Protocol 9: Related Work of Lameness Detection

14.02.2019

Lameness is a critical issue in dairy cattle, and locomotion scoring provides a way to systematically assess the lameness level of the cattle. To ensure an objective assessment, many automated lameness detection systems have been proposed. The approaches can be divided into vision- and sensor-based.

Vision-Based Methods

There are many automated lameness detection systems using computer vision techniques, most of which are based on back posture.

1. Vision-based trackway analysis in cow's locomotion [1]

- **Reference:**

  Song, Xiangyu, et al. "Automatic detection of lameness in dairy cattle – Vision-based trackway analysis in cow's locomotion." Computers and electronics in agriculture 64.1, pp. 39-44, 2008.

- **Cattle:** Fifteen lactating cows at the Gent University Research Farm (scored visually by four trained observers)

- **Input data:** Side-view images (1024 * 768 pixels) from videos (15 fps)

- **Method:** Calculate trackway overlap from segmented images.

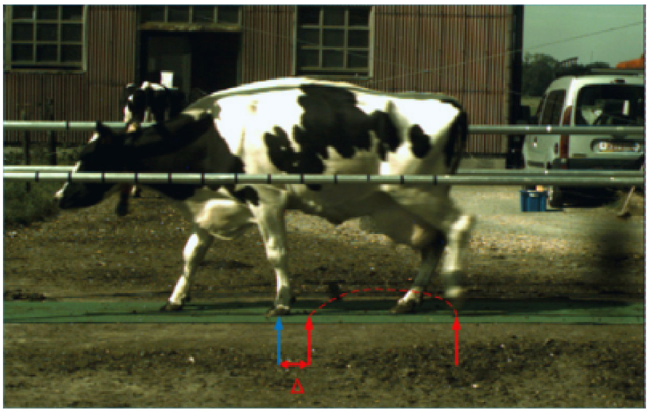

Figure 1: Defined trackway overlap.

- **How likely to solve the task:** The method can only be used to detect lame cows, but may not predict locomotion score.

- **Difficulty:** It would be difficult to select the frames in which hooves land.

- **Open source:** No

2. Lameness detection by shape analysis of cow [2]

- **Reference:**

  Poursaberi, Ahmad, et al. "Real-time automatic lameness detection based on back posture extraction in dairy cattle: Shape analysis of cow with image processing techniques." Computers and Electronics in Agriculture 74.1, pp. 110-119, 2010.

- **Cattle:**

- Database 1: 28 lactating Holstein cows at ILVO
  - Database 2: 156 lactating Holstein cows at ILVO

- **Input data:** videos (640 * 480 / 1024 * 768 pixels, 30 fps); four frames (hind hooves in contact with ground) were selected for each cow
- **LS:** 3-point locomotion scoring
- **Method:** Use traditional vision methods to extract the cows, and a curve is fitted through three points on the back of the cows. The average of the curvature of the fitted circle was used as a feature for lameness classification.

