Cow Udder Detection in Thermal Images of Cows

M. Patašius[1,2*], D. Beliavska-Aleksiejūnė[3], Ž. Garbenytė[3], K. Musayeva[3], A. Sederevičius[3]

[1]*Department of Applied Informatics, Kaunas University of Technology, Lithuania*

[2]*Institute of Biomedical Engineering, Kaunas University of Technology, Lithuania*

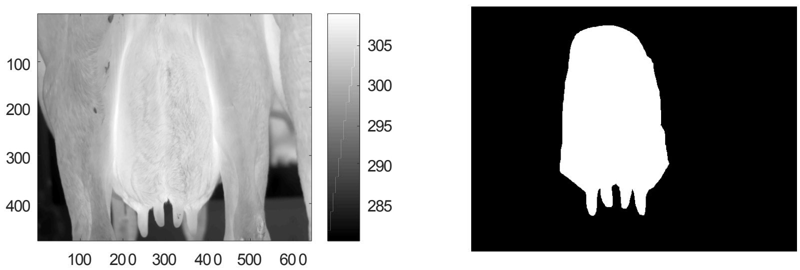
[3]*Lithuanian University of Health Sciences, Veterinary Academy - Department of Anatomy and Physiology, Lithuania*

[*]*E-mail: Martynas.Patasius@ktu.lt*

Introduction. Mastitis (inflammation of the udder) causes agricultural businesses significant losses - for example, it is estimated that it costs USA 11% of milk production [1].

The mastitis detection methods that are currently used generally depend on analysis of milk [2, 3, 4]. It is likely that methods based on thermal imaging would be faster and encourage more testing. There are numerous papers [3, 4] exploring the use of thermal images. However, the automated detection of udder, which would be the first step towards using those images, hasn't received much attention. Thus this paper discusses possible ways to detect udder in thermal images and suggests a method based on marker guided watershed transform.

Materials and Methods. 491 image of 37 Lithuanian Black and White cows taken using FLIR T-640 camera have been used for research. Out of them, 33 images were marked manually (Fig. 1) for use as "golden standard".



(a) (b)

Fig. 1. An example of a thermal image used in the study (a) and the udder mask (b)

Different udder detection methods were compared using sensitivity

$$S = \frac{TP}{TP + FN}, \tag{1}$$

specificity:

$$Sp = \frac{TN}{TN + FP} \qquad (2)$$

and Matthews correlation coefficient:

$$MCC = \frac{TP \cdot TN - FP \cdot FN}{\sqrt{(TP + FP) \cdot (TP + FN) \cdot (TN + FP) \cdot (TN + FN)}}. \qquad (3)$$

Here TP is the number of true positives (correctly recognised udder pixels), TN - the number of true negatives (correctly recognised background pixels), FP - the number of false positives and FN - the number of false negatives.

Sensitivity, specificity and MCC are calculated for each image and then averaged.

The proposed method for udder detection uses marker guided watershed transform [5]. It exploits the fact that the sides of the udder (touching the legs) and the "middle line" tend to be the warmest parts of the image.

At first, the cow mask is generated using Otsu thresholding (cow body is warmer than the environment) for image filtered by 25 pixel averaging filter.

Then, the udder marker is found iteratively. In each iteration the image is thresholded using the sum of mean temperature of "cow" pixels and standard deviation of that temperature with a coefficient. The starting value of that coefficient is 1.5 and it is decreased by 0.01 until the number of connected components is at least 10. Afterwards the centroid of those pixels is found and each pixel is moved 9/10 of the distance towards the centroid. Otsu thresholding (multilevel - 20 levels) is used again for the "cow" pixels and the pixels in the last level are processed analogously (although they are moved half way to the centroid). The udder marker includes the centroid morphologically dilated by disc structural element with radius of 15 pixels and all moved thresholded pixels dilated by disc structural element with radius of 3 pixels.

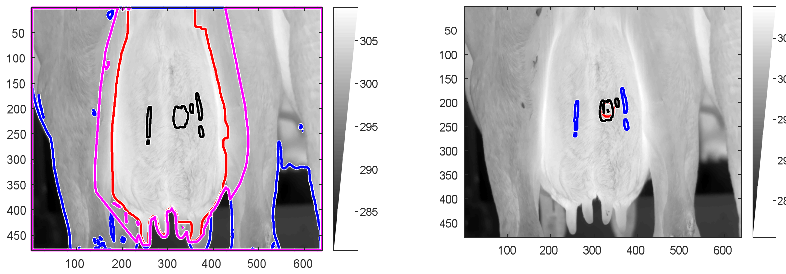
The background marker is found starting from the pixels that do not end up in the convex hull of the largest connected component including pixels warmer than mean plus 0.25 standard deviation of the "cow" pixels. This set of pixels is morphologically eroded (structural element is the disc with radius 20 px). After that pixels that do not belong to the "cow mask" and pixels below the first Otsu threshold (3 thresholds are found for "cow" pixels) after erosion (using disc with radius 3px) are added to the marker.

Finally, in order to make sure there is a distance between the markers, both markers are dilated (using disc with 3 px radius) and subtracted from one another.

Then the marker guided watershed transform is applied, although the gradient image is multiplied by the thermal image (as the limits will tend to have high temperature). Sample results of this method can be seen in Fig. 2.

Results. The results of the udder detection can be seen in Table 1.

It can be seen that the proposed method achieves reasonable quality of detection. The marker for udder reaches high specificity, indicating that practically none of non-udder pixels ended up in it, while the background marker shows high sensitivity, indicating that almost none of the udder pixels went into it.



(a) (b)

Fig. 2. An example of a thermal image used in the study with limits of cow mask (outside), both markers and found udder mask (between limits of markers) shown (a) and the different components of udder marker (b)

Table 1. Comparison of methods of udder detection (mean and standard deviation)

Method	**Sensitivity**	**Specificity**	**MCC**
Full proposed method	0.9320 (0.1033)	0.8189 (0.0653)	0.6159 (0.0927)
Udder marker	0.0656 (0.0291)	0.9997 (0.0006)	0.2239 (0.0529)
Inverted background marker	0.9991 (0.0029)	0.6298 (0.0621)	0.4782 (0.0864)

Conclusions. A method for detection of udder in thermal images has been proposed. The method has achieved reasonable udder detection quality.

In the future this method could be further improved by choosing still better markers of udder and background.

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Mastitis (inflammation of the udder) causes agricultural businesses significant losses. It is likely that mastitis detection methods based on thermal imaging would be faster and encourage more testing. However, they automated detection of udder, which would be the first step towards using those images, hasn't received much attention. Thus this paper discusses a possible way to detect udder in thermal images. The proposed method is based on marker guided watershed transform. It has achieved the average sensitivity of 0.9320, average specificity of 0.8189 and average MCC of 0.6159.