# USE OF THERMAL IMAGING FOR CONTROL OF THE PROCESS HYPOTHERMIA CARDIAC

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**Abstract:** Qualitative comparative analysis of thermal infarction was carried out using a thermograph in the spectral range of 8-14 microns. A quantitative assessment of myocardial temperature measurement accuracy was made which depends upon the ambient temperature. Based on the proposed approach to the analysis of infarction thermal images, research of thermoabnormal zones on the surface of the myocardium was made, which gives a clear picture regarding the distribution of the internal temperature and the level of the microcirculation in the myocardium and vessels.

**Key words:** thermogram; myocardium; temperature distribution; vascular pathology.

## Introduction

Many pathological processes change the normal distribution of temperature on the surfaces of thermoabnormal zones, and the closer the pathological portion of the body is to the surface the clearer those changes. In many cases, local temperature changes occur prior to other clinical features, which is very important for early diagnosis and early treatment [1]. The method of non-contac control of heart temperature helps to reveal the interrelation between electromechanical characteristics of a myocardium (according to an electrocardiogram) and temperature fluctuations on a myocardium surface. Thermography allows specifying the location of the functional changes in the myocardium, the activity of the process and its distribution, the character of functional changes – inflammation or malignancy.

## The Feature of this Method

When applying the non-contact method of heart temperature control FLIR i7 thermograph was used to spectral range of 8-14 microns on the basis of not cooled matrix of $320 \times 240$ elements size and with temperature sensitivity of 0.1°C. The method of comparative analysis for thermograms of myocardium allows description of the thermal picture for an open heart [2]. Also, the method allows us to control the functional condition of the body in vivo when studying the thermoabnormal zones on the skin surface and gives a clear picture regarding the distribution of internal temperature and microcirculation in the myocardium and vessels.

The lowest temperature of an operational field is registered with infrared scanner in the point of focusing of Sp1 – 33.2°C, and 12 min after cooling in the point of Sp1 – 29.7°C, i.e. on the exposed surface areas of the myocardium the temperature difference can reach 3 – 4°C. Thermograms of the operative field, before and after cooling are shown in Fig. 1.

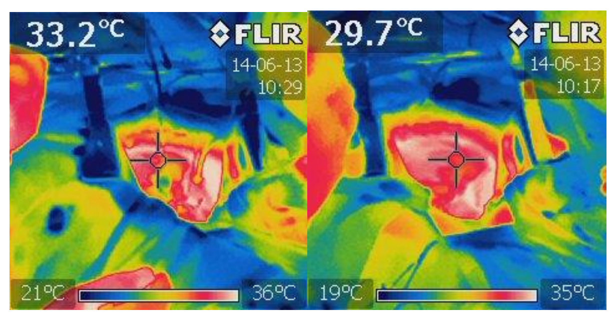


Fig. 1: Heat Portrait of Operative Field and Myocardium.

Temperature variations on the surface of myocardium in the researched area are clearly defined during hypothermia and hyperthermia under extracorporeal circulation (EC). Propagation of electrical excitation and mechanical contraction of the heart muscle cause temperature fluctuations on the surface of the myocardium in the researched areas, which have a certain periodic regularity of temperature change in the range of 28.1°C at the minimum to 32.1°C at the maximum. The operative field with a heat portrait of myocardium is shown in Fig. 2.

## Determining the areas with the largest cooling temperature

The method for determination of areas with a minimum temperature cooling is necessary to use for control of the process hypothermia after cardiac arrest. Determining the area with the highest temperature cooling is based on using

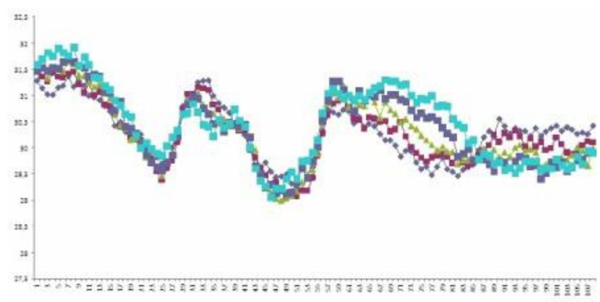

Fig. 2: Graphic Image of Thermal Portraits Myocardium.

a circuit termohramy image that has zero as the biggest one-dimensional function (LSF) that involves the widening of its evolution in representing the zero level function.

