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# STABILITY ANALYSIS OF INFRARED CAMERAS IN VIEW OF THEIR APPLICATION IN HEALTH CARE

*Наведено застосування техніки теплоспостереження за окремими ділянками людського тіла, де вона стає все більш поширеною. Використання інфрачервоних відокамер в системі охорони здоров'я, як правило, зосереджено на контролі якості; це найбільш доступний спосіб для визначення різниці температури, а не її точне значення. Оскільки відмінності температури шкіри можуть бути не дуже значними, тому важливо правильно інтерпретувати теплову карту, отриману в ході випробувань за даними теплоспостережної камери. У зв'язку з великою кількістю інфрачервоних відеокамер наявних на ринку, для порівняльного дослідження необхідно зробити висновок про ефективність цих пристроїв у медичних цілях. Для того, щоб це зробити були відібрані дві відеокамери і проводився аналіз їх сталої роботи в лабораторних умовах.*

*The paper presents the application of the thermovision technique in medicine where it becomes more common. The use of infrared cameras in health care is usually focused on quality testing – it is most important to determine the temperature differences rather than the accurate temperature value. Because the differences in skin temperature might not be very significant it is essential to properly interpret the thermal map obtained during the tests with a given thermovision camera. Due to a large number of infrared cameras available on the market a comparative study is needed to conclude about the usefulness of these devices in medical applications. In order to do this two cameras were selected and stability analysis was performed on them in laboratory conditions.*

Ключові слова: теплоспостереження, інфрачервона камера
Keywords: thermovision, infrared camera

## INTRODUCTION

Thermovision is widely used in many fields of technology – most commonly in mechanical systems where it is applied as a tool to assess thermal performance of machine parts. In this case it is possible to determine which elements dissipate too much heat and, consequently, are likely to operate improperly. Electrical engineering or environment protection are also fields of growing potential use of this technique. Significant area of interest is also the building industry with heat losses being in focus of investigations. An overview of such applications has been given e.g. in [1].

However, infrared technology is also used in medicine. It is a non – contact method of temperature measurement. Moreover, the results are obtained immediately in real time, which is a significant advantage of this technology. In medical applications it is important to determine differences in temperature, which might indicate illness conditions. If small temperature differences occur, a proper interpretation of the results requires the knowledge of the sources of errors, measurement uncertainties and physical fundamentals of the operation of the infrared devices as well as experience in such testings.

There are a lot of infrared cameras on the market and the buyers might be interested in checking whether there is any significant difference in measurement stability between them in view of their use for medical imaging. In order to perform a comparative analysis, two cameras of the same manufacturer were selected – the older model (which will be called in this paper – 1$^{st}$ generation) and the new model (called in this paper – 2$^{nd}$ generation). Naturally, the new model is about two times more expensive and has better parameters, but in this paper only stability analysis will be performed, while the other parameters are intended to be left the same to draw proper conclusions.

## OVERVIEW OF THERMOVISION USE IN HEALTH CARE

The infrared technology can be used in medicine. It has been applied in tests for breast cancer and cancers of other organs. This technique enables to detect warmer spots and abnormalities which could then be analysed in detail with different diagnostic techniques.

In sports medicine and rehabilitation, thermovision is useful to determine the level of exhaustion and assessment of rehabilitation effectiveness. Long – term contracted muscle, whose blood vessels are contracted, is colder than the healthy one, which can be detected with an infrared camera. The situation is similar in case of spinal curvature, in which colder areas are located opposite the curvature [2]. Thermography can also be used in knee joints illnesses – Rusch et al [3] proposed a method of dynamic thermography based on a rewarming curve of the skin over the knee joints. By plotting the slope in the logarithmic scale the warming phenomenon in the skin overlying inflamed joints can be determined and further analysed.

Infrared technology is used in surgery and orthopedics to test osteomyelitis, posttraumatic, degeneration and cancerous conditions as well as in the processes of wound and fracture healing [2].

Dental applications can cover, among others, investigations of temperature changes during polymerization of composites thorough measuring infrared emissions from surfaces of resin composite restoration during photocuring [4].

