DETECTING OF APPROACHED INTERACTION WITH CATTLE IN ESTRUS BASED ON COMMUNITY TRANSITION AND CATTLE DISTANCE

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ABSTRACT

In stock breeding of beef cattle, it is essential to efficiently produce calves to maintain stable management. For this purpose, most farmers conduct artificial insemination, which should be performed after half a day of estrus detection. Therefore, in order to perform artificial insemination successfully, it is necessary to detect cattle in estrus precisely. Generally, searching the estrus is performed visually. Sometimes, a pedometer or a temperature sensor is used to grasp cattle's condition. These methods, however, do not consider the fact that the cattle live in a community with other cattle. Taking such cattle's sociality into account may enable to grasp the change in cattle's condition and detect cattle in estrus more accurately. This study focuses on the sociality of grazing cattle and aims to detect estrus by grasping the change of social behavior. Cattle in estrus tend to be approached by other cattle continuously for several hours. The behavior of approaching or being approached (stated as approaching-approached behavior from here on) is quantified by using the position information. In order to minimize the influence of momentum in quantification, we propose a method focusing on the direction of the cattle during movement. Moreover, we employed weight based on community history and distance between two cattle in order to reduce noise due to unintended approaching-approached behavior. Furthermore, we performed anomaly detection with a state-space model to detect cattle in estrus based on the quantification of the approaching-approached behavior in real-time. We verified the effectivity of the quantification for estrus detection with performed artificial inseminations. As a result, the precision was 0.579, the recall was 0.733 and F-measure was 0.647, and thus, confirmed the effectivity of our method.

Keywords*:* Cattle, Cow, Estrus detection, Heat detection, Anomaly detection, GPS*.*

1. INTRODUCTION

In stock breeding of beef cattle, there is an obstacle to efficiently produce calves by performing artificial insemination (AI). It is necessary to find cattle in estrus in order to perform AI successfully. Currently, livestock workers who have knowledge about the change in cattle's condition and behavior take an observation of cattle. Therefore, as the area of a pasture and the number of cattle become larger, it is more difficult to find out the cattle in estrus. In order to reduce their burden in human

resources, in this study, an attempt is made to detect cattle in estrus by focusing on the approaching-approached behavior. The approaching-approached behavior is observed frequently in cattle in estrus because it tries to avoid other cattle that tend to approach. In the previous year, we attempted to quantify the approaching-approached behavior when in estrus (Fukumoto et al., 2018). This method focused on the moving direction of cattle which were the target for estrus detection. However, there are several drawbacks in the method. First, the method did not consider the situation in more than three cattle and thus, the behaviors of more than two cattle are ignored. Second, the unintended approaches are likely to affect the quantification, and thus may cause errors for estrus detection. In order to deal with such problems, in this paper, after quantification of the approaching-approached behavior between two cows, we try to get rid of the unintended approaches from the quantification by assigning a weight for each cow based on community transition and distance. After that, we verify the effectivity through an experiment. In Section 2, we describe the method of the approaching-approached behavior, Section 3 shows an experimental result to evaluate method and finally, Section 4 summarizes our work with future tasks.

2. METHODOLOGY

2.1 Extraction of Interaction Information Related to Cattle in Estrus

Cattle are animal with sociality and express particular interactions among them when in estrus. For example, smelling their buttocks each other and standing are symbolic actions of that (Roelofs at al., 2005). During these interactions, abnormally approaching is frequently observed. The left side of Figure 1 shows the appearance of abnormally approaching toward a cow in estrus by another cow. Cattle in estrus are more likely to generate other cattle's interest and continue to be approached by any other cattle because their vulva becomes swollen and hyperemic. As a result of that, interactions such as standing are caused. Abnormally approaching during estrus lasts for a few hours and such an interaction is less likely occurred except cattle in estrus. Therefore, it is said that this behavior is a good indicator of cattle in estrus (Roelofs at al., 2005). That is why it is probably useful for estrus detection to quantify the approaching-approached behavior and detect the state of being abnormally approached with high accuracy.

We put GPS (Global Positioning System) receiver around their neck to acquire position information of each cow (stated as the GPS collar from here on). The overview of a GPS collar is shown on the right side of Figure 1.

