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ROBUST TRACKING OF CATTLE USING SUPER PIXELS AND LOCAL GRAPH CUT FOR MONITORING SYSTEMS

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Abstract. *This paper proposes a robust tracking method of Japanese black cattle. Development of a cattle monitoring system using non-contact and non-invasive methods to improve productivity is a strong demand from livestock farmers in aged society. As one of elemental technologies to realize it, we focus on tracking of cattle for detecting estrus behaviors using video camera. The conventional methods like inter-frame difference and background subtraction do not work well under supposed environment. So we propose a new updating method of ROI (Region of Interest) and Scribbles (for foreground and background) according to the movement of the centroid of the extracted cattle region. SP (Super Pixel) and LGC (Local Graph Cut) are adopted for robust cattle region extraction. The tracking without updating soon fails before cattle goes out of frame, but the tracking with the proposed updating has been successfully continued until cattle has gone out. Through the experimental results carried at Sumiyoshi Field attached to Miyazaki University, the effectiveness of the proposed method has been confirmed.*

Keywords: Tracking, ROI, Scribble, SP, LGC, Centroid, ***VGP*** (Virtual Grounding Point)

1. **Introduction.** Figure 1 shows an overall view of an estrus detection system of cattle. Cattle's behavior is constantly monitored by video cameras which are connected to LAN. When estrus is detected, farmers are notified. The situation may be confirmed by watching the video which has been already recorded or in real time if necessary. In a cattle monitoring system, cattle region extraction is one of essential tasks. However, it is not so easy, because cattle move slowly in general, and the skin of Japanese black cattle is similar to soil in color. Furthermore, the system is usually used in dusty pasture, and the conventional methods like inter-frame difference and background subtraction do not work well under such conditions. So we propose a new method to update ROI and Scribbles according to the movement of cattle which can be estimated from the centroid of extracted cattle region. ROI and Scribbles are manually set at the start of observation, and thereafter it is automatically updated. The newly introduced concept ***VGP*** of cattle is

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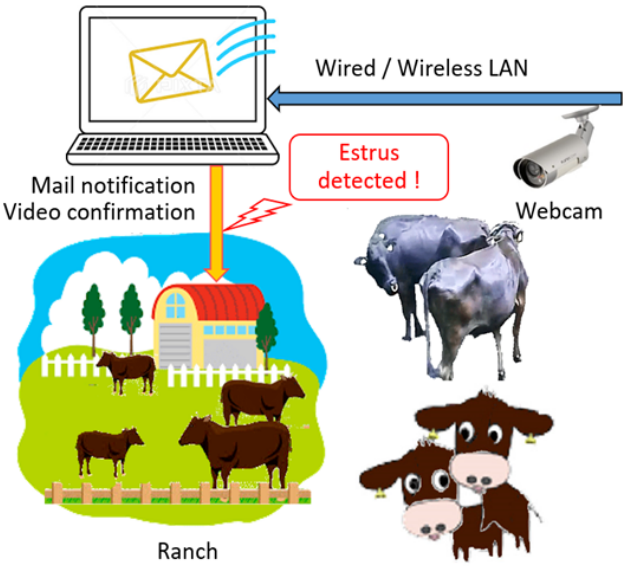


FIGURE 1. Overall view of an estrus detection system of cattle

estimated from the centroid by linear approximation. One piece of indispensable information for an estrus detecting system is cattle positions on three dimensional ranch ground which can be defined by ***VGP***. An SP-based model for object tracking in the Bayesian framework has been proposed [1]. We adopt the method based on SP [2,3] and LGC [4-8] to extract robustly cattle regions. Here pixels of an original image are converted into SPs, and the input image is processed in units of SPs with similar brightness and color instead of in units of pixels. ***VGP*** on a two dimensional image space is converted to a point in a three dimensional plane assumed as ranch ground. Here we focus on robust extracting cattle regions and estimating centroids for tracking under bad conditions.

