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Lameness Identification System in Cattle Breeding Units †

Dimitrios Kateris [1,*], Anastasios Mitsopoulos [2], Charalampos Petkoglou [2] and Dionysis Bochtis [1]

[1] Institute for Bio-Economy and Agri-Technology (iBO), Centre for Research and Technology-Hellas (CERTH), 6th km Charilaou-Thermi Rd., 57001 Thessaloniki, Greece; d.bochtis@certh.gr
[2] Ergoplanning Ltd., Karatasou 7, 54626 Thessaloniki, Greece; tmitsop@ergoplanning.gr (A.M.); x.petkoglou@ergoplanning.gr (C.P.)
* Correspondence: d.kateris@certh.gr
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Abstract: Lameness is one of the most significant problems in cattle breeding. It is a major factor that causes discomfort and significantly reduces the welfare of affected animals. Lameness can result in a decrease in milk production or, if not detected early enough, may require the animal to be culled, leading to severe direct and indirect economic consequences for the business. The delayed recognition of lameness is often due to the methods used for detection, which mainly rely on the observation of animal mobility by the breeder. These methods almost exclude the early detection of the problem. This work aims to establish a new detection system that will be able to identify on time, reliably, and at an early stage the lameness symptoms based on the movement parameters of the animals.

Keywords: lameness; animal health; accelerator sensors; machine learning; cattle

1. Introduction

In the last decades, animal production in Greece has experienced rapid growth due to increased demand for animal products. This demand has led to a shift from traditional to intensive breeding systems, to intensify production. Cattle, being one of the most significant livestock animals, contribute significantly to the country's economic development. However, because of these changes, unknown health problems have emerged, or existing ones have worsened, mainly due to improper management of intensively farmed animals. Lameness, as one of the most significant issues concerning animal health, leads to a reduction in milk and meat production and an increase in healthcare costs for animals [1]. Therefore, it is crucial to detect lameness in a timely and reliable manner [2] to reduce costs and ensure animal welfare. Animals suffering from this disease exhibit various symptoms, such as difficulty walking [3], increased lying time compared to healthy animals [4], and reduced grazing behavior [5].

Until today, many studies have dealt with the accurate prediction of lameness. However, existing methods are unclear and unreliable [6], especially those attempting to approach lameness through computational analysis. The methods aiming to predict the condition vary from study to study. Some research endeavors seek to address the issue using optical technologies. Song et al. [7] attempted to diagnose lameness using high-resolution images and videos, while Viazzi et al. [8] tried to identify the condition using 2D and 3D cameras. Another way to determine the problem was the use of force sensors, with the help of which attempts were made to record and recognize animals displaying lameness [9].

In this direction, this work aims to present the architecture of a new detection system that will be able to identify lameness symptoms in different infection stages in cattle using machine learning algorithms capable of identifying lameness at an early stage, thus avoiding the economic consequences of production losses for livestock units.

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2. Methodology

In our days, lameness detection in cattle is carried out through visual assessment of the mobility index. This happens using a simple five-level numerical scale that rates the animal's posture as "1" for normal stance and "5" for permanent elevation of the affected limb during walking. To assess the index, an "expert" observes the gait of each animal and based on the deviation from the normal movement pattern, assigns it the corresponding numerical score. However, this scale is subjective and lacks reliability, especially when the observation is made by cattle breeders lacking specialized knowledge. As a result, lameness issues are often underestimated and not on time detected for immediate treatment. This can be avoided by using a reliable lameness symptom recognition system in cattle.

The proposed system provides a solution to this problem. The system combines effectively and successfully several commercial wearable sensors (triaxial accelerometers) placed on the feet of animals for recording their kinesiological parameters (Figure 1). All this information feeds the proposed system to provide the user with an early diagnosis. The proposed system uses machine learning algorithms properly adapted to diagnose lameness at an early stage, even if the symptoms are not visually evident. This ability is due to the system's ability to highlight differences in the kinesiological signatures of diseased animals and compare them to those of healthy ones.

(**a**) (**b**)

Figure 1. (**a**) Locations of the four wearable sensors on the cattle legs and (**b**) the wearable sensors (Blue Trident, Vicon).

The Proposed System Architecture

This section presents the architecture of the proposed system, for detecting anomalies in a cattle's gait, which involves using four sensor devices placed on the cattle legs to capture motion data. The approach of the proposed system encompasses two key phases: the training phase and the detection phase. In the training phase, a machine learning model of the typical gait of cattle using a machine learning algorithm.

