University of Applied Sciences, Technology, Business and Design,
Faculty of Engineering and
University of Kassel, Faculty of Organic Agricultural Sciences

Erprobung eines Messsystems zur automatischen Früherkennung von Lahmheit mittels akustischer Analyse des Körperschalls verursacht durch den Bewegungsablauf von Milchkühen als Qualitätssicherungssystem

Masterthesis
Department of Quality Management
Department of Agricultural and Biosystems Engineering

1. supervisor: Prof. Dr.-Ing. Daniela Schwerdt
2. supervisor: Dr. Hubertus Siebald

Presented by**: Boris Kulig**

Witzenhausen, September **2019**

Summary

This thesis is part of the research project "SoundHooves: Automated early diagnosis of hoof diseases by means of acoustic analysis of the footfall sound of cattle", funded by the project management agency "Bundesanstalt für Landwirtschaft und Ernährung" (BLE), grant number 2817902015, [cf.(BLE, 2016)].

It deals with the testing of a measuring system for the automated early detection of lameness by means of acoustic analysis of the structure-borne sound caused by the motion sequence of dairy cows as a quality assurance system. The following task resulted: (1) Design of a suitable measuring system (measuring bench); (2) Determination of suitable descriptors from the structure-borne sound files in order to make the running behaviour of the dairy cows traceable (Chapter 3.1.2.3); (3) Selection of a manual visual bonitur scheme for the classification of lameness; (4) Identification of suitable modeling approaches (Chapter 2.7.3) for the classification of lameness and development of prediction models; (5) Testing (Chapter 3.2) and evaluation (Chapter 3.3) of the model approaches.

In the context of a literature review, it could be emphasized that structure-borne sound measurement represents a noteworthy metrological approach for the task (Chapter 2.6). Furthermore, the importance of animal welfare (Chapters 2.1 to 2.5) in general and lameness in particular as an animal welfare indicator for agricultural quality

assurance and agricultural quality management were discussed. The theoretical prerequisites for machine learning and the selection of suitable models were described (Chapter 2.7).

Within the framework of testing the measurement system, both "Neural Networks" and "Random Forest" were used as machine learning algorithms for the detection of lameness.

Unfortunately, it turned out that the manual visual bonitur scheme for lameness used in the context of this work was only limitedly suitable as a target variable for the classification model. In the best case only a concordance of Cohen's Kappa = 0.62 against a confirmed diagnosis from parallel claw care was found (see chapter 3.2.3.1). Classification models were therefore calculated with the score made by the diagnosis from claw care.

The best model found was a Random Forest with target value "diagnosis from claw care". The prediction model found had an R^2 of 0.67 in the training data set and in the validation the R^2 was only 0.03. The misclassification rate was 7 % in the training part and 29 % in the validation part. An overfitting could not be excluded. A change of the costs in the misclassification matrix by shifting the cutoff value for the assignment in class "lame" from 0.5 to 0.4 resulted in a significantly better model result (Cohen's Kappa between diagnosis and prognosis value = 0.80; sensitivity = 0.81 and specificity = 0.97), but the model must still be regarded as not stable and not sufficiently capable.

Basically, the preferred model has a similar certainty compared to other automatic and manual visual assessments and prediction models [cf. Chapter 2.3 and (Schlageter-Tello et al., 2014)]. The found model alone is not sufficient as a prediction model, but interaction with other animal welfare indicators results in synergies [cf. Chapters 2.1, 3.4 and (Beer et al., 2016; Singh et al., 2018)]. A risk index formed from the existing prediction model combined with data from other sensor systems in milking parlours (udder health), condition sensors (body condition score) and sensors for recording locomotion and eating behaviour would be conceivable.

An integration of the found model into a herd management or a QMS is possible and recommended. The measurement system developed and tested in this work can contribute significantly to a risk assessment model for lameness.

As a conclusion, from the conditionally suitable quality of the prediction models found, improvements were proposed essentially for the hardware of the measuring stand but also for the descriptors from the structure-borne sound files and the model conception (cf. Chapter 3.3).

A further development of the measurement system and the selected machine-learning approach is recommended and is considered promising.