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Procedia Computer Science 218 (2023) 1247–1256

Procedia Computer Science

www.elsevier.com/locate/procedia

International Conference on Machine Learning and Data Engineering

Muscle temperature analysis, using thermal imaging, applied to the treatment of muscle recovery

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Abstract

The images help in the different processes where a visual interpretation of a scene is required, in this sense we find many applications where images are used to analyze, interpret and classify certain objects within the image, there are different types of images generated by different sensors, in this paper describes a method to analyze the behavior of the muscle, mainly of the knee, when performing rehabilitation exercises, coupled with an optical image where you can see the state of the muscle and the location, the method proposed as a super position between optical and thermal images, with the intention of being able to know the state of the optical image and to have the same image with information of the behavior of the temperature, the super position that we propose is to have as a base the optical image and on placing the thermal image, the results that are presented are oriented in proposing a new way of analyzing data with thermal information of the behavior of the muscles, by means of a complex image with optical and thermal information, the method is an aid in the treatment of muscular recovery, with the benefits of being scalable and applicable to other muscles and parts of the human body.

Keywords: Imaging; thermal; optics; super position; analysis; heat; temperature.

10.1016/j.procs.2023.01.103

1. Introduction

Thermal imaging is being used in multiple applications, where it is required to analyze, verify and evaluate the behavior of the temperature in the body and materials, we have works where the automatic and remote monitoring of body temperature is analyzed through an ocular location of various views which are considered valuable in the livestock industry for the purpose of detecting the body temperature of cattle in order to detect signs of fever or local inflammation helping farmers to maintain control over the temperature can identify cattle at risk to make decisions, However, many times this is difficult due to the amount of existing animals with traditional methods which are considered invasive and time consuming, so it is sought to develop alternative methods for this process which could be automated in order to measure the temperature efficiently and accurately with which would provide benefits to the industry, Therefore, a new technique of infrared thermography (IRT) is implemented, which has the ability to perform a measurement of body temperature by analyzing an infrared thermal image of the eye region in real time, performing an eye segmentation and a computer vision method for the detection of faces of multiple views in cattle, so this method of computer vision has created 3 types of multiple-view face detection, which uses Histogram Oriented Gradient (HOG) as features and Support vector machine (SVM) as classifier, so it proposed a new automated eye segmentation method based on thresholding techniques, which worked in the indoor environment in order to locate the cattle eye region by measuring the temperature from different orientations, angles and positions after the implementation of method proved high accuracy with the following average sensitivity of sensitivity 0. 9780, precision 0.7212, F-measure of 0.8024 and misclassification 0.0455, this method works in relation to the indoor environment in order to locate the cattle eye region by measuring the temperature from different orientations, angles and positions [1].

We found works where the heating of the original asphalt pavement is considered as a key role in the whole construction procedure of hot in-place recycling (HIR), Currently, the temperature of the heating process in HIR is taken with an infrared temperature gun with single or multiple test points which have limits in real situations without being able to perform an accurate quantification of the heating quality, so a system of infrared thermal imaging (ITI) is implemented. Infrared thermal imaging (ITI) system with which the HIR heating process can be monitored and the combination of digital image processing (DIP) and artificial neural network (ANN) applied for extraction and correction of distorted thermal images in order to restore the pavement surface temperature, HIR [2] [3].

We found works where it is analyzed about nondestructive testing and evaluation (NDT & E) used for industrial quality control for which various thermal schemes are used where pulse compression favorable frequency modulated thermal wave imaging, sensitivity improves defect detection along with improved test resolution so our main objective is to present the noise rejection capability using post-processing schemes based on principal component analysis (PCA) which helps to perform an efficient interpretation of the thermographic data in order to eliminate artifacts produced from few images which show below surface defects in the test sample [4].

In the present research we analyze about the additive manufacturing applied to traditional manufacturing technologies with which the understanding about the relationship between the parameters is realized, microstructure and functional properties of the parts that have been constructed with which the process of additive manufacturing is optimized and the construction parts with the desired properties for which it is presented in situ high speed images and thermal conductivity measurements about the direction of construction of manufactured parts which are based on polymer extrusion in order to understand about the effect of the process parameters where the frame rate is considered [5].