The image segmentation methods of an input image using graph cuts have been widely used, which is a semi-automated technique. Since graph cut segmentation does not require accurate initialization, a big tolerance can be set. This is the major reason in adopting the graph cut here. After drawing ROI and Scribbles on the image to distinguish roughly the foreground and the background, image segmentation is automatically done based on ROI and Scribbles, which divides the image into foreground and background. Many of segmentation methods resulted in a binary labeling problem that optimized certain energy functions to give a foreground or background label for each pixel. Here, after an input image is converted into SPs at first, it is segmented by the algorithm LGC which applies graph theory to image processing to realize fast and robust segmentation.

If estrus can be detected earlier and more accurately, production efficiency can be greatly improved. To do so, it is necessary to detect estrus precursor behaviors besides mounting and standing. And it is important to capture the movement characteristics of estrus precursor behavior such as "moving around irritably and nervously, smelling and moving around and around in opposite positions and so on" [9]. There are many estrus detection systems using video camera which are cost effective and give less stress on cattle [10-13]. However, almost all of them are based on detecting mounting. There are other methods such as painting on the tail head, wearing a thermometer and judging whether or not mounting occurs by using a detection rod. However, these methods are not non-contact and non-invasive and give a stress on cattle [9,14]. Here, we focus on tracking of cattle, but the final goal of this research is to construct an entire system that reduces the burden on farmers without stress on cattle.

The rest of this paper is organized as follows. Section 2 introduces variables and definitions, and the proposed method is discussed. Experimental results and evaluation are presented in Section 3. Finally, we conclude this paper and explain the future works in Section 4.

2. **Proposed Method.** In this section, we propose a new method to update ROI and Scribbles for tracking of cattle. At first, we provide an overview of the proposed cattle monitoring system to detect estrus, and summarize variables and definitions. Figure 2 shows the overall process flow diagram. Because it takes time to process the actual video as it is, in order to speed up the processing, each input image is reduced to the size $(512 * 384)$ which is experimentally determined. Our system transforms the reduced input image into SPs, and extracts the cattle region using LGC. The LGC is a method of extracting a foreground region of cattle by setting ROI in the image and drawing