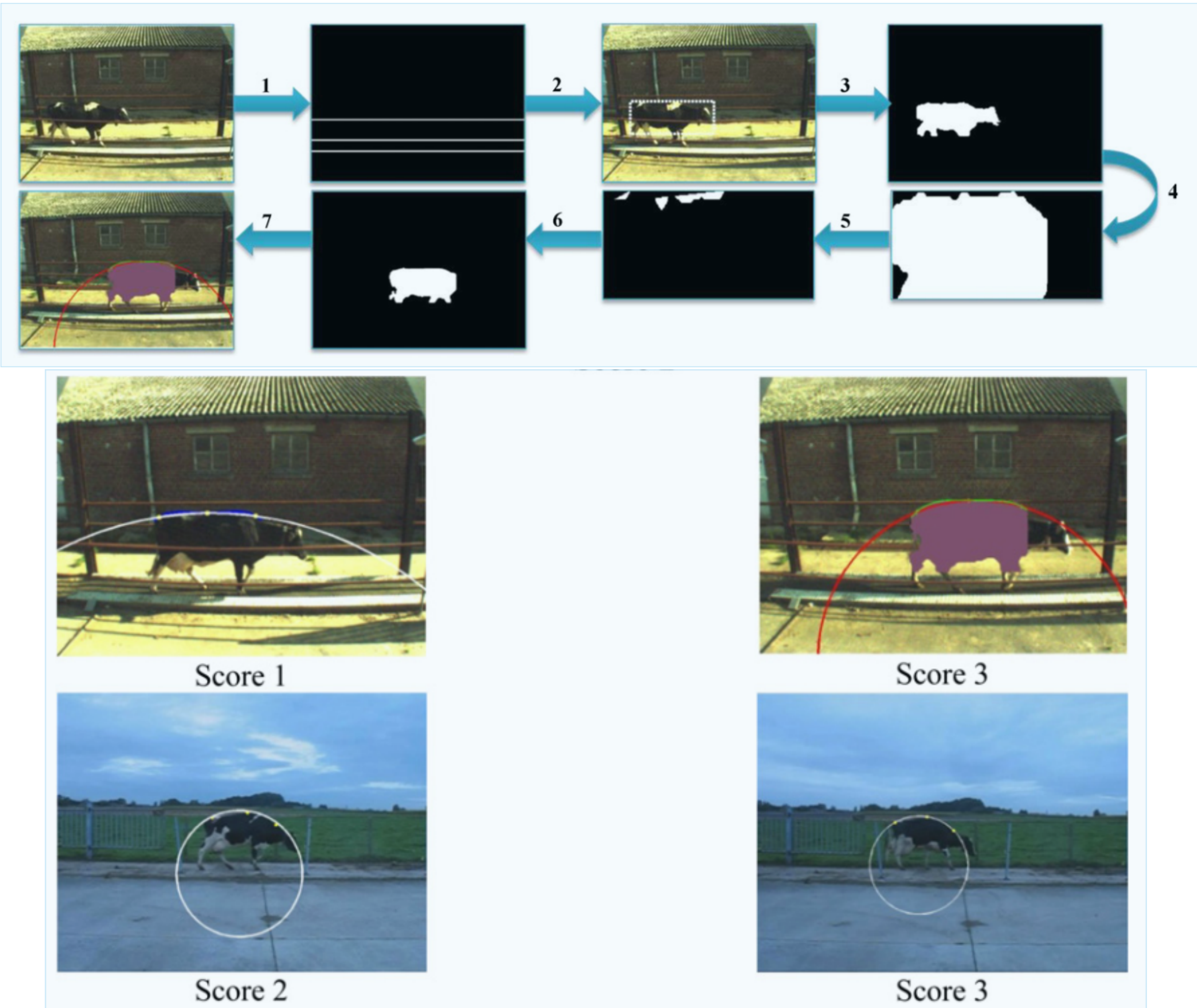

Figure 2: Back shape analysis.

- **How likely to solve the task:**
  - An accuracy of around 96% was reported in the paper.
  - The feature changes when the distance between the cow and the camera changes.
- **Difficulty:** Selecting the frames in which hind hooves contacting the ground would be difficult.
- **Open source:** No

3. Pressure mat with camera for lameness detection [3]

- **Reference:**

  Pluk, Arno, et al. "Automatic measurement of touch and release angles of the fetlock joint for lameness detection in dairy cattle using vision techniques." Journal of dairy Science 95.4, pp, 1738-1748, 2012.

- **Cattle:** 75 lactating Holstein cows (visually scored from recorded videos by a trained observer) at ILVO

- **Input data:** 2219 measurements (75 cows) of pressure data (used to find matching image in which the hooves land or release) and images

- **LS:** 3-point locomotion scoring

- **Method:** Combine force plates and a 2D side-view images (1024 * 768 pixels) to analyze gait variables: range of motion (ROM) and touch/release angles.