A Contouring Method based on one of the basic features of digital signal – discontinuity of brightness. The most general way to find discontinuities is by processing the image using filter-masks, which are a transition function which is a square matrix corresponding to specified group of pixels of the original image.

The brightness gradient of function is defined as a vector quantity that indicates the direction the fastest increase of some magnitude. In this case, this value is a function of two-dimensional function of one-dimensional function (LSF):

$$\vec{g} = gradI = \left(\frac{dl}{dx}, \frac{dl}{dy}\right)$$

I – is starting the function the image brightness.

The contouring process is based on a simple moving of a mask filter from point to point on an image. In each image point $(x, y)$ of the filter response is calculated using predefined connections. In the case of linear spatial filtering the response given by the sum of the product of the filter coefficients corresponds to pixel values in an area that is covered by a mask filter. For mask of 3×3 element is shown in Fig. 3, the outcome (the response) R linear filtering at the point $(x, y)$ image is given by:

$$\begin{aligned} R = & w(-1,-1)f(x-1,y-1)+ \\ & + w(-1,0)f(x-1,y) + w(0,0)f(x,y)+ \\ & + w(1,0)f(x+1,y) + w(1,1)f(x+1,y+1) \end{aligned}$$

According to this formula the sum of the mask coefficients corresponding to the brightness of pixels under the mask is determined. The coefficient $w(0, 0)$ corresponds to the value function $f(x, y)$, indicating the mask alignment relative to the point $(x, y)$. In identifying changes brightness using discrete analogs derivatives of first and second order is used. The first derivative of one-dimensional function $f(x)$ is defined as the difference between the values of neighboring elements.

$$\frac{dx}{dy} = f(x+1) - f(x)$$

Similarly, the second derivative is determined as the difference between neighboring values of the first derivative:

$$\frac{d^2 f}{dx^2} = f(x+1) - f(x-1) - 2f(x)$$

Calculating the first derivative of the two-dimensional brightness function $f(x, y)$ for a digital image based on various approximations of discrete two-dimensional gradient. The gradient of the image at the point $(x, y)$ is given by:

$$\nabla f = \begin{bmatrix} gx \\ gy \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

The maximum brightness function $f(x, y)$ is achieved in the direction of the vector $\nabla f$. The angle between the direction vector $\nabla f$ at the point $(x, y)$ and x-axis is given by:

$$a(x,y) = arctg\left(\frac{Gy}{Gx}\right)$$

So, the direction of the contour at the point $(x, y)$ is defined in the direction perpendicular to the gradient vector $\nabla f$ at this point.

In Fig. 4 you can watch the initialization proliferation of each circuit – warmed from chilled (red lines) and cooled to a warmed (blue line) and combining contour lines on grayscale image.

The regulation of the proliferation area contour was carried out using a double value potential at the point (x, y), for which the dependence presented in Fig. 5.

The application of Contouring Method for thermographic image provides visual details of edge detection myocardium. The result of evaluating the function of brightness, which varies from heated to a refrigerated sections myocardium, shown in Fig. 6.

Using the method for the selection areas on the thermogram myocardium with clearly defined transition from the refrigerated sections to a heated and conversely, allows the improvement of non-invasive control of process hypo- and hyperthermia heart with a sharp temperature gradient.

## Temperature Control of the Heart and Brain

Electrical activity of the brain was registered using „ExpertTM" – the 16-channel electroencephalograph which is part of medical diagnostic telemetry complex „Tredeks".