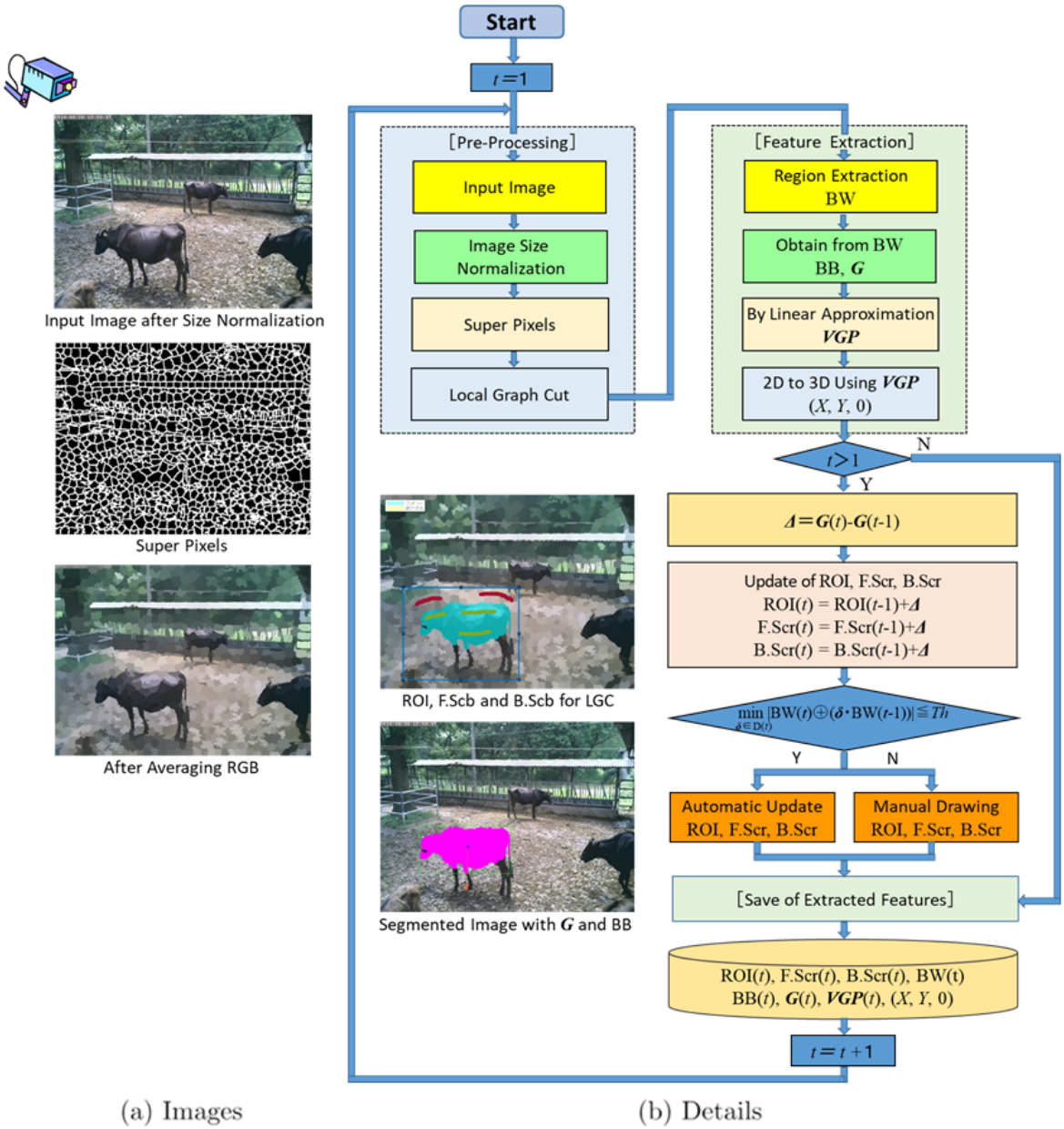


FIGURE 2. Overall process flow diagram

Scribbles in the ROI. ROI and Scribbles are manually set at first, and they are updated according to cattle movement which can be estimated from the movement of the centroid of the extracted cattle region. The estimated centroids of two consecutive frames are very closer, and the change is very small. This is the point of this paper, and it is the basis that ROI and Scribbles can be updated automatically because of great tolerance.

Variables and definitions are summarized in Table 1. Updating ROI and Scribbles is done as follows. If the following Equation (1) is satisfied, then ROI, F.Scr and B.Scr are automatically updated. Otherwise they are manually redrawn.

$$\min_{\boldsymbol{\delta}\in \mathrm{D}(t)} |\mathrm{BW}(t) \oplus (\boldsymbol{\delta} \cdot \mathrm{BW}(t-1))| \leqq Th \tag{1}$$

where $\mathrm{D}(t)$ shows a range in the neighborhood, for example, $\mathrm{D}(t) = \{(i,j)\colon\ i,j = -2,-1,0,1,2\}$. Furthermore, $\oplus$ and $(\boldsymbol{\delta} \cdot \mathrm{BW}(t-1))$ mean an operator of "Exclusive OR" and the region where $\mathrm{BW}(t-1)$ is shifted by $\boldsymbol{\delta}$, respectively. When Equation (1) is satisfied, $\mathrm{BW}(t)$ and $\mathrm{BW}(t-1)$ are very close in shape. Otherwise, they are fairly different from each other.

Table 1. Variables and definitions

Variables	Definitions
t	Frame Number, t is sometimes omitted for simplicity
$\mathrm{ROI}(t)$	Region of Interest
$\mathrm{F.Scr}(t)$	Foreground Scribble
$\mathrm{B.Scr}(t)$	Background Scribble
$\mathrm{BB}(t)$	Bounding Box
$\mathrm{BW}(t)$	Extracted Region (Binary Image)
$\boldsymbol{G}(t)$	Centroid of $\mathrm{BW}(t)$, $= (G_x(t), G_y(t))$
$\boldsymbol{VGP}(t)$	Virtual Grounding Point, $= (V_x(t), V_y(t))$
$\lvert\mathrm{R}\rvert$	Size of a Region R
(x,y)	Point on an Image
$(X,Y,0)$	Point on 3D Plane, assuming ranch ground
$\mathrm{D}(t)$	A Range in the Neighborhood
$\boldsymbol{\delta}$	An Element of $\mathrm{D}(t)$
$\Delta(t)$	$= \boldsymbol{G}(t) - \boldsymbol{G}(t-1)$

Principle idea for automatic tracking is shown in Figure 3. Suppose cattle move by $\Delta(t)$, then it is natural to judge ROI and Scribbles move by $\Delta(t)$, and shift them by $\Delta(t)$. The process is as follows.

