Computers and Electronics in Agriculture 127 (2016) 242–248

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Classification of healthy and mastitis Murrah buffaloes by application of neural network models using yield and milk quality parameters

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ARTICLE INFO

Article history:
Received 9 December 2015
Received in revised form 20 May 2016
Accepted 14 June 2016

Keywords:
Electro-chemical properties of milk
Error back propagation
Mastitis
Milk yield
Murrah buffaloes
Neural network model

ABSTRACT

This paper describes a Neural Network (NN) model to classify healthy and mastitis Murrah buffaloes using pH, electrical conductivity, dielectric constant and yield of milk as input parameters and California Mastitis Test (CMT) score as the output parameter. The purpose of this study was to develop such a cost-effective and intelligent classification model, which would serve an alternative to the prevailing Somatic Cell Count (SCC) based techniques to detect mastitis in Murrah buffaloes, because the latter techniques are sophisticated, lengthy and time consuming as well as necessary instruments for carrying out the tests are not, generally, available at the grassroots level or to the small dairy holders. Accordingly, a total of 534 milk samples were collected from 100 lactating Murrah buffaloes, which were scrutinized for mastitis using CMT. The animals were classified into three categories, i.e., healthy, subclinical and clinical mastitis buffaloes and assigned CMT scores as 1, 2, and 3, respectively. The NN models were based on error back propagation learning algorithm with Bayesian regularization mechanism and various combinations of internal parameters. The performance of NN models was compared with that of conventional Multiple Linear Regression (MLR) models also developed in this study. The classification accuracy achieved by the best NN model was 8.02 Root Mean Square percent error (%RMS) while that attained by MLR model was 26.47 %RMS. Further, for classifying healthy vs. subclinical mastitis Murrah buffaloes, sensitivity, specificity and Diagnostic Odds Ratio (DOR) with the best NN model was found to be 98%, 97.72% and 54.87, respectively, having Area under Relative Operating Characteristic (ROC) Curve (AUC) as 0.96 vis-à-vis MLR model attaining the same as 58.87%, 76.72%, and 52.26, respectively, and AUC as 0.81. In case of classifying healthy vs. clinical mastitis Murrah buffaloes, the best NN model achieved sensitivity, specificity and DOR as 99%, 97.28% and 57.92, respectively, with AUC as 0.98 while that with MLR model were determined as 69.23%, 78.20% and 55.46, respectively, and AUC as 0.87. Evidently, the NN model outperformed classical MLR model, in this study. Hence, it can be deduced that NN paradigm has potential to efficiently detect healthy and mastitis Murrah buffaloes on the basis of milk yield and milk quality parameters.

1. Introduction

Mastitis is the most costly disease in dairy animals and remains one of the main problems for the dairy-industry because it leads to reduced milk production, involves treatment cost, milk withholding following treatment and premature culling (Hogeveen et al., 2011; Sawhney, 2013). It is evident from the studies conducted in the United States of America that costs associated with mastitis on dairy farms are approximately US $200 per cow/year leading to annual loss of US $2 billion for dairy industry (Bogni et al., 2011). In India, annual economic loss incurred by dairy industry on account of udder infections has been estimated to be US $908 million and out of which loss of US $655.40 million (70–80%) has been attributed to subclinical mastitis (Srivastava et al., 2015). In another report from India (Anon., 2011), the annual economic loss due to mastitis has been calculated as US $1075.8 million; losses being almost same for cows (US $548 million) and buffaloes (US $528 million). Subclinical mastitis has been estimated to account for 57.93% (US $623.2 million) of the total economic loss due to mastitis.

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http://dx.doi.org/10.1016/j.compag.2016.06.015
0168-1699/

Thus, the early diagnosis and prevention of subclinical mastitis must be a priority for each dairy holder, because of the degradation of quality of milk and infection that may spread in animal sheds and also, for prevention of economic losses. The identification of subclinical infected gland is urgently required for successful control of mastitis in dairy animals. In cows, the somatic cell count (SCC) is a useful predictor of subclinical mastitis; and, therefore, it is an important component of milk in terms of quality, hygiene and mastitis control. Milk with a high somatic cell concentration or elevated milk SCC can be harmful to human health and contains less casein and yields lower cheese. It contains increased amount of enzymes, which have effect on the quality of protein, change in fatty acid composition, lactose, ion and mineral concentration; and a higher pH of raw milk. The presence of these enzymes in milk increases the potential for off flavors and odors. Srivastava et al. (2015) emphasized 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. Although a lot of work has been done on detection of mastitis in cows, but this information is limited in case of buffaloes, which are major contributors of milk in Asia. Also, it is thought that buffaloes have more resistance for mastitis due to their tight teat sphincters. However, exploiting buffaloes for more milk production has increased the incidence of mastitis among these animals (Dang et al., 2010).

