Framework of Cow Calving Monitoring System Using Video Images

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***Abstract*—In modern dairy farms, calving is a very critical point in the life cycle of productive cows and has played a major role in making farm profits and welfare of cows. In this time, a tremendous number of researchers have been studied the problem of calving mostly to predict the time about to calve and to investigate calving process by using wearable sensors. Like human beings, cows also have environmental pressures by wearing sensors on their bodies sometimes may cause calving difficulties. Thus in this paper, an automatic video based cow monitoring system is proposed to reduce losses of dairy farms caused from calving problems. Specifically, this paper investigates some behaviors of cows to predict time for calving process including cow movements, tail up, stretching the legs, repeating standing and sitting. In doing so, we focus on increasing movement and tail up. Here, the inter-frame difference is used for analyzing the movement and count in every frame. In addition, by extracting the head and tail position the activity of tail up or not will be recognized so that time for calving can be estimated. Finally, the proposed method for calving is confirmed by using self-collected video sequences.**

***Index Terms*—calving behavior, cow monitoring, motion feature, tail up, image processing**

I. Introduction

According to the livestock statistics which has been published by ministry of agriculture, forestry and fisheries of Japan, as of February 1, 2015, the number of dairy farming had been decreasing by 900 units compared with 2014. Meanwhile, the number of beef cattle farming had also been declining by 3,100 units. On the other hand, number of dairy cows per household increased by 2.5 head while number of beef cattle per household increased by 1.2 head. The burden per one famer is increasing as the number of cattle per household has a tendency to increase in Japan. Especially, livestock farmers have to be careful than as usual when the cows act calving behavior. Therefore, recently an automatic monitoring system for calving behavior has been studied and developed using wearable sensor. The application of precision technologies in calving detection has used primarily of maternal body temperature sensor system. Maternal body temperature has been shown to change 48 h before calving [1], [2]. Utilizing this feature, a commercially available temperature sensor system detects calving. Moreover, since feeding and ruminating behavior of cows gradually decreases in the last two weeks before calving and suddenly decreases at the time of calving studies are being conducted to detect these changes using a sensor [3]-[5]. However, these are costly because they are necessary for each cow. Thus, we use the camera to detect automatically calving instead of them. It can be economical and reduce the burden on the cow. Applied research on cattle, using cameras has been actively conducted in recent years. For example, there are lameness detection, estrus detection, body condition score and cow identification. Detection for lameness detection has been carried out using images moving from the barn to the milking machine. This method showed more than 96% correct rate of classification which reveals the high potential of the developed technique [6]. To detect estrus, a camera was set on the side, only images of a certain height were extracted and mounting detection was performed [7]. Moreover, an automatic evaluation of body condition of dairy cow is basically practicable with the developed 3D camera [8]. In addition, individual identification has been presented by using the image of the cow's nose [9] and using shape information of pointed pattern [10]. However, to the best of our knowledge, there is no research in cow calving monitoring using image processing technology.

The details of the proposed system are presented in Section III and the experimental results are shown in Section IV. In Section V, we conclude our paper and discuss the future works.

II. Motivation

In previous studies, we found that there are some behaviors before and after calving. For example, number of postural changes, amount of movement and ricking the calf are monitored. We define the behaviors as action feature, stretch one’s legs and tail up as appearance feature. The calving behavior is shown in Fig. 1. In this paper, we focus on one action feature (movement) and one appearance feature (tail up).

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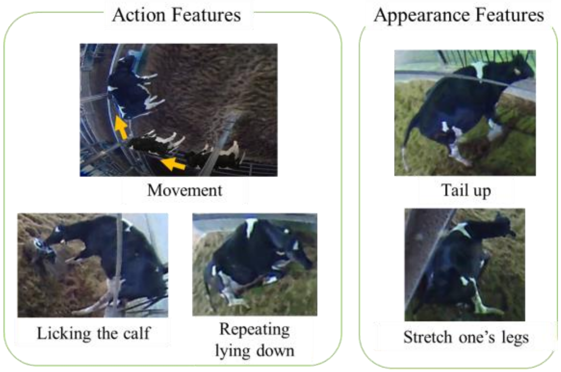


Figure 1. Some sample feature of calving behavior.

III. Proposed System

The proposed method is divided into three main parts: (i) the detection of cow's position, (ii) the extraction of feature, and (iii) the judgment of calving behavior. In this paper, detection of cow's position is described in Section III.A and followed by feature extraction in Section III.B.