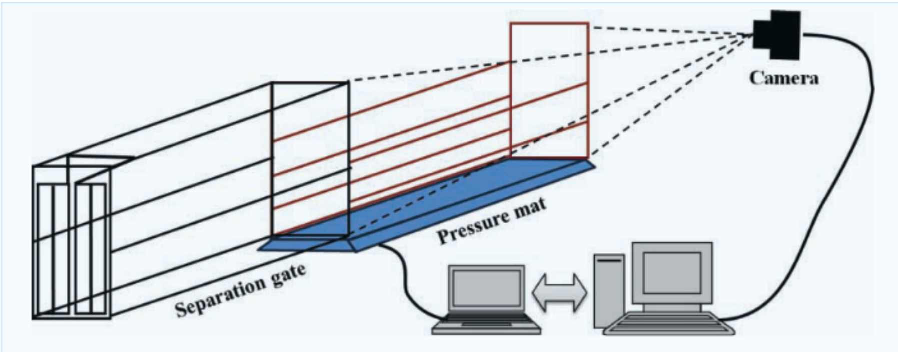

Figure 3: Schematic overview of system setup.

- **How likely to solve the task:** Since the method combines two types of measurements, it is likely to detect lameness of cows. However, the system did not achieve high accuracy because it only considered touch /release angles of the cows' hooves and did not take other features into account.

- **Difficulty:** The setup for data measurement is complicated, and may not be applicable in real situations.

- **Open source:** No

- **Note:** Lameness can be detected by a decrease in the range of motion or an increase in the release angle of the front hooves.

4. Lameness detection from back pose using 3D camera [4]

- **Reference:**

  Van Hertem, Tom, et al. "Automatic lameness detection based on consecutive 3D-video recordings." Biosystems Engineering 119, pp. 108-116, 20014.

- **Cattle:** 186 cows at Agricultural Research Organization (ARO) in Israel (manually scored on-the-spot) with four observations

- **Input data:** Images from a 3D camera (30 fps) in top down perspective, triggered by photocell.

- **Method:** Four parameters (Figure 5) from the recorded images were combined to calculate a back curvature measurement. Different regression models were implemented to predict locomotion scores. Bootstrap aggregating (bagging) was applied to the 5-fold cross-validated classification to improve the models.

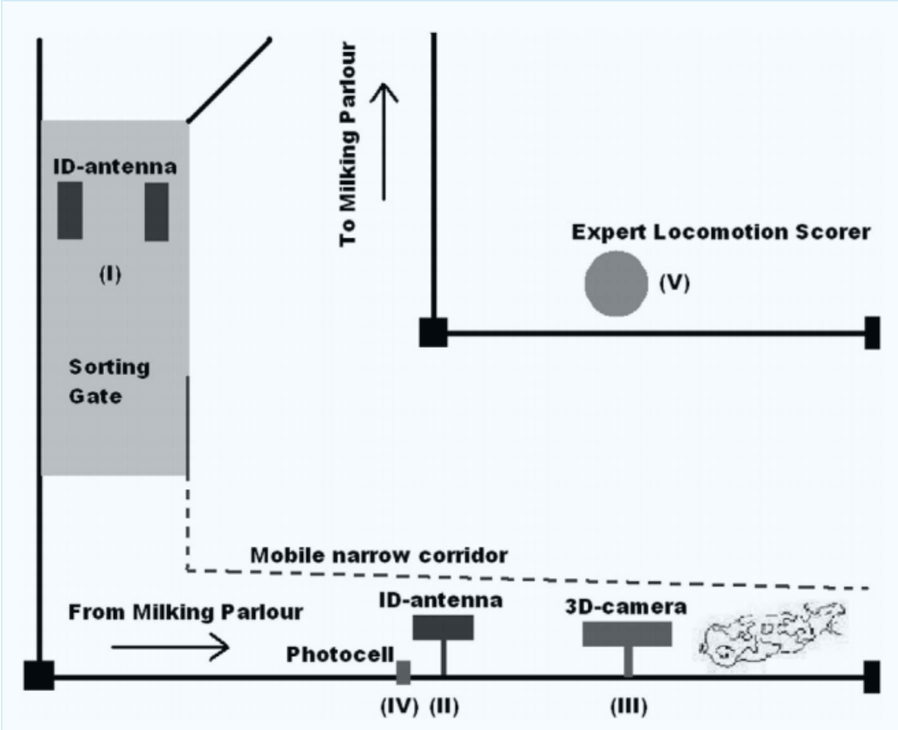

Figure 4: Top view layout of the 3D-camera setup.