Figure 1. Approaching-approached behavior (left) and GPS collar (right) *Note.* The source of the pictures: (Fukumoto et al., 2018)

The GPS collar is made by putting a GPS receiver and a USB battery (ARKNAV Co., Taiwan) in a waterproof box. The position information is recorded into the text file as a log at daily intervals and it

contains latitude, longitude, velocity on the ground and so on. From the time series data of position information, we can calculate the distance and angle between two positions.

Cattle form some groups to live and the interactions are likely to be observed inside those groups. Therefore, we express the unit of those groups as communities and focus on the approaching-approached behavior inside the communities. In order to determine the community, we use Louvain algorithm based on the total time for which the distance between two cattle are less than 10 m (Blondel et al., 2008).

2.2 Quantification of approaching-approached behavior

A method of the quantification of the approaching-approached behavior is nearly the same as the previous year's (Fukumoto et al., 2018). This method focuses on the angle between a moving vector $V_{c_i}^t$ and a direction vector D_{c_i,c_j}^t. The cow c_i is the target for estrus detection. $V_{c_i}^t$ has the moving direction. D_{c_i,c_j}^t has the direction from cow c_i to any other cow c_j. On the other hand, the method in this paper focuses on the angle between two vectors shown in Figure 2.

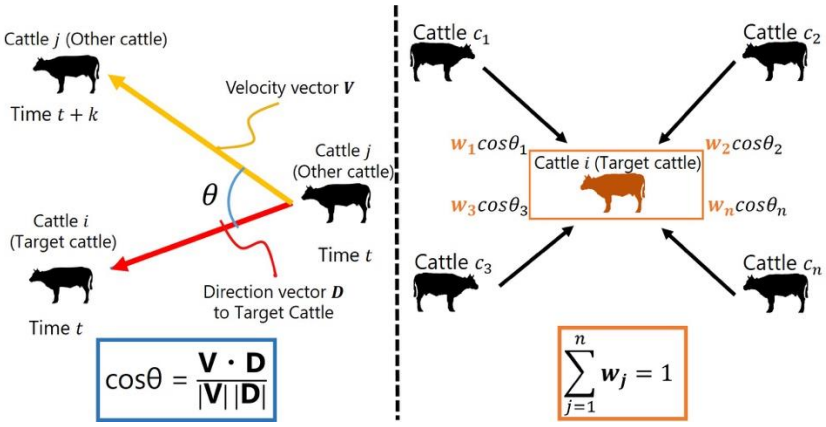

Figure 2. Concept of the proposed method

One is a moving vector $V_{c_j}^t$ of any other cow c_j, and the other is a direction vector D_{c_j,c_i}^t which has the direction from any other cow c_j to a target cow c_i. The approached index between two cows S_{c_i,c_j}^t at time t is calculated by

$$\textbf{Approached index between two cows}: S_{c_i,c_j}^t = \frac{\boldsymbol{V}_{c_j}^t \cdot \boldsymbol{D}_{c_j,c_i}^t}{\left\|\boldsymbol{V}_{c_j}^t\right\| \left\|\boldsymbol{D}_{c_j,c_i}^t\right\|}. \quad (1)$$

The approached index between two cows S_{c_i,c_j}^t is expected to become nearly 1 when a target cow is approached by any other cow and become -1 when a target cow is approaching toward any other cow.

2.3 Employing weight based on cattle distance and community transition

During grazing, unintended approaching-approached behavior can occur accidentally because of feeding behavior and so on. Considering such things, we make an attempt to quantify the approaching-approached behavior among more than three cattle. At first, we decided to assign weights towards other cattle to get rid of the effect of the cattle's behavior which has nothing to do with the target cattle's behavior. These weights are assigned to only cattle which belong to the same community as the target cattle. The weights are determined by considering two factors as below.

The first is past community records. Most of the approaching-approached behavior in estrus are performed between friendly cows. These cows are more likely to travel with each other and thus, more

likely to belong to the same community. Therefore, it is possible to assign more weights toward friendly cows to get rid of unintended approaching-approached behavior. The weights based on community transition is determined by the function of the number n_{c_j} that the cow c_j became the same community as the target cattle in the past X times.

The second is the distance to the target cattle. The distance at the approaching-approached behavior in estrus is smaller than the one when feeding and resting. Therefore, the approaching-approached behavior is more likely to occur with the nearer cow especially even in the same community. The weights based on cattle distance is determined by the function of the mean distance d_{c_j} between the target cow and any other cow c_j of every community generation interval Y.