A. *Detection of Cow's Position*

The inter-frame difference is applied to detect the position of cow in the video frame. The flowchart of detection of cow's position is shown in Fig. 2. Firstly, inter-frame difference is performed by using current frame and previous frame. To reduce the processing time, it has been divided into regions and then calculate average value in each region.

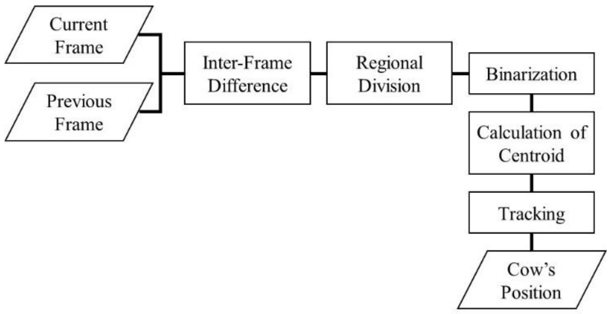


Figure 2. Flowchart of cow's position detection.

Moreover, the centroid is calculated by using the average value. The detail of each process is explained as follows.

1) Binarization

After regional division, white pixel in each region is counted and then the average intensity (gray scale) value in each region is calculated. In the next, binarization is performed by using threshold. Frequency, image values are different from left side value and right side value due to lighting conditions, threshold will be changed in each region. The flowchart of binarization method is shown in Fig. 3. Firstly, gray-scale image is divided into equal size perpendicular regions and then calculate the average value of intensity in each region (m_i). After that, those values are used to normalize for defining the threshold value as described in Equation (1).

$$Th_i = \frac{m_i}{m} \times \alpha, \qquad i = 1,2,\ldots,8, \tag{1}$$

where α be arbitrary constant and decided to become suitably value in left side region (dark region). Here m be the maximum value among m_i. Finally, binary image is processed by using calculated threshold value.

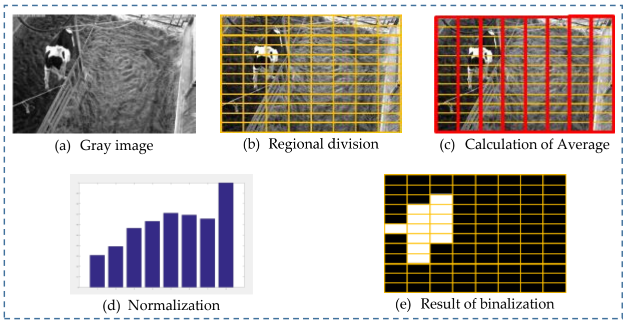


Figure 3. One example of binarization.

2) Calculation of centroid

Firstly, labeling process is performed to decide the number of cows within image. However, ordinary labeling method cannot work well label distance is larger than 1. Here, we use Chebyshev distance between in the proposed system to recognize as the same label when the label distance is less than or equal 2.

3) Tracking

Current positions of cows are detected by calculation of centroid. When the cow regions close to each other, the label of cows in the image become merge and the label number may change. In such situation, we use the label value of previous frame instead of the current frame.

B. *Feature Extraction*

In this study, two types of feature are used. One is action feature and another one is appearance feature. 'movement' [11] and 'tail up' are used as representative for each type of feature.

1) Movement feature

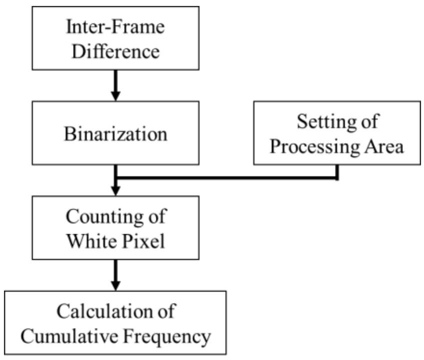


Figure 4. Process of feature extraction of movement.

The flowchart of movement feature extraction is shown in Fig. 4. Firstly, processing area is set by using cow's position obtained at Section III.A. Then, white pixels in processing area are counted. Finally, histogram is created and performed cumulative frequency. The detail of each process is explained as follows.

Processing area is set in the area that can surround the entire cow from centroid of cow. Then, amount of change is detected by using inter-frame image.

Therefore, total white pixel is counted in processing area. When the cow moves, it becomes greater. Finally, the histogram $h(i)$ is computed in each hour. Then cumulative frequency $c(i)$ and the second order difference $d(i)$ are calculated. Here $c(i)$ and $d(i)$ are defined in Equation (2) and Equation (3), respectively.

$$c(i) = \sum_{j=0}^{i} h(i) \tag{2}$$

$$d(i) = c(i+1) + c(i-1) - 2 \times c(i) \tag{3}$$

2) Apperance feature

The flowchart of appearance feature of tail is shown in Fig. 5(a). Firstly, angle of object is calculated by moment and then the rotation process is performed. After extraction of head and tail region, four features are extracted to detect tail position.