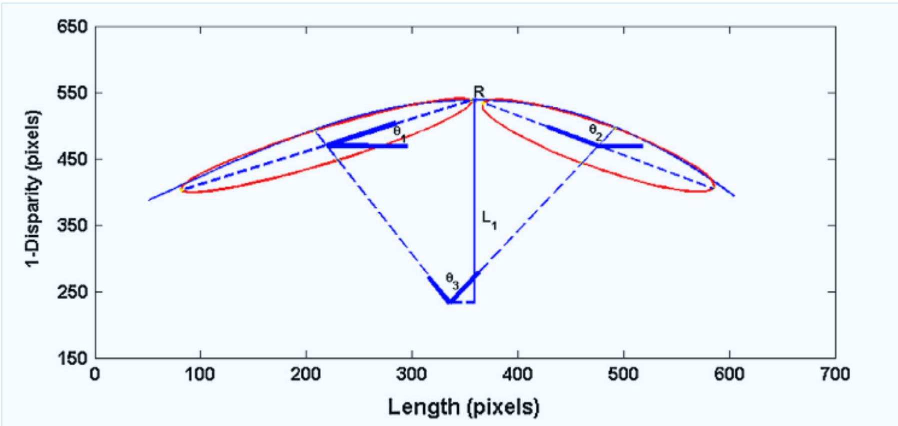

Figure 5: Parameters of back curvature measurement.

- **How likely to solve the task:** The method looks promising since 3D cameras can overcome the difficulty of segmentation. However, the proposed system did not consider other factors other than back pose, which may lead to mis-classification.
- **Difficulty:** The setup was developed for indoor use because of the top-view camera and the sensitivity to natural light of 3D cameras. That being said, the system can only be applied in constrained environment.
- **Open source:** No
- **Notes:**
  - Even though the method is complicated, combining parameters into one that maps directly to the locomotion score makes classification simpler.
  - This paper applied similar method proposed in an earlier study [1], which compared 2D and 3D cameras for lameness detection.

[1]Viazzi, Stefano, et al. "Comparison of a three-dimensional and two-dimensional camera system for automated mea-

– 3D cameras outperforms 2D cameras in terms of object segmentation.

– The drawbacks of using 3D cameras include small field of view, sensitivity to natural light, and single variable (back pose) for detection.

5. Lameness detection from spine and hook features using 3D camera [5]

- **Reference:**

  Jabbar, K. Abdul, et al. "Early and non-intrusive lameness detection in dairy cows using 3-dimensional video." Biosystems Engineering 153, pp. 63-69, 2017.

- **Cattle:** 22 Holstein Friesian cows at Bridge Farm in United Kingdom, scored by an experienced observer.

- **Input data:** Images from a 3D (depth-sensor) camera (30 fps)

- **Method:** Extract features of the cows hind limbs and spine from the processed 3D images. Since the over-view camera cannot observe the limbs, the vertical motion of hooks is used as the proxy of limb feature. The features are used to classify the lameness level of the cows.

