Automated Long-Term Contactless Temperature Monitoring in Animals via a Thermographic Camera*

Lesya Anishchenko, Alexander Tataraidze, Aleksandr Bugaev, Vladimir Razevig

Abstract— **The paper deals with a problem of a remote prolonged temperature monitoring of biological objects. It presents an algorithm for automatic analysis and processing of video recording from a thermographic camera. Special attention is paid to the limitation of the method taking into account the possibility of its utilizing in laboratory conditions. The proposed algorithm of video analysis has three looped stages: animal location tracking, detecting specific points in the region of interest, and estimation of temperature in these points. The presented method for measuring temperature of the biological object has the following advantage: it minimizes influence on the object of the interest, and thus allows clearer understanding of animal reaction to medication or treatment.**

I. Introduction

Small laboratory animals are still widely used as biological models while testing new medicine, toxic agents or hazard factors. The most popular animals are rodents (e.g. rats and mice), because of handling simplicity, and fast reproduction rate. In sleep medicine rodents are used to study new methods of treatment different sleep disorders.

Standard methods, which are currently used in such experiments for prolonged monitoring of laboratory animal vital signs, are mostly contact [1] or even invasive [2]. The main drawback of these methods is the necessity of constraining the animal, which may influence the registered physiological parameters values. In case of invasive implanted sensors a surgery is needed to implant them, which is a time and labor consuming task. Of course, there are methods, which do not require contact probes usage, such as special home-cage observation systems [3, 4], however, they are expensive and suitable only for a specific animal type. Furthermore, such systems cannot be used for body temperature monitoring, which is essential in circadian rhythms studies.

The above listed facts make development of non-contact methods, which will be suitable for a prolonged body temperature monitoring of different types of the animals, an up-to-date task. In the presents paper we propose to use infrared thermorgaphy camera to solve this problem. In medical practice, thermorgaphy is used in applications with a stable biological object [5-7]. In case of prolonged temperature monitoring, the tracking of the object is required. This is a challenging task for thermal images. In present work we describe a video processing algorithm allowing tracking of the animal and estimating variation of its body temperature.

The paper structured as follows. Section II describes used method and experiments. Section III gives information about experimental data processing algorithm. The experimental data processing results are discussed in Section IV. Section V concludes the paper.

II. Methods and Experiments

We used as the temperature camera a Testo 885 thermal imager [8]. Its accuracy is 2 % according to the manufacture specification. The camera was configured with linear temperature measurement ranges of 24-38°C or 22-32°C depending on the room temperature. The temperature range of 24-38°C was picked for the experiments conducted during the summer period, when room temperature was above 25°C. While the second temperature range was use for experiments with room temperature of about 20°C. We used 8 bits quantification for making the estimation of pixels temperature. Therefore, the temperature interval was 0.039°C (slightly better for the second temperature range). The thermal camera has the valid protocol of conformity that is why in the present study the accuracy of the camera was not validated.

Experiments were carried out at Remote Sensing Laboratory, Bauman Moscow State Technical University and Institute of Higher Nervous Activity and Neurophysiology of Russian academy of science (Moscow, Russia). Three female adult Wistar rats were examined. The animal experiments consisted of three videos. Each record was of approximately 15 minutes duration and had a 320x240 resolution. The standard camera lens was used in all experiments.

During the experiment the animal was placed in a plastic box with an open top, the thermograpic camera was angled down toward the box in a way allowing observation of the inner space of it. We used boxes of two sizes 60x60x60 cm and 60x20x60 cm. The distance from the camera to the box floor was approximately 1 m. The camera was mounted on a tripod, and connected through the USB cable to the laptop to record the data. The scheme of the experiment and a single frame of the experimental video data are given in Fig. 1 and Fig. 2.

Prior to each experiment the thermal camera was manually focused on the area in which animal may be found during the experiment. This step is essential for efficient performance of the animal tracking algorithm.

*Research supported by the grants of Russian Foundation for Basic Research (15-07-01510 A, 17-07-00166 A).

L. Anishchenko, A. Tataraidze, and V. Razevig are with Bauman Moscow State Technical University, Moscow, 105005, Russian Federation (e-mail: anishchenko@ rslab.ru).