In order to detect the tail up, the rightmost and leftmost region with size of 1/6 width of the whole region will be cropped as head and tail. After cropping the nominated head and tail region, somethings there are more than one label within the region. For such case, we use only large label to further process. Finally, they is resized as square matrix to compare. In Fig. 5(b), the process of how to get head and tail region is described. In this part, this system decided whether the tail up or not by using four types of features:

1) Area ratio in the center circle,
2) Labeling number,
3) The calculated area ratio after equally splitting the region into two parts, and
4) Symmetry ratio

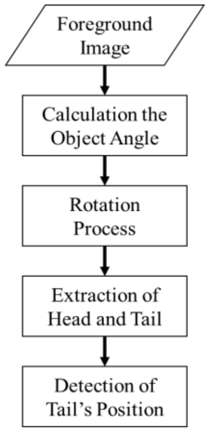
Judgment of tail up is shown in Fig. 5(c). If all of these conditions are satisfied, we can say that it is 'tail up'. The detail of those conditions are as follow. When it is head or tail down, they have a large area in the center circle. However, when it is tail up, it has a small area in the center circle. Then, we decided the tail up or not by using this feature. Fig. 5(d) describes how to calculate area ratio. In this time, when area ratio is greater than 0.6, this system determined that this image is head or tail down. In Fig. 5(e), the left image the sample of extracted head side. For removing the leg region, the system can apply the labeling processing. If labeling number is greater than 2, the system decided that this image is head or tail down. Image in Fig. 5(e) is false recognition image in previous features. Because cow's head is biased in one direction.

Thus, the image is divided into upper and lower halves, and with the area ratio calculated for each sub-region as show in Fig. 5(f).

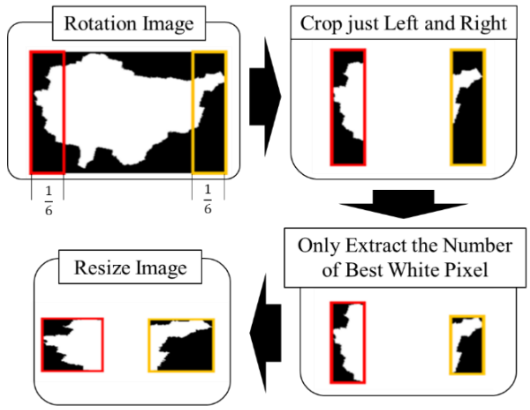
If area ratio is greater than 0.7, this system also determined that this image is head or tail down. Finally, the image cannot be accurately decided as shown in Fig. 5(g). At first glance, it is likely to be determined by using "Area Ration in the Center Circle". However, we could not decide accurately due to extracting narrow head. Therefore, we determine whether it is symmetry or not. Firstly, the region is divided into two sub regions in the upper and lower part. Then XOR processing is applied between two sub regions for calculating symmetric ratio as shown in Equation (4).

$$\text{Symmetry ratio} = \frac{\text{number of matched pixels}}{\text{total number of pixels}} \tag{4}$$

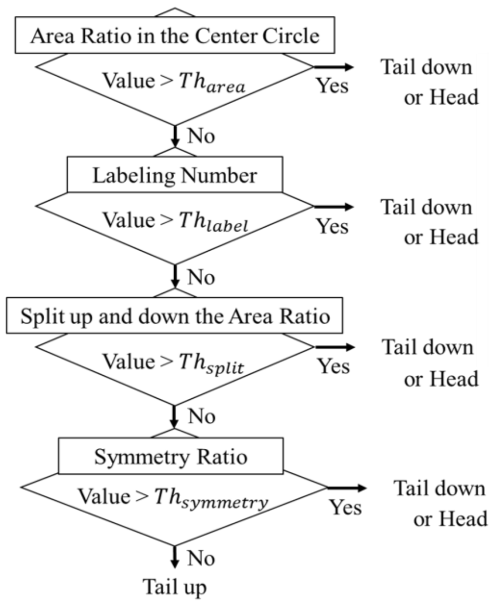
If symmetry ratio is greater than Th_s (here $Th_s = 0.8$), this system this image is head or tail down.