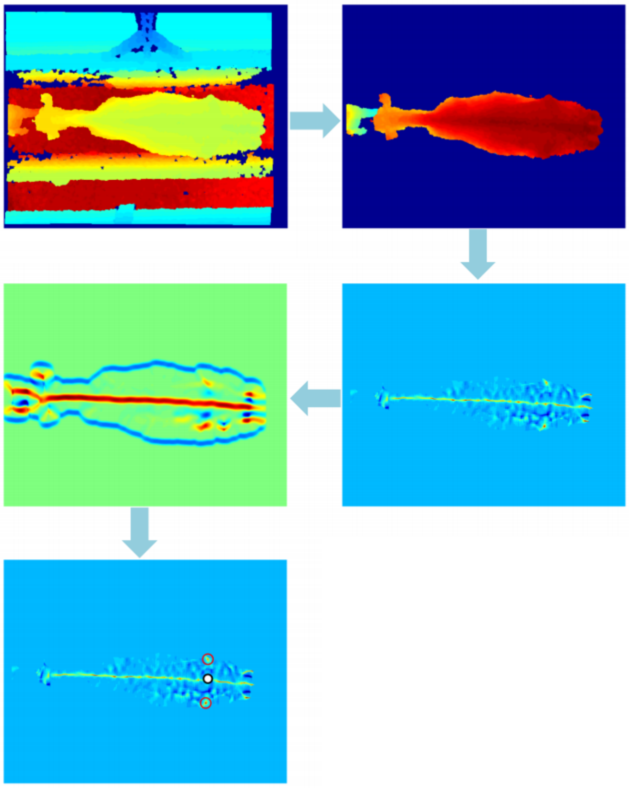

Figure 6: Image processing to extract features of the hooks and the spine from a single 3D cow image.

- **How likely to solve the task:** The method is more reliable than the previous one that only considers one variable.

- **Difficulty:** 3D image processing is more complex than 2D processing.

- **Open source:** No

surement of back posture in dairy cows." Computers and Electronics in Agriculture 100 (2014): 139-147.

Sensor-Based Methods

There are some methods that measure the load of cows' legs. Although this approach does not necessarily require the cows to stand still, the features for detecting lameness are different from manual observation. Compared to vision approach, using load sensors is more cumbersome in terms of system setup.

1. Load cell-based lameness detection using neural networks [6]

- **Reference:**

  Pastell, M. E., and Minna Kujala. "A probabilistic neural network model for lameness detection." Journal of Dairy Science 90.5, pp. 2283-2292, 2007.

- **Cattle:** 73 cows at Helsinki University (training/test: 37/36)

- **Input data:** 4-balance platforms (load cell at 10 Hz) measuring dynamic load of each leg of cows during milking. (9942 measurements: 5074/4668). Leg weight ratio (LWR) and number of kicks are the input fed to neural network.

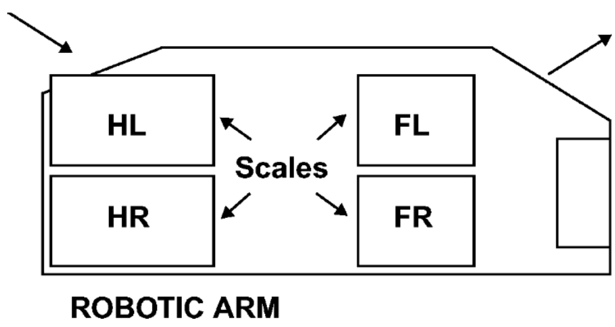

Figure 7: Balance platforms in the floor ofthe milking robot.

- **LS:** 5-class locomotion scoring, but the model was a binary classifier (sound/lame)

- **Method:** A two-layer neural network classifies sound and lame cows based on the LWR and number of kicks per milking period

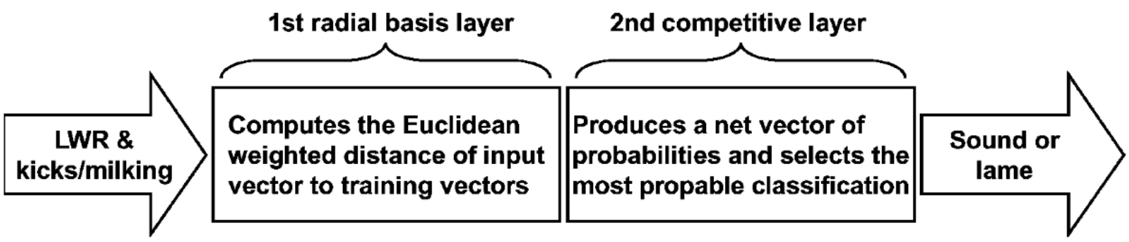

Figure 8: Operation of the PNN (probabilistic neural network) model. LWR = leg weight ratio between the heavier and lighter hind leg.

- **How likely to solve the task:** The model is simple, so it can be used to detect lameness but not predict locomotion scores.

- **Difficulty:** As the authors mentioned, the system is limited to farms using milking robots.

