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Mastitis detection in dairy cows by application of fuzzy logic

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Abstract

The aim of the present research was to develop a fuzzy logic model for classification and control of mastitis for cows milked in an automatic milking system. Recording of data was performed on the University of Kiel's experimental dairy farm "Karkendamm". A data set of 403,537 milkings from 478 cows was used. Mastitis was determined according to three different definitions: udder treatments (1), udder treatment or somatic cell counts (SCC) over 100,000/ml (2) and udder treatment or SCC over 400,000/ml (3). Mastitis alerts were generated by a fuzzy logic model using electrical conductivity, milk production rate and milk flow rate as input data. To develop and verify the model, the data set was randomly divided into training data (284,669 milkings from 319 cows) and test data (135,414 milkings from 159 cows). The evaluation of the model was carried out according to sensitivity, specificity and error rate. If the block-sensitivity was set to be at least 80%, the specificities ranged between 93.9% and 75.8% and the error rate varied between 95.5% and 41.9% depending on mastitis definition. Additionally, the average number of true positive cows per day ranged from 0.1 to 7.2, and the average number of false negative positive cows per day ranged from 2.4 to 5.2 in an average herd size for the test data of 39.7 cows/day. The results of the test data verified those of the training data, indicating that the model could be generalized.

Fuzzy logic is a useful tool to develop a detection model for mastitis. A noticeable decrease in the error rate can be made possible by means of more informative parameters.

Keywords: Dairy cow; Mastitis; Automatic milking; Fuzzy logic

1. Introduction

Mastitis is the most costly disease in dairy cattle today and remains one of the major problems for the dairy industry (Heald et al., 2000; Seegers et al., 2003). Average economic losses due to mastitis are estimated to be around 150 euros per cow and year (DVG, 2002). De Mol and Ouweltjes (2001) indicated that early detection of mastitis is very important, not only because of the economic impact due to yield losses, but also because of the negative effects on the animals' welfare. In herds with an Automatic Milking System (AMS), identification of udder infections is no longer based on visual observation. In contrast, control programmes managing the health status of the cows are introduced based on sensor measurements. Detection of mastitis can be automated by using an integrated system with sensor measurements of milk yield, milk temperature and the electrical conductivity of the milk (Frost et al., 1997). The suitability of electrical conductivity for mastitis detection has been analysed in previous research (Cavero et al., submitted for publication). An improvement on the

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reported results was expected by multivariate analyses of the traits. Wendt et al. (1998) indicated the possibility of using the milk production rate as meaningful additional information to electrical conductivity to detect mastitis.

Fuzzy set theory provides a strict mathematical framework for dealing with vague conceptual phenomena to describe uncertainties in real life situations and models fuzzy relations (Zimmermann, 1991). Fuzzy logic is a well-known application method in decision support, classification and controlling processes that have no simple mathematical approach (Grauel, 1995). Fuzzy logic has already been used for oestrus detection with good results (Firk et al., 2003; Yang, 1998); moreover, it has been also used to improve sensitivity and specificity of systems using conductivity as the main information source for mastitis detection (De Mol and Woldt, 2001). Köhler and Kaufmann (2002) stated that identification of mastitis using only conventional reasoning was difficult and suggested that the use of fuzzy logic could improve the reliability of detection.

The aim of this research was to develop and test a fuzzy logic model for the detection of mastitis using electrical conductivity (EC), milk production rate and milk flow rate. Such a management aid would allow early detection of mastitis at an initial stage with minimum labour requirements.

2. Materials and methods

2.1. Data

Data were recorded at the University of Kiel's experimental farm Karkendamm between July 2000 and March 2004. During this period observations from 403,537 milkings were accumulated from 478 Holstein Friesian cows with a total of 645 lactations. The mean herd size was 124 cows on average per day and 85% of the cows were in the first lactation. Milking took place in an AMS with four boxes. The average number of milkings per cow per day was 2.4 and the 305-day milk yield was approximately 9200 kg on average.

The data set was randomly divided into two data subsets with different cows. Two thirds of the original data were the training data, used to develop the fuzzy logic model. The other part of the data was the test data used to test whether the developed model could be generalized.

The highest value of the electrical conductivity of the milk was measured in each 200 ml of milk and an average value of the whole milking was recorded by the AMS. EC ranged between 2 and 8 mS/cm, with an average of 5.3 to 5.5 mS/cm. The milk production was defined as milk yield per milking, divided by the intervals between milking. The average milk flow rate of the whole milking was supplied by the AMS. Descriptive statistical information about the traits is shown in Table 1.

2.2. Mastitis definitions

Udder health was classified on the basis of the cows' SCC, which was measured weekly from pooled quarter milk samples taken from each cow, as well as information on udder treatments. A total of 52,535 SCC tests were carried out with 195,000 cells/ml on average. The Deutsche Veterinärmedizinische Gesellschaft e.V. (German Veterinary Medicine Association) has stated a value of 100,000 cells/ml as the threshold for mastitis (DVG, 2002). Harmon (1994) showed an SCC for uninfected cows under 200,000 cells/ml, but for first lactating cows SCC of uninfected quarters may be under 100,000 cells/ml. Such a low threshold ensures that most of the mastitis cows are recognised but also supplies a large list of cows classified as infected. The threshold of 100,000 cells/ml was used in the present study, as well as another less strict threshold of 400,000 cells/ml, which represents the European Union maximum bulk milk SCC legal limit for saleable milk. Three variants of mastitis definition were used in this investigation:

(1) Treat: treatment performed without consideration of SCC,
(2) Treat+100: treatment performed or a SCC> 100,000 cells/ml,
(3) Treat+400: treatment performed or a SCC> 400,000 cells/ml.

The milking days were classified as "days of health" or "days of mastitis". If two succeeding SCC measurements either both exceeded the threshold or both did not, all days between these measurements were also defined

Table 1
Means (ξ) and standard deviations (s) for the traits milk yield, milk flow rate, time between milkings and electrical conductivity (EC)

Trait	Unit	Number of observations	ξ	s
Milk yield	kg/milking	390,900	12.4	4.06
Average milk flow rate	kg/min	390,694	2.6	0.92
Time between milkings	h	403,537	9.9	2.61
Milk production rate	kg/h	388,867	1.4	0.87
EC right hind quarter	mS/cm	390,288	5.5	0.58
EC left hind quarter	mS/cm	398,326	5.3	0.56
EC right front quarter	mS/cm	395,619	5.4	0.57
EC left front quarter	mS/cm	392,110	5.4	0.59