(a) Flowchart of appearance feature of tail

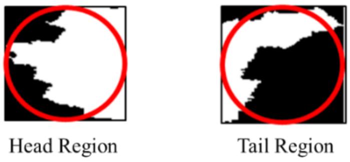


(b) How to get the head and tail region

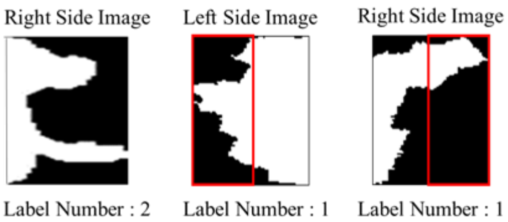


(c) Detecting tail up feature

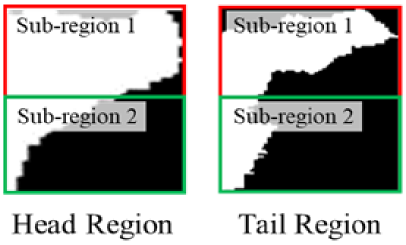
$$Area\ Ration = \frac{number\ of\ white\ pixel\ in\ circle\ filter}{all\ pixel\ in\ circle\ filter}$$



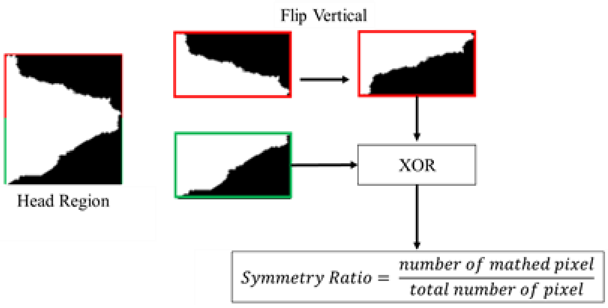
(d) Procedure for calculating area ratio



(e) Labeling process



(f) Calculating area ratio of sub region



(g) Symmetry ration process

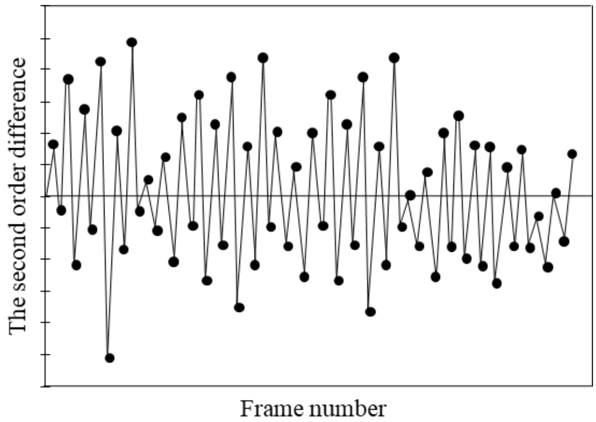
Figure 5. Process of appearance feature.

C. Judgment of Calving Behavior

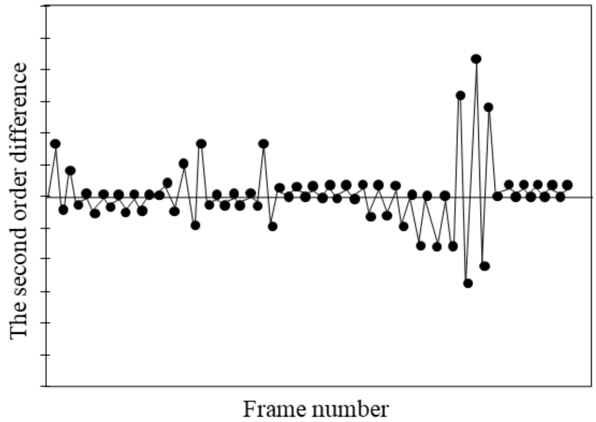
The characteristics obtained in Section III.B are used to determine whether calving behavior was close. Section III.C.1) describes the detection method for the displacement feature, and Section III.C.2) describes the detection method for the tail-up feature.

1) Judgment for movement feature

The example of analyzing and calculating the movements in each event are described in Fig. 6. These figures describe the temporal movement parameter (the second order difference of pixels in cow region) between successive frames. We can see that very close to calving period, the temporal movements become a large number of data. On the other hand, there are very few or less data in normal situation. Moreover, we apply the predefined threshold (Th_m) for the movement amount, and we count the frequency if the temporal movement is greater than Th_m. The number of movement frequency is shown in Table I. In this table, we can recognize that the movement frequency of closing to calving is very higher while comparing with normal situation.



