision support systems that help farmers and veterinarians make optimal decisions on veterinary treatment and culling are most often focused on individual animals only. A decision regarding an individual animal, however, may also affect the rest of the herd. The example presented in this paper is the quota restriction on milk production that applies to countries of the European Union. In the quota system a farmer is allowed to produce a limited amount of milk per quota year. When the amount is exceeded a milk levy has to be paid. In the situation with a quota system a decision that is optimal for an individual cow may become sub-optimal from a herd level point of view, especially at the end of a quota year. Keeping all cows with a positive future value may lead to exceeding the milk quota and therefore a sub-optimal farm income in the short term. On the other hand, culling profitable animals will help to reduce the levy to be paid but will also reduce the income in the next year(s). An other example where an optimal decision for an individual animal can conflict with an optimal decision from a herd level point of view is culling a cow with mastitis. Culling a cow with mastitis may reduce the further spread of mastitis in the herd, and therefore such benefits should be included in a model that optimises herd level decisions.

The technique used to optimise replacement decisions on herd level is a genetic algorithm. Genetic algorithms are search algorithms based on the mechanics of natural selection and natural genetics (Goldberg, 1989). They combine the survival-of-the-fittest principle among string structures, with a structured yet randomised information exchange. In each iteration, a new generation of artificial creatures (chromosomes) is created using bits and pieces of the fittest of the previous generation with an occasional change in chromosomes to keep variation between the chromosomes within a generation.

GENETIC ALGORITHM

Most methods for optimising decisions (such as dynamic programming and linear programming) calculate a perfect optimum. For very complex problems this perfect optimum can take too much time to calculate. In these situations a genetic algorithm is a good alternative. In a relative short time the algorithm calculates a near optimal solution for the problem.

The genetic algorithm has besides its limited calculation time other advantages over more often used optimising techniques. The genetic algorithm needs no information on the function to be optimised other than the function itself, where other techniques sometimes need information on the first or second derivative of the function to optimise. Even though a genetic algorithm is a search algorithm, it has no problems with functions that have multiple optima. The genetic algorithm is a fast search method when all possible solutions of a problem need to be evaluated. The genetic algorithm is able to recognise good parts of the solution of the problem and keeps it for next generations (Goldberg, 1989).

Chromosome

A chromosome represents a possible outcome of the problem to optimise. In the first iteration a generation of e.g. 100 chromosomes is created. In this paper the chromosome used is a string in which each position in the

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string represents a decision for a cow. The decision for a cow can be either one or zero. When a position in the string has the value one the decision is to replace the cow, a position in the string that has the value zero represents that the cow is kept.

Object function

The object function is the function to be optimised. With the help of the object function the fitness of a chromosome is calculated. In the example in this paper the object function calculates the Herd Value. This is the total expected profit of all cows in the herd minus a milk levy for the herd which is a result of a replacement decisions for cows in the herd.

Processes in selection of chromosomes

Reproduction is a process used in a genetic algorithm to transfer a complete chromosome from a generation to the next generation. The genetic algorithm gives chromosomes with a high value for fitness a higher chance of reproduction and therefore a higher presence in the next generation than chromosomes with a low value for fitness. To create (promising) new chromosomes, parts of chromosomes are combined with parts of other chromosomes. Again the genetic algorithm makes use of the knowledge of the fitness of a chromosome to give chromosomes with high fitness more chance of taking part in this cross-over. To keep variation between chromosomes in a generation, an occasional mutation is made in a chromosome. Reproduction, cross-over and mutation transfer chromosomes from generation to generation. This process stops after a fixed number of generations or when the change in result of the object function reaches a pre-defined criterion.

EXAMPLE

For the research in this paper a 16-cow herd was simulated with the dynamic probabilistic TACT-Dairy Animal Management model (Jalvingh, 1993) and followed over time for two years. The probability distribution over states in which cows can be at the end of the second year, was used to generate 10 herds of 16 cows, representing different situations the initial herd could have reached after two years. For each cow the retention pay off value (RPO, that is the expected profit of the cow in the future over a replacement heifer) and her expected milk production in the remaining month of the quota year were determined using dynamic programming (Houben, 1995). The genetic algorithm used in this paper was the genetic algorithm described by Houben (1995). The RPO and the milk production in the remaining month were used in the object function to calculate the total herd value. With object function A the profit for the current year was optimised which resulted in a replacement decision 1 month before the end of the quota year. The same calculations were also made for replacement decisions 2 and 3 months before the end of the year.

