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Mastitis detection in dairy cows by application of neural networks

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Abstract

The aim of the present research was to investigate the usefulness of neural networks (NN) in the early detection and control of mastitis in cows milked in an automatic milking system. A data set of 403,537 milkings involving 478 cows was used. Mastitis was determined according to two different definitions: udder treatment or somatic cell counts (SCC) over 100,000/ml (1) and udder treatment or SCC over 400,000/ml (2). Mastitis alerts were generated by an NN model using electrical conductivity, milk production rate, milk flow rate and days in milk as input data. To develop and verify the model, the data set was randomly divided into training and test data subsets. The evaluation of the model was carried out according to block-sensitivity, specificity and error rate. When the block-sensitivity was set to be at least 80%, the specificities were 51.1% and 74.9% and the error rates were 51.3% and 80.5% for mastitis definitions 1 and 2, respectively. Additionally, the average number of true positive cows per day ranged from 1.2 to 6.4, and the average number of false negative positive cows per day ranged from 5.2 to 6.8 in an average herd size of 24 cows per day for the test data. The results for the test data verified those for the training data, indicating that the model could be generalized. The performance of the NN was not satisfactory. A decrease in the error rate might be achieved by means of more informative parameters.

Keywords: Dairy cow; Mastitis; Automatic milking; Decision aid; Neural networks

1. Introduction

Mastitis is the most costly disease in dairy farming today and remains one of the major problems concerning the dairy industry (Heald et al., 2000; Heringstad et al., 2000; Seegers et al., 2003). Barkema et al. (1998) found a mean annual incidence of clinical mastitis between 25 and 30 cases/year per 100 cows. Average economic losses due to mastitis are estimated to be around 150 Euro per cow and year (DVG, 2002). Early detection of mastitis would reduce milk yield losses (Nielen et al., 1995a,b). Moreover, early treatment has significantly limited the severity of the disease and, in many cases, prevented the appearance of clinical cases (Milner et al., 1997). To sum up, early detection of mastitis is very important not only because of the reduction of the economic impact, but also because of the benefits to the animals' welfare (De Mol et al., 1999).

In herds with an Automatic Milking System (AMS), identification of udder infections is no longer based on visual observation. In contrast, control programs managing

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the health status of the cows have been introduced, based on sensor measurements. The detection model should generate alerts for mastitis that are meant to draw the attention of the farmer to a cow that may be ill (De Mol et al., 1999). 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). Mottram (1997) argued that the future development of dairy farms as efficient producers of good quality milk from healthy cows depends on the advancement of disease detection, whereby monitoring systems would play an increasingly important part in that process.

The suitability of electrical conductivity (EC) for mastitis detection has been widely analysed in the literature (e.g. Nielen et al., 1992; Hamann and Zecconi, 1998; Mele et al., 2001; Norberg et al., 2004; Cavero et al., accepted for publication). An improvement in the results reported in the literature based only on EC is expected by multivariate analyses including other traits. Wendt et al. (1998) indicated the possibility of using the milk production rate as meaningful additional information to EC to detect mastitis. The risk of mastitis changes depending on the lactation stage, therefore Nielen et al. (1995a) already used the lactation stage to detect subclinical mastitis. The traits milk production rate, milk flow and days in milk were included in the present study as meaningful extra information in addition to EC to detect mastitis.

NN performs better than traditional statistical methods in the field of prediction and classification issues (Haykin, 1999; Heald et al., 2000). The application of artificial intelligence techniques is therefore proposed for the development of a mastitis detection model. Neural networks (NN) were adopted based on the inherent ability of learning algorithms to detect patterns in data. An NN is a system that is designed to model the way the brain performs a particular task (Haykin, 1999).

The aim of the present paper is to develop and test a mastitis detection model with sufficient accuracy by application of an NN using electrical conductivity (EC), milk production rate, milk flow and days in milk. Such a management aid would allow early detection of mastitis 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 of observation 403,537 milkings were accumulated from 478 Holstein Friesian cows with a total sum of 645 lactations, the average herd size was 124 cows per day. Milking took place in a "Leonardo" AMS with 4 boxes and an extra cleaning box made by WestfaliaSurge GmbH. 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 AMS measured the highest value of the EC of the milk every 200 ml for each udder-quarter and at the end of the milking the average of these values 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 rate was defined as milk yield per milking, divided by the respective milking interval. The trait 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 168 treatments and 22,911 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). 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

Table 1
Means ($\bar{x}$) and standard deviations (s) for the traits milk yield, average milk flow rate, time between milkings and electrical conductivity

Trait	Unit	Number of observations	$\bar{x}$	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