



Adipose Tissue Detection and Analysis System using Thermal Images

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Abstract

In this thesis we present a system for automatic detection and analysis of adipose tissue in experimental data using thermal images. The algorithm that we developed is based on clustering techniques for image segmentation and the use of geometric and anatomical features of mice in order to extract the detection domain of adipose tissue to monitor its thermal activity. The system detects locally maximum temperatures in the regions of adipose tissue to decide on thermal activation.

For the experimental process of this diploma thesis and the acquisition of the thermal images, we exploited the equipment of the Digital Signal Processing and Telecommunications Laboratory of the Department of Computer Engineering and Informatics of the University of Patras and specifically the FLIR E-60 thermal camera. The thermal images acquisition of mice took place at the Pharmacology Laboratory of the Medical School of the University of Patras. Additionally, the MATLAB environment was used to create the proposed system and the graphical user interface.

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Introduction

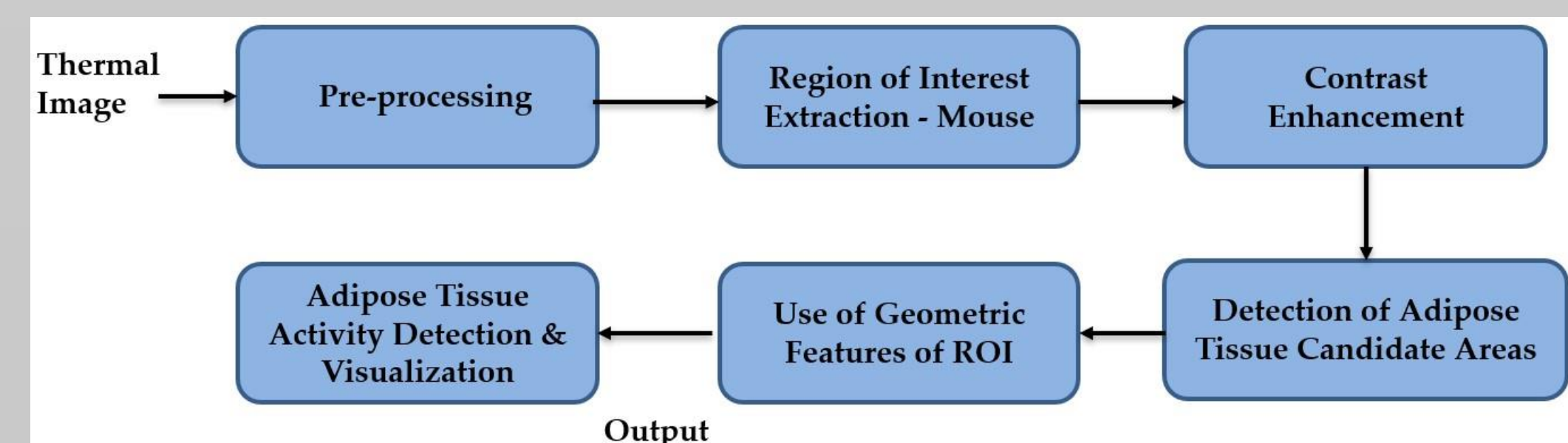
In this age of automated processes, computer vision and digital image processing provide the solution to a great number of problems regarding medical and biological issues. Recently, there is an increased development of the automated medical image analysis and processing algorithms, in order to find new, accurate methods in prognosis, diagnosis and treatment of diseases that generally provide assistance to improve the living conditions of human beings. This thesis focuses on the analysis and processing of thermal images resulting from experiments conducted on mice in order to detect the activity of brown and white adipose tissue. Unlike other approaches on this subject, the proposed method in this thesis is a non-invasive attempt to visualize the thermal activity of adipose tissue.

Research has shown that exposure of mice in a low temperature environment leads to activation of brown adipose tissue and the adoption of brown adipose tissue features from the white adipose tissue, which implies in thermogenesis, normalization of their glucose tolerance and reduction in body weight. Therefore, a system of non-invasive monitoring of adipose tissue activity could contribute to long-term analysis of tissue behavior and data collection to produce new drugs to combat obesity and diabetes.

In this work, we present our proposed method for the detection and analysis of the Interscapular Brown Adipose Tissue (BAT) and Gonadal Visceral White Adipose Tissue (WAT) [1].

Proposed System

Algorithm Overview



Proposed System (cont.)