Each function adopted to the determination of the weight is shown in Figure 3.

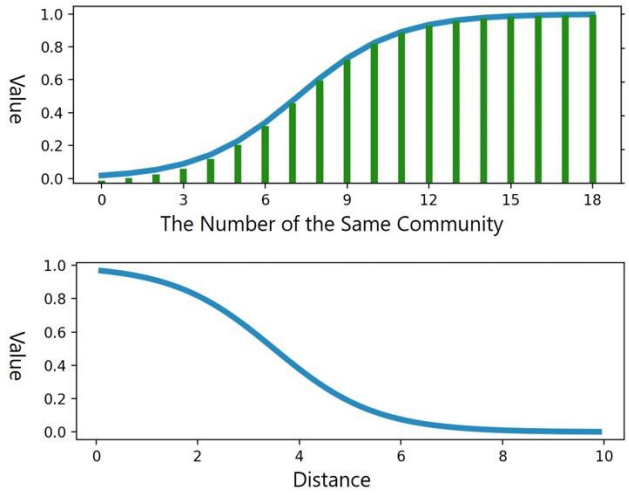

Figure 3. Functions used to determine the weights

These functions are generated based on sigmoid function. The weights $\boldsymbol{w_{c_j}^t}$ of cow $\boldsymbol{c_j}$ are calculated by

$$\textbf{Approached index}: \ \boldsymbol{w_{c_j}^t = \lambda \frac{w_{n_{c_j}}^t}{\sum_{c_j \in C} w_{n_{c_j}}^t} + (1-\lambda) \frac{w_{d_{c_j}}^t}{\sum_{c_j \in C} w_{d_{c_j}}^t}}, \quad (2)$$

where $w_{n_{c_j}}^t$ are the weights based on the community transition, $w_{d_{c_j}}^t$ are the weights based on distance to the target cattle and λ is the coefficient which indicates the rate of two weights.

The approached index $S_{c_i}^t$ at time t is calculated by

$$\boldsymbol{S_{c_i}^t = \frac{\sum_{c_j \in C} w_{c_j}^t \times S_{c_i,c_j}^t}{\sum_{c_j \in C} w_{c_j}^t}}, \quad (3)$$

where S_{c_i,c_j}^t is the approached index between 2 cows and $w_{c_j}^t$ is the weight. This expression adopts the form of weighted mean and thus the sum of all weights become 1, which are expected to prevent community size from affecting values. The rest of the process adopts from the previous year's (S, Fukumoto et. al, 2018). In short, we calculate the mean $y_{c_i}^t$ for T from time t for the purpose of detecting the state that the target cattle are abnormally approached by any other cow. The mean $y_{c_i}^t$ is calculated by

$$\boldsymbol{y_{c_i}^t = \frac{k}{T} \sum_{l=0}^{T/k} S_{c_i}^{t+k \times l}}, \quad (4)$$

where k is the interval of GPS acquisition. We express this $y_{c_i}^t$ as the approached value in this paper. The range of the value becomes $-1 \leq y_{c_i}^t \leq 1$ as same as the cosine similarity.

3. Experiment Result and Evaluation

3.1 Experimental setting

We put GPS collars on the cattle which have been bred at the Food Resources Education and Research Center, Graduate School of Agricultural Science, Kobe University in order to examine the possibility of estrus detection. The position of each cow was measured for eight months from May 1, 2018, to December 31, 2018. The measurement was conducted for thirty-six cattle during this period. The detection interval for location information by GPS was 5 seconds. Communities are generated in every $Y = 10$ min. The weights based on community transition are determined by the community of latest $X = 18$ times. We adopted three kinds of the coefficient $\lambda = 0.0, 0.5, 1.0$. The interval of calculating approached values is $T = 180$ min and we calculated the approached value every 10 min. We adopted the local-level model which is a kind of the state-space model for anomaly detection (Durbin et al., 2012). We evaluate the proposed method by Precision, Recall, F-measure. The detector examines whether the cattle are in estrus or not every half a day. We compare the case when pedometers are used in conjunction with the proposed method with the case when pedometer are used solely. The pedometers have the same functions as previous year's (Fukumoto et al., 2018).