Many diagnostic tools of mastitis have been employed earlier, some of which are currently used in the industry. Generally, SCC of milk has been the most commonly used measure being highly correlated with mastitis (Ankinakatte et al., 2013; Srivastava et al., 2015). However, diagnosis of subclinical mastitis with SCC is a lengthy and time consuming process. These methods have certain limitations; there is an urgent need to develop a rapid, specific, sensitive and reliable diagnostic test suitable under field conditions where sophisticated instruments are not available. Unlike the developed nations where automated systems of dairying are practiced in which screening of animals for milk SCC is a routine practice, it is not possible in India owing to smaller dairy units (Lam, 2010).

The Electrical Conductivity (EC) of milk is another proven measure that can be exploited to detect changes in milk composition, which are associated with mastitis. Thus, EC of milk is now being used increasingly in the dairy industry to detect mastitis (Mammadova and Keskin, 2013). Also, it is a well-known fact that mastitis is associated with increased conductivity of udder tissue and changes in ionic composition of milk. Similarly, it is associated with decreased levels of certain mineral substances and increased levels of Na^+ and Cl^-. This phenomenon leads to increase in EC (Hamann et al., 2010). The modern enterprises equipped with computer-assisted herd management system can automatically record such important quantitative information as milk yield and milk's EC during the milking process. These systems identify dairy animals with excessive deviation in EC pointing towards incidence of mastitis (Tangorra et al., 2010). The EC of milk may also change due to interaction of factors other than mastitis, such as, temperature, animal breed, stages of lactation and environmental conditions (Sundhan and Sharma, 2010). Therefore, a combination of above parameters would give more precise information on mastitis as compared to a single parameter and the detection of mastitis at different stages would improve considerably.

As the prediction of mastitis is a complex and nonlinear phenomenon, its prediction with classical statistical tools may not be appropriate (Tasdemir et al., 2011). In case of multiple linear regressions, the linear prediction equations do not consider the inter-dependency among explanatory variables (independent variables), which leads to biased results. However, Artificial Neural Network (ANN) model or simply, Neural Network (NN) model accounts for the same as well as nonlinearity in the data sets; therefore, now-a-days, it is receiving more importance for prediction of mastitis in dairy cattle. Hence, NN paradigm has been explored to detect mastitis in Murrah buffaloes. These models are adopted based on their inherent ability of learning algorithms to detect hidden patterns in the data (Tasdemir et al., 2011). NN models are systems that are designed to model the way the brain performs a particular information processing task. An NN model consists of layers of highly interconnected processing units called artificial neurons. Knowledge is acquired by the network from the data through a learning process. Interneuron connection strength (i.e., synaptic weights) is used to store the knowledge acquired (Haykin, 2003). Multiple layers with nonlinear transfer function allow the network to learn linear and nonlinear relationships between model inputs and outputs.

Application of NN models in different fields of dairying is also growing. Various studies have been conducted by different researchers that demonstrated application potential of NN models in dairying especially in predicting mastitis and ketosis risk in dairy animals. Cavero et al. (2008) investigated the usefulness of NN models in the early detection and control of mastitis in cows milked in an automatic milking system. Hojsgaard and Friggens (2010) developed a state-space model for the degree of infection using SCC, EC, and Lactate dehydrogenase (LDH), and also discussed the use of milk yield as an indicator of mastitis, as reduction in milk yield is associated with mastitis. Kamphuis et al. (2010) reviewed the potential of using decision-tree induction to develop models for the detection of clinical mastitis with automatic milking. Sun et al. (2010) developed ANN models for detection of mastitis and its stage of progression by automatic milking systems. Ankinakatte et al. (2013) developed NN models and Generalized Additive Models (GAMs) for predicting mastitis in dairy cows; and found that both the paradigms were similar in their ability to detect mastitis, with a sensitivity of almost 75% and 80% of fixed specificity. Rutten et al. (2013) have also emphasized the importance of using sensor data in dairy management. Ehret et al. (2015) used genomic and metabolic information as well as milk performance records for prediction of subclinical ketosis risk via ANN models and found that predictive performance of metabolic as well as milk performance-based models was higher than that of models based on genetic information. Mammadova and Keskin (2015) developed an ANN model to detect mastitis in Holstein cows using variables such as EC, season; lactation ranks and daily milk yield.

Evidently, there was no study to identify mastitis in Murrah buffaloes using NN models. Moreover, the NN models developed for exotic cattle were based on individual parameter. Hence, in this paper, NN paradigm has been investigated on the basis of yield and other quality parameters of milk for diagnosing mastitis in the Murrah buffaloes. These models would not only help in rapid detection of raw milk quality but also facilitate timely isolation of animals susceptible to subclinical mastitis, for proper treatment to avoid the economic losses. The classifying ability of NN models has been evaluated in comparison with that of conventional Multiple Linear Regression (MLR) models, which have also been developed in this study.

2. Materials and methods

2.1. Data

The investigations were carried out on 100 lactating Murrah buffaloes maintained by Livestock Research Centre at ICAR – National Dairy Research Institute, Karnal, India for a period of one year, i.e., March, 2013–February, 2014. A total of 534 milk