In the present research we analyze about additive manufacturing (AM) processes which counts with a lower stability compared to traditional counterparts where it has been found inconsistencies of the process leads to anomalies in the construction hindering the wider adoption of AM in the manufacture of critical structural components, for which we take into account the flows of real-time thermal images captured from AM processes

are considered the most informative signatures of process stability focusing on in-situ detection, which performs the extraction of features and their relationship with process configuration parameters and their properties so it is proposed to develop a statistical process control (SPC) with which to detect changes in the process that when present based on the predefined distribution of tracking statistics considering 2 challenges the first is the complex spatial interdependence in the thermal images and the current engineering knowledge is not sufficient to describe all the variability, and thermal images suffer from large data volume, low signal to noise ratio and faulty structure with missing data so a multilinear principal component analysis (MPCA) approach is used to extract low dimensional features and residuals by proposing an online dual control charting system leveragingbT2 and Q-control charts to detect changes in extracted low dimensional features and residuals [6].

In the present research we analyze about the pests and diseases which affect about the quality and yield of crops in order to improve the usage rate of pesticides for which a fast thermal infrared image processing system of insect pests based on Android has been implemented using powdery mildew of corn tumor with the object of research was used an infrared thermal imaging lens based on Android system with which to obtain images of corn disease, using OpenCV technology for image processing, to achieve a good infrared thermal segmentation effect was analyzed segmentation effect which was based on traditional Otsu algorithm (Otsu) and Otsu single threshold segmentation method based on basic fireworks algorithm (BBFWA), From the results obtained, it was found that the Otsu single threshold segmentation method based on BBFWA has a good effect on the thermal segmentation of infrared images which will be influenced by the ambient temperature, for which the shooting should be performed in cloudy or overcast conditions calculating the value about the existing ratio between the total number of pixels within the white area and the total number of pixels of the binary image which is divided with which the degree of pest infestation is determined providing referenced data according to the amount of the UAV to a certain point [7].

In the present research we analyze the processing sidewalk of the vibrational components of the facial thermal image of a person in order to evaluate the current functional and psycho-emotional state, for which an individual model about the thermal image of the face is created, this model includes the graphic components containing information about the computer areas which are based on the point of view about the unconscious vibrations and facial expressions of the facial manifestation so that the areas of the face deliver pronounced manifestations of the modulation effect due to the cardiac and respiratory activity of a person, taking as a reference point with which we can link with the above components of an image being a different graphical format being a possibility to implement a selective processing of the recorded vibrational components of the thermal image of a person's face allowing to isolate the components of psychomotor reactions which are formulated differences, typical about the approaches with only facial image processing in the visible spectrum, showing weak and uneven facial illumination, the presence of fog and smoke lead to a decrease in the reliability of the obtained estimates mimicking typical situations about the nodes of emergency operations of dangerous objects about the correct and timely diagnosis of the current state of the personnel is more in demand [8].

In the present research we analyze about infrared thermography using an effective non-destructive technique to detect cracks in the metal surface taking into account the factors involved in the infrared thermal image maintaining a low definition compared to the visible image about the contrasts that exist between the cracks and the sound areas that are different from the thermal image frames that have been recorded for a while being able to obtain an accurate detection just by taking a look at the thermal video. The detection of cracks and sound areas that are different from the frames of thermal images that have been recorded for a while can obtain an accurate detection just by looking at the thermal video being a difficult job where the experience of the operator will influence the accuracy of the detection results for which we propose a framework for processing infrared thermal images that was based on an algorithm of superpixels which has managed to perform the detection of cracks automatically, then we have proceeded to compare 2 superpixel algorithms by selecting one of them, on the combined features of superpixels taken from both the raw gray level image and high pass filtered image with a fuzzy c-means clustering is used to group superpixels to segment to infrared thermal image from this experiment the results has shown that it can automatically recognize cracks on the surface of metal through infrared thermal

image [9].

In the present research we analyze about the automatic toll gate at the entrance and exit of the highway which should classify to realize the fare collection at night for which a method of categorization of vehicles in night traffic using thermal image processing and statistical analysis has been proposed, with it can differentiate the type of vehicle using the statistical relationship between thermal characteristics of the engine heat, the windshield first automatically determined the threshold values to perform thermal classification, within the entire image area has been divided into blocks and thermal characteristics classifying by blocks taking from the threshold values which are integrated to categorize the type of vehicle after performance evaluation proved that it can correctly differentiate and categorize experiments with 2937 samples of cars, vans and trucks [10].

in the use of artificial vision systems, thermal sensors play an important role, recently we have available low cost devices that perform the registration of temperature behavior, one of the important factors is the calibration, for which it is necessary to have mechanisms to improve the registration, we found works where they recommend different techniques for the calibration of these cameras [11].

we find applications where the use of thermal imaging is used to measure compensatory muscle performance, using deep learning algorithms, which can effectively detect compensatory movements to evaluate the performance and effects of rehabilitation exercises [12].

