Farm-specific economic value of automatic lameness detection systems in dairy cattle: From concepts to operational simulations

Tim Van De Gucht,*† Wouter Saeys,† Jef Van Meensel,‡ Annelies Van Nuffel,*[1] Jurgen Vangeyte,* and Ludwig Lauwers‡§
*Technology and Food Sciences Unit, Institute for Agricultural and Fisheries Research, Burg. van Gansberghelaan 115, 9820 Merelbeke, Belgium
†Department of Biosystems, Katholieke Universiteit Leuven, Kasteelpark Arenberg 30, 3001 Leuven, Belgium
‡Social Sciences Unit, Institute for Agricultural and Fisheries Research, Burg. van Gansberghelaan 115, 9820 Merelbeke, Belgium
§Ghent University, Department of Agricultural Economics, Coupure Links 653, 9000 Ghent, Belgium

ABSTRACT

Although prototypes of automatic lameness detection systems for dairy cattle exist, information about their economic value is lacking. In this paper, a conceptual and operational framework for simulating the farm-specific economic value of automatic lameness detection systems was developed and tested on 4 system types: walkover pressure plates, walkover pressure mats, camera systems, and accelerometers. The conceptual framework maps essential factors that determine economic value (e.g., lameness prevalence, incidence and duration, lameness costs, detection performance, and their relationships). The operational simulation model links treatment costs and avoided losses with detection results and farm-specific information, such as herd size and lameness status. Results show that detection performance, herd size, discount rate, and system lifespan have a large influence on economic value. In addition, lameness prevalence influences the economic value, stressing the importance of an adequate prior estimation of the on-farm prevalence. The simulations provide first estimates for the upper limits for purchase prices of automatic detection systems. The framework allowed for identification of knowledge gaps obstructing more accurate economic value estimation. These include insights in cost reductions due to early detection and treatment, and links between specific lameness causes and their related losses. Because this model provides insight in the trade-offs between automatic detection systems' performance and investment price, it is a valuable tool to guide future research and developments.

INTRODUCTION

Lameness in dairy cattle causes significant economic losses and strongly deteriorates cows' welfare. Welfare deteriorations are instigated by pain and stress often caused by painful hoof lesions (Whay et al., 2003; Dyer et al., 2007; Rushen et al., 2007). Economic losses include high treatment costs (Bruijnis et al., 2010), decreased milk production (Hernandez et al., 2001; Green et al., 2002), reduced fertility (Hernandez et al., 2001; Garbarino et al., 2004), and early culling (Booth et al., 2004; Sogstad et al., 2007). Farmers tend to underestimate the economic effect as well as the prevalence and severity of lameness in their herd (Wells et al., 1993; Whay et al., 2003; Leach et al., 2010). As a result, lameness is often only detected in an advanced stage when the cow is clearly limping. Treatment is often done long after detection (Alawneh et al., 2012a), which may imply a long healing process and even no complete curing. Correct and early detection of lame cows and timely and proper treatment could reduce economic losses, improve animal welfare, and lower on-farm lameness prevalence (Hernandez et al., 2005; Espejo et al., 2006; Leach et al., 2012).

Detecting lame cows is, however, not straightforward and is usually done using a visual locomotion scoring system. Visual locomotion scoring is labor intensive, time consuming, and requires a lot of experience, making it difficult to use in daily practice (Brenninkmeyer et al., 2007; March et al., 2007; Horseman et al., 2013). On top of that, lack of application of visual locomotion scoring in practice often results in bad diagnoses, untreated lameness, and associated losses. To solve this problem, research started on the development of automatic lameness detection systems using a wide range

of sensor techniques such as cameras (Nikkhah et al., 2005; Viazzi et al., 2013; Van Hertem et al., 2014), pressure plates (Neveux et al., 2006; Chapinal et al., 2009), pressure mats (Maertens et al., 2011; Van Nuffel et al., 2015), and accelerometers (Chapinal et al., 2009; Pastell et al., 2009). Research, however, has principally focused on sensor development and data interpretation (Rutten et al., 2013), whereas studies on the economic added value of such systems for farmers are scarce. Researchers and industry members have indicated the importance of bridging this knowledge gap (DairyCare, 2015), but the complexity of the lameness problem, uncertainties about performance and price of upcoming system prototypes, and farm dependency of prevalence and treatment may have hampered economic assessment.