1st part: Pre-processing

- Grayscale Image Conversion
- Unsharp Filtering

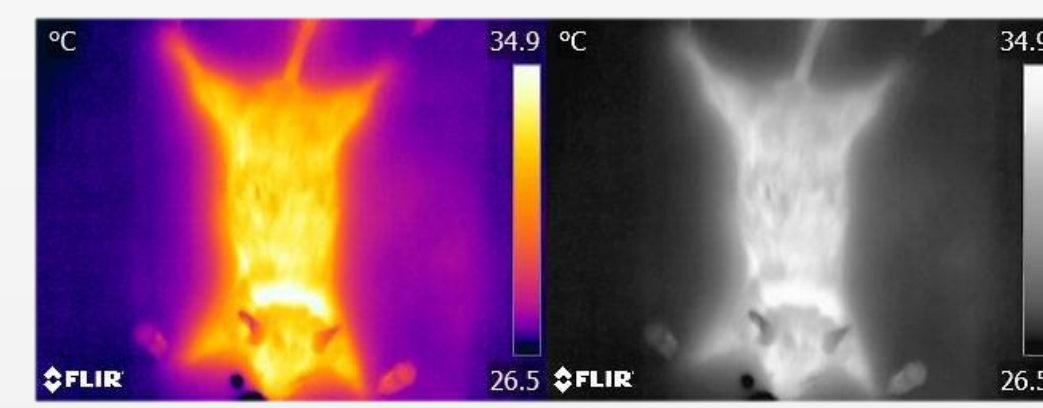


Figure 1: Input (left) and Output (right) Image

2nd part: Region of Interest Extraction - Mouse

- Modified K-Means Algorithm Implementation [2].

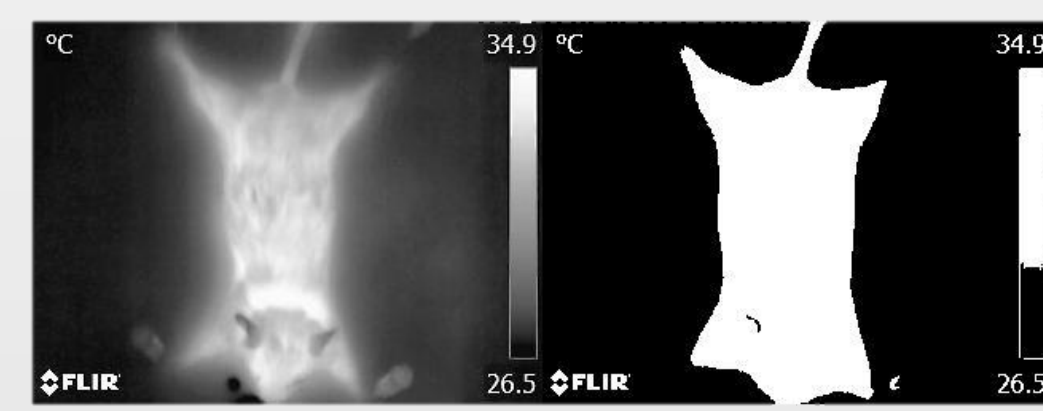


Figure 2: Grayscale (left) and Binary (right) Image

- Morphological Reconstruction by Dilation for filling holes [3].



Figure 3: filled holes

3rd part: Contrast Enhancement

- Mouse Isolation and Contrast Limited Adaptive Histogram Equalization (CLAHE) using exponential distribution.

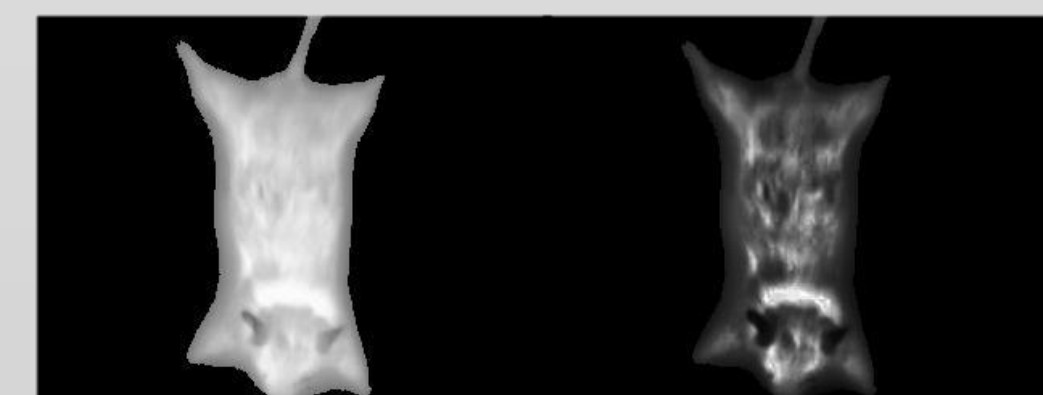


Figure 4: ROI after CLAHE

4th part: Detection of Adipose Tissue Candidate Areas

- Use of an adaptive K-Means algorithm (without knowledge of the number of clusters) based on the mean (as seed value) and standard deviation (as cluster bandwidth) of data [4].