One of the important factors in the process of adaptation of orthopedic prostheses, for which the process of familiarization in the use of the prosthesis is important, adapting the muscle is important to withstand the pressure and friction, through the use of thermographic images can be shown as the muscle gets used to the new pressures [13]. In the rehabilitation process of the lower limbs, we find that the knee is one of the most important parts, currently many techniques are being tested for treatment in rehabilitation, in this sense the power to provide heat to the knee is part of the technique, through the use of thermal cameras, you can check the temperature that is the knee [14].

currently being evaluated uses and applications of thermal cameras, which provide a thermal image that is directly proportional to body heat, in this sense we present a mechanism to assess the temperature of the mouth based on thermal imaging, checking with the measurement of body temperature, using a direct measurement of the mouth, in this sense the average sensitivity is 88.5% [15].

In this research, we present a method to analyze the behavior of muscle temperature at the time of performing rehabilitation exercises, with the intention of verifying which muscles are working as reflected by temperature monitoring. We present as a result an evaluation in the process of working with optical images and thermal images, captured by the same device and performing superimposition processes to locate the area under study.

2. Methods and Materials

The case that we present, consists of being able to analyze the method to be able to evaluate the behavior of the muscle, when rehabilitation exercises are being performed, we present as a case, a patient who has metal supports in one of the knees. The exercises are related to recover the mobility for which it is necessary to recover the muscle mass, for this reason the rehabilitation exercises is necessary and a way to know if the necessary muscles are being worked, the method indicates that if the muscle is working should present a higher temperature, which corroborates the muscle activity.

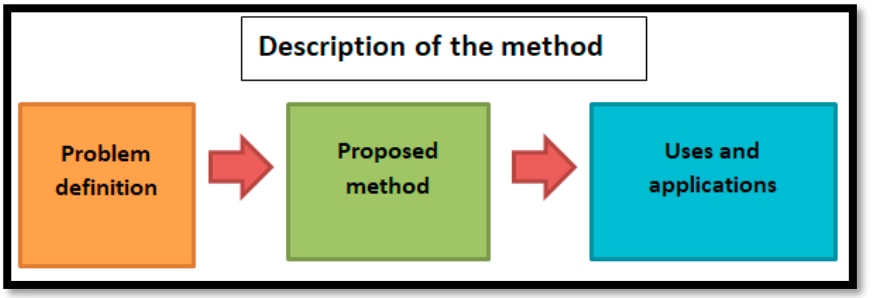

Fig. 1. Description of the method

The method that we present consists of being able to analyze two types of images, the first one an optical image and a second image which is a thermal image, both images are acquired by the same device so that the sequence of images is performed one after the other in order to be able to register the images for later analysis.

The method consists of being able to register both images, in the thermal image to identify the working temperature of the desired muscle, in this sense as there is a difference between the lenses of the cameras as well as in the location, we proceed to make a superposition of both images, to be able to verify the muscle that we are exercising.

2.1. Problem definition

The problem that we present is dedicated to describe the mechanisms that are used at the time of performing physical therapy exercises, one of the considerations in the treatment is dedicated to muscle work, always trying to recover its mass and thus be able to help the patient. Commonly before the rehabilitation exercises the muscle is ready to work, in this case the use of warm wet cloths is used to raise the temperature of the muscle and thus be ready to work. After finishing the exercises, the muscle needs to rest for which is resorted to the use of cold cloths with the intention of cooling the muscle, the mechanisms of being able to define if it reached the working temperature, is usually done by touching the affected area, with the use of temperature can improve this procedure through the use of thermal imaging.

2.2. Proposed method

The methodology proposes the use of both images simultaneously, for which it is necessary that the images are recorded in the same acquisition conditions, to have the same resolution and that both images can be superimposed later. The optical and thermal images are described below.