- **Open source:** No

- **Notes:**

- Locomotion scoring was observed weekly during normal gait.
- Most lameness problems were in hind legs.
- The paper mentions another scoring system for hoof lesions.
- Features used: leg weight ratio, kicks, steps
- Cows tend to lift (kick) the affected leg more often.

2. The GAITWISE system [7]

- **Reference:**

  Maertens, Willem, et al. "Development of a real time cow gait tracking and analysing tool to assess lameness using a pressure sensitive walkway: The GAITWISE system." Biosystems Engineering 110.1, pp. 29-39, 2011.

- **Cattle:** 159 cows on ILVOs experimental farm (scored visually by trained observer using video images)

- **Input data:** Pressure values with location and time. A linear discriminant analysis was carried out to discriminate the level of lameness.

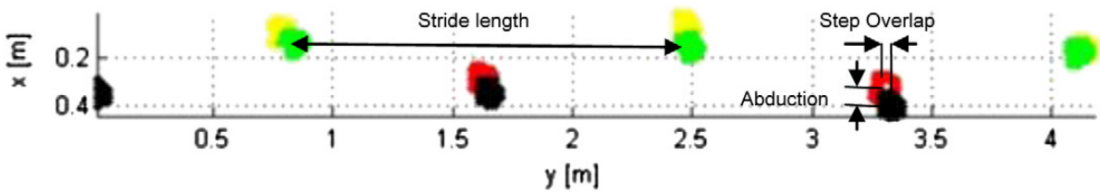

Figure 9: Kinematic variables for lameness detection.

- **LS:** 3-class locomotion scoring

- **Method:** Predict locomotion scores based on spatio-temporal kinematic and force variables using a pressure sensitive walkway (GAITRite sensor).

- **How likely to solve the task:** It can be used for experiments in a constrained environment

- **Difficulty:** Data acquisition is difficult

- **Open source:** No

- **Note:** The paper applied many spatio-temporal gait features.

Summary

To sum up, there are several proposed systems using either images or pressure measurement for lameness detection; the former usually makes use of back pose features while the latter is mostly based on gait features. All the studies do not provide open source implementation; one reason may be the parameters vary from animal to animal; besides, the measurements are specific in each case.

Since our study falls into the vision-based approach, the former ones are more of our concern. As can be seen, most vision-based studies only considered spatial information, particularly the back pose, and the standard 5-point locomotion scoring was not often employed. To improve the detection of lameness level, both pose and gait features as well as temporal information will be considered. Different machine learning methods, including deep neural networks will be applied for comparison. However, one common drawback (as in many studies) is the small amount of dataset, which would make deep learning tricky.

Bibliography

[1] X. Song, T. Leroy, E. Vranken, W. Maertens, B. Sonck, and D. Berckmans, "Automatic detection of lameness in dairy cattlevision-based trackway analysis in cow's locomotion," *Computers and electronics in agriculture*, vol. 64, no. 1, pp. 39–44, 2008.

[2] A. Poursaberi, C. Bahr, A. Pluk, A. Van Nuffel, and D. Berckmans, "Real-time automatic lameness detection based on back posture extraction in dairy cattle: Shape analysis of cow with image processing techniques," *Computers and Electronics in Agriculture*, vol. 74, no. 1, pp. 110–119, 2010.

[3] A. Pluk, C. Bahr, A. Poursaberi, W. Maertens, A. Van Nuffel, and D. Berckmans, "Automatic measurement of touch and release angles of the fetlock joint for lameness detection in dairy cattle using vision techniques," *Journal of dairy Science*, vol. 95, no. 4, pp. 1738–1748, 2012.

[4] T. Van Hertem, S. Viazzi, M. Steensels, E. Maltz, A. Antler, V. Alchanatis, A. A. Schlageter-Tello, K. Lokhorst, E. C. Romanini, C. Bahr, *et al.*, "Automatic lameness detection based on consecutive 3d-video recordings," *Biosystems Engineering*, vol. 119, pp. 108–116, 2014.

[5] K. A. Jabbar, M. F. Hansen, M. L. Smith, and L. N. Smith, "Early and non-intrusive lameness detection in dairy cows using 3-dimensional video," *Biosystems Engineering*, vol. 153, pp. 63–69, 2017.

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