Figure 5: Candidate Areas Selection

5th part: Use of Geometric Features of ROI

- Use of the largest ellipse inscribed in ROI and parabolas at the Interscapular Brown Adipose Tissue (BAT) and Gonadal Visceral White Adipose Tissue (WAT) respectively.

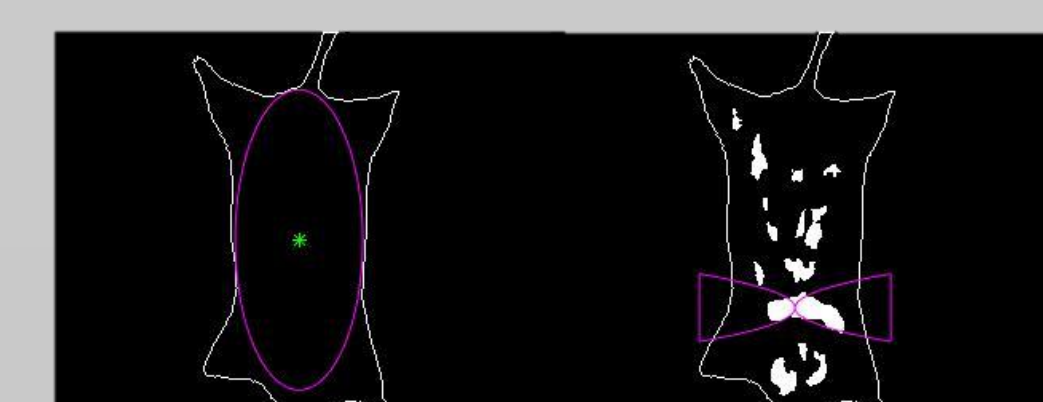


Figure 6: Geometric Features of ROI

Proposed System (cont.)

6th part: Adipose Tissue Activity Detection & Visualization

- Adipose Tissue Isolation is achieved by selecting the region in which the pixel nearest to the top of the parabolas belongs to. A prerequisite for that pixel is to belong to the intersection region of the ellipse and parabolas. Temperature value per pixel is provided in a CSV file by Flir Tools application. The images' format is JPEG, hence we are not able to extract temperature accurately, through pixels values [5].



Figure 7: Adipose Tissue Isolation

Experiments & Results

Mice were exposed to different temperature conditions and for different duration in order that we evaluate our system and analyze the results.