We know as optical image, an image produced by an optical sensor, which performs the registration through the sensors, normally in the cellular equipment we find optical cameras for the registration of images, then we present an optical image captured with a cellular equipment, of the patient who is performing rehabilitation exercises.

In the image 2, an image of the lower limbs is presented, at the time of performing rehabilitation exercises, in the right foot you can see the scar of an operation by which the need to recover muscle mass and thus the mobility of the patient is evident.

In the image 1, the cut image is presented in the part that corresponds to the knees, which is the object of study, it can be noticed by visual means a difference in the size of both knees, indicating that the knee where the scar of the

operation is appreciated, an increase in size is evidenced in comparison with the other knee, which is evidenced that this inflamed, product of the same exercise.

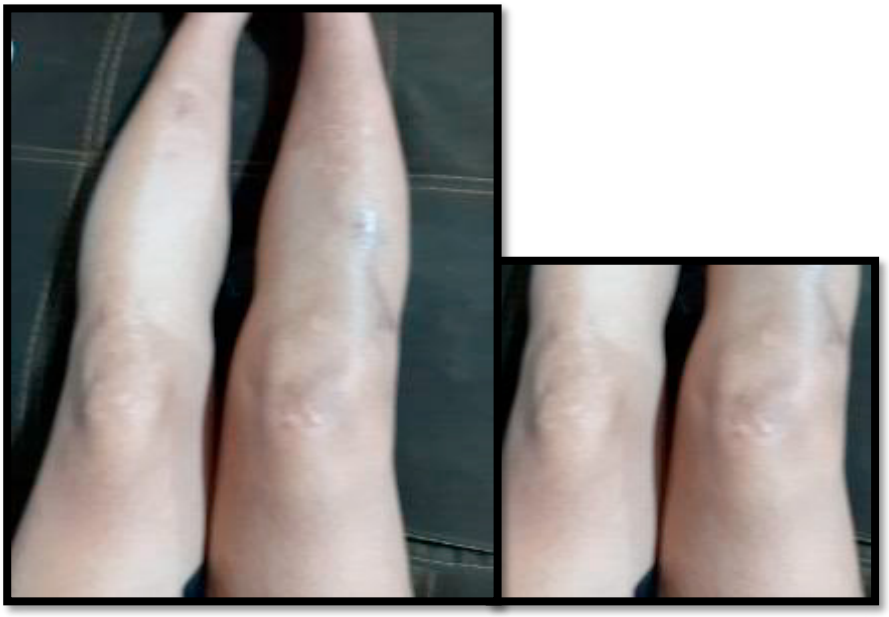

Fig. 2.Optical image captured by cellular equipment y Zone of interest of the optical image

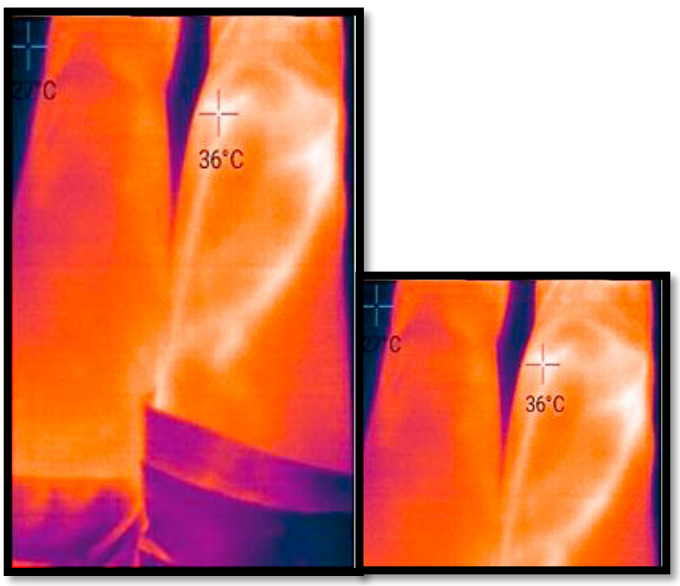

Fig. 3.Optical image captured by cellular Thermal image captured at the time of the rehabilitation exercise and the area of interest

The thermal image is a representation of the temperature that the thermal sensor is capturing, in this sense the image that is formed is represented by a color scale that represents the temperature. For our case study, the temperature of the knee is being evaluated at the time that rehabilitation exercises are being performed, in our case study, a person with knee problems is being evaluated, which presents an operation, in this way the muscles are being worked to be able to recover the muscle mass and thus recover mobility.