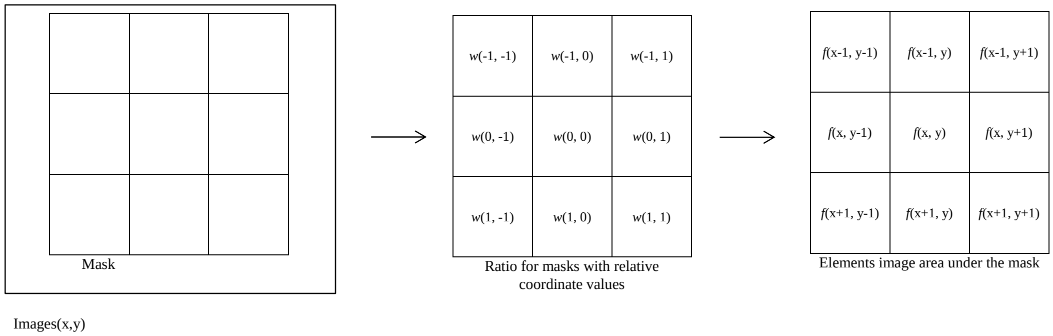


Fig. 3: The Use of Masks in the Spatial Filtering Image.

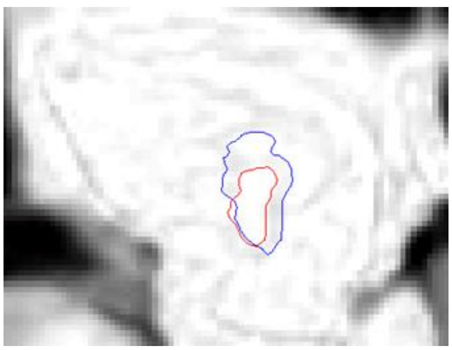

Fig. 4: Initialization Proliferation Circuit Function of Brightness.

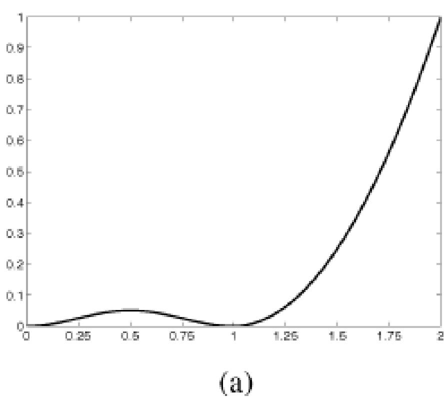


Fig. 5: Double Magnitude the Potential at the Point (x, y)

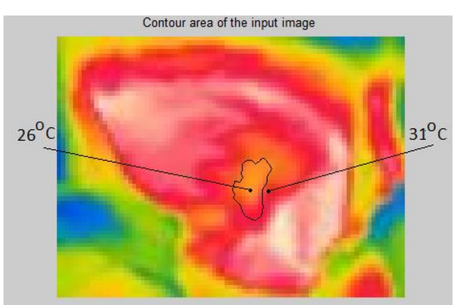


Fig. 6: The Visual Image of Edge Detail Infarction

The recording of electroencephalogram (EEG) was performed on the background of anesthesia before the start of extracorporeal circulation at the stages of cooling and warming patients (Fig. 7).

Fig. 7: Recording EEG in the Operating Room on the Background of Anaesthesia and Extracorporeal Circulation.

The temperature decrease of the Heart and Brain from +36°C to +18°C is the main factor of protection from hypoxic damage of the Brain under exclusion of those organs from circulation during open heart surgery.

The method of producing graphic image thermal portraits of myocardium for open heart and brain allows for the controlling of the temperature of operating area during operations on the brain and heart. The developed comprehensive approach with the remote control of temperature allowed us to define the uniformity of thermal protection, the level of cooling in different temperature zones and significantly improve the security of controlled cessation of circulation in vitally important organs.

## Conclusions

It is shown that at every point of the myocardium the measured and actual temperature (true temperature) of the object are linearly related among the temperature on the surface of thermoabnormal zone (measuring zone), the temperature in the volume of the given zone (temperature at depth) and the temperature of the environment (an operational zone). At every point of myocardium there is a correlation between the measured and true temperature within the temperature coefficient which is a value of blood emissivity.

The proposed method control of the process hypothermia cardiac which is based on the use of thermographic images allows the estimation of uneven temperature distribution on the surface of myocardium and automatically identify local areas with extreme temperature values.

## Literature

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