Develop a video monitoring system for dairy estrus detection at night

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Abstract

Milk, one of the important human foods, can not only be drunken directly but also be processed to produce more products. It is a critical issue for owners of ranches to effectively manage the pregnancy, reproduction, and milking of dairy cows. In current ranches, artificial insemination is performed to make dairy cows pregnant. Accurate estrus detection of dairy cows is essential for the success in artificial insemination. The traditional method to detect estrus of dairy cows is visual observation, whose success rate largely depends on the observers' experience and the frequency of observation. Therefore, several direct-contact monitor systems have been developed. But these sensors which directly contact the skin of dairy cows induce their discomfort. In this study, a non-contact video monitor system will be developed to avoid the contact-related discomfort. Infrared cameras will be used to record the imaging of dairy cows at night, when the frequency of estrus is the highest. Then the dairy cows with estrus-specific behaviors will be identified by imaging processing. Finally only simple judgments by owners are required to decide whether artificial insemination will be performed.

Key words: Dairy estrus detection, Artificial insemination, Infrared camera, Imaging processing

Introduction

Due to technical progresses, the human life has improved for decades and also the food intake has become variable. According to the world wide survey, the value of dairy products has reached 335.8 billion US Dollars since 2014, and is estimated to reach 424.3 billion US Dollars in 2019 by the 5% annual growth rate [1]. Therefore, the need for food processing using milk as the raw material is increasing. As a dairy owner, the most important issue is to effectively manage the pregnancy, delivery, and milking of dairy cows.

Currently in dairy farms, artificial insemination is used to make dairy cows pregnant. A good plan for artificial insemination can effectively identify which cow is in estrus to avoid prolonged emptiness. If the detection for estrus is not appropriate, the timing of breeding will be missed, which decreases the pregnancy rate and prolongs the pregnancy-free interval of dairy cows, leading to the economic loss of dairy owners. If the pregnancy-free interval of cows exceeds 12.5 months, the dairy owner will suffered 2-4 US Dollars loss per day. In order to avoid this loss, dairy cows have to be re-pregnant within 100 days after delivery. In these 100 days, there are around 3 breeding possibilities [2].

There are 3 characteristics of dairy cows which are typically detected during estrus. The first characteristic refers to behavior changes. Mounting is the most common behavior detected during estrus. Wowing, enhancing activity, walking along the fence, laying the lower forehead onto the back ridge of other cows can also be observed more frequently during estrus. The second characteristic refers to body changes, such as dirty lateral abdomen, hair clutter and hair loss over the tail root, and redness and swelling over the perineum. The last characteristic includes poor appetite and urinary frequency [2]. The traditional estrus detection relies on close observation by humans. But the observer should stay around the farm for long time and also can make mistakes by missing those characteristics.

In order to reduce the possibility of misjudgement by direct human observation, many technologies have been developed to help owners to monitor and manage the estrus detection in dairy cows. Afimilk Co. in Israel has developed a AfiTag pedometer to record the numbers of cow steps. Since the activity of dairy cows is increased during estrus, the numbers recorded by the pedometer placed over the cow ankle can be further analyzed by the computer. The analyses can help owners to identify if the cows are under estrus or not [3]. Besides, Shen et al. [4] have developed a skin-attached sensor which can detect the cow movement acceleration over 3 axes (x, y, and z axis), which than can be analyzed by the computer algorithm to further classify the cow movement into static or dynamic (slight or sharp motion) status. This helps owners to identify if the dairy cow is under estrus or healthy or not. In addition, DVM system LLC. has designed a gastric temperature-measuring product which can be swallowed by the cow. This product includes a temperature sensor and a RFID chip. The reader which can receive signals is placed at the entrance of the milk squeezing area. The ID and the corresponding temperature signal of the cow can be recorded each time when the cow passes the entrance. The temperature changes of cow can help to evaluate if the cows are under estrus or sick [5]. Also, Kwong et al. [6] have used low power consumption sensor nodes as the base elements of a data gathering and communication infrastructure to monitor the physical and physiological conditions of cows. This infrastructure can be utilized over both dense house and free grazing cows. However, in direct contact monitor systems proposed, the sensors directly contact the cow skin leading to