In image 3, we present the registration of the thermal image, captured at the time of the rehabilitation exercise, the capture of the image was performed with emphasis on the regions where the image shows higher temperature, which is related to the knee area.

If the need is to be able to analyze which part of the image is being affected by the temperature, we perform a visual analysis of the image and evidence where there is more color in the image, in image 4, the thermal image is presented, cut in the area that corresponds to the knees, which shows that the right knee has some areas of yellow color, which is the one that has temperatures around 36 degrees Celsius, this area corresponds to the veins and arteries that irrigate the leg and knee, which if we compare it with the left knee, the right knee is being affected by a temperature pattern outside the normal range.

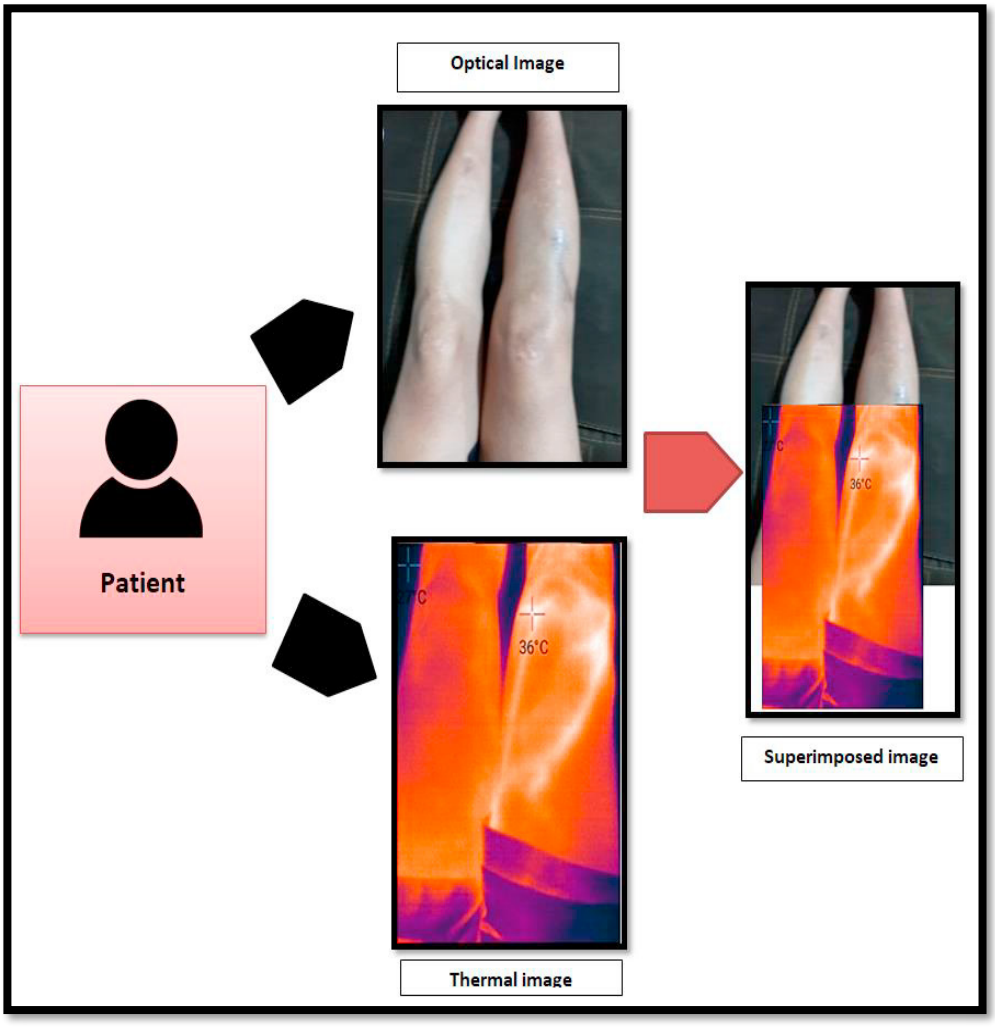

Fig. 4. Description of the methodology

In Figure 4, we present the diagram of the use of the methodology, where the way of working can be seen, it should be considered that the registration should be performed to the same patient at the same time, in order to superimpose both images for a later evaluation.

