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Retraction: Thermographic imaging for use in artificial intelligence and vision algorithms (*IOP Conf. Series: Materials Science and Engineering* **872** 012035)

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Thermographic imaging for use in artificial intelligence and vision algorithms

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Abstract. The constant technological innovation in devices for the acquisition of digital images such as: energy-efficient and high-pixel sensors, memories with greater storage capacity and processors capable of sampling digital signals more quickly, have made it possible to digitize with greater reliability real life scenes in an instant of time, making it possible to analyze and interpret different physical phenomena [1][2][3] such as fractures in materials, evasion of obstacles, weather conditions, injury detection, among others, giving rise to a new line of research called Artificial Vision (AV) focused on generating algorithms to improve image quality, segment characteristics of interest and eventually recognize patterns, in order to make more efficient image processing for the solution of problems in robotics, automation, security, medicine, veterinary, and others. The research aims to develop a database of thermographic images of pregnant and non-pregnant sheep, providing a tool for specialists in the area of computer intelligence and artificial vision.

1. Introduction

In the scientific and technological field, the use of infrared thermography has been oriented towards veterinary, medical and safety applications. Among the studies developed using infrared technology, it is possible to find the work done by [4], in which a study of the inflammation caused by mastitis in the mammary glands of women was carried out, making use of a data bank of thermographic images using the gray scale color palette [5]. In the veterinary field, thermal analysis has helped to detect different diseases in animals through the interpretation of the hot spots obtained in the thermograms. Among the works in this area, a study in [6] detected the presence of virus serotype 1 and virus serotype 8 of the bluetongue disease through a correlation between rectal temperature and the temperature obtained in the thermograms; [7] analyzed with thermograms the superficial changes in the udders of cows infected by mastitis after having experimentally induced the intestinal tract bacteria *Escherichia Coli*, concluding that thermography is very useful in these applications; In [8], they evaluated with thermograms and rectal temperature the gestation of mares, detecting a difference in temperature between pregnant and non-pregnant mares, which allows their classification between these two states regardless of the breed and color of the animal.

The present study proposes the creation of a database of thermographic images that were treated with an artificial vision algorithm to enhance the areas with the highest heat emission in the ventral area of



pregnant and non-pregnant sheep. This database aims to provide useful material for the development and testing of artificial intelligence and vision algorithms such as: pattern recognition and classification.

2. Methods

For this paper 114 sheep of the Dorper breed were selected as study subjects, obtaining the thermograph and the digital image in the visible spectrum under fasting conditions for each one, by means of a Flir C2 thermographic camera [9] which has the following characteristics shown in Table 1.

Table 1. Measurement characteristics of the FLIR C2 thermographic camera.

Characteristics	Value
Spectral range	7.6-15 μm .
Object temperature range	-10 $^{\circ}\text{C}$ a + 151 $^{\circ}\text{C}$.
IR Resolution	80X60 (640 pixels of measurement)
Thermal sensitivity	< 0.10 $^{\circ}\text{C}$
Emissivity values	0.70, 0.80, 0.96

The characteristics of the FLIR C2 camera allow the visualization of the heat in the ventral part of the sheep during the thermogram capture stage. The first stage is the selection of parameters in the camera that allow a better capture of the thermogram considering the conditions of the study subject. It was determined that the focal length to be selected within the parameters of the camera is 0.25 m, because the captures of the ventral zone of the animal were taken in a range of 15 to 25 cm between the camera and the object of study. It should be noted that the latter was the distance that experimentally shows the greatest amount of heat areas in this zone of the animal [10].

The temperature range was set at 0 $^{\circ}\text{C}$ -40 $^{\circ}\text{C}$ considering that non-pregnant and pregnant sheep reach a maximum temperature in the belly between 37 $^{\circ}\text{C}$ and 37.5 $^{\circ}\text{C}$. The emissivity value that determines the amount of temperature radiated by the object of study was selected experimentally, determining that the value of 0.80 allows visualization of the temperature zones used as reference and what is considered to be the fetus, values of 0.70 and 0.96 of emissivity did not favor the study. The color palette selected was Rainbow, since it allows the capture of better-defined color shades in comparison with the other available color palettes (Rainbow HS, Iron, Gray) [11] granting a better inspection and detection of the analyzed areas, helping to differentiate between pregnant and non-pregnant sheep. Figure 1 shows the comparison of the different color palettes with which a thermogram can be taken through the FLIR C2 camera.