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the discomfort of cows. Therefore, non-contact monitor systems are then developed. Tsai and Huang [7] have established an estrus detection system of dairy cows based on the imaging processing technology. But this system can only be used at daytime, which cannot detect estrus-related behaviors usually occurring at night. It then becomes a disadvantage of this system.

In order to overcome the problems of cow estrus detection systems currently developed, a non-contact video monitor system is developed in this study. The infrared cameras are utilized to record images at nighttime when the cow estrus happens most frequently. Then the images are analyzed by the imaging processing software to identify the cows with typical estrus-related behaviors. By this system, the owners can decide the timing of artificial insemination more effectively.

Methodology

A. Introduction to imaging processing technology

In this non-contact video monitoring system, the behaviors recorded by the cameras are judged by pre-established identification methods. This system is beneficial because it avoids influencing the animal lives directly and reduces the cost of direct contact devices. To establish the imaging interpretation system, only setting up the camera, the logical method for imaging recognition and the computer system to operate and record images are needed.

B. Detection of cow estrus by imaging recognition

Tsai and Huang [7] have developed a dairy cow estrus detection system based on the video imaging technology. Initially they did the dynamic energy analyses of video images and then found out the blocks which moved most significantly in the image. These blocks would receive the binary image processing to define the length of a dairy cow within a minimum rectangular frame. When the dairy cow has the specific mounting behavior due to estrous, the length of dairy cow in the images will increase to approximately 2 cattle length firstly due to the initial contact between 2 cows and then become shorter to due to approximately 1.5 cattle length due to the mounting behavior. To detect these changes in length is our rule to identify the cows under estrus. The events which fit our rule will be recorded as videos and saved in the computer. Then these events will be further evaluated by the owners later on.

C. Image acquisition

This study is conducted in the dairy farm of National Pingtung University of Science and Technology (NPUST), where Holstein cows are bred in roofed cowsheds. A camera was set up over the roof of the cowshed. The camera is located 3.6 meters above the ground, and the observed field is 4 x 5 m^2, which can include about 4-6 cows. The highest resolution of an image is 2MP pixels Full HD with a frame rate of 25 fps.

D. Image processing

The mounting behavior is difficult to be detected by a single static image. Therefore, motion analysis is utilized to recognize the initial following and then mounting behavior. The motion region, defined as the area with high levels of motion, is identified first in the video frame.

In order to increase the image contrast in the cowshed, the mode-based background modeling method is selected to do the foreground segmentation [8]. This method is suitable for use to process the images under light changing and low-contrast conditions. When dividing the motions regions for the dairy cow behavior, the method of region-growing segmentation is used. The process needs to find the pixel which has maximum motion strength to be the initial point and then expends to the 8 neighbors of it. Finally, in order to get the actual length of dairy cow, the mode-based foreground segmentation is used. The final region of the dairy cow is enclosed with a rectangle and the longer side is the length in motion.

Result and Discussion

A. Original images from the camera in the night

In addition to daytime, dairy cows also eat and move at night. Because of lack of light after sunset, the breeders turn on the light of cowsheds at night for feeding and cleaning. The last time for forage preparation is 9PM to 10PM. After preparation, the light of cowsheds is turned off except the light on the aisle, which is preserved for night rounds. According to experience, the estrus-specific behavior happens at night, no matter the light is on or off. Therefore, nighttime images are recorded no matter the light is on or off. The nighttime image which was taken when the light was on or off is shown in Figure 1 and 2. According to our recorded videos, at night dairy cows still moved and acted frequently, including walking, approaching to others, following, body contact, no matter when the light was on or off.