[Step 1] Suppose cattle move a little, then cattle region can be well extracted for the current frame t using $\mathrm{ROI}(t-1)$, $\mathrm{F.Scr}(t-1)$ and $\mathrm{B.Scr}(t-1)$ for the 1st frame. They have been drawn with an enough amount of space between the cattle and the ROI boundary. Then using extracted region, the new centroid $\boldsymbol{G}(t)$ is computed. When Equation (1) is satisfied, $\Delta(t)$ is considered as the movement of cattle. Then they are automatically updated as follows:

$$\Delta(t) = \boldsymbol{G}(t) - \boldsymbol{G}(t-1), \quad \mathrm{ROI}(t) = \mathrm{ROI}(t-1) + \Delta(t) \tag{2}$$

$$\mathrm{F.Scr}(t) = \mathrm{F.Scr}(t-1) + \Delta(t), \quad \mathrm{B.Scr}(t) = \mathrm{B.Scr}(t-1) + \Delta(t) \tag{3}$$

Otherwise, $\mathrm{ROI}(t)$ and $\mathrm{F.Scr}(t)$ and $\mathrm{B.Scr}(t)$ are manually redrawn. Here $\mathrm{ROI}(t)$ is shifted $\mathrm{ROI}(t-1)$ by $\Delta(t)$.

[Step 2] For the current $(t+1)$-th frame, ROI and Scribbles for the previous t-th frame are applied, and tracking cattle becomes possible by repeating the same process.

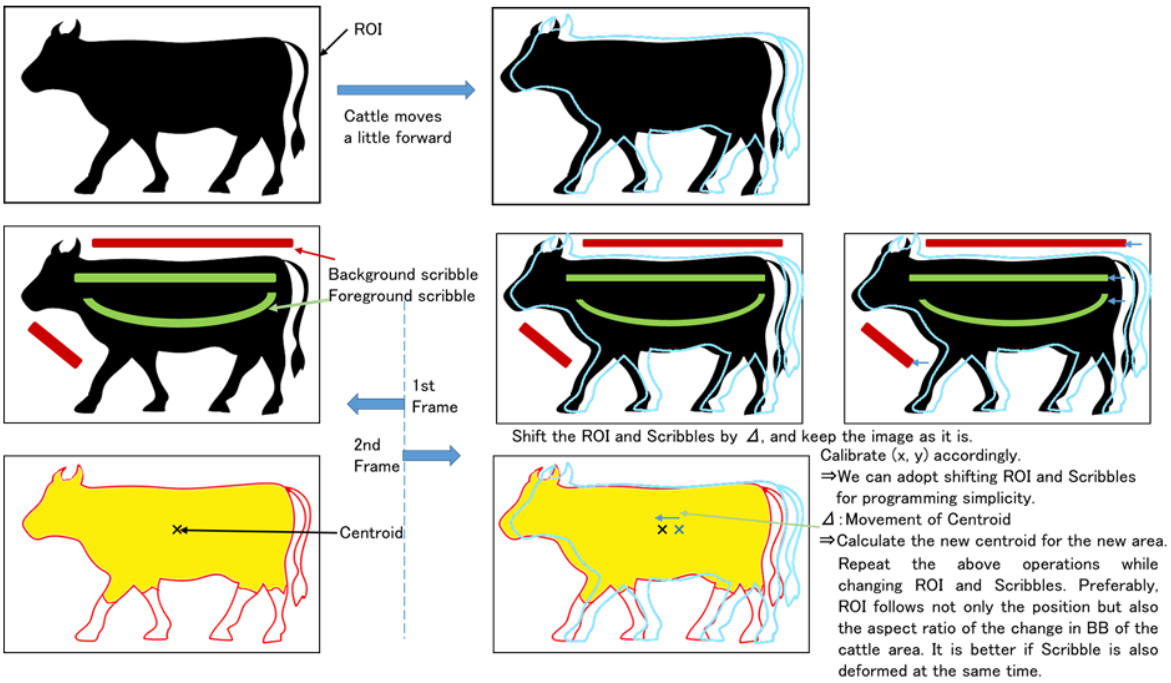
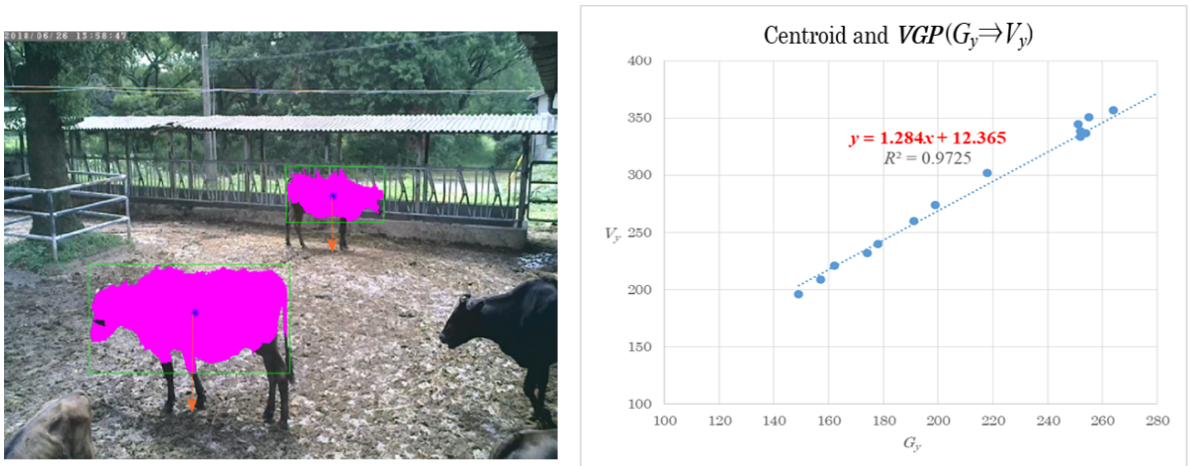