A. Bugaev is with Moscow Institute of Physics and Technology, Dolgoprudny, Moscow Region, 141701, Russian Federation.

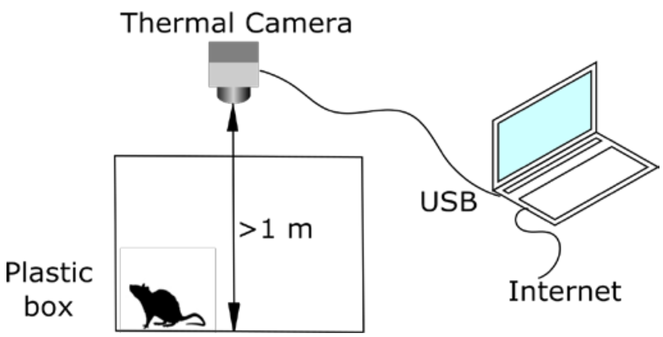

Figure 1. Scheme of the experiment.

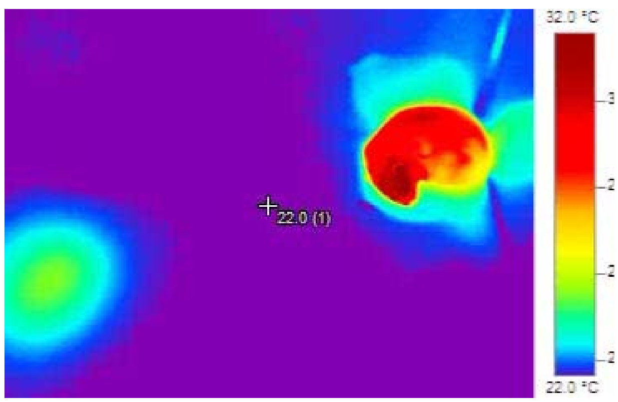

Figure 2. Registered thermogram of a sleeping rat.

Between the camera and animal should not be any objects, because almost all materials are opaque for mid-wavelength infrared (8-12 μm) utilized in the thermographic camera. Furthermore, draft should be cut out in the room, where the experiment takes place, because currents of air may be the cause of incorrect evaluation of the animal body temperature by the thermographic camera.

III. Data Processing Algorithm

Experimental data processing software has been designed using MATLAB environment. It consisted of following steps (Fig. 3).

- Infrared (IR) video record loading and extracting the first frame: at the beginning, the data gathered by the thermal sensor is loaded from the file and the first frame of the video record is selected for further processing.
- Temperature scaling: for each pixel in the frame temperature is estimated due to its color by the procedure given below.

  a) The temperature scale from the right part of the frame (Fig. 2) is divided into n intervals (in the present case n = 255); knowing the temperature for the endpoints (t_{min} and t_{max}) we can estimate the temperature of j-th point as

$$t_j = t_{\min} + \frac{t_{\max} - t_{\min}}{n} j$$

  b) After that j-th pixel from the temperature scale and corresponding to it RGB values are associated with exact temperature values.

  c) On the next step, RGB values for each pixel compared to the RGB values for the temperature scale pixels. The temperature, which corresponds to the pixel with minimum Euclidian distance between these RBG values, is assigned to the analyzed thermal image pixel.