(a) Calving situation



(b) Normal situation

Figure 6. The temporal movement between consecutive frames.

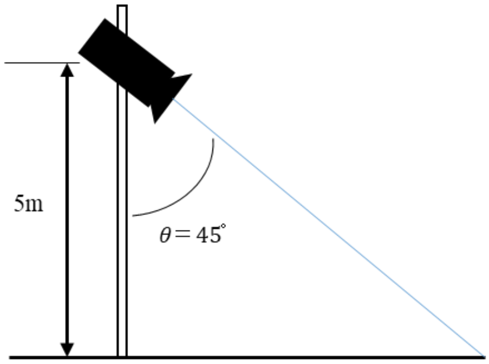
Therefore, the proposed system can provide the important information in which this situation is closed to calving process, or not, using the movement frequency.

2) Judgment for movement feature

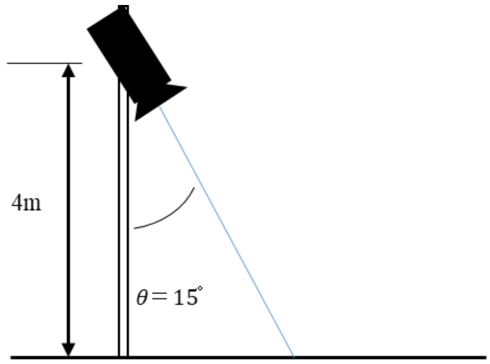
In the first step, the appearance of tail should be decided as it is 'tail up' or not. There are two behaviors in tail up. The first one is evacuate behavior and the latter one is calving behavior. The difference of these two actions is tail up time. The time of evacuate behavior is about 15 seconds and calving behavior time is lager then evacuate behavior. So, we use the tail up time for deciding parameter as calving behavior or not. Here we decide that if tail up time is more than 30 seconds, the action should be calving behavior.

IV. Result

In order to investigate the validity and performance evaluation, the self-collected video sequences were taken at Sumiyoshi Livestock Science Station at University of Miyazaki and a large-scale dairy farm in Oita prefecture. Image frame size is 640×480. In the proposed system, two cameras are set up as shown in Fig. 7. To confirm the proposed system performance, there are two evaluation experiments for movement feature and appearance feature of tail. Evaluation experiments are described as follows.



(a) Large-scale dairy farm (Oita)



(b) Sumiyoshi livestock science station (University of Miyazaki)

Figure 7. Camera setting.

A. *Evaluation for Movement Feature*

To analyze and calculate the temporal movements in calving situation and normal situation, we use 5 video sequences which are 1 hour before calving (closed to calving period), and another 5 video sequences which are a few days before calving (normal situation). These video sequences are taken at large- scale dairy farm in Oita. As a result, the proposed system can give the accurate judgments for all videos.

B. *Evaluation for Appearance Feature of Tail*

In order to confirm the proposed system performance, another 6 videos are used in the experiment. Among them, there are 2 abnormal case videos and 4 normal case videos. From these videos, 4 videos are used as training data and the other 2 videos are for testing. The accuracy rates of tail up in training videos and teat videos are shown in Table I and Table II, respectively. The accuracy of all training data is greater than 90% and the test data is greater than 80%. According to the system performance, this system accurately decided even though the action is abnormal.

TABLE I. ACCURACY OF TAIL UP IN TRAINING DATA

	Number of Frames		Precision	Result
Video	**Existing**	**Detected**		
Calving	60	60	92%	Calving
Normal (1)	60	48		Normal
Normal (2)	60	56		Normal
Normal (3)	60	57		Normal

TABLE II. ACCURACY OF TAIL UP TEST DATA

	Number of Frames		Precision	Result
Video	**Existing**	**Detected**		
Calving	60	60	88%	Calving
Normal	60	48		Normal

V. CONCLUSION

This paper proposed the cow calving monitoring system using image processing with two main types of features: movement feature and appearance feature of tail. In movement feature, the method could detect whether the behavior approaches to calving behavior or not. In appearance feature, the method gives whether the action was tail up or not. Therefore, the proposed method can decrease burden on livestock farmer and cows to detect the calving behavior. Finally, this system detects only whether it is calving action or not. In future work, we shall extend to detect various kinds of abnormal behavior in cow calving process.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

AUTHOR CONTRIBUTIONS

Kosuke Sumi, Ikuo Kobayashi and Yoichiro Horii conducted the research; Kosuke Sumi and Thi Thi Zin analyzed the data; Kosuke Sumi wrote the paper. All authors had approved the final version.

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