Thermovision method can also be used to detect abnormalities on the skin – for example in bacteria infections, e.g. postoperative Clostribium perfringens infection with proximal forearm myonecrosis [5]. In this case it was applied to reveal the full extent of tissue viability in a gas gangrene patient. This technique is also regarded to be a valuable tool to replace cranial computed tomography (CCT) as a screening method to test shunt function in hydrocephalic patients. It is important, because CCT is associated with radiation and, thus, should not be overused. Thermovision can offer cheap, quick and non – invasive alternative testing. CCT scanning would not be replaced completely, but it seems possible to reduce the number of these investigations [6].

According to [7] infrared measurements seem to be well suited in studies on circulation and metabolism in the hands and feet of diabetes. The tests proved that thermovision revealed abnormalities in the emission patterns from feet and hangs for all the investigated diabetic patients. Healthy people showed stronger emissions over the toes' tips and fingers than over the dorsi of feet and hands as opposed to the results in the group of diabetics.

However, thermography should not be regarded as always the best method and needs to be applied wisely. Luk et al [8] compared the reliability of this method with the doppler technique and clinical judgment of the experienced surgeon in the case of the determination of the level of amputation for an ischaemic lower limb. The studied patients had ischaemic lower limbs associated with atherosclerosis, diabetes mellitus or Buerger's disease. The comparison showed that thermography was the least accurate method of those tested. Its application would results in a higher than necessary amputation levels on legs, while the clinical assessment by the surgeon proved to be most accurate in the analysed case.

## STABILITY ANALYSIS OF TEMPERATURE READINGS

Temperature determination with the thermovision technique is based on the detection of infrared radiation emitted by every body of temperature above 0 K. The radiation is received by a detector – the most important part of a thermovision camera, and then, after the conversion into a digital signal, is used to calculate temperature values according to the Stafan – Bolzmann law, in which heat flux is a function of emissivity, temperature and a constant. The software of infrared devices also needs to take into account other parameters such as humidity, ambient temperature and temperature of surrounding objects as well as the distance between the observed surface and the camera, because these parameters might influence the temperature readings of the observed object. The operator of a thermovision camera should input their correct values to ensure that the measurements are most accurate.

The infrared measurements are easy in itself, however, there are many sources of errors that might significantly influence the results. The most important one is the incorrect value of emissivity. In laboratory conditions it might be possible to cover e.g. parts of machinery with paints of known emissivity in order to determine their temperature more precisely. Hot objects located nearby can also impact the measurements, especially if the temperature of the observed element is lower than the surroundings. When infrared testing takes place from a considerable distance, atmosphere can influence the readings, because part of the object's radiation can be absorbed. It is particularly important in case of concentrations of carbon dioxide and water vapour in the air [9].

In the experiment two infrared cameras bought from the same manufacturer were used. The first one was equipped with a detector of 240x240 pixels, thermal resolution 0,05– 10 $^{o}$C and scanning angle 30$^{o}$x30$^{o}$ (in the next part of this paper called the 1$^{st}$ generation camera) and the other (2$^{nd}$ generation), bought about 2 years later had a detector of 384x288 pixels, maximal thermal resolution 0,08$^{o}$C at 30$^{o}$C and the view field of 22$^{o}$x16$^{o}$. Naturally, the newer device has better parameters (including smaller measurement error) and more advanced software, but the aim of the project is to compare the stability and reading accuracy of the two (with other parameters kept constant, even the production technology, which should be ensured by testing cameras from the same manufacturer). Similar work has been done at Kielce University of Technology, but the comparison took into account cameras of different producers [10].

The tests were performed on the laboratory stand whose main element was a bakelite plate (part of a vessel) heated by hot liquid from the inside. The outside was kept dry in the air and was open to observation performed by the thermovision cameras. The emissivity of the plate was high, which reduced measurement errors. Figure 1 presents the temperature distributions recorded by the two infrared devices. The temperature of the plate was almost identical in both cases.

As can be seen in Figure 1 temperature is not uniform along the line and changes more significantly for the camera of the second generation. In this case the standard deviation for 55 measurement points was 0,12 $^{o}$C, while the highest difference between the minimal and maximal readings was 0,46 $^{o}$C. The first generation camera showed readings of 0,06 $^{o}$C standard deviation and highest temperature difference of 0,26 $^{o}$C. In this case temperature was recorded for only 20 points, which results from the fact that the detector of the newer camera is more denser (the measurements were carried out for a similar distance between the experimental stand and the thermovision cameras).

