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Lameness Detection in Side-View Videos of Dairy Cows Based on Pose Estimation and Deep Learning

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ABSTRACT

Lameness is a critical factor affecting milk production and remains a major concern in dairy farming. Conventional lameness detection relies on visual observation and veterinary judgment, which are subjective and labor-intensive. This study proposed a non-contact lameness detection system integrating pose estimation and machine learning. A YOLOv11-pose model was trained to detect cow keypoints, and features such as back curvature, head swing, and Back Posture Measurement (BPM) were extracted. These features, combined with veterinary scores, were classified using XGBoost. Experimental results indicated that the pose estimation model achieved 99% precision and 100% recall. The grading model reached 78% accuracy. Future work will enhance grading performance and enable large-scale application for smart dairy management.

Keywords: dairy cow, lameness detection, pose estimation, deep learning.

INTRODUCTION

Milk yield in dairy cows is strongly affected by environment, stress, and diseases [1], with locomotor disorders being a major challenge. Hoof problems cause pain, uneven gait, and arched backs, resulting in lameness. Lameness has traditionally been assessed by farmers and veterinarians through visual observation of posture and gait, with severity scored using the Locomotion Scoring of Dairy Cattle [2], which classifies cows into five levels: normal, slightly lame, mildly lame, moderately lame, and severely lame. However, conventional methods are subjective and time-consuming. To overcome these limitations, this study introduces a non-contact lameness detection and grading system that enables objective, quantitative monitoring of cows' posture, thereby improving efficiency in livestock management.

MATERIALS AND METHODS

POSE ESTIMATION

In this study, the YOLOv11m-pose model was used for pose estimation to identify dairy cows by bounding boxes, extract their center coordinates, and detect keypoints on the head and back. For data annotation, the CVAT (Computer Vision Annotation Tool) was employed. Five anatomical keypoints were labeled, including the nostril, forehead, withers, 13th thoracic vertebra (T13), and first sacral vertebra (S1).

LAMENESS SCORING

Video data were processed frame by frame using the pose estimation model, and the detected results were converted into quantitative lameness features. Nine parameters were designed: Average Back Curvature, Maximum Back Curvature, Minimum Back Curvature, Back Curvature Range, Maximum Head Swing, Average Nose Y-Coordinate, Average Forehead Y-Coordinate, Back Posture Measurement (BPM), and Walking Speed. These features were then normalized using the Min-Max method and input into the XGBoost classifier. Veterinary locomotion scores served as ground truth for training and testing. Lameness was categorized into three classes: L0 (Normal), cows walk normally; L1 (Moderately Lame), gait shows mild instability; L2 (Severely Lame), cows show clear severe abnormalities.

RESULTS & DISCUSSION

Images and videos were collected during morning milking, totaling 840 images and 98 short clips. After 100 training epochs, the pose estimation model rapidly converged, achieving Precision=0.993, Recall=1.000, and mAP50–95=0.995 for keypoints, while bounding box detection was similarly accurate (Precision=0.995, Recall=1.000). On the test set, the model remained highly reliable, with Precision=0.991 and Recall=0.995 for keypoints and Precision=0.995 and Recall=1.000 for bounding boxes.

The initial XGBoost grading model, trained with nine features, reached an accuracy of 77%. Feature importance analysis revealed that average forehead Y-coordinate and average back curvature contributed least. Removing these redundant features improved stability. The optimized seven-feature model achieved Accuracy=78% (±0.04), Recall=0.77 (±0.03), and F1-score=0.77 (±0.04) through 3-fold cross-validation. Classification by severity showed that normal (L0) and severely lame (L2) cows achieved F1-scores of 0.88 and 0.80, respectively, while moderately lame (L1) cows were harder to identify (F1=0.71).

CONCLUSIONS

This study combined YOLOv11m-pose and XGBoost to develop a non-contact lameness detection and grading system for dairy cows. The pose estimation model achieved high performance, with Precision and Recall above 0.99, ensuring reliable feature extraction. The initial nine-feature grading model reached 77% accuracy, which improved to 78% after removing redundant features. However, L1 (Moderately Lame) remained the most difficult to classify, suggesting the need for more data and dynamic features. Overall, the system provides a quantitative tool for lameness monitoring and supports smart livestock farming.

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