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Non – contact temperature measurements in medical diagnostics

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Abstract

In the paper the thermovision technology of non – contact temperature measurements has been presented with the focus on medical applications. The physical phenomena of operation of infrared devices has been given. Basing on the experimental results of the temperature measurement along a selected line an impact of the chosen parameters, namely emissivity, temperature, distance between the camera and the observed object as well as humidity, has been analysed.

Key words: medical diagnostics, temperature measurement, thermovision

Introduction

Temperature can be measured with traditional contact devices such as thermometers, thermocouples, thermistors and etc. However, in technical measurements the location of detectors can influence the thermal field on the object. What is more, it is often required to conduct testing of the temperature distribution on a surface rather than determining temperature at a selected point. To overcome such challenges infrared measurements usually with thermovision cameras are conducted.

Thermovision devices are commonly used in mechanical and electrical engineering to detect machinery or electrical units' defects and to analyse the physical condition of machine parts, in the building industry to determine areas of heat losses in buildings as well as in other fields of engineering. Nowadays, the infrared technology also becomes more and more popular in medical diagnostics. The most common application of this technique is tumour detection basing on the thermal map of a patient obtained with a thermovision camera.

The infrared measurements are quite fast and easy to conduct, however, the interpretation of the results can be very challenging. Moreover, the results are influenced by a number of parameters, e.g., emissivity value, distance between the object and the camera, ambient temperature, temperature of objects in the vicinity or humidity, whose impact should be well understood to properly conclude about the temperature distribution. The impact of these parameters is analysed in the paper with a special focus on the conditions of medical diagnostics.

Infrared temperature measurements: physical fundamentals and technical devices

Infrared temperature measurements are based on the equation for the radiation intensity, calculated according to the Stefan – Bolzmann law. According to this law a radiation intensity of a body whose temperature exceeds 0K is expressed as:

$$W = \varepsilon \sigma T^4 , \qquad (1)$$

where ε is the emissivity value, which depends on the kind of the surface, temperature and wavelength, while σ is the Stefan – Boltzmann's constant (σ= 5,67x10^{-8} $W/(m^2K^4)$).

The infrared camera is equipped with a detector that detects and processes infrared the radiation energy emitted from the observed body. This detection can be conducted either by a single detector (often found in older generation of cameras) or a matrix of detectors. The signal produced by the detector is amplified and transformed into a digital signal, which is then used to calculate temperature.

Currently, a matrix of detectors is commonly used – usually 320x240 or 640x480 pixels. Naturally, the cost of a thermovision system is higher if detectors of higher density are used. Generally, taking into account physical phenomena of radiation detection the detectors can be devided into two groups [1]:

- photonic – in which radiation is absorbed as a result of the interaction between photons and electrons and the output signal is produced as a consequence of changes in energy distribution of carriers,
- thermal – in which temperature of the material is elevated as a result of radiation absorption and the signal is produced because of the changes of a selected material property with temperature, for example, electrical resistance.

In reality the camera's detector receives radiation emitted not only by the observed element but also other sources. Consequently, in order to properly determine temperature of this element from the radiation beam, the software of the device needs to take into account radiation reflected from the object and coming from sources in the surroundings (ot) and atmospheric radiation (at). The software of the thermovision system uses the following equation for the total radiation intensity [2]:

$$W = \tau W_{ob} + (1-\varepsilon)\tau W_{ot} + (1-\tau)W_{at} \qquad (2)$$

where τ is the atmosphere transmissivity.

There are generally two types of cameras available on the market: short – wave (2 – 5 μm) and long wave (8 – 14 μm). The difference is in the radiation wavelength which they utilize. Additionally, infrared cameras might have inbuild digital cameras to make photos of the analysed objects. In many models it is also possible to change lenses (narrowing or widening the view) with the aim to obtain close – up images of particular areas or panoramic views – especially in building measurements.

Apart from the infrared cameras other non – contact temperature measuring devices are used, for example pyrometers which utilise the same physical phenomena to conduct measurements, however, they can only determine temperature of single spots rather then producing a thermal map. Nevertheless, their undoubted advantage is the price, which is much lower than of the thermovision cameras.

The temperature distribution on the surface can also be measured using different methods of surface coating – for example layers of materials with known melting points or temperature – indicating paints and pigments, which might be used as self – adhesive stickers. Similar stickers with thermochromic liquid crystals are also available [3].

Application of infrared measurements in medical diagnostics

Medical application of thermovision has been mostly focused on cancer tests due to the fact that during the measurements warmer areas of the skin can be detected. Consequently, it is possible to determine if any abnormalities occur which might indicate illness conditions. Haga et al. [4] investigated the significance of the locoregional hyperthermic area observed with thermography with regard to the maximum density of tumor enhancement by IV – DSA. It has been stated that thermovision may predict the prognosis of the disease in patients who suffer from the breast cancer.