BAT activity detection of mice exposed to 24 Celsius Degrees environment

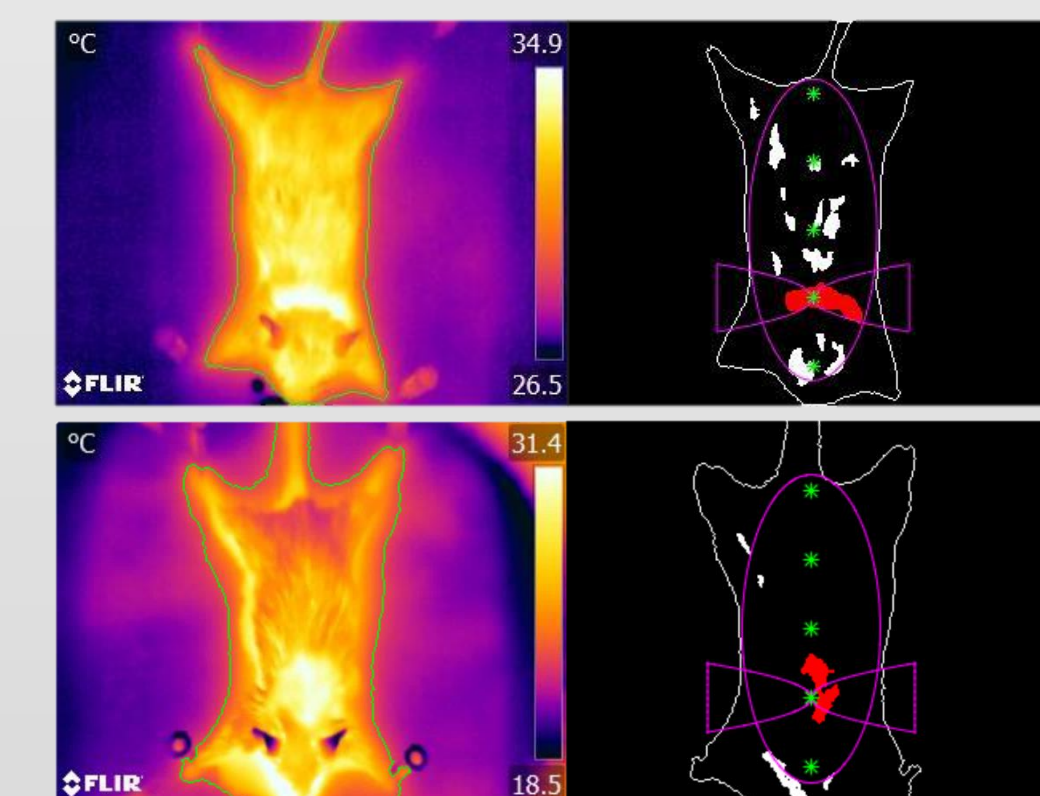


Figure 8: Mouse 1 (up) and Mouse 2 (down)

NO	BAT/MOUSE AREA	MAXIMUM TEMP OF BAT (CELSIUS DEGREES)	MEAN TEMP OF BAT (CELSIUS DEGREES)	MEAN TEMP OF BAT/MEAN BACKGROUND TEMP	MEAN TEMP OF BAT/MEAN BACKGROUND TEMP
1	3.8011 %	35.433	34.5767	1.0861	1.285
2	1.9247 %	31.414	30.753	1.1994	1.46

BAT activity detection of mice exposed to 7 Celsius Degrees environment for 24 hours

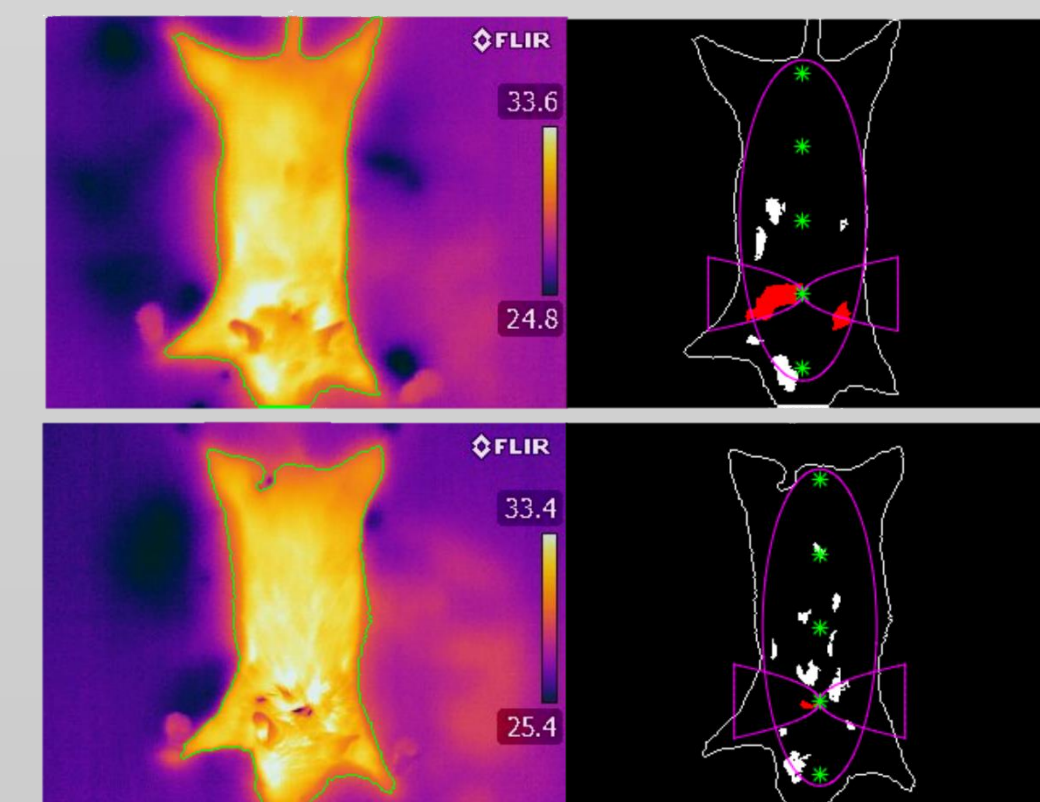


Figure 9: Mouse 1 (up) and Mouse 2 (down)