In order to conclude about stability of the cameras it is necessary to consider how temperature changes in time for the same measurement points. Figures 2a and 2b present the temperature distributions recorded for 3 measurements taken shortly after one another.

Generally, the results differ slightly for both cameras – the median of the standard deviation for the 1$^{st}$ generation device was 0,07 $^{o}$C, while for the 2$^{nd}$ generation 0,12 $^{o}$C. It is worth noting that this test is more important since in the observation from Figure 1 measurement errors (reflections from the radiation sources located nearby, surface imperfections, random experimental errors) could have contributed to the obtained result, especially that the differences are in the order of magnitude of the thermal resolution.

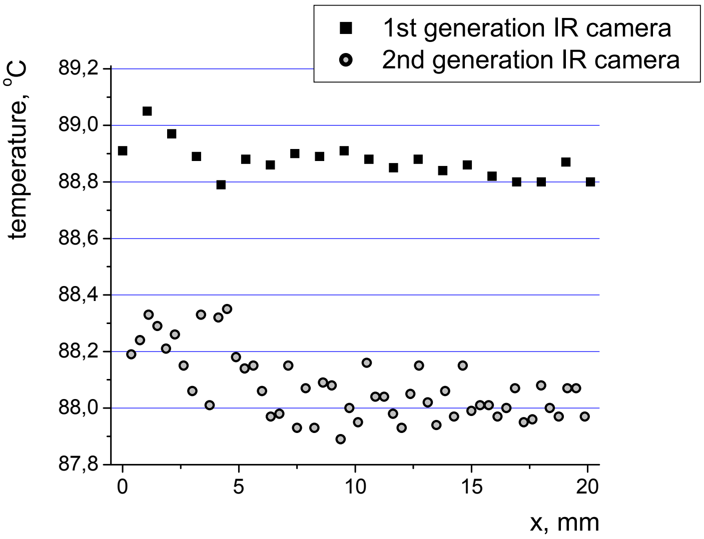


**Fig. 1. Temperature distribution along the line for two infrared cameras**

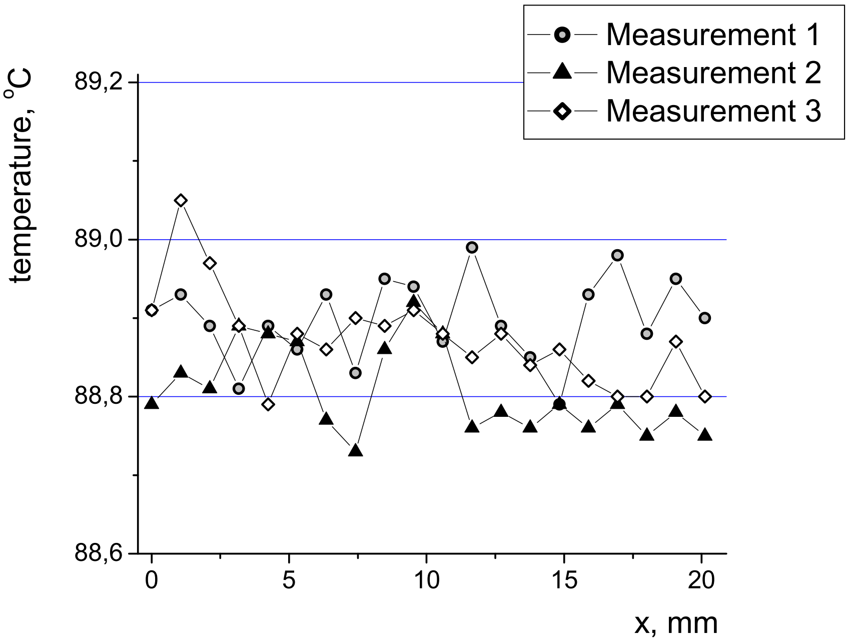


**Fig. 2a. Temperature readings for the selected line for 3 consecutive measurements – 1st generation camera**

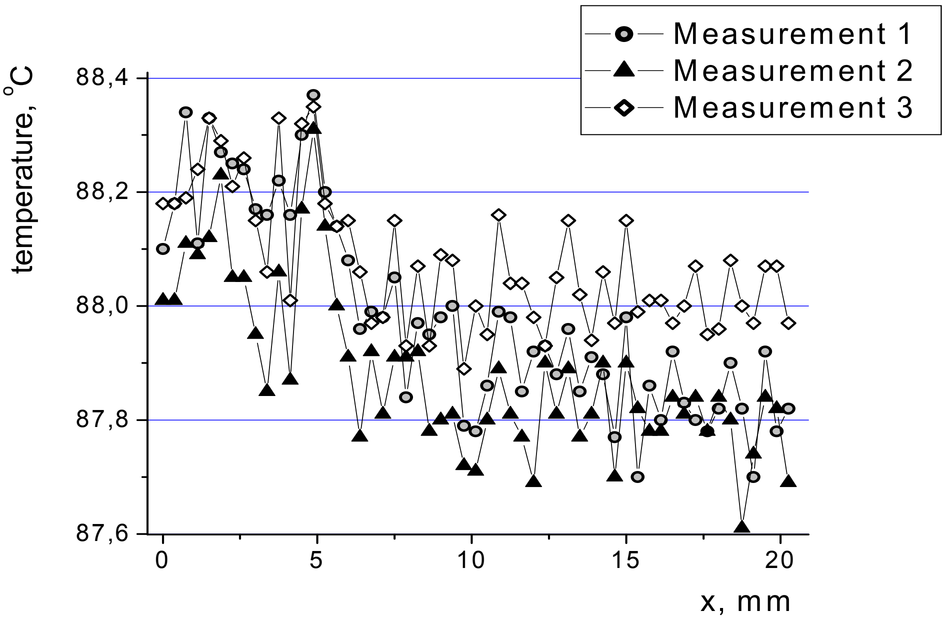


**Fig. 2b. Temperature readings for the selected line for 3 consecutive measurements – 2nd generation camera**

Further analysis reveals that the most common deviations ranged between 0,04 $^{o}$C and 0,08 $^{o}$C for the 1$^{st}$ generation camera and between 0,12 $^{o}$C and 0,16 $^{o}$C for the 2$^{nd}$ generation camera, which has been presented in Table 1.

Table 1

**Deviation ranges for both cameras in the present test**

| | | Deviation range, $^{o}$C | | | | |
|---|---|---|---|---|---|---|
| | | 0– 0,04 | 0,04– 0,08 | 0,08– 0,12 | 0,12– 0,16 | 0,16– 0,20 |
| Counts, % | 1$^{st}$ generation camera | 15,0 | 50,0 | 35,0 | 0 | 0 |