3.2 Result and Discussion

Table 1 shows each Precision, Recall, F-measure of the case when pedometers are used solely and are used with the approached value (no weight, $\lambda = 0.0, 0.5, 1.0$).

Table 1. Evaluation scores of each method

Method	Precision	Recall	F-measure
Pedometer only	0.378	0.933	0.538
Pedometer+Approached value (no weight)	0.529	0.600	0.563
Pedometer+Approached value ($\boldsymbol{\lambda = 0.0}$)	0.579	0.733	0.647
Pedometer+Approached value ($\boldsymbol{\lambda = 0.5}$)	0.524	0.733	0.611
Pedometer+Approached value ($\boldsymbol{\lambda = 1.0}$)	0.526	0.667	0.589

During the data acquisition period, there were thirty-seven days on which the artificial insemination was performed while both GPS data and the pedometer data were obtained. Among those days, pregnancy was confirmed fifteen times during that period. The increase in the number of steps occurred fourteen times out of the fifteen. This fact confirmed the improvement of F-measure due to the proposed method. Moreover, the approached value with weight has higher F-measure than that without weight every time. Especially, the weight based on the community transition has the highest Precision, Recall, F-measure. Figure 4 shows the result of the pedometer, the approached value without weights and the approached value with weights. We performed the artificial insemination to the cow on 24th, October and later on, the cow became pregnant . This indicates the cow was in estrus during the period framed in red. In addition, the artificial insemination was also carried out in the morning of 29th, August and 17th, September. There are sharp increases in the approached value during both of these days. In such cases, even though the artificial insemination failed, this peak may also resemble estrus because these periods corresponds to that of cow's estrus. Thus, the positive effect of quantification could be confirmed. Particularly, the weights based on community transition are working well and eliminating unintended approaching-approached behavior to some extent.

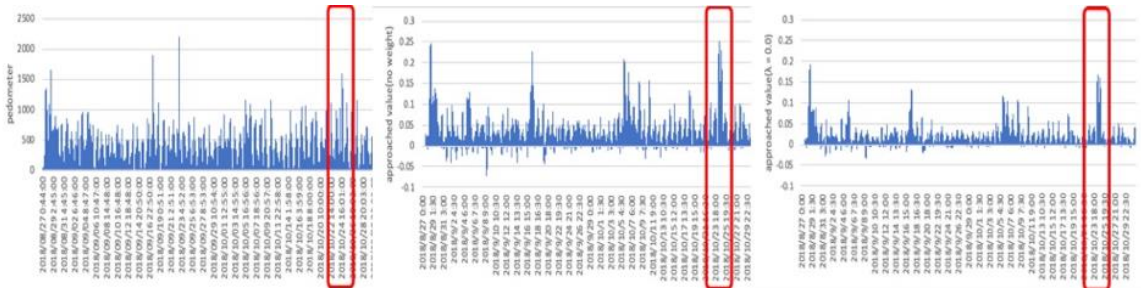

Figure 4. Result of cattle 20295 from pedometer (left), approached value with no weight (middle) and approached value with weight (right)

The weights based on cattle distance are also feasible but its effectivity is inferior to that of the weights based on community transition possibly due to positioning error. The communities were generated by clustering based on the time when the cattle distance became less than 10 meter, which is the reason the weights based on community transition are robust to temporarily positioning error. On the other hand, the weights based on cattle distance were generated by considering only the distance itself and thus, they are vulnerable to the positioning error. Therefore, we conceive that the approached value ($\lambda = 0.0$), which adopts the weights based on the community transition, is the most effective method.

4. Conclusions

In this paper, we focused on the approaching-approached behavior and applied the knowledge that the cattle in estrus are more likely to be approached. In quantification, we added weights to consider cattle's community and distance. When our method was combined with the conventional method using the pedometer, F-measure rose by 2.5% and we could grasp the estrus cycle more precisely. There is a certain effect of employing weight, which raised F-measure by another 8.4%. However, we assume that our method is much effective because we did not examine some missed estrus. This is because in this work, our method was used together with the data of pedometer and the implicit estrus has been observed which the pedometer itself cannot detect. Thus, it is necessary to verify the usability of the proposed method by conducting artificial insemination for the implicit estrus of cows detected from only the approached value, which cannot be seen from the pedometer.

Acknowledgement

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