NO	BAT/MOUSE AREA	MAXIMUM TEMP OF BAT (CELSIUS DEGREES)	MEAN TEMP OF BAT (CELSIUS DEGREES)	MEAN TEMP OF BAT/MEAN BACKGROUND TEMP	MEAN TEMP OF BAT/MEAN BACKGROUND TEMP
1	2.8315 %	34.682	33.6281	1.0683	1.2634
2	0.19258 %	34.018	33.727	1.0673	1.2525

Experiments & Results (cont.)

BAT activity detection of mice exposed to 7 Celsius Degrees environment for 72 hours

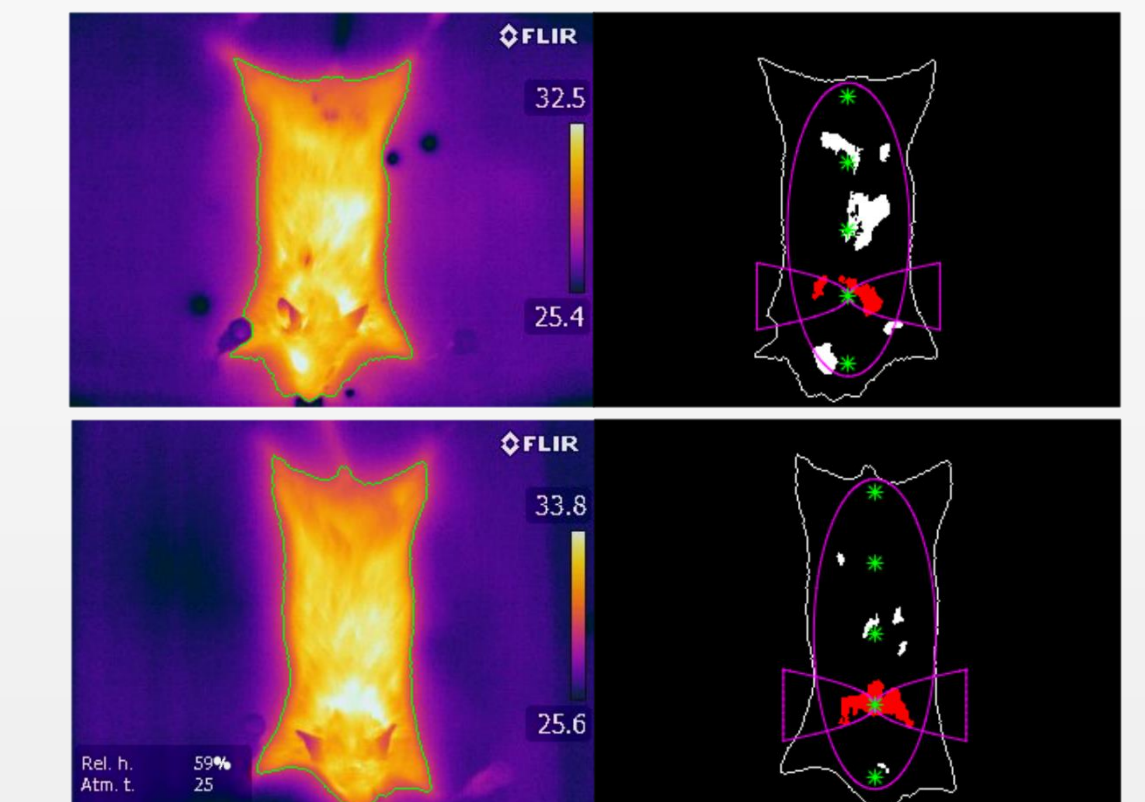


Figure 10: Mouse 1 (up) and Mouse 2 (down)

NO	BAT/MOUSE AREA	MAXIMUM TEMP OF BAT (CELSIUS DEGREES)	MEAN TEMP OF BAT (CELSIUS DEGREES)	MEAN TEMP OF BAT/MEAN BACKGROUND TEMP	MEAN TEMP OF BAT/MEAN BACKGROUND TEMP
1	2.0098 %	33.417	32.4833	1.0585	1.2092
2	3.7317 %	35.006	33.9832	1.0767	1.2721