Infrared imaging can also be used to determine the level of exhaustion and assessment of rehabilitation effectiveness. In case of long – term contraction of muscles, whose blood vessels are contracted, the skin on them appears as colder than on the healthy muscle – in such a situation thermovision can help detect these colder areas. The similar situation occurs with regard to a spinal curvature, in which colder areas are located opposite the curvature [2]. Thermography can also be used in rheumatology in knee joints illnesses as a dynamic testing method [5].

In dentistry infrared testing can cover temperature changes measurements during polymerization of composites through measuring infrared emissions from surfaces of resin composite restoration during photocuring [6]. The infrared technology might be a valuable tool to replace the cranial computed tomography as a screening method to test shunt function in hydrocephalic patients. The importance of this stems from the fact that the cranial computed tomography is associated with radiation and, consequently, should not be overused [7].

Obviously, skin diseases might be analysed with the presented technique. It has been applied, for example, in postoperative Clostridium perfringens infection with proximal forearm myonecrosis to reveal the full extent of tissue viability in the right upper extremity [8].

The application of thermovision technology covers surgery and orthopaedics in testing osteomyelitis, posttraumatic, degeneration and cancerous conditions as well as in wound and fracture healing [2]. This technique was also used to determine the amputation level of the limb on patients suffering from diabetic foot [9].

The infrared testing can also be applied to monitor inflammation on the reticular dermis or the lipid layer of the knee in case of linear scleroderma as presented in the case report in [10].

Impact of selected parameters on measurement accuracy

The measurements with a thermovision camera require to input some parameters into the software of the device in order to properly determine temperature of the observed object, which is conducted basing on the general Eq. 2. These parameters include emissivity, the distance between the object and the camera, the ambient temperature and the temperature of the elements in the surroundings as well as humidity.

The infrared measurement was performed on a vertical surface normal to the thermovision camera in the indoor laboratory conditions under which medical measurements are usually conducted. The surface was smooth and its temperature can be considered as equal across the whole surface. The infrared camera with a bolometric detector of 384x288 pixels and thermal resolution 0,08°C at 30°C equipped with 20° lens was used in the presented experiment. The test was performed on the flat surface whose emissivity was 0,85 at the ambient temperature and the temperature of the surrounding objects of 20°C, while the distance between the observed element and the measuring device was ca. 500 mm. Since these parameters are input into the device, it has been determined how improper values of the parameters influence the measurement accuracy for the applied camera. The results of the temperature readings along the selected line for different values of emissivity, distance and temperature have been presented in Fig. 1–3, respectively.

The analysis of Fig. 1 – 3 leads to a conclusion that inputting improper values of emissivity as well as the ambient temperature and the temperature of the surroundings has the most significant impact on determining the correct values of temperature readings of the observed object. Consequently, it is very important to supply the proper values of these parameters into the camera's software. It might involve performing callibration measurements with contact temperature measuring devices in the case of emissivity. Otherwise, the thermal map of the surface, which is the result of the tests, may be incorrect and lead to wrong conclusions.

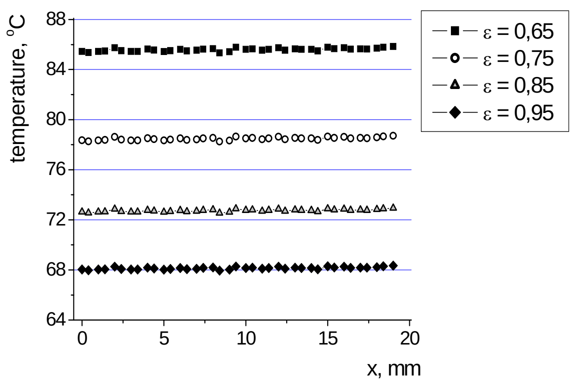

Fig. 1. **Temperature readings for different emissivity values with other parameters kept constant (distance 500 mm, ambient temperature and temperature of surrounding objects 20°C, humidity 50%)**

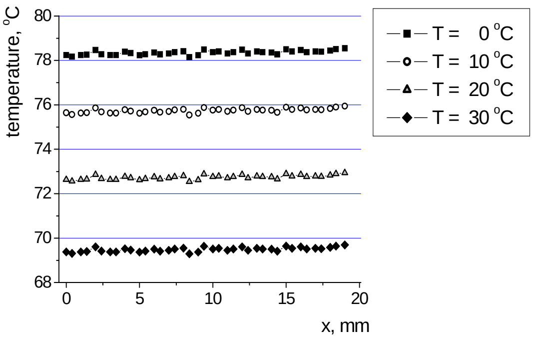

Fig. 2. **Temperature readings for different ambient temperature and temperature of surrounding objects with other parameters kept constant (emissivity 0,85, distance 500 mm, humidity 50%)**