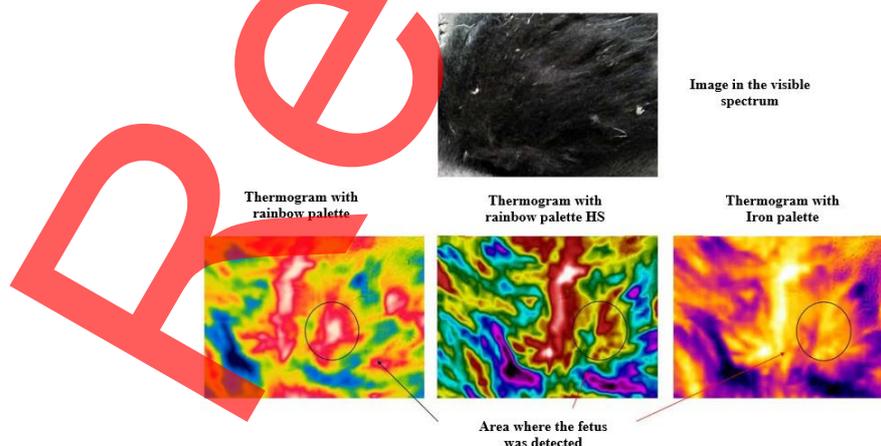


Fig 1. Comparison of thermograms with different color palettes possible on camera.

Once the camera has been set up, the second stage is to select the study subject from the herd of sheep that have not yet been validated as pregnant. The third stage is the measurement of rectal temperature, and then the fourth stage is the adaptation of the animal's posture to later capture the thermograms [12], in such a way that two different postures of the animal were considered, since this being a quadruped makes it difficult to capture in the ventral zone in a natural way, therefore, the posture of the sheep is adapted under the direction and supervision of the veterinarian so as not to affect the health of the sheep. The first posture of the animal for the capture of images was to place the hind legs on the floor and the back of the animal leaning on the thighs of the person holding the sheep, holding the front legs with the hands to maintain a stable posture. Figure 2 shows the first posture of the animal for the image capture, where the sheep can be observed showing the area of interest, having the udders as a reference point to perform the samples.



Fig 2. Adaptation of the first position for the capture of thermograms.

The second posture required setting up a base to make the capture from the bottom of the sheep allowing a natural posture for the sheep [13]. The base allowed for better manipulation of the sheep, preventing it from becoming stressed during image capture. Figure 3 shows the sheep on the base and the way in which the capture is made from below, placing the camera in the ventral zone with the udder as a reference as in the captures of the first posture.



Fig 3. Thermogram capture from underneath the base.

After the capture of the thermograms, in the sixth stage, the enhancement of shades was performed, for which it is necessary to change the RGB (Red, Green, Blue) [14] color mode to HSV (Hue Saturation Value) [15] mode, which is a function of its Hue, Saturation and Value [16] components. The red areas represent the areas of specific heat present in the ventral part, udder and joints of the sheep. Figure 4

shows a thermogram with the enhancement of the heat zones: a) and b) joints c) udder, d) cross of the sheep, e) and f) skin without fur, g) area where the fetus was detected.

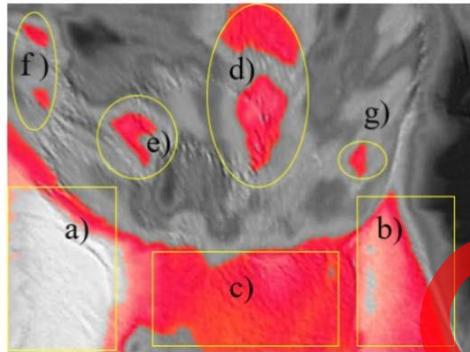


Fig 4. Accentuation of areas of interest in the thermogram.

The color accentuations shown in Figure 4 correspond to all heat zones present in the sheep during the capture of the thermograms, using a) and b) as reference for capture, in the case of e) and f) they are often confused with the fetal zone with the naked eye, but are discarded on veterinary inspection. In the case of (d), it is present in all catches and in some thermograms the fetal zone is very close to it.