Object function A : calculation of HerdValue (HV)

$$\text{HerdValue} = \sum_i^{\text{nr.cows}} (\text{RPO}_i) - \text{MilklevyHerd}$$

This lead to some undesired results when the herd had produced relatively a lot of milk in the first part of the quota year. The model then advised to cull a lot of (high producing) cows to reduce the milk levy to pay in the current year (Table 1). When this happens the production capacity of the herd in the next year is reduced and losses occur in the year after the replacement decision supported by the genetic algorithm (Table I).

To overcome the problem of lack of production capacity in the year after the decision was supported by the genetic algorithm the object function was adapted. When the herd could not produce the quota in the next year, the amount of milk that the herd produced below the quota was valued by the milk price and exceeding the quota was valued by the same penalty as in the current year. In words the new object function advises to cull or replace cows so that the future profit of the herd is optimised under the condition of maintaining production capacity for the next year and minimising the milk levy for exceeding milk quota in the current year. This is expressed and summarised in object function B.

Object function B: calculation of the Herd Value with the condition of maintaining production capacity

$$\text{HerdValue} = \sum_i^{\text{nr.cows}} (\text{RPO}_i) - \text{MilklevyHerd} - \text{Penaltyproductioncapacity}$$

Decisions made by the genetic algorithm with the object function B that took into account the losses that could occur in the year after the decision were less radical with regard to the number of culled cows. This resulted in a higher milk levy to pay in the current year but a higher total result over the two year period (see also table I).

Table I
Results of replacement decisions (Dutch guilders)

Results of the replacement decision when only current year was taken into account (object function A)					
Herd	HV quot	levy	loss	total	herdsize
1	13751	2211	12923	-1383	-3
2	13751	2211	11223	317	-3
3	13751	2211	14327	-2787	-3
4	13751	2211	8170	3370	-3
5	13751	2211	15319	-3779	-3
6	13751	2211	9376	2164	-3
7	13751	2211	5143	6397	-3
8	13751	2211	5881	5659	-3
9	13751	2211	9293	2247	-3
10	13751	2211	9692	1848	-3
avg.			10135	1405	
std dev.			3363	3363	
Results of the replacement decision when also next year was taken into account (object function B)					
Herd	HV quot	levy	loss	total	herdsize
1	14040	4125	447	9468	1
2	14049	4126	344	9579	1
3	14117	4554	593	8970	2
4	13839	3505	2	10332	0
5	14117	4554	599	8964	2
6	13841	3041	116	10684	-1
7	13872	3042	496	10334	-1
8	13917	3470	270	10177	0
9	13863	3618	70	10175	0
10	14117	4554	70	9493	2
avg.	13977	3859	301	9818	
std dev.	122	602	228	603	
HV quot = Total of the RPO values of the cows in the herd levy = The milk levy paid in the current year loss = The loss in the year after the replacement decision total = HV quot minus the milk levy and the loss in the next year					

VETERINARY APPLICATION OF THE GENETIC ALGORITHM

An example of using the genetic algorithm for making replacement decisions where also veterinary restrictions have to be taken in consideration is the case of replacement of cows with mastitis. In that case an optimal decision for an individual animal can conflict with an optimal decision from a herd level point of view. The restriction of production capacity in the year after the replacement decision could be replaced with a restriction on a total infection level for the herd. Cows that have mastitis would contribute more to this level than cows without mastitis. This is considered an interesting application for the genetic algorithm that deserves further research.

CONCLUSION

The genetic algorithm is able to determine near optimal replacement advises in the situation where all combinations of replacing and keeping animals have to be compared with each other at both animal and herd level. This near optimal solution is reached when conflicts between individual animals and herds are considered.

REFERENCES

- Goldberg, D.E., 1989. Genetic algorithms in search, optimisation and machine learning. Reading : Addison Wesley.
- Jalvingh, A.W., 1993. Dynamic livestock modelling for on-farm decision support. PhD thesis Departments of Farm Management and Animal Breeding, Wageningen Agricultural University.
- Houben, E.H.P., 1995. Economic optimisation of decisions with respect to dairy cow health management, Chapter 6 : Genetic algorithm to link decisions at animal and herd level on dairy farms. PhD-thesis, Department of Farm Management, Wageningen Agricultural University.