Fig. 1 The original image when the light is on

Fig. 2 (b) The original image when the light is off

B. Identification of the length and movement of cows

The image of cow walking when the light was on is shown in Figure 3. The body of the moving cow was marked in the red rectangle. The length of this cow was defined by the length of this rectangle. This cow firstly went close to the other cow in the right side, passed by along its left side of the buttock, and then walked away.

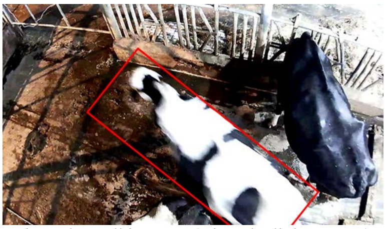


Fig. 3 the walking cow (when the light was on)

The image of body contact between tow cows is shown is Figure 4. These two cows were marked by the red rectangle. The length of these cows was defined by the length of this rectangle. The cow with black-colored skin got close to the railing, contacted the left side of the white-colored cow, and then passed away.

Fig. 4 The body contact between two cows (when the light was on)

The image of two cows fighting head to head is shown in Figure 5. These two moving cows were marked by the red rectangle. The length of these moving cows was defined by the length of this rectangle. At this moment, the length of these two cows equaled to 2 cow length. During this fighting process, two cows moved either forward or backward. Therefore, the length of these two cows sometimes became shorter, which was similar to the condition of estrus-specific mounting behavior.

Fig. 5 The image of tow cows fighting each other (when the light was on)

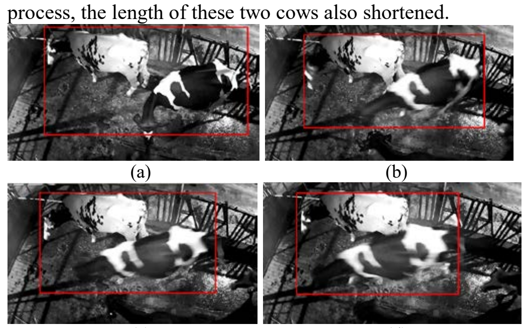
One of the situations, shown in Figure 6 (from a to d), may mimic the mounting behavior. The length of the red rectangle, which marked tow cows, represented the total length of two cows in contact. On the right side, there was a cow sitting on the ground. The other cow came close to it and then passed along the side of this sitting cow. During this process, the length of these two cows changed from 2 cow length to 1.5 cow length, which mimicked what happened in mounting behavior.

(a) (b)

(c) (d)

Fig. 6 The serial images (a to d) of one cow passing by the other cow sitting on the ground (when the light was on)

The following behavior of one cow after the other cow is shown in Figure 7. The length of the red rectangle, which marked two cows, represented the total length of two cows in contact. The cow on the right side followed the cow on the left side, passed through it, and then walked away. During this process, the length of these two cows also shortened.



(a) (b)

(c) (d)

Fig. 7 The serial images (a to d) of the following behavior (when the light was off)

Conclusion and Future work

Since dairy cows sleep at night, most of the light in the dairy farm should be turned off after 10pm and only light for night inspection is preserved. Under weak light, the shadow of cows is a problem for imaging recognition system. This problem can be solved by the method of binary image. In addition, the record area of only one camera cannot cover all the dairy farm. Therefore, the night fisheye camera with low illumination will be used instead to record activities of cows in a wider area. By this camera, the monitor area can be broaden without combining several images from different cameras.

In this study, the specific imaging processing technology and the logic to identify cows under estrus have been ascertained and then applied to the dairy farm in the university. In the future, firstly the current system will be improved to effectively identify the estrus-specific mounting behavior at night. Then the automated ID identification of each cow will be developed to reduce the work of cow identification by staffs. Moreover, a new database and management strategy system, based on automated ID identification and statistics of estrus-specific behaviors, will be set up to help breeders in artificial insemination of dairy cows.

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