Stages 7 and 8 consist of gestation prognosis from thermographic images and gestation validation by the veterinary doctor. The technique used by the clinician to evaluate the sheep is ventral palpation to locate the fetus [17], as shown in Figure 5. Another factor analyzed is the size of the udder, which is larger in a pregnant sheep than in a non-pregnant sheep. It should be noted that validation of gestation is complex as it requires a veterinarian with experience in ventral palpation and sensitivity to touch of the belly of these animals.



Fig 5. Evaluation of gestation by the veterinary doctor.

The prognosis is made from the inspection with the thermographic camera in the ventral area to locate small areas of heat that can be interpreted to locate the fetus [18]. Figure 6 shows the areas of heat that the camera captures during the inspection for the prognosis from thermographic images: a) Umbilical scar, b) Skin coat, c) Area where the fetus was detected, d) Fold between the udder and the belly.

As a final step in the proposed methodology, a decision is made based on the prognosis from the thermographs and validation by the physician [19][20]:

- If both validations agree that the sheep is pregnant, it is moved to the corral with the other pregnant sheep to receive veterinary care and special feeding for its state of gestation.
- In the case that the validations do not agree, the sheep is transferred to the breeding corral so that it can continue with its menstrual cycle and, at some point, be a new subject of study.

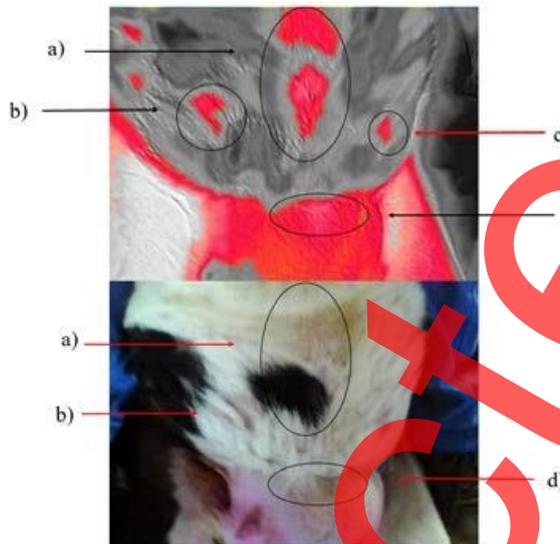


Fig 6. Heat zones in the ventral part of the sheep.

3. Results

The images obtained during the whole process contemplating the two capture positions are shown in Table 2.

The number of pregnant images is not so far from the number of images of non-pregnant sheep, both as digital images in the visible spectrum and thermograms, in the case of the color-accented thermograms were only made for pregnant sheep, this due to the enhancement of the areas of interest as mentioned above. The characteristics for each image are shown in Table 3.

Table 2. Images obtained during experimentation.

Pregnant sheep			Non-pregnant sheep	
Digital images in the visible spectrum	Thermograms	Thermograms with color accentuation	Digital Imaging in the visible spectrum	Thermograms
2145	2145	2145	2685	2685

Table 3. Characteristics of images in experimentation.

Image	Width	High	Resolution	Format
Thermogram	330 pixels	240 pixels	79.200 pixels	JPEG
Digital image	650 pixels	490 pixels	318.500 pixels	JPEG
Thermogram with color accentuation	1014 pixels	754 pixels	766.556 pixels	JPEG

All images have the same JPEG format. The differences were shown in size and resolution, having higher resolution to the thermograms treated, and lower resolution to the thermograms provided by the thermal camera. The difference of visible characteristics in the images of pregnant and non-pregnant sheep is very noticeable, a comparison of both images is shown in Figure 7.



Fig 7. Comparative images of pregnant and non-pregnant sheep posture adjustment.

The thermographs captured with the first posture are shown below. Figure 7 shows the comparison between pregnant and non-pregnant sheep in the first position, where more heat areas can be seen in the pregnant sheep than in the non-pregnant sheep, without excluding the other heat areas mentioned in Figure 6.