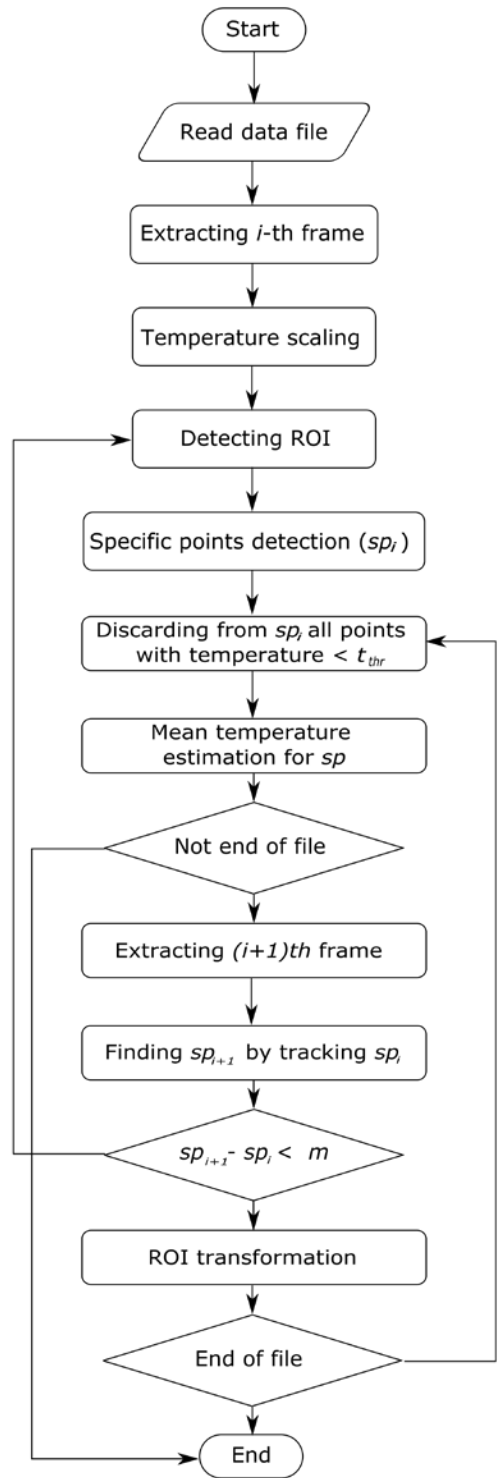

Figure 3. Flow-chat of the algorithm for thermal video processing

- Selecting region of interest (ROI): In the analyzed frame rectangular region with animal thermal image inside is distinguished. To do so we use two assumptions:

  a) Temperature of the animal on the thermal image at least 5 °C higher than the room temperature.

  b) There is only one animal in the field of view.

  The second assumption is needed to distinguish between the animal and its thermal trace or reflection in the walls of the box. Thermal trace is a result of the plastic box floor heating while contacting the animal. After the animal has left this area or shifted the body the plastic surface is cooling down not rapidly, which may result in more than one area in a frame with the temperature 5 °C higher than the room temperature. In such a case, the algorithm would pick the area with maximum temperature. Fig. 4 shows the selected by the algorithm ROI, the thermal trace and reflections of the animal in the box walls.

- Selecting specific points (sp_i) in the i-th frame for further tracking: we used minimum eigenvalue algorithm developed by Shi and Tomasi [9, 10], which is realized in MATLAB to find specific corner points in ROI.

- Checking if each specific point corresponds to the animal and estimating of the animal mean temperature: we discarded all points with the temperature value lower than threshold t_{thr}. The t_{thr} value is empirically chosen as a median temperature for all ROI points minus 5°C. The mean temperature of the animal for the frame is estimated as a mean temperature value for the remained specific points.

- Analyzing the next (i+1)th frame: if it is not the end of file, we extract the next video frame.

- Tracking sp_i: we used Kanade-Lucas-Tomasi (KLT) algorithm [11] realized in MATLAB to track sp_i and find sp_{i+1}. If number of sp_{i+1} is less than $sp_i - m$ (where m=4 was empirically chosen), which means that tracker lost the object, algorithm returns to the detecting ROI step.

- Transformation of ROI: the geometric transformation between sp_i and sp_{i+1} is estimated and applied to the ROI boundaries.

- Estimation of mean temperature for selected points: return to the specific point checking step.

IV. Results

The thermal video processing algorithm described in the Section III was used to analyze experimental data. Fig. 5 shows the rat body temperature variation during one of the experiments. A large variation of the temperature obtained by the proposed methods (around 1.4°C) is caused by the specific point's localization errors. We used a median filter with window width of 100 samples to minimize this error.

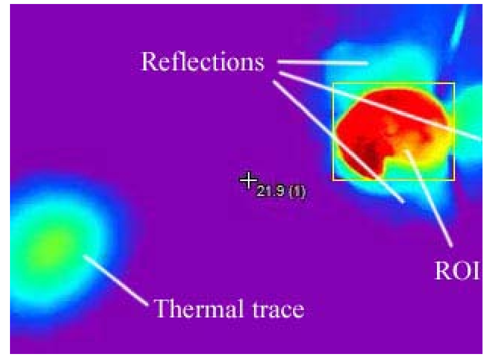

Figure 4. Thermal image with selected ROI.

