Detection of Estrus in Cattle by using Image Technology and Machine Learning Methods

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***Abstract*—Detection of estrus in cattle in early phase is especially vital in the era of precision farming. This paper focuses on the detection of estrus in cattle by using image processing techniques and machine learning methods. In doing so, we first utilize an image analysis to investigate some behaviors of cattle in estrus, which is standing when mounted by the other cattle. We then extract some statistical measures based on polyline shape features of detected cattle images and utilize these measures as an input to machine learning algorithms. Specifically, in this paper, we employ the three supervised machine learning methods, which is Support Vector Machine (*SVM*), Logistic Regression (*LR*), and Multiple Linear Regression (*MLR*) classifiers. Some experimental works are performed by using real-life video sequences. The results show promising and capable to detect the behavior of estrus both cost-effectively (only image) and specifically with the detection rate of SVM is 97%, LR is 94%, and MLR is 94%, respectively.**

Keywords—cattle's estrus behavior, feature extraction, machine learning, support vector machine, logistic regression, multiple linear regression

I. Introduction

In livestock management system, recognizing estrus signs in the early stage is extremely considerable for a herd's successful reproduction, which has advantages in both increasing in rates of conceptions for the herd and production of milk. The peak noticeable estrus signs are the mounting and following. The primary signs of estrus are standing heat, sniffing another cattle vulva, resting chin on other cattle's back and mount another cattle (attempt to) [1]. The secondary sign of estrus are hard to determine in the image which are restless (which could only be detected in the video) and grouping (there may be a lot of cattle in the image frame but we could not be able to realize that whether they are estrus or not).

We will emphasis on the primary sign of estrus which are mounting and following behavior in this paper. We do a polyline normalization by using Visual Geometry Group (*VGG*) annotator, extract the polyline features of the cattle regions in the image. We manually annotate the estrus and not-estrus behavior of the cattle. We calculate the 15 features from each annotated region for training of *x* and *y* values. After that, these features are used as inputs to the supervised machine learning methods which are *SVM*, *LR* and *MLR*.

II. Related Works

In advancement in the technology sector, adequate identification of estrus detection affects herd productivity in numerous ways. In the literature, there are so many works with either combining video image and sensor information or using laser range sensor system of estrus detection methods [2,3] using different features have been projected for estrus detection but rarely for using only Image-based technology. Moreover, the proposed behavior of cattle estrus detection algorithm is effective, an image technology-based estrus detection system using it recognized the behaviors of other farm animals could be also implemented, which reduces the system cost.

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III. Proposed Methods

An architecture of proposed estrus detection system consists three main stages namely, preprocessing stage, feature extraction and classification stage as described in Fig. 1. In the preprocessing, polyline shapes of cattle regions are extracted by using the technique of VGG annotator. A pattern recognition approach is applied to learn the behaviors of cattle in estrus and not-estrus from the labeled images. The feature extraction stage performs to convert the extracted polyline shapes into feature vectors each containing 15 attributes. We then utilize these feature vectors as an input to a classifier in the classification stage which classifies the estrus or not-estrus class that each feature vector belongs to. The detailed procedures are explained in the following.

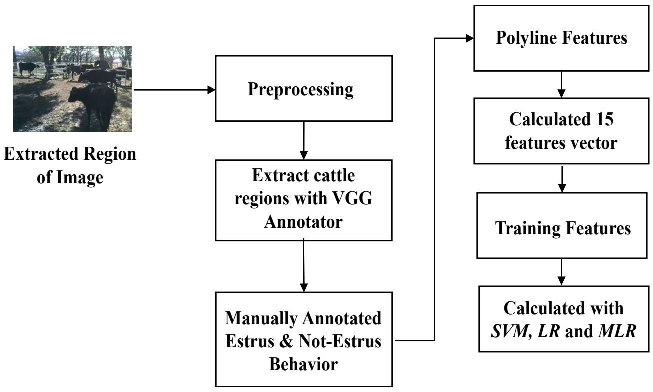

Fig. 1. The overall system diagram of the proposed method.

A. Pre-processing Stage

In this proposed system, the feature is extracted by using manually annotated polyline for each frame. For the training process, 3364 sub-regions from 2265 frames are extracted. The details of selecting appropriate frames from the video can be seen in Fig. 2.

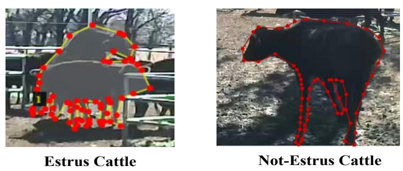

Fig. 2. Manually annotated Estrus and Not-Estrus Cattle.

B. Feature Extraction Stage

A common strategy in image processing to deal with recorded video sequences is the division of the original records into fixed length of segments or frames. We then transform each image in every frame into a feature vector. To be specific, each polyline shape is converted into a feature vector. In order to do so, we assume there are N boundary points with coordinates $(x_1, y_1), \ldots, (x_N, y_N)$.

