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Monitoring individual cow udder health in automated milking systems using online somatic cell counts

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ABSTRACT

This study presents and validates a detection and monitoring model for mastitis based on automated frequent sampling of online cell count (OCC). Initially, data were filtered and adjusted for sensor drift and skewed distribution using ln-transformation. Acceptable data were passed on to a time-series model using double exponential smoothing to estimate level and trends at cow level. The OCC levels and trends were converted to a continuous (0–1) scale, termed elevated mastitis risk (EMR), where values close to zero indicate healthy cow status and values close to 1 indicate high risk of mastitis. Finally, a feedback loop was included to dynamically request a time to next sample, based on latest EMR values or errors in the raw data stream. The estimated EMR values were used to issue 2 types of alerts, new and (on-going) intramammary infection (IMI) alerts. The new alerts were issued when the EMR values exceeded a threshold, and the IMI alerts were issued for subsequent alerts. New alerts were only issued after the EMR had been below the threshold for at least 8 d. The detection model was evaluated using time-window analysis and commercial herd data (6 herds, 595,927 milkings) at different sampling intensities. Recorded treatments of mastitis were used as gold standard. Significantly higher EMR values were detected in treated than in contemporary untreated cows. The proportion of detected mastitis cases using new alerts was between 28.0 and 43.1% and highest for a fixed sampling scheme aiming at 24 h between measurements. This was higher for IMI alerts, between 54.6 and 89.0%, and highest when all available measurements were used. The lowest false alert rate of 6.5 per 1,000 milkings was observed when all measurements were used. The results showed that a dynamic sampling scheme with a default value of 24 h between measurements gave only a small reduction in proportion of detected mastitis treatments and remained at 88.5%. It was concluded that filtering of raw data combined with a time-series model was effective in detecting and monitoring mastitis status in dairy cows when based on IMI alerts, and by using a dynamically adjusting sampling scheme almost full performance was still obtainable. However, results were less desirable when based on new alerts most likely because of the used gold standard for mastitis, which may not necessarily reflect the onset of and IMI case in contrast to a new alert.
Key words: dairy cattle, mastitis detection, automated milking, online somatic cell count

INTRODUCTION

Mastitis in dairy cattle is a serious disease that causes reduced milk quality and animal welfare, substantial losses due to production loss, increased treatment costs and labor, and higher culling rates (Halasa et al., 2007). Therefore, close monitoring of individual cow udder health is essential for identification of cows in the early stages of an IMI case, as well as timely initiation of treatment and assessment of recovery. Where cows are milked in traditional milking parlors, mastitic cows are identified by the milker, who visually inspects the milk from each quarter for signs of mastitis before milking, sometimes with the aid of sensor technology (i.e., measurements of quarter-based electric conductivity; Hamann and Zecconi, 1998).

In herds using automatic milking systems (**AMS**), no milker is present to visually assess the milk quality of each cow. In Denmark and other milk-producing countries within the European Union, visual control of milk for signs of IMI and color changes is mandatory (EU Directive EC/853/2004). Therefore in AMS, the herd manager must rely on in- or online sensor systems for identification of cows with milk not meeting quality standards (i.e., cows with IMI). Although a range of sensor systems are available, there is a shortage of described and validated detection systems that convert multiple sensor-level information into decision support

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in an effective way, allowing the herd manager to be adequately equipped for the best short- and long-term decisions (Rutten et al., 2013). In the simplest of cases, the herd manager is presented with the raw sensor data only and historic information is not well treated, and because different persons may interpret such data differently this may very well lead to erratic or subjective decisions.

The use of frequently recorded sensor data could allow for a close monitoring of udder health if suitable software interpreting new and historic data were available. The idea of close monitoring of individual cows is 3-fold: (1) to raise alerts if deviations from healthy status occur, (2) to focus on the sick cows for decision making about treatment, and (3) to follow the recovery from IMI as long as it takes. Sensor-based alerts may be detectable long before treatments would usually be initiated, thus allowing for more detailed diagnosis and dedicated treatment. Sensor-based monitoring may also be helpful in detecting recurrent cases where culling would be the ultimate decision; however, the quality and usefulness of any monitoring system depends on its performance. An ideal monitoring system produces a low number of false alerts, that is, high specificity (**SP**), while alerting in a timely manner and with emphasis on the more severe cases (Mollenhorst et al., 2012).

It is generally agreed that IMI cause high SCC levels (Harmon, 1994). The online cell counter (**OCC**; DeLaval International AB, Tumba, Sweden; henceforth DeLaval) was built to use the cell count changes as indicator of IMI and is dedicated for use with AMS for continuous monitoring of cow udder health.

The first objective of our study was to develop an IMI-monitoring system utilizing frequently sampled OCC measurements from AMS-milked dairy cows to provide the dairy manager with daily accurate information about individual cow udder health. The proposed monitoring system aimed to point out cows with IMI and to keep them under surveillance as long as the infection persisted. The second objective was to validate the proposed monitoring system using data from 6 commercial dairy herds.

MATERIALS AND METHODS

This study aimed first at developing an algorithm for detection and monitoring of IMI using OCC data taking a time-series approach on research station data and next to evaluate the monitoring model using OCC data from 6 commercial herds. Technical details of the OCC algorithm and the subsequent optimization procedure are described in the Supplementary Material (http://dx.doi.org/10.3168/jds.2015-8823).

OCC Data

Data for our study was collected via remote access to 1 research herd (**DCRC**; Danish Cattle Research Center, Tjele, Denmark) and 6 commercial dairy herds each using AMS (VMS, DeLaval) fitted with OCC measuring units. The commercial herds had between 103 and 284 Holstein cows and 2 to 5 AMS units. The research herd consisted of 175 cows (2 groups of Holstein and 1 Jersey group) and each group milked in 1 of 3 AMS units. Data from DCRC was used for model development and optimization. It was collected from January 1 to November 30, 2012, and consisted of 150,468 milkings from 387 cow lactations with between 1 and 1,137 milkings. A total of 117,399 milkings were associated with an OCC measurement excluding values equal to zero (i.e., indication of failed measurement). The validation data were collected from the 6 commercial herds from January 1 to December 1, 2012, except 3 herds where OCC units had been out of use for a period and were restarted for this project at April 1, May 16, and May 17, respectively. The edited validation data set consisted of 595,927 milkings from 1,938 cow lactations with between 1 and 1,138 milkings. A total of 519,871 milkings also had OCC measurements. In all cases only milkings between 0 and 305 DIM were used.

Initial Assessment of OCC Versus SCC

A first assessment of the raw OCC data quality was obtained by comparing OCC measurements with test-day SCC data using data for the year prior (2011) to the data collection period (2012) in the 6 commercial herds and the DCRC herd. Milk samples were collected during regular milk recording test days using a basic milk sampler (XMS, DeLaval) attached to the AMS units in each herd. Each milk sample was barcoded and stamped with time of milking. Subsequently, the milk samples were analyzed for SCC at the certified laboratory for DHI analysis (Eurofins, Holstebro, Denmark) using CombiFoss equipment (Foss Electric, Hillerød, Denmark). The ln-transformed OCC and SCC measurements were then compared by linear regression using the REG procedure in SAS (version 9.3, SAS Institute Inc., Cary, NC) to assess the measuring accuracy of each OCC unit.

Model Architecture

The IMI detection algorithm consisted of modules (Figure 1) which are described in details in the Supplementary Material (http://dx.doi.org/10.3168/jds.2015-8823). Briefly, in the first module, the raw data filter-