| | 2$^{nd}$ generation camera | 9,1 | 10,8 | 31,0 | 47,3 | 1,8 |

Basing on the obtained experimental results, it might be stated that for the analysed infrared cameras from the same manufacturer the 1$^{st}$ generation device performed slightly better than the 2$^{nd}$ generation camera, although the newer device should be more technically advanced in every way. The reason might be the noises of the detector of the 2$^{nd}$ generation device. With the matrix containing more pixels (384x288) it seems to be more challenging to properly design the electronic signal treatment for each pixel. However, the thermal resolution of both the cameras should not exceed about 0,1 $^{o}$C, so the subtle difference between their deviation ranges is comparable to this resolution.

**CONCLUSIONS**

Medical applications of thermovision usually require determination of temperature differences rather than accurate values of temperature. The performed stability analysis proved that both tested cameras are able to detect small temperature differences fairly well. The deviations of readings with time were similar for both devices (comparing to the measurement resolution), although a little better for the 1$^{st}$ generation camera. One of the advantages of the second generation is a possibility to obtain more detailed images due to the matrix of 384x288 = 110592 pixels – almost twice more than in the previous generation.

It should be noted, however, that this study was only limited to stability analysis and dealt with cameras from one manufacturer. In order to obtain more information further tests on cameras from other manufacturers might be needed.

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