Thermographs captured with the aid of the base do not show all areas of heat (umbilical scar or fold between udder and belly), even in the color accentuation of the thermographs, however, it is possible to visualize the fetus. Figure 8 shows thermograms captured from below the base, and Figure 19 shows a comparison of the thermograms and color-accented images with respect to the two positions used for the shots. As in the first position, the areas of heat present in a pregnant sheep are very different than in a non-pregnant sheep, even the presence of some, such as the umbilical scar and the fold between the udder and the belly, are not present in the second position. Figure 10 shows a comparison of the heat zones captured during the capture of the thermographs of the sheep in the second position.

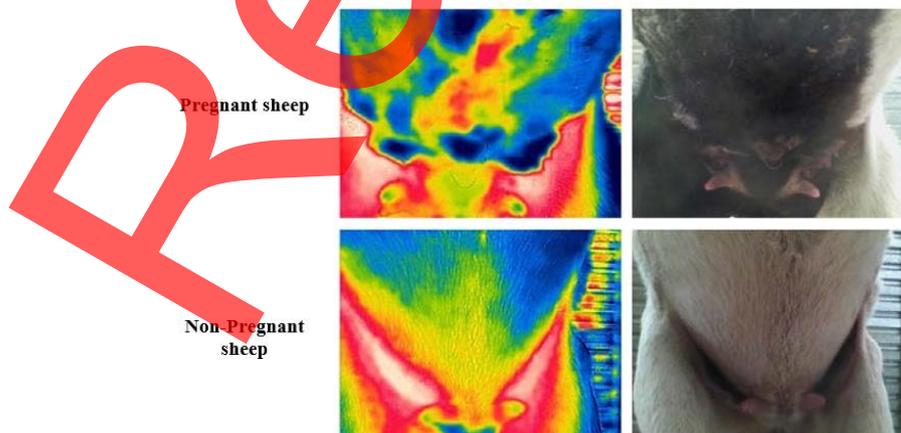


Fig 8. Images of pregnant and non-pregnant sheep (below the base).

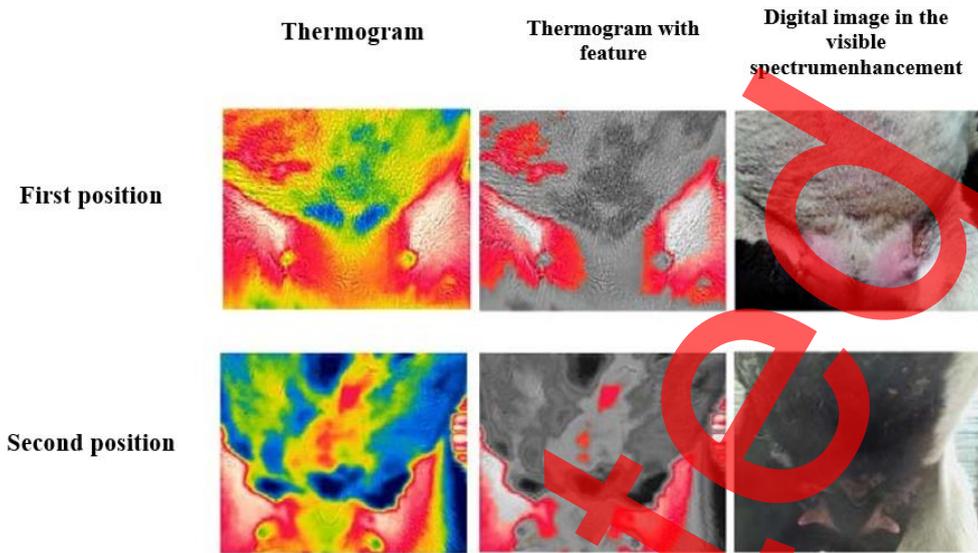


Fig 9. Enhanced thermographs and visible spectrum images of pregnant sheep.