The capture device consists of being able to record both images at the same instant that the rehabilitation exercises are performed, for which the cameras of the cellular equipment and the thermal camera installed in the same device are used. It is important to record the images simultaneously, because it will allow recording both images at the same moment and to record the temperature present at the moment of the exercise to be able to be evaluated later.

Fig. 5. Optical and thermal image capture

In the figure 5, we can notice that both images are out of phase due to an acquisition condition, in this sense, if it is required to analyze more accurately the affected area, it is necessary to perform a process of oversampling of the thermal image on the optical image, this procedure is explained in the chapter corresponding to the results.

2.3. Uses and applications

The uses and applications of the proposed methodology have the potential to be exploited in the evaluation of the thermal behavior of muscles when performing rehabilitation exercises, where it is necessary to be able to analyze how the muscle responds as the exercises are being performed. The evaluation of the temperature of the muscle can be evaluated in two stages: when the exercises are started, it is estimated with the heating of the muscle, and when the therapy exercises are finished, it is necessary to analyze the cooling of the muscle; in both cases it is necessary and important to evaluate the temperature of the muscle.

3. Results

The results that we present are related to the description of the method of analysis of the muscle temperature at the exact moment of performing rehabilitation exercises, the intention is to be able to analyze the muscle that is working and thus to know its working temperature, the technique of superposition of images, indicates that a process of standardization of the images has to be performed, trying at all times that both images have close dimensions to locate the same area of the muscle in both images.

A second procedure is to be able to locate both images, in such a way that they have the same reference to be able to make the over position of both images, this procedure is important because it will allow locating one image over the other image, we must consider that we have to locate a reference to be able to make some modifications referring to the modification of the pixel size and the location of the over position.

In image 6, a demonstration of the procedure of over positioning of the images is presented, where reference is made to be able to place the thermal image over the optical image, in this case, it is evident that to be able to observe in the image, the part of the knee is with elevated temperatures, which is represented by the color with a yellowish tone. In this way the staff dedicated to evaluate the therapy, may have the necessary information to perform any procedure in order to improve patient treatment, the technique we present, we propose an alternative to evaluate the behavior of the muscle with respect to the exercises that are performed based on the analysis of the temperature.

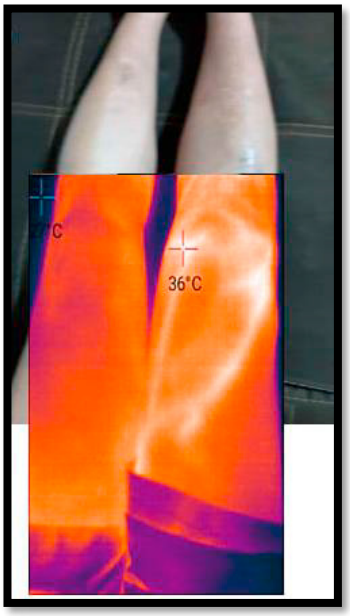

Fig. 6. Superposition of the thermal image on the optical image.

4. Conclusions

The conclusions we reached in our proposal, is mainly based on being able to exploit thermal imaging in the area of health, mainly in monitoring the temperature of the muscle, when performing rehabilitation exercises, knowing the muscle performs work when performing the exercises, so when we are indicating that performs work is also producing heat and you can measure that work by analyzing the temperature, with this analysis we can indicate that you can distinguish the operation of the muscle with respect to the exercises and the heat it produces.

The proposal that we present, is related to analyze optical and thermal images of the same patient, when we are performing rehabilitation exercises, to perform a super position of these images in such a way to analyze the behavior of the muscle with respect to temperature, helped with the location of the muscle that is working, this super position helps the staff responsible for monitoring the rehabilitation exercises based on the thermal analysis of the muscles, with which they can perform the necessary procedures for the benefit of the patient, we can indicate that the procedure presented is scalable and applicable.

Making a comparison with the articles taken as a reference, we present similar solutions, from a perspective of the thermal behavior of the muscle and relate it to muscle physiology, in the activities performed by professionals in charge of rehabilitation, they encounter situations where they have to take measurements of the temperature of the muscle being worked, with the proposed methodology helps in the quantitative evaluation of the thermal behavior of the muscle, when it is subjected to rehabilitation exercises.

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