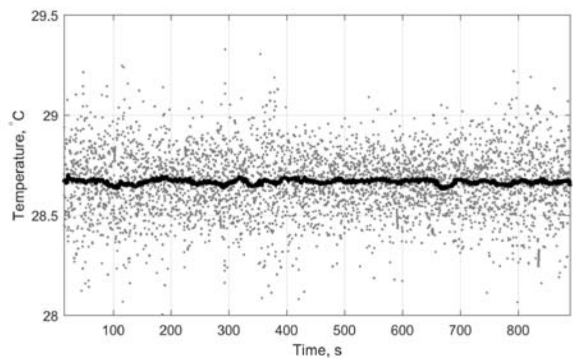

Figure 5. Animal body temperature variation in time. Mean temperature of spesific points for each frame (dots) and its median for window width of 100 samples (solid line).

It is worth mentioning that the temperature estimated by this method is several degrees lower than the real body temperature because the animal body is covered in fur, which decreases heat loss. This thermal shift may be taken into account by calibrating the system prior to the experiment. In [12] this problem is solved by shaving the area on the rat's body for further tracking or using for this purpose less covered in fur body areas such as the rat's head. However it is not a solution for routine experiments because these areas may not be always visible by thermographic camera.

V. Conclusions

The work has presented a feasibility study on the thermal camera usage for contactless monitoring of the laboratory animals temperature. Experiments were performed in laboratory conditions by using a commercially available thermographic camera Testo 885 thermal imager. For video processing we proposed the method of detecting animal position in the thermal video record (ROI), selecting specific points in ROI and estimating temperature for them. The proposed method was tested on the experimental thermal data from rats. The work might contribute to the development noncontact system for long-term monitoring of animals, which might be helpful for sleep medicine studies.

The future activity will consider expanding the data set and caring out verification experiments, which will help in estimation of temperature shift in the thermographic data caused by fur.

REFERENCES

[1] MLT1010 Pulse Transducer, http://m-cdn.adinstruments.com/product-data-cards/MLT1010-DCW-15A.pdf, accessed Sep. 2016.

[2] Stellar Telemetry: Implantable animal telemetry system measuring blood, pressure, heart rate, biopotentials, temperature and activity, http://www.tse-systems.com/products/implantable-telemetry/animal-telemetry-system.htm, accessed Sep. 2016.

[3] Buxco Respiratory Products, http://www.datasci.com/products/buxco-respiratory-products, accessed Sep. 2016.

[4] PhenoMaster/LabMaster, http://www.tse-systems.com/products/ metabolism/ home-cage/phenomaster/index.htm, accessed Sep. 2016.

[5] A. Wakankar, G. R. Suresh and A. Ghugare, "Automatic Diagnosis of Breast Abnormality Using Digital IR Camera," Electronic Systems, Signal Processing and Computing Technologies (ICESC), 2014 International Conference on, Nagpur, 2014, pp. 145-150.

[6] T. Wirthgen, S. Zipser, U. Franze, S. Geidel and G. Lempe, "Automatic infrared based temperature measuring system for health monitoring in veterinary applications," Sensors, 2011 IEEE, Limerick, 2011, pp. 1800-1803.

[7] C. Hildebrandt, C. Raschner, and Kurt Ammer, "An Overview of Recent Application of Medical Infrared Thermography in Sports Medicine in Austria," Sensors, 2010, 10, pp. 4700-4715.

[8] Testo 885, Instruction manual, https://media.testo.com/ media/9b/38/965364330406/testo-885_Instruction-Manual.pdf, accessed Sep. 2016.

[9] Shi, J., and C. Tomasi, "Good Features to Track," Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, June 1994, pp. 593–600.

[10] Lucas, Bruce D. and Takeo Kanade. "An Iterative Image Registration Technique with an Application to Stereo Vision,"Proceedings of the 7th International Joint Conference on Artificial Intelligence, April, 1981, pp. 674–679.

[11] Shi, Jianbo and Carlo Tomasi. "Good Features to Track," IEEE Conference on Computer Vision and Pattern Recognition, 1994, pp. 593–600.

[12] Guillaume-Alexandre Bilodeau et.al., " Body temperature estimation of a moving subject from thermographic images ", Machine Vision and Applications. March 2012, Volume 23, Issue 2, pp. 299–311.