FIGURE 3. Principle idea for automatic tracking



(a) Segmented region, centroid and BB

(b) Linear approximation of G_y and V_y

FIGURE 4. The y-coordinate of $\boldsymbol{VGP}$ from that of $\boldsymbol{G}$

[Step 3] Using newly obtained centroid, $\boldsymbol{VGP}$ can be got by linear approximation. Furthermore, $\boldsymbol{VGP}$ is supposed a point on ranch, so we can get three dimensional position $(X, Y, 0)$ from two dimensional coordinates (x, y) of centroid. These aspects are shown in Figure 4. Figures 4(a) and 4(b) show "extracted region, centroid and BB" and "linear approximation of G_y and V_y", respectively. In this graph, we can confirm very strong correlation between G_y and V_y.

3. **Experimental Results.** The experiments were carried out at Sumiyoshi Field attached to Miyazaki University, and the validity of the proposed method was verified. Figure 5 shows the case where cattle moved almost linearly. When using the same ROI

FIGURE 5. Comparison of using the proposed methods and fixed ROI and Scribbles

and Scribbles, the F.Scr and B.Scr protruded from cattle region in the 11th frame. Therefore, the extraction of cattle region failed, so the head region is not completely inside the foreground. On the other hand, when ROI and Scribbles were updated according to moving of the centroid, it was possible to track until Scribbles protruded the frame (by 20th frame). The tracking of cattle walking successfully resulted in most cases. Without proposed updating, it was not trackable when Scribbles protruded cattle region.

4. **Conclusions.** In this paper, we proposed a new method for tracking of cattle using SP and LGC. We carried out experiments about the new proposed method to update ROI and Scribbles according to cattle movement which can be estimated from the movement of the centroid of the extracted cattle region. Through the experimental results, the effectiveness of our proposed method has been confirmed. This paper is the development of acquisition method of cattle position, which is one of the elemental technologies with estrus detection technology in mind. Furthermore it is necessary to verify robustness of the method under more difficult conditions for more scenes. By converting the two dimensional motion on a video image into the motion on a three dimensional plane assumed as ranch ground, the walking speed and trajectory of cattle will come closer to the actual movement, and relative actions will be recognized by three dimensional relative movement of multiple cattle. The new concept ***VGP*** introduced here may be useful for it. These are near future works to be solved.

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