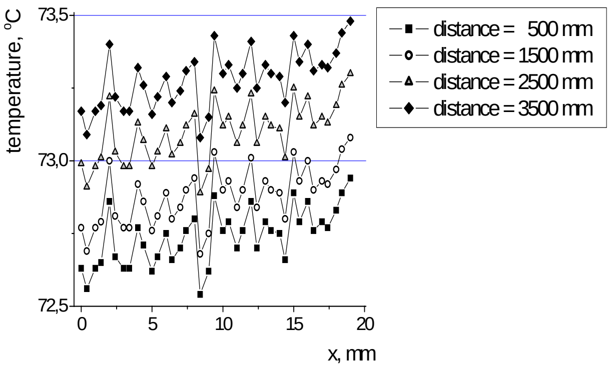

Fig. 3. **Temperature readings for different distance values with other parameters kept constant (emissivity 0,85, ambient temperature and temperature of surrounding objects 20°C, humidity 50%)**

The wrong value of distance has less considerable influence in the considered laboratory tests with differences of ca. 0,2 °C with every meter. Naturally, higher distance values might produce more significant errors in infrared temperature readings.

It has also been determined that humidity does not influence the readings in the considered case of measurements conducted indoors under controlled laboratory conditions such as during medical check – ups.

Conclusions

Thermovision technology is currently used in many engineering and scientific applications. It also becomes more and more common in medical diagnostics, because it is non – invasive, non – contact and easy to use. However, the knowledge of the physical fundamentals and sources of errors is necessary to properly determine temperature with infrared measurements. The most significant impact has the values of emissivity as well as the ambient temperature and the temperature of the surroundings. Lower values of these parameters result in elevated temperature readings. Consequently, it is necessary to properly determine these parameters and input them in to the camera's software to ensure correct temperature readings.

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Temperatūros matavimų metodas medicinos diagnostikoje

Reziumė

Temperatūra gali būti matuojama tradiciniais įtaisais, tokiais kaip termometrai, termoelementai, termistoriai ir t. t., tačiau techninių matavimų vietų detektoriai gali lemti šilumos laukus objekto paviršiuje. Be to, reikia dažnai atlikti temperatūros paskirstymo paviršiuje bandymus, bet ne nustatyti temperatūrą pagal pasirinktą punktą. Norint išspręsti tokias problemas, infraraudonosios spinduliuotės matavimai paprastai atliekami terminio vaizdo kameromis.

Termovizijos prietaisai, pvz., mechaninės ir elektros inžinerijos, naudojami mašinos ar elektros vienetų defektams aptikti ir fizinei būklei analizuoti – tiek mašinų dalių, tiek statybos pramonėje, siekiant nustatyti šilumos nuostolių pastatuose sritis, tiek kitose inžinerinėse srityse. Šiandien infraraudonosios spinduliuotės technologija ypač populiarėja medicinos diagnostikoje. Dažniausiai šiuo metodu nustatomas navikas - remiamasi šiluminiu paciento žemėlapiu, gautu terminio vaizdo kameromis.

Infraraudonosios spinduliuotės matavimai atliekami gana greitai ir lengvai, tačiau paaiškinti rezultatus gali būti labai nelengva. Be to, rezultatams turi įtakos keletas kriterijų, pavyzdžiui, spinduliuotės vertė, atstumas tarp objekto ir fotoaparato, aplinkos temperatūra, netolimi temperatūros objektai arba drėgmė. Toks poveikis turėtų būti gerai suprastas, kad tinkamai galima būtų sudaryti paskirstymo temperatūras, ir išnagrinėtas, ypač kalbant apie medicinos diagnostiką

Termovizijos technologija šiuo metu naudojama daugelyje technikos ir mokslo programų. Ji tampa vis įprastesnė ir medicininei diagnostikai, nes tai – ne invaziniai metodai. Darbe buvo matuojama ir tiriama infraraudonosios spinduliuotės temperatūra, svarbiausias poveikis spinduliuotei, aplinkos temperatūrai ir temperatūrai aplinkoje. Mažesnes šių parametrų vertės sukelia padidėję temperatūros rodmenys. Todėl norint užtikrinti tinkamus temperatūros rodmenis, būtina gerai nustatyti šių parametrų ir kamerų programinę įrangą.

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