Therefore, the objective of this study is to provide an operational framework for estimating the economic value of automatic lameness detection systems based on their detection performance and farm-specific variables. First, a conceptual framework illustrating the complexity and essential elements for estimating economic value is developed by mapping various drivers for economic value and their relationships. Second, the framework is operationalized, imposing necessary simplifications and assumptions. The effect of input variables used in the framework on economic value for 4 system types (i.e., walkover systems using a pressure mat, walkover systems using pressure plates, accelerometers attached to the cow, and camera systems) is assessed by performing sensitivity analysis. Based on these results, recommendations for future research are made.

MATERIALS AND METHODS

Conceptual Framework

General Concept. The economic value of automatic lameness detection systems depends on their cost (purchase, installation, depreciation period, paid and fictive interests, and maintenance), avoided losses due to better detection and earlier treatment (Leach et al., 2012), and treatment costs. Estimating this economic value is possible by comparing total lameness costs when using automatic detection with a reference situation (i.e., current visual detection by the farmer). The reference situation differs between farms and depends on initial lameness prevalence (Somers et al., 2003; Espejo et al., 2006; Barker et al., 2010) and lameness management (e.g., time between detection and treatment). For high lameness prevalences, higher costs can be expected due to more or more severe lameness cases, and consequently more losses can potentially be avoided. As a result, the avoided loss, and hence the economic value

of automatic detection systems, is farm specific. Likewise, automatic detection systems will have different detection performances, rendering the economic value also system specific.

Background of Lameness Dynamics. Lameness costs are influenced by the prevalence, incidence, and average duration of a lameness case, which can be determined as follows (Whay, 2002):

$$\text{prevalence} = \frac{\text{no. of lame cows at the time of observation}}{\text{herd size}}(\%),$$

$$\text{incidence} = \frac{\text{no. of new lameness cases during 1 yr}}{\text{herd size}}\left(\frac{\%}{\text{yr}}\right),$$

$$\text{duration} = \text{time from onset until healing or culling }(\text{d})$$

$$= \frac{\text{mean lameness prevalence }(\%)\times 365 \text{ d}}{\text{annual lameness incidence }(\text{cases / 100 cows per yr})}.$$

[1]

Prevalence is often determined using 3 possible statuses: non-lame, mildly lame, and severely lame. As prevalence is only a snapshot in time (Whay, 2002) and does not indicate the number of (new) lameness cases during 1 yr, each lameness case entails specific costs dictated by its nature (e.g., digital dermatitis vs. sole ulcers), the severity of the lesion, the duration of lameness, and the time of detection and treatment. A combination of the incidence, duration, and severity of lameness is hence most informative for estimating economic loss and can be tracked by keeping records of each lameness case. In practice, such reliable farm records are generally not available (Whay et al., 2003; Laven, 2013).

Effects of Detection Performance and Lameness Management on Lameness Costs. The value of a detection method, whether visual or automated, depends on its detection performance. Performance can be expressed as several correctly and incorrectly detected (undetected lame cows or non-lame cows detected lame) lameness cases. Timely detection and subsequent proper treatment can reduce lameness costs by reducing the duration of lameness and lowering the severity of the lesion by preventing it from worsening (Hernandez et al., 2005; Alawneh et al., 2012b; Leach et al., 2012). Whether treatment was necessary or not, checking the claws and performing hoof trimming results in additional costs for both correctly and incorrectly detected lameness cases.

The current detection method used in practice, visual detection, results in farmers detecting only 1 in 4 severely lame cows when compared with expert scoring (Whay et al., 2002; Fabian et al., 2014). As only those cows detected as lame will be treated, a high number of lame cows do not get the necessary treatment. More-