The average feature for x is defined in (1),

$$f_1 = \frac{1}{N}\sum_{i=1}^{N}(x_i)^2 \tag{1}$$

where x is the coordinate point, and N is total the number of boundary points. For the x and y value, energy is calculated by average features. Moreover, x and y values of maximum and minimum values are calculated. The difference of maximum and minimum values: max(x_N) - min(x_N) and max (y_N) – min (y_N) are then computed.

The standard deviation is then obtained by,

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}} \tag{2}$$

where σ is the standard deviation, μ is the mean, x is the each value of coordinate point, and N is the total number of coordinate points.

The value of z is calculated from the x and y *values*,

$$z = \sqrt{x_1^2 + y_1^2} \tag{3}$$

where x, y *and* z are the coordinate points. Likewise, x and y values, z value is also computed. In this way, features vectors consist of 15 attributes are calculated. The bounding box rectangle is decided according to the lower left point (x_{max}, y_{max}) and upper right point (x_{min}, y_{min}) as illustrated in Fig. 3. where x_{min}, x_{max} and y_{min}, y_{max} are maximum and minimum values of x and y coordinates respectively.

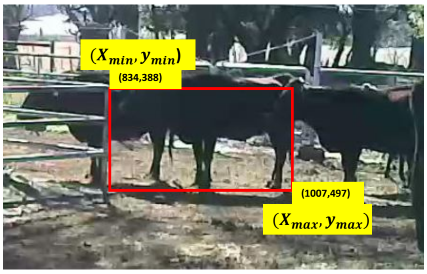

Fig. 3. Calculated minimum and maximum values of x and y.

C. Classification Stage

In the classification, Support Vector Machine (*SVM*), Linear Regression (*LR*), and Multiple Linear Regression (*MLR*) are used to classify the Estrus and Not-Estrus behaviors of cattle. *SVM* is the function of hyperplane and is utilized to distinguish among features in the dataset. The function is used to classify between features is a line in 2-D function. *LR* is a linear classifier which distinguishes between the Estrus and Not-Estrus behaviors in the dataset and it can be defined as :

$$f(x) = b_0 + b_1 x_1 + \ldots + b_r x_r \tag{4}$$

where, the variables $b_0 + b_1, \ldots, b_r$ are the estimators of regression coefficients. In the *MLR,* the independent variables and dependent variable of the linear relationship is defined to distinguish the behavior of estrus that we would like to predict.

IV. Experimental Results and Discussion

Experiments are conducted by using the real-life 15 video sequences taken in Sumiyoshi Livestock Science Station, University of Miyazaki, Japan. The dataset contains 2265 color images of which resolution is 1280*800 pixels. A side view camera is used to monitor the cattle behavior to decrease the system costs. For the evaluation, sequences of videos are utilized with different frame rates because cattle motion is different in each video. We firstly extract the 3364 sub-regions from the frames, and it includes the 38.40% of Estrus and 61.60% of Not-Estrus. Splitting the 80 % (2692 sub-regions) for training dataset and 20 % (672 sub-regions) for testing dataset. The comparison results of three methods (*SVM, LR, MLR*) are described in Table 1. The Confusion Matrix of Estrus and Not-Estrus behaviors for 20 % of testing dataset is shown in Fig. 4.

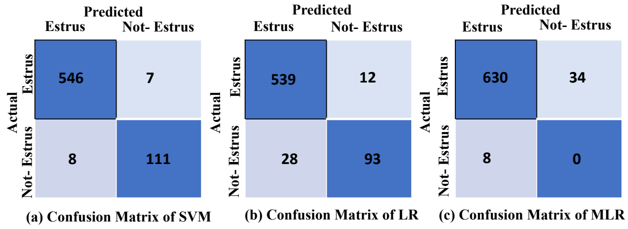

Fig. 4. Confusion matrix for the comparison of three methods

TABLE 1. CLASSIFICATION REPORT FOR COMPARISON OF THREE METHODS

Behavior	Algorithm	Precision (%)	Recall (%)	F1Score (%)	Accuracy (%)
Estrus	SVM	0.97	0.99	0.98	0.97
	LR	0.94	0.99	0.96	0.94
	MLR	0.89	0.77	0.82	0.94
Not Estrus	SVM	0.96	0.93	0.94	0.97
	LR	0.96	0.70	0.81	0.94
	MLR	0.95	0.98	0.96	0.94

V. Conclusion

In this paper, we presented a comparison of Support Vector Machine (*SVM*), Logistic Regression (*LR*) and Multiple Linear Regression (*MLR*) for estrus detection with Image-based technology. Among these three methods, SVM outperformed the best accuracy rate. Currently, we are doing with manual polyline extraction for features vector. We expect that our research to be a first move of only Image-based estrus detection system with features vector. For the future work, we will try to get the automatic polylines for feature extraction.

References

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