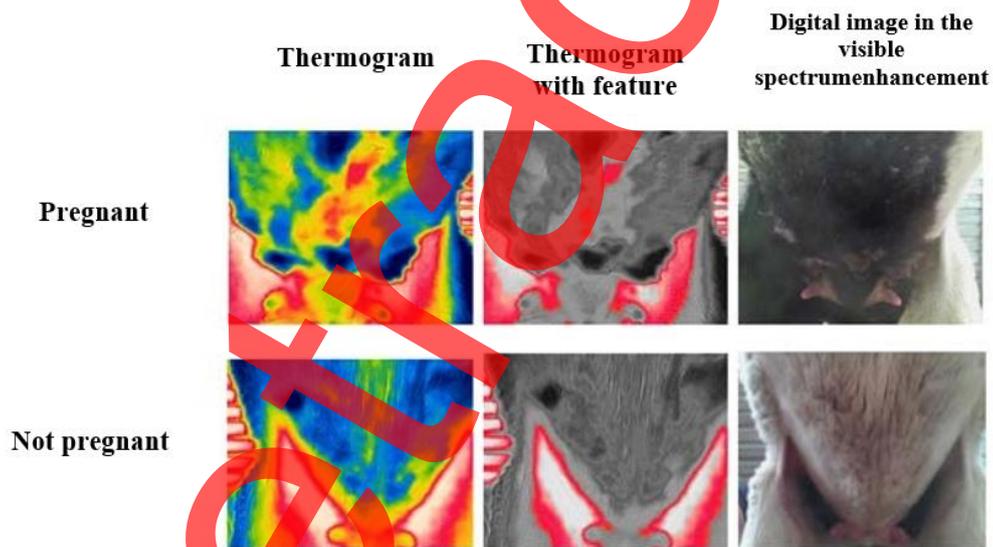


Fig 10. Comparison of images captured from the sheep in the second position.

A record of the breed, age and number of births is kept for all the sheep, and in the case of pregnant sheep, the weight and gestation time indicated by the veterinary doctor are recorded to monitor the catches and the sheep. The first thermographs captured from pregnant sheep correspond to a gestation time of three months, considering that the gestation time of a sheep is 5 months on average. Figure 11 shows a comparison of the growth of the heat zones where the fetus was detected.

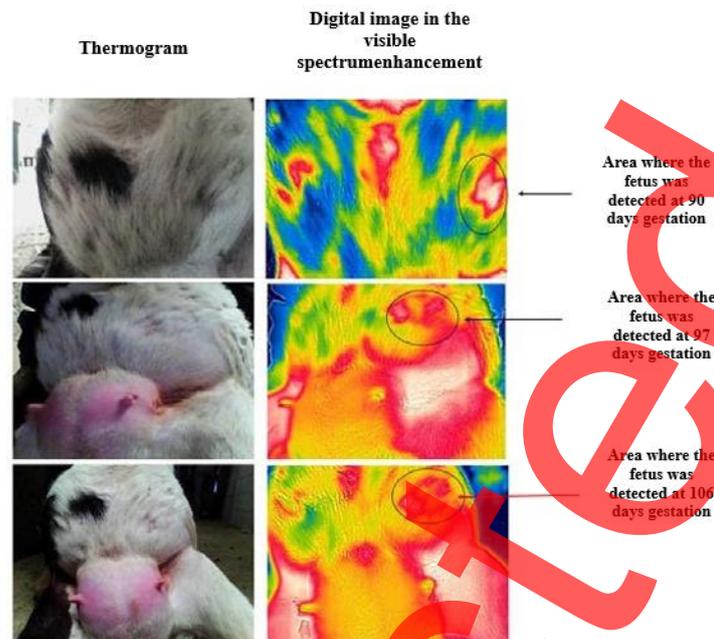


Fig 11. Comparison of the growth of the heat zone where the fetus is detected.

4. Discussion and conclusions

The amount of images obtained provide information for the development of a database, with two classes, positive and negative sheep on the subject of gestation, considering the morphology of the red shade that represents the area with the highest temperature in the ventral zone of the sheep, considering, by veterinary validation that is the place where the fetus is.

The shade enhancement proposed in consideration of the Hue channel, in the HSV color mode, allows to specifically segment the warm areas where the main object of interest, a fetus, is located, with reference to the folds of the sheep's hind legs and udder.

As a consequent study, it is suggested to apply the binarization technique to the image enhanced in red shades, with the purpose of extracting the morphology of the ovine fetus in different days of gestation from the 150 possible ones, using edge detection algorithms, based on different methods such as gradients, canny or laplacian, thus obtaining an irregular shape from which to extract characteristic features, which will serve for the classification of ovine pregnancy, making use of artificial intelligence algorithms.

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