WAT activity detection of mice exposed to 7 Celsius Degrees environment for 72 hours

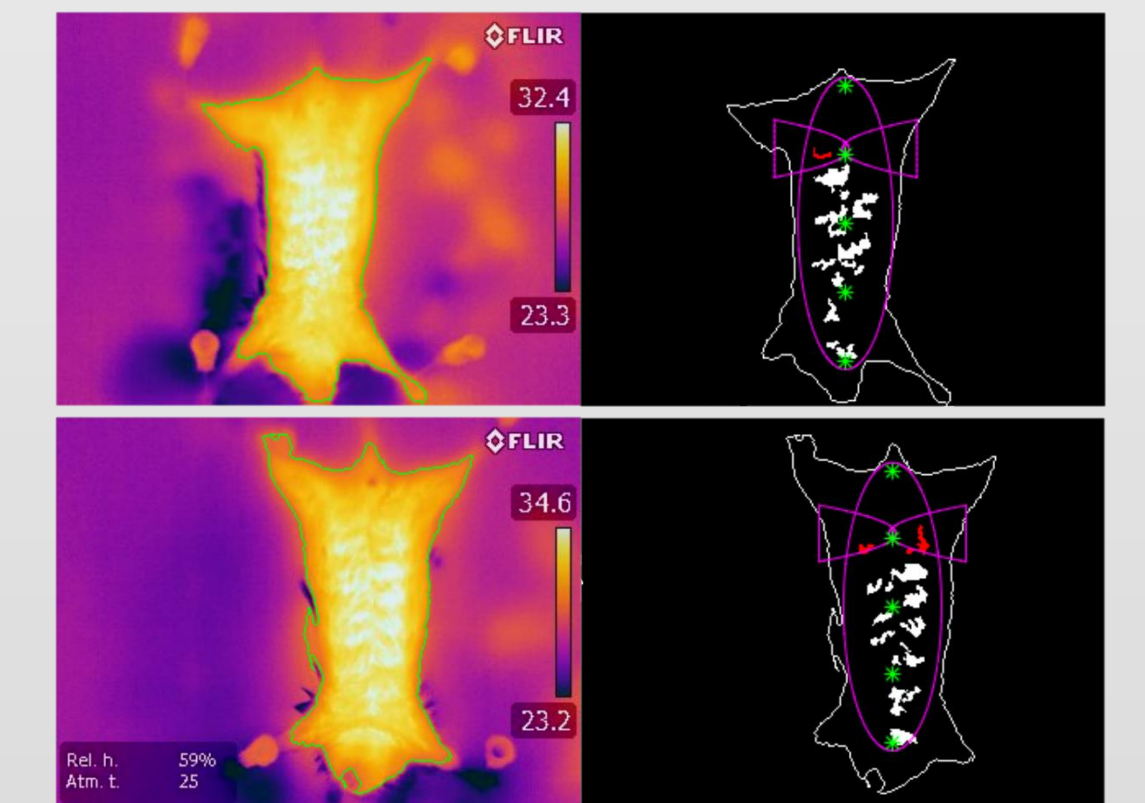


Figure 11: Mouse 1 (up) and Mouse 2 (down)

NO	WAT/MOUSE AREA	MAXIMUM TEMP OF WAT (CELSIUS DEGREES)	MEAN TEMP OF WAT (CELSIUS DEGREES)	MEAN TEMP OF WAT/MEAN BACKGROUND TEMP	MEAN TEMP OF WAT/MEAN BACKGROUND TEMP
1	0.13343 %	32.118	31.9509	1.0504	1.2059
2	0.74084 %	34.592	34.2583	1.0724	1.2594

Discussion

The proposed system, as designed and created on a graphical user interface, is very effective in detecting the appropriate areas of brown and white adipose tissue. In the case of brown adipose tissue, detection is extremely effective as tissue is thermally active even at ambient temperatures of 24 Celsius degrees. In addition, regarding white adipose tissue, we find that, exposure of mice at ambient temperatures of 7 Celsius degrees for 72 hours leads to a very significant and clear detection of thermal activation. We have to mention that the adipose tissue is not heat-insulated and so its heat dissipates, resulting in an overall increase in body temperature. Consequently, if adipose tissue is thermally active, the neighboring tissues will become warmer, so there will be an overall increase in the temperature of the mouse. Hence, the most important parameter for the analysis of the data presented is that of the ratio of the average temperature of the adipose tissue to the average temperature of the thermo-neutral background.

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