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Review

Prioritizing alarms from sensor-based detection models in livestock production - A review on model performance and alarm reducing methods

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ABSTRACT

The objective of this review is to present, evaluate and discuss methods for reducing false alarms in sensor-based detection models developed for livestock production as described in the scientific literature. Papers included in this review are all peer-reviewed and present sensor-based detection models developed for modern livestock production with the purpose of optimizing animal health or managerial routines. The papers must present a performance for the model, but no criteria were specified for animal species or the condition sought to be detected. 34 papers published during the last 20 years (1995–2015) are presented in three groups according to their level of prioritization: "Sheer detection models" based on single-standing methods with or without inclusion of non-sensor-based information (19 papers), "Improved detection models" where the performance of the described models are sought to be improved through the combination of different methods (12 papers) and "Prioritizing models" where the models include a method of ranking or prioritizing alerts in order to reduce the number of false alarms (3 papers). Of the three methods that rank or prioritize alerts; Fuzzy Logic, Naive Bayesian Network (NBN) and Hidden phase-type Markov model, the NBN shows the greatest potential for future reduction of alerts from sensor-based detection models in livestock production. The included detection models are evaluated on three criteria; performance, time-window and similarity to determine whether they are suitable for implementation in modern livestock production herds. No model fulfills all three criteria and only three models meet the performance criterion. Reasons for this could be that both sensor technology and methods for developing the detection models have evolved over time. However, model performance is almost exclusively presented by the binary epidemiological terms Sensitivity (Se) and Specificity (Sp). It is suggested that future research focus on alternative approaches for the output of detection models, such as the prior probability or the risk of a condition occurring. Automatic monitoring and early warning systems offer an opportunity to observe certain aspects of animal health, welfare, and productivity more closely than traditionally accomplished through human observation, and the opportunities for improving animal welfare should continue to be a driving force throughout the field of precision livestock farming.

Contents

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1. Introduction

Livestock production has moved from extensive production to intensive production over the last few decades (Sorensen et al., 2010). Society's demand for high-quality animal products is continuously increasing while the number of farmers producing the products is decreasing (Kashiha et al., 2013; Berckmans, 2014). The natural consequence of this situation is a centralization of the production units with increasing numbers of animals at each site (Sorensen et al., 2010; Kashiha et al., 2013).

This centralization, together with the 2008 financial crisis, has changed the conditions of the whole managerial situation leaving the farmer with fewer personnel and less time for each of the daily management tasks creating an increasing market for technical solutions. Technology in livestock production includes automatic monitoring and management information systems (MIS), which gathers available information, and decision support systems (DSS), which analyses the available information, in order to detect and control the health and welfare status of the animals at any given time, by providing early warnings of potential problems (Sorensen et al., 2010; Kashiha et al., 2013; Berckmans, 2014).

Giving the right alarm at the right time is a crucial property of an early warning system, and too many false alarms represent a recurring challenge throughout the field of building models for early warning systems. The false alarms are time-consuming and diminish the trust in the system which in livestock production might lead to the consequences of farmer or personnel either ignoring the alarms from time to time or making personal prioritization of the alarms based on experience, time expenditure, gut feeling and work enthusiasm. In such cases, both animal welfare and gross margin are at risk of being compromised and in order to optimize the benefit of an early warning system for the farmer, a prioritization of alarms must be made ensuring communication of only the relevant alarms to the farmer.

Prioritization of alarms can be done at two levels; either by a reduction in the number of false alarms produced by the early warning system, or by a prioritization of alarms. A reduction in the number of alarms can be done through a satisfying level of performance of the early warning system, while a prioritization of alarms seek to rank true positive (TP) and false positive (FP) alarms. Ranking can be done according to severity of the condition in focus, for example lameness, from those that need immediate attention to those that can be attended within a given period of time. The ranking can be made according to different overall motivations such as animal welfare, costs or production efficiency.

The aim of this review is to evaluate methods for prioritizing sensor-based alarms in livestock production in order to reduce the number of false alarms. The evaluation will be done through a presentation of the different methods described in the scientific literature. Then the advantages and disadvantages of the methods, for their realistic implementation in commercial livestock production, are discussed.

The studies included in this review are of such a variety in terms of study-designs, conditions in focus, and definitions of case (a condition, which should be detected by the model) vs non-case (a condition, which should not be detected by the model), that a true comparison of methods and results are not possible. Therefore, this review does not focus on one species, one condition, or on one type of sensor. Instead, it strives to elucidate the general development of sensor-based detection models with a focus on the prioritizing methods. The challenging task of expressing biological variation through statistical methods at an implementable level of accuracy is hereby sought illustrated.

2. Conceptual framework

2.1. Sensor-based detection systems

The idea of a sensor-based detection system is to automatically detect a condition based on observations from one or more sensors installed in the pen or the barn. Examples of conditions include