The next phase is the "detection phase". In this phase, the trained model is used to classify the cow's health condition as a healthy cow, a cow with lameness in the early stage, or a cow with lameness in an advanced stage by comparing its current gait with the model generated during the training phase. Both phases include the following computational steps:

- Data Acquisition: Sensor signals are collected from the sensor devices at the animal legs and stored in memory;
- Preprocessing: The collected data is filtered to remove any noise;
- Feature Extraction: Information characterizing the cow's gait is extracted from each stride. This information is imprinted in a set of features, which provide descriptive information about the cow's gait;
- Training and Testing data: The collected data are shared in two different groups, 70% training, and 30% testing, to use them for the training and the validation of the model. During the training phase, these features are used to train a machine-learning model;

- Classification: In the detection phase, this pre-trained machine learning model assigns a label of "normal" or "abnormal" to each set of features, which we call "Classification".

All these phases of the proposed system are presented in the following Figure (Figure 2).

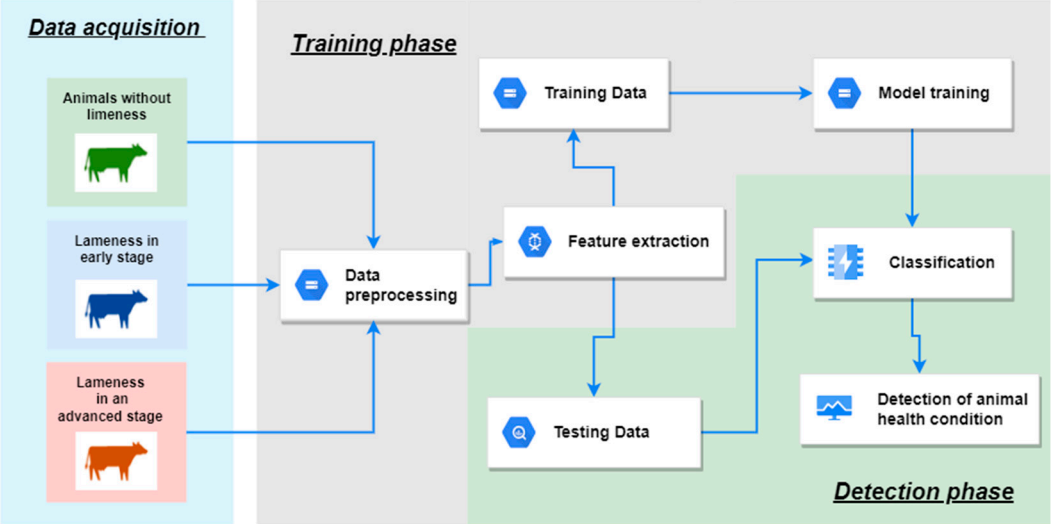

Figure 2. Overview of the proposed system architecture.

3. Results and Discussion

With the timely and rapid diagnosis of lameness, it becomes possible to avoid the discomfort of diseased animals and consequently reduce the daily milk production loss and premature culling. In addition to preserving the animal capital, given the high percentage of affected animals, between 5 and 7%, and a 20% reduction in milk production capacity, an increase of 1–1.4% in overall lifetime production is expected. The actual benefit is even greater and depends on how the situation is managed. If pharmacological treatment affecting milk production is administered, losses for a period are 100%, and if there is premature culling, the losses are even greater as a significant period of productive animal life is lost. Moreover, there are significant reductions in expenses associated with veterinary care for affected animals and a decrease in the transmission of lameness cases among livestock animals.

All of these can be achieved using the proposed system for early diagnosis of lameness. The breeders will have a reliable tool in their hands, which will enable them to improve the efficiency of the herd by avoiding the premature slaughter of animals with lameness. It will also significantly enhance the milk production capacity of the animals through rapid diagnosis of disease symptoms in their early stages. Optimization of estrus detection and reproductive management of the herd, as well as identification of nutritional and health disorders in the animals, will be achieved. The operational costs of the unit will be reduced due to a decrease in corresponding expenses for medication and veterinary services. These outcomes will result in the upgrading of local products, the improvement and expansion of business operations, and the strengthening of the local workforce.

Finally, it should be mentioned that the proposed system has been tested with data from public lameness data libraries and the results were highly encouraging. In the next stage, the proposed system will be tested in four different cattle breeding units to confirm the effectiveness of the system in real conditions.

4. Conclusions

In conclusion, the proposed system is being implemented for the first time in cattle breeding units, as it is a product of innovative laboratory research. Given that lameness detection is currently mainly based on subjective visual estimation by both breeders and

veterinarians, the proposed system provides a reliable and affordable solution for timely lameness diagnosis. It has been proven that the use of a 5-point scoring scale does not provide significant reliability in diagnosing lameness, while other modern methods rely primarily on the use of visual means, such as images and videos, to diagnose lame animals. The drawback of these methods lies in their difficulty in continuously monitoring the animal in its natural environment. Therefore, the need to establish a new method for lameness detection with continuous recording of the animal's kinematic characteristics in its natural habitat, using new machine learning algorithms, provides a clear and accurate solution